Foreword from the Organizing Committee

On behalf of the Organizing Committee, we sincerely welcome you to the 11th International Symposium on Modern Optics and its Applications (ISMOA), and thank you for your continued support and contribution to this meeting.

This is the first time for ISMOA to be held outside Institut Teknologi Bandung. Bogor Agricultural University or Institut Pertanian Bogor (IPB) in Bahasa have an honoured to jointly organize this important event with the Indonesian Optical Society (InOS). As a university that mainly focus on tropical agriculture and biosciences, IPB also deals with Optics through Biophotonics, such as conducting studies on bioluminescence characteristics in natural organisms and its application.

We are glad to note that in spite of the difficulties in economic situation in the region, we still manage to keep up more or less the same size of the event. We have in our record a total over 50 confirmed speakers, consisting of 10 distinguished Invited and 42 Contributing Speakers scheduled which are originated for 11 countries worldwide including the host country. We are also delighted to see the frontier topics will be presented by speakers especially from our distinguished invited speakers, featuring the important recent researches ranging from fundamental aspects to useful applications. We hope that this meeting will bring benefits to all participants for conducting scientific mutual collaborations among researchers and students in this country and other countries in this region with researchers from developed countries.

Finally, we would like to convey our grateful appreciation to the Physics Department of IPB, Directorate of Research and Innovation of IPB, Mr. Henri Lukito Setiawan the director of PT. Halilintar Lintas Semesta (Test and Measurement Specialist Company), the office of Overseas Naval Research Global (ONRG), USA, for their support for this event. Also the Optical Society (OSA) for their endorsement.

Bogor, August 2017

Husin Alatas

Chairman of ISMOA 2017
Foreword from President of InOS

Dear distinguished guests, speakers, and participants,

Firstly, I would like welcome all of you to The 11th International Symposium on Modern Optics and Its Applications (ISMOA 2017). Secondly, I would like to thanks our colleagues from the Department of Physics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University (IPB) for hosting this great conference in such a wonderful city of Bogor.

In the last symposium, in 2015, we all gathered in the spirit of The International Year of Light 2015. This year, the symposium is organized in the dawn of proclamation of an important day for optics community, The International Day of Light. We all are waiting UNESCO to proclaim every May 16th as the International Day of Light in its General Conference in the coming November 2017. In such spirit, we all come to this symposium to share with each other, how light plays important roles in communications, energy, sensing, medicine, health care, arts, instrumentations, etc.

This symposium was initiated by two of the founders of The Indonesian Optical Society (InOS), Prof. Tjia and Dr. Alexander Iskandar in 2001 under the support of KNAW, The Royal Netherlands Academy of Arts and Sciences and several colleagues from University of Twente. As time goes by, after the founding of InOS in 2011, ISMOA was co-organized by InOS in collaboration with ITB. Today, we witness that for the first time, ISMOA is co-organized by InOS with another group not from ITB, of course still with strong support by InOS members from ITB. We hope this will mark the grow of other centers of development of modern optics in Indonesia.

For 11 times, this symposium has been marked as the largest conference of the kind in Indonesia which not only gather modern optical scientists from all around Indonesia, but also from the region, as well as from Europe, Japan, Australia, and Mexico. This symposium would not be possible without support from colleagues travelling a long trip around the globe to share their research developments. We also acknowledge the support and sponsorship from IPB, The Office of Naval Research Global (ONRG), USA, and sponsoring company like PT. Halilintar Lintas Semesta.

Lastly, I would like to wish you all a fruitful conference and a nice stay in the rainy city of Bogor.

Yours sincerely,

Henri P. Uranus

President of the Indonesian Optical Society
Welcoming Address by the Rector of Bogor Agricultural University

It is a great pleasure for us to witness the implementation of the 11-th International Symposium on Modern Optics and its Applications (ISMOA), which is jointly organized by the Department of Physics, Bogor Agricultural University (IPB), and the Indonesian Optical Society (InOS), and to give this welcoming address to this forum. First of all, I would like to extend on behalf of IPB, our warm welcome to IPB to all participants of this scientific meeting. I would also like to express our appreciation to all distinguished invited speakers and contributed speakers, for your important contributions to this forum.

I understand that the area of optics as one of the oldest branches of physics and sciences has rapidly evolved to serve the growing needs of the scientific and technological activities, as well as the human welfare in general. Its advances have been proven to play important roles in the discovery of large variety of new phenomena and supporting the development of novel technological applications. High speed and high capacity optical communication and information systems, nano optics, plasmonics and nano biophotonics, bio-medical optics and quantum optics are the examples of important contributions of this field. In the field of agriculture and life sciences in general, I believe that optics will play a very significant contribution especially in the sensor technology for precision agriculture applications.

Based on this, we are happy to be the host of this important scientific meeting under the theme of “Light for Life”, which we believe will not only stimulate the studies and researches of this broad area, but also to deliver a fruitful international scientific networks and research collaborations. We also hope that this symposium will help to facilitate a cross cultural exchange and mutual understanding among the participants.

Finally, I wish you all successful meeting and enjoy your stay in Bogor.

Bogor, August 2017

Prof. Dr. Ir. Herry Suhardiyanto, M.Sc
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11th International Symposium on Modern Optics and its Applications Committees

International Scientific Program Committee

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The Optical Society
General Information

Period of Activities:

- 7 August 2017 (Tutorial Workshop)
- 8 – 9 August 2017 (Symposium)
- 10 August 2017 (Excursion)

Venue

- R. Botani – Baranangsiang Campus (Tutorial Workshop)
- Ballroom 3, IPB International Convention Center (Symposium)

Official Language

English

On-Site Registration

Ballroom 3, IPB International Convention Center (Symposium)

Submission of manuscript for publication

For publication, selected papers presented in the symposium will be submitted to the Journal of Nonlinear Optical Physics and Material Sciences (JNOPM), Journal of Mathematical and Fundamental Sciences (JMFS), or Journal of Physics: Conference Series.

Social Events

- Welcoming Reception, 7 August 2017, 17:00 – 19:00 at Baranangsiang Campus
- Conference Banquet hosted by the Bogor Agricultural University, 8 August 2017, IPB International Convention Center

Information for Oral Presentation

- All presentation will be delivered in plenary session.
- Speakers are requested to upload their presentation before the session.
- Speakers are requested to come to the presentation room 100 minutes before the start of the appropriate session and notify the chair person of their presence.
Information for Poster Presentation

The poster presentation will be held in a special session on the first day of the symposium (Tuesday, 7 August 2017), preceded by a 2 (two) minutes oral summary of the research in the format of consisting of 2 (two) slides containing: introduction (rationale of your research work), methods, and brief summary of results.
Tutorial Workshop on Modern Optics and its Applications

Monday, 7 August 2017
PROGRAM SCHEDULE

MONDAY, 7 August 2017

Tutorial Workshop

Venue: R. Botani, Baranangsiang Campus

08.00 – 08.30 : Registration

08.30 – 08.40 : Opening Ceremony and Opening Address by Dean of Faculty of Mathematics and Natural Sciences, IPB

08.40 – 09.00 : Coffee Break

09.00 – 10.00 : Lecture Session 1
   Kurt HINGERL (Johannes Kepler University, Linz, Austria)
   Tutorial on coherence, decoherence and partial Polarization

10.00 – 10.30 : Discussion on Lecture 1

10.30 – 11.30 : Lecture Session 2
   Kaoru TAMADA (University of Kyushu, Japan)
   Multi-dimensionally assembled metal nanoparticles and their property and applications

11.30 – 12.00 : Discussion on Lecture 2

12.00 – 13.00 : Lunch

13.00 – 14.00 : Lecture Session 3:
   David SAMPSON (University of Western Australia, Australia)
   Fundamentals of light scattering in tissue and the basics of optical coherence tomography

14.00 – 14.30 : Discussion on Lecture 3

14.30 – 15.30 : Lecture Session 4:
   Henri URANUS (Universitas Pelita Harapan, InOS)
   Optical Waveguiding and Mode Solving Practice

15.30 – 16.00 : Discussion on Lecture 3

16.00 – 17.00 : Coffee Break

17.00 : Welcoming Reception
Tutorial Lecture Abstracts
**TL-1**

**Tutorial on Coherence, Decoherence and Partial Polarization**

Kurt Hingerl  
Center for Surface and Nanoanalytics, Physics Department, Johannes Kepler University Linz, Linz, Austria  
kurt.hingerl@jku.at

**COHERENCE AND INTERFERENCE**

Interference is a topic in optics which undergraduate physics, optics and EE students already learn in their second year. Assuming that the electric field behaves as a plane wave, one can explain well the colors of thin coatings, diffraction effects due to Huygens, the spectral response of Bragg gratings, and many more optical phenomena. We all learn (and teach in undergraduate courses) that one has to sum the electric field vectors. However, writing down a plane wave and using the mathematical techniques does usually not give the correct explanations for some experiments. Plane waves, behaving as $\vec{E}(\vec{r}, t) = \vec{E}_0 e^{i\vec{k}\vec{r} - i\omega t - \varphi}$ are solutions of Maxwell equations in any homogenous region, but they do not grasp the physics of real wave trains or photons in two respects. Using them one assumes:

1) Along the propagation direction the field (photon) is infinitely long;  
2) and perpendicular to the propagation direction $\vec{k}$ the field (photon) is infinitely wide;

Despite for understanding some physical effects plane waves are helpful, there are two shortcomings inherently connected with them:

1) There is no photon (or wave train) which has in infinitely long coherence length, but the expression above gives the impression that the phase $\varphi$ is well defined for any instant and any point in space along the propagation direction. We all know from experience that each wave (photon) has a **finite coherence length**.  
2) and there is also no wave field which has normal to the propagation direction $\vec{k}$, which is shown with Young’s double slit experiment if the two slits are far apart. This has been used by two astronomers Hanbury-Brown and Twiss to determine the size of stars in other galaxies. or in other words: Even if only monochromatic light is used, each photon has also a **finite coherence area** $\Delta A = R^2 \lambda^2 / \Delta s$ with the areal size of the light source $\Delta s$, the distance $R$ and the quasimonochromatic wavelength $\lambda$. The quantity $\sqrt{\Delta A}$ is sometimes called **coherence distance**.

**ONLY INTENSITIES ARE MEASURABLE QUANTITIES**

Any optical detector for optical radiation never measures the field, all measure **intensities**! And because each intensity measurement takes long against the oscillation period of light ($\sim 10^{-15}$s) always intensities are measured. (Perhaps fast sampling oscilloscopes work up to 10 GHz, but this is still far away from optical frequencies. So, in the case of two interfering fields, e.g. from a Michelson interferometer, or from two different slits in Young’s experiment, (respectively Huygen’s principle), the measured intensity is always $I = \varepsilon_0 n c \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} \left( E_1(t) + E_2(t) \right)^2 dt$. Provided $E_1(t), E_2(t)$ are deterministic and well defined quantities over time and space, the square of the sum can be formed straightforward yielding
interference terms; however, if \( E_1(t), E_2(t) \) are not well correlated any more due to a finite coherence length / distance, and their mutual correlation vanishes, then instead of coherence terms yielding a cosinusoidal intensity variation, the sum of intensities is measured. All the arguments above are only classical and I just note in passing that quantum optics yields \( \Delta N \Delta \phi \geq 1 \), with \( \Delta N \) as standard deviation for the photon number, (which implies that beams with a definite photon number have a totally undefined phase). In the following I will discuss physical realizations for both effects.

**Finite Coherence Length**: Interference is a topic in optics which undergraduate physics, optics and EE students already learn in their second year. The colorful pattern of a thin oil film on water arises from this effect; however, when asking students why a thicker oil film (> ~1 µm) does not show such interference colors anymore, many explanations are proposed, but seldom the correct one that the coherence length of light is already too small to yield interference (with our eyes as broadband detector and the photons from the sun as broadband source!). Decoherence means that the phase of a wave is not well defined anymore: it becomes a stochastic quantity.

**Finite Coherence Distance**: For Young’s experiment respectively Huygen’s principle in diffracting structures, which requires the superposition of the fields, there is not an everyday example as for the thick oil film above. In a certain measurement technique, called speckle interferometry is commonly used to determine the structure or rough surfaces and correlations on different distance scales. So, summing up this part, the procedure of summing the fields relies on a deterministic phase. Optical effects change and the necessary mathematics must be modified towards statistical optics if the phase becomes partially random, as discussed in the simple example above. The measured intensity then changes, as interference terms contribute differently and intensities have to be added. Besides interference, measurable (de-)polarization effects also become important, as will be discussed in this presentation.

**EFFECT ON POLARIZATION**

Until now we have just argued with scalar electrical fields and discussed for intensity measurements autocorrelation functions \( <E(\vec{r}, t + \tau)E(\vec{r}, t) > \) which manifest their correlation by the sharpness (visibility) of fringes in Michelson’s (temporal) or Young’s (spatial) interference experiments. Polarization measurements are usually done by measuring the (time averaged) correlations of different components of the electric field at a single point in time and space (loosely written as \( <E_i(\vec{r}, t)E_j(\vec{r}, t) > \)). In optics, we do not measure the electric fields, since the available detectors are much too slow, but their statistical second moments (see the correlation function 2 lines above). R. Ossikovski and K. Hingerl recently published how the effect of decoherence can be formulated analytically to describe the effect of decoherence on depolarization. For both cases, it turns out that the intensity measurement, or better the four intensity measurements to determine the Stokes parameters, can be predicted by 16 measurements (Müller Matrix elements) for all possible input and output polarization vectors.

**Keywords**: metamaterials, decoherence, depolarization

**Acknowledgment**: The authors acknowledge the ECH2020 grant No.692034 (TwinFusyon).

**References**

Multi-dimensionally assembled metal nanoparticles and their property and applications

Kaoru Tamada

Institute for Materials Chemistry and Engineering, Kyushu University
(E-mail: tamada@ms.ifoc.kyushu-u.ac.jp)

A collective excitation of localized surface plasmon resonance (LSPR) has been studied extensively on 2D crystalline sheet composed of metallic nanoparticles [1]. The particle sheets are fabricated by self-assembly at air-water interface and deposited on solid substrates by Langmuir-Schaefer method. Both the experimental and the FDTD simulation data revealed a unique optical property of the 2D sheet, where the homogeneously coupled LSPR in 2D sheet results in not only a significant red-shift of LSPR band but also an additional amplification of electric field at the interface.

Recently, we found a drastic reflection color change of Ag and Au nanoparticle multilayers on metal substrate (‘plasmonic full color’) [2, 3]. This phenomenon originates from the peak splitting of absorption spectra due to the electromagnetically induced transparency (EIT), selectively occurring on metal substrates [4]. Here the layer number dependent light confinement in the multilayered nanoparticle sheet was clearly demonstrated in the experimental data, and well reproduced by the calculation based on the Transfer-Matrix method by employing the effective medium approximation. Here the Ag nanosheets act as a plasmonic metamaterial light absorber with a large oscillator strength.

This plasmonic full color technique was applied to colorimetric sensing devices. By use of Ag nanoparticle sheets as a substrate to immobilize probe molecules instead of simple glass or metal substrates, we could obtain enlarged color change by the adsorption of target Au nanoparticles (~30% surface coverage) [5]. This sensor could be utilized for the detection of remote photocatalytic reaction in high sensitive as well [6].

In the tutorial, the principle of metal nanoparticle-related nano-plasmonics study will be lectured.
References


Fig.2. Colorimetric detection of an airborne remote photocatalytic reaction using Ag nanoparticle sheet [6].
TL-3

Fundamentals of light scattering in tissue and the basics of optical coherence tomography

David Sampson

University of Western Australia, Australia

N/A
Optical Waveguiding and Mode Solving Practice

Henri P. Uranus

1 Department of Electrical Engineering, Universitas Pelita Harapan, Indonesia.
(E-mail: henri.uranus@uph.edu)

ABSTRACT

Optical waveguides are the basic building blocks of many optical devices. This tutorial will briefly introduce the participants to the principles and parameters of optical waveguides. Then, a brief introduction to the importance of finding the modes of optical waveguides, examples of modes of several kinds of common optical waveguides, and variety of methods used in optical mode solving. Finally, the participant will be guided to perform practice in using free resources from the internet to perform mode solving of simple planar waveguides made of isotropic, lossless materials, including analysis of a planar directional coupler.
Symposium on Modern Optics and its Applications

Tuesday, 8 August 2017
Wednesday, 9 August 2017
PROGRAM SCHEDULE

TUESDAY, 8 August 2017

Symposium Day 1

Venue: IPB International Convention Center

08.00 – 08.40 : Registration
08.40 – 09.00 : Opening Ceremony and Opening Address by Rector of IPB

Session 1, Chairperson : Jasper KNOESTER

09.00 – 09.30 : Invited Paper 1
Carsten ROCKSTHUL
*Artificial Optical Materials Made From Complex Scatterers*

09.30 – 10.00 : Invited Paper 2
Kurt HINGERL
*A Classical Model for Depolarization by Temporal and Spatial Decoherence*

10.00 – 10.30 : Coffee Break

Session 2, Chairperson : Carsten ROCKSTHUL

10.30 – 11.00 : Invited Paper 3
Andrivo RUSYDI
*Probing spectral weight transfers using high-energy optical conductivity in oxides heterostructures and 2-dimensional system*

11.00 – 11.30 : Invited Paper 4
Guangyuan LI
*Single theoretical framework for plasmonic waveguide design for nanolasing and four-wave mixing*

11.30 – 12.00 : Invited Paper 5
Yong-Hee LEE
*Funnelling of Photonic Energy into a Point Space*

12.00 – 13.00 : Lunch

Session 3, Chairperson : Agus M. Hatta

13.00 – 13.15 : Contributed Paper 1
Robeth V. MANURUNG
*Localized surface plasmon resonance of Gold nanorods to enhance...*
absorption and emission in NaYF₄:Yb, Er/SiO₂ core-shell type upconversion nanoparticles

13.15 – 13.30 : Contributed Paper 2
Adalberto ALEJO-MOLINA
Isotropic and Anisotropic Parts for the Susceptibility Tensor Calculated Using Simplified Bond-Hyperpolarizability Model

Anas A. LATIFF
The MoS₂ Saturable Absorber for Eye-safe Mode-locked Fiber Laser Generation

13.45 – 14.00 : Contributed Paper 4
Indra KARNADI
k-space analysis of photonic crystal slab resonator bonded on a high index substrate, with small mode-volume and low optical-loss

14.00 – 14.15 : Contributed Paper 5
Sulaiman W. HARUN
Nickel Oxide film saturable absorber for mode-locking operation at 1.55-micron region

14.15 – 14.30 : Contributed Paper 6
Vebi NADHIRA
Non-Iterative Model Based Image Reconstruction of Diffuse Optical Tomography Based on the DE and RTE in Quality Control on Agricultural Produce Studies

Session 4, Chairperson : Hendradi HARDHIENATA

14.30 – 15.30 : Oral Introduction to Poster Presentations
15.30 – 17.00 : Poster Session and Coffee Break

19.00 – 21.00 : Symposium Banquet

WEDNESDAY, 9 August 2017

Symposium Day 2

Venue: IPB International Convention Center

Session 5, Chairperson : B.M. Azizur RAHMAN

09.00 – 09.30 : Invited Paper 6
David SAMPSON
High-resolution, Label-free Tissue Imaging: Angiography, Lymphangiography, Elastography, and Polarisation Contrast Extensions of Optical Coherence Tomography and Their Applications

09.30 – 10.00 : Invited Paper 7
Kaoru TAMADA
LSPR-mediated high axial and temporal resolution fluorescence imaging on metal nanonparticle sheet

10.00 – 10.30 : Coffee Break

Session 6, Chairperson : Yong-Hee LEE

10.30 – 11.00 : Invited Paper 8
Jasper KNOESTER
Optical properties and dynamics of excitons in self-assembled tubular molecular aggregates

11.00 – 11.30 : Invited Paper 9
B.M. Azizur RAHMAN
Nonlinear Acousto-optical Interaction in Optical Waveguides

11.30 – 12.00 : Invited Paper 10
Harith AHMAD
Application of 2D Materials in Generating Q-Switched Linear Pulses

Session 7, Chairperson : Sulaiman W. HARUN

13.00 – 13.15 : Contributed Paper 7
Yusuf N. WIJAYANTO
Wireless Terra-Hertz Detection Using Metamaterial Antenna on Optical Modulator

13.15 – 13.30 : Contributed Paper 8
Agus. M. HATTA
An SMS fiber structure for respiratory monitoring

13.30 – 13.45 : Contributed Paper 9
ISNAENI
Optical Properties of Toluene Soluble Carbon Dot from Laser Ablated Coconut Fiber

13.45 – 14.00 : Contributed Paper 10
Tony SUMARYADA
Non-linear Performance of Al$_{0.3}$Ga$_{0.7}$As/InP/Ge Multijunction Solar Cells Upon Multiplication of Solar Irradiance
14.00 – 14.15 : Contributed Paper 11
Hendradi HARDHIENATA
Nanoscale Surface Characterization using the Bond Model in Nonlinear Optics

14.15 – 14.30 : Contributed Paper 12
Briliant A. PRABOWO
Preferences and characterization of brightness enhancement film for OLED-based SPR sensor

Azrul AZWAR
Refractive Index Sensing with Ultra–High Figures of Merit using Core-Multishells Silver Nanotube

14.45 – 15.00 : Contributed Paper 14
Siti CHALIMAH
Detection of Dye Molecules Adsorbed inside a Mesoporous Layer by Surface Plasmon Resonance and its Comparison to Simulation Results

15.00 – 15.15 : Contributed Paper 15
Ali KHUMAENI
Laser-Induced Gas Plasma Spectroscopy for the Analysis of Carbon in Soil

15.15 – 15.30 : Contributed Paper 16
Priastuti WULANDARI
Study of Charge Generation in Hybrid Polymer-Inorganic Solar Cell and the Effect of Incorporated Metal Nanoparticles

15.30 – 15.50 : Closing Ceremony

15.50 – 16.15 : Coffee Break

Indonesian Optical Society Session

16.15 – 17.00 : General Meeting of the Indonesian Optical Society

THURSDAY, 10 August 2017

09.00 – 14.00 : Excursion to Bogor Botanical Garden and Lunch
Plenary Oral Presentation
Abstracts

Tuesday, 8 August 2017
Artificial Optical Materials Made From Complex Scatterers

C. Rockstuhl*1,2, M. Fruhnert1 and I. Fernandez-Corbaton2

1 Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany
2 Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany
(E-mail: carsten.rockstuhl@kit.edu)

INTRODUCTION

The design of novel optical materials very often starts by considering individual scatterers that have a complicated shape, that are made out of different materials, and that are potentially an assembly from different sub-structures. Controlling the way such scatterers interact with an external field is the key to discover novel artificial optical materials with unprecedented properties. In this contribution, we give an overview on our efforts first from a methodological perspective to study the scattering properties of complex objects and detail afterwards multiple materials width various emerging properties.

RESULTS AND DISCUSSION

From a methodological side, we concentrate on the T-matrix of an object, expressing how a spherical harmonic of an incident field is coupled to a spherical harmonic of the scattered field. The T-matrix constitutes a comprehensive representation of the object in the interaction process. Any quantity of interest that is exchanged between the incident field and the scatterer can be computed from it. We detail how such a T-matrix can conveniently be calculated for an arbitrary object [1] and show how conservation laws can be formulated with it [2].

The calculation of this T-matrix usually requires the solution of multiple full-wave simulations, where the scattering response of the object to a specific illumination is solved. Projecting the scattered field on the basis sets allows to deduce the T-matrix by solving a system of linear equations in a least-square sense or exactly, depending on whether a single incident mode has been used for the illumination. In our work, we use finite-element-simulations based on the program JCMsuite and rely on a plane wave basis for the illumination.

We focus on, but do not wish to restrict our consideration exclusively to, meta-atoms that can be fabricated with self-assembly techniques. These meta-atoms consist of a larger number of metallic nanoparticles that are assembled into complicated geometries. As an example of the analysis, Fig. 1 shows some illustrative results of our approach along with some further explanations.

From an applied side, we detail multiple materials with fascinating properties that come in reach when considering complex scatterers as their basic building blocks. We study novel non-scattering materials, self-assembled metamaterials with a strong magnetic response, and maximal electromagnetic chiral materials, i.e. materials that interact with light of only one helicity while being transparent to the opposite. Such materials find application in helicity filtering glasses in stereoscopic cinema projection systems or for a twofold resonantly enhanced and background-free circular dichroism measurement setup that can be use in pharmaceutical production lines [3].
Figure 1. a) General configuration to compute the $T$-matrix of an arbitrarily shaped object. Many individual plane waves are considered as illumination, the full-wave response is computed and from the scattered field of each plane wave the $T$-matrix is constructed. b) Basic example of a silver dimer made from spheres with a radius of 30 nm and a center-to-center separation of 63 nm. The scattering cross section for a specific illumination as shown in inset has been solved with Mie theory (solid line) and a finite-element solver (crosses). c) The overall structure how we present the $T$-matrix, where the different electric, magnetic, and electric-magnetic entries are seen. We consider here up to a quadrupolar order. d) Amplitude of the entries of the $T$-matrix for the dimer at the frequency indicated by the solid line in b).

Keywords: Scattering, Plasmonics, Metamaterials, Chirality, Nanooptics, Theory

References
IP-2

A Classical Model for Depolarization by Temporal and Spatial Decoherence

Jean-Pierre Perin and Kurt Hingerl
Center for Surface and Nanoanalytics, Physics Department, Johannes Kepler University Linz, Linz, Austria

kurt.hingerl@jku.at

DECOHERENCE AND DEPOLARISATION

Interference is a topic in optics which undergraduate physics, optics and EE students already learn in their second year. The colorful pattern of a thin oil film on water arises from this effect; however, when asking students why a thicker oil film (> ~1 µm) does not show such interference colors anymore, many explanations are proposed, but seldom the correct one that the coherence length of light is already too small to yield interference (with our eyes as broadband detector and the photons from the sun as broadband source!). Decoherence means that the phase of a wave is not well defined anymore: it becomes a stochastic quantity.

Although we all learn (and, again, teach in undergraduate courses) that one has to sum the electric fields, the procedure of summing the fields relies on a deterministic phase. Optical effects change and the necessary mathematics must be modified towards statistical optics if the phase becomes partially random, as discussed in the simple example above. The measured intensity then changes, as interference terms contribute differently and intensities have to be added. Besides interference, measurable (de-)polarization effects also become important, as will be discussed in this presentation.

The change of polarization of light at a reflection on an interface is normally measured with (spectroscopic) ellipsometers (SE) or (spectroscopic) Müller matrix systems (MM). It is then found that one of these sample/light source properties gives rise to a measurable depolarization: 1) a finite spectral resolution and/or 2) an imperfectly collimated beam and/or 3) an (areal) extended light source and/or 4) an (areal) extended detector and/or 5) a sample with a varying over layer thickness. All these effects produce depolarization in a SE or MM measurement. Despite these experimental findings on intensity measurements, known since ~150 years, there have been no physical models published which trace the origin of depolarization back to the structural sample properties or the properties of the light source. However, before discussing depolarization, the effect of cross polarization has to be introduced.

REFLECTION AT STRUCTURED SAMPLES

Reflection occurring on structured samples consisting of material A and B (e.g. Si and Au), on the other hand, as shown in Figure 1, yields different polarization states if the beam is reflected on Si or Au, and even different ones close to the interface. If the reflected electric fields are coherent, with well-defined spatial and temporal phase, then their vectors can be added and provide an elliptical polarization state which is deterministic and well-defined; this polarization state will be called cross polarization. Cross polarization states are still totally polarized states, because there exists, for a given wavelength, a compensator angle and an analyzer angle, such that the measured intensity after passing through these devices can be perfectly nulled, respectively extinguished. With partially polarized states, this full extinction can never be achieved.

DECOHERENCE AND DEPOLARISATION

In optics, we do not measure the electric fields, since the available detectors are much too slow, but their statistical second moments. R. Ossikovski and K. Hingerl recently published how the effect of decoherence can be formulated analytically to describe the effect of decoherence on depolarization. For both cases, it turns out that the intensity measurement, or better the four intensity measurements
to determine the Stokes parameters, can be predicted by 16 measurements (Müller Matrix elements) for all possible input and output polarization vectors.

The goal here is not to repeat the derivations, but we want to highlight that, for each case, the fundamental representation of the measurement process can be written as a convolution of the sample response with a specific instrumental coherence function. Decoherence has two underlying basic sources: either it is due to temporal decoherence, represented by an always finite decoherence length of the beam, or by spatial decoherence, which is due to the fact that light does not originate from a single spot from the light source.

In homogeneous samples with thick transparent overlayers, it turns out that depolarization arises through the temporal decoherence of photons, and the measured MM elements are given by a convolution of the spectral width of the light source and a sample property: the thickness of the transparent overlayer.

For inhomogeneous samples, the coherence area $\Delta A$ is related by the Hanbury Brown and Twiss formula to the areal size of the light source $\Delta s$, the distance $R$ and the quasimonochromatic wavelength $\lambda$: $\Delta A = R^2 \lambda^2 / \Delta s$. As $\Delta A$ is of the order of $(50 \mu m)^2$ for typical SE and MM setups, the single polarization directions from structured samples with distances $\geq 10 \mu m$ have to be added incoherently. In Figure 2, the propagation of the single beams from the light source to all points of the substrate, and from there to an idealized pointwise detector is shown, according to the Huygens-Fresnel principle.

**Figure 1.** Spatially different polarization states resulting at an interface of two adjacent materials with a purely incident $p$-polarization (defined through the plane of incidence) at an angle of incidence of $45^\circ$.

**Figure 2.** Reflection polarimetry measurement configuration showing the sample and the light source reference frames.

**Keywords:** metamaterials, decoherence, depolarization

**Acknowledgment:** The authors acknowledge the ECH2020 grant No.692034 (TwinFusyon).

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IP-3

Probing spectral weight transfers using high-energy optical conductivity in oxides heterostructures and 2-dimensional system

Andrivo RUSYDI
National University of Singapore

INTRODUCTION

In this talk we will demonstrate potency of a combination of spectroscopy ellipsometry, synchrotron-based vacuum ultraviolet reflectivity and dc conductivity, to probe spectral weight transfers in correlated electron systems. Such a combination experimental method leads to a stabilized Kramers-Kronig transformation in a broad energy range and is powerful to reveal electronic and magnetic structures in complex systems [1,2].

We, first, discuss the observed high-energy spectral weight transfers associated with a sharp insulator-metal transition in LaAlO$_3$/SrTiO$_3$. Different mechanisms of charge transfer and redistribution are observed in LaAlO$_3$/SrTiO$_3$ as a function of LaAlO$_3$-film-thickness and most of charges are localized [3,4]. In fact, in case of SrTiO$_3$, we observe electron-electron (e-e) and electron-hole (e-h) interactions yielding to different type of excitons, resonant excitons and bound Wannier-like exciton with an unexpectedly higher level of delocalization [5]. Such as surprisingly strong e-e and e-h in SrTiO$_3$, perhaps, is one of main reasons for rich physical phenomena in SrTiO$_3$ based systems, including LaAlO$_3$/SrTiO$_3$ heterostructures.

In the second part of the talk, if time permits, we apply this method to unraveling local spin polarization of Zhang-Rice singlet in lightly hole-doped cuprates[6] and a new type of plasmons in SrNbO$_3$[7,8]. In cuprates, we observe a surprisingly strong spin polarization of the local spin singlet with enhanced ferromagnetic correlations between Cu spins near the doped holes. The changes of the local spin polarization manifest strongly in the temperature-dependent optical conductivity at $\sim$7.2 eV, with an anomaly at the magnetic stripe phase ($\sim$ 25 K), accompanied by anomalous spectral-weight transfer in a broad energy range. Supported by theoretical calculations, we also assign high-energy optical transitions and their corresponding temperature dependence, particularly at $\sim$2.5, $\sim$8.7, $\sim$9.7, $\sim$11.3, and $\sim$21.8 eV. Our result shows the importance of a strong mixture of spin singlet and triplet states in hole-doped cuprates and demonstrates a new strategy to probe local magnetic correlations using high-energy optical conductivity in correlated electron systems.

References
Single theoretical framework for plasmonic waveguide design for nanolasing and four-wave mixing

Guangyuan Li *1,2, Stefano Palomba1,3 and C. Martijn de Sterke1,2

1 Institute of Photonics and Optical Science (IPOS), School of Physics, The University of Sydney, Australia.
2 Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), School of Physics, The University of Sydney, Australia.
3 Australian Institute for Nanoscale Science and Technology (AINST), The University of Sydney, Australia.
(E-mail: guangyuan.li@sydney.edu.au)

INTRODUCTION

Lasers and nonlinear photonic devices based on frequency conversion process, specifically degenerate four-wave mixing (DFWM), are key photonic components for generating or amplifying coherent optical signals in diverse applications. Conventional devices are limited by the diffraction of light, whereas this limit can be overcome by using plasmonic waveguide modes. Plasmonic nanolasers [1] and plasmonic DFWM devices [2], have evolved separately because their underlying physics is totally different. Since 2009, both types of devices follow the plasmonic waveguide designs used in the first demonstrations. After an initial rapid progress, both areas are at an impasse.

RESULTS AND DISCUSSION

In order to design superior waveguides, a plasmonic nanolaser requires (i) the maximum Purcell factor $F_{\text{max}}$ of the waveguide mode should be as large as possible, and (ii) the threshold gain $g_{\text{th}}$ to compensate the loss should be as low as possible; a plasmonic DFWM device requires (i) the maximum driving power $P_{0,\text{max}}$ for reaching the material’s nonlinear strength $\Delta n_{\text{max}}$ should be low, and (ii) the conversion efficiency $\eta$ should be high. We reformulate these requirements into (i) a small effective area $A_{\text{eff}}$ since $F_{\text{max}} = \frac{3}{\pi} \frac{A_{0}}{A_{\text{eff}}}$ and $P_{0,\text{max}} = A_{\text{eff}} I_{\text{max, bulk}}$, and (ii) a large $k_0 g_{\text{th}}$ or a large $F/\Delta n_{\text{max}}$ since $F$ quantifies the maximum conversion efficiency via $\eta_{\text{max}} = \frac{4F^2}{27}$, which is achieved at the optimal interaction length $L_{\text{opt}} = \ln(3) L_{\text{att}}$ with $L_{\text{att}}$ the attenuation length [3]. In other words, we propose a single theoretical framework for the waveguide design for both lasing and DFWM in lossless and in plasmonic waveguides, in spite of the distinct physics.

With this framework, we perform a broad comparison of plasmonic waveguide configurations. Figure 1 shows that the best performing configurations can be classified into three families typified by $\text{MDM}$, $\text{MDA}$ and $\text{MDHA}$. Here ‘M’ means the lossy metal, ‘D’ is the active dielectric with gain/nonlinearity, ‘H’ and ‘L’ are high-index and low-index dielectric, and ‘A’ is air. Results show that the characteristics of each plasmonic configuration for use as a nanolaser and as a DFWM device are essential the same, except that nanolasers need a thin buffer layer to avoid quenching. In the deep-subdiffraction region, the $\text{MDM}$ family is the best; whereas in the moderate- and near-subdiffraction regions, the $\text{MDHA}$ family is the best. For plasmonic nanolasers, we discover that a high-index buffer performs better than a traditional low-index buffer because the ‘H’ layer also improves the confinement in the active ‘D’ medium. This leads to two novel and superior designs, the $\text{MDHM}$ and the $\text{MDHA}$, which have even better performance than state-of-art $\text{MLDLM}$ and the $\text{MLDA}$ designs in the literature. More importantly, the ‘H’ layers can be a semiconductor and thus can enable electrical pumping for...
plasmonic nanolasers. The combination of better performance and novel capacities make the conventional designs superfluous, and may solve the long-standing challenges of low-threshold, electrically pumped plasmonic nanolasers. Figure 2 shows the best performing MHDHM design for nano-lasing and MDHM design for DFWM, with the thin ‘H’ buffer the only difference. This may inspire single devices acting as two functions, nanolasers and nanoscale nonlinear DFWM devices, depending on the way they are driven [4].

Figure 1. (a) $k_0 / g_{th}$ for nanolasers and (b) $\mathcal{F}/\Delta n_{max}$ for DFWM devices versus normalized effective area $A_{eff}/A_0$ as the D layer thickness $t_D$ decreases from 1,300 nm to 5 nm or 20 nm. Blue, green, yellow and white regions mean deep-, moderate-, and near-subdiffraction, and diffraction limited regions, respectively. $A_0 = \lambda/(2n_0)$ is the diffraction-limited size with $n_0$ the D layer’s refractive index. Configurations including quenching are shown by dashed curves in (a).

Figure 2. Schematics of the best performing MDHA and MHDHA plasmonic waveguide designs for (a) DFWM, (b) optically pumped nano-lasing, and (c) electrically pumped nano-lasing. The only difference on the designs is the additional thin ‘H’ buffer layer in nanolasers to avoid quenching.

Keywords: Plasmonic waveguide, nanolasers, four-wave mixing.

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References
IP-5

Funneling of Photonic Energy into a Point Space

Yong-Hee Lee and Myung-Ki Kim*

1Department of Physics, Korea Advanced Institute of Science and Technology (KAIST)
Daejeon 305-701, South Korea
*KU-KIST Graduate School of Converging Science and Technology, Korea University
145 Anam-ro, Seongbuk-gu, Seoul 136-701, Korea

INTRODUCTION

Recent progresses on metallic nano-resonators and their nonlinearities are summarized. A three-dimensionally (3D) tapered metallic nano-gap resonator with modal volume of $\sim 1.0 \times 10^{-7} \lambda^3$ is to be discussed in detail. From a 4-nm-air-gap gold resonator, second harmonic signals are generated in a point-like space where the electromagnetic energy is highly concentrated. The nonlinear signal from the 4-nm-gap resonator is found to be stronger than that from a 100-nm-gap counterpart by a factor of $>27,000$. Rich nonlinear optical characteristics observed from nm-scale proteins and ZnSe/ZnS quantum dots and that are trapped in the nano-gap will also be discussed. The possibility of extreme photon squeezing could open up a new platform for bio-nanoscopy and small space nonlinear optics with minimal pump power.

References

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Localized surface plasmon resonance of Gold nanorods to enhance absorption and emission in NaYF$_4$:Yb, Er/SiO$_2$ core-shell type upconversion nanoparticles

Robeth Viktoria Manurung$^*$1, Yusuf Nur Wijayanto1, Chien Ting Wu2, Dadin Mahmudin1, Surojit Chattopadhyay3

1 Research Center for Electronics & Telecommunication, Indonesian Institute of Sciences, Bandung, Indonesia.
2 Nano Device Materials Characterization Division, National Nano Device Laboratories, Hsinchu, Taiwan.
3 Institute of Biophotonics, National Yang Ming University, Taipei, Taiwan.
(E-mail: robe007@lipi.go.id)

INTRODUCTION

The low quantum yield is a major problem for the application of lanthanide doped up-conversion luminescent nanoparticles (UCNPs) in optical bioimaging.1 UCNPs absorb low energy near-infrared (NIR) light and emit high-energy shorter wavelength photons by multiphoton absorption.2 The relatively low quantum yield prompts a need for developing methods for fluorescence enhancement. An engineered plasmonic gold nanorods, specifically designed to couple with the 980 nm radiation, is shown to enhance the near infrared-to-visible upconversion luminescence.3,4 The synthesis of the UCNPs, NaYF$_4$:Yb, Er was done by thermal decomposition process which involves dissolving organic precursors in high-boiling-point solvents such as oleic acid (OA), and octadecene (ODE).5 The core–shell structure NaYF$_4$:Yb, Er/SiO$_2$ microspheres were prepared by coating the NaYF$_4$:Yb,Er phosphors by silica, as spacer, via reverse microemulsion process.5 Scanning electron microscopy, transmission electron microscopy, specific area electron diffraction, and photoluminescence were applied to characterize these samples.

Here, we report a novel plasmon-enhanced fluorescence system between gold nanorods and NaYF$_4$:Yb, Er/SiO$_2$ core-shell structure in which the aspect ratio of the gold nanorods was tuned to resonate with the absorption band of the UCNPs. By modulating the aspect ratio of gold nanorods on Si substrate, localized surface plasmon resonance (LSPR) wavelength at 980 nm was obtained, matching the native excitation of UCNPs resulting in maximum enhancement. The proposed design of Metal Enhanced Fluorescence (MEF) of Gold nanorods and UCNPs shows in Figure 1.

Results and Discussion

In our proposed design, fixed volume core-shell UCNPs dispersed on clean silicon served as the control (Figure 1a). Gold nanorods (Au NRs) was prepared uniformly on silicon substrate for the maximum
luminescence from the same volume of UCNPs dispersed on them (Figure 1b). We have carefully prepared Au NRs dispersed on c-Si substrates by drop wise and optimized for the best MEF. Although a range of enhancement factors have been reported in the literature, these values should be carefully compared. The enhancement factors depend on a lot of parameters including UCNPs size, number density, dispersion (solid or solution state), shell thickness, luminescent band, power and frequency of excitation, and several others. In this study, we report a high enhancement factor of ~16 for the green emission band at 540 nm for the Er doped UCNPs as showed in the following figure.

![Figure 2](image)

**Figure 2.** Up-conversion luminescence spectra, and power dependence of the (a) 520, (b) 540, and (c) 655 nm peak emission of NaYF_4:Yb,Er/SiO_2 on Si only (square) and Si with Au NRs (triangle). (d) The maximum enhancement factor of 520, 540, and 655 nm peak emission from Si and Au NRs sample configuration normalized with respect to the control (Si only) assumed to be 1. Laser power range from 0.3-1.8 W was used in (a-c). The line joining the data points in (a-c) represents linear fits to the data points (symbols).

**Keywords:** gold nanorods, metal enhance fluorescence, plasmonic field, lanthanide, silica, up conversion nanoparticles.

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**References**
CP-2

Isotropic and Anisotropic Parts for the Susceptibility Tensor Calculated Using Simplified Bond-Hyperpolarizability Model

Adalberto Alejo-Molina*1 and Hendradi Hardhienata2

1 CONACYT Research Fellow—Center for Research in Engineering and Applied Science (CIICAp), Institute for Research in Pure and Applied Science (IICBA), UAEM Cuernavaca, Mor. 62209, Mexico. (E-mail: adalberto.alejo@uaem.mx)
2 Department of Physics, Bogor Agricultural University, Jl. Meranti, Gedung Wing S, Kampus IPB Darmaga, Bogor 16680, Jawa Barat, Indonesia. (E-mail: hendradi@ipb.ac.id)

INTRODUCTION

In general a tensor can be separated in the symmetric and the antisymmetric part or in the isotropic and the anisotropic part [1]. The latter procedure is our interest here, because for second harmonic generation (SHG) on crystals for the surface or the bulk, a common technique is to rotate the crystal around the normal (usually labeled z-axis). This technique is known as Rotational Anisotropy of the SHG (RA-SHG) and the experimental results can be well described using Simplified Bond-Hyperpolarizability Model (SBHM) [2]. Then the intensity of the SH (second harmonic) signal is a function of the azimuthal angle and changes sinusoidally with an integer number of periods for a complete revolution of the crystal.

The SHG response of an object is described by its susceptibility tensor, the polarization is given according to SBHM by [3]

\[
\vec{P} = \frac{1}{V} \sum \left[ \alpha_{ij} \hat{b}_i \otimes \hat{b}_j \right] \vec{E} + \frac{1}{V} \sum \left[ \alpha_{2ij} \hat{b}_i \otimes \hat{b}_j \otimes \hat{b}_j \right] \vec{E} \otimes \vec{E} + \ldots
\]

where \( V \) is the volume of the conventional cell, \( \alpha_{ij} \) denotes the linear polarizabilities, \( \alpha_{2ij} \) and \( \alpha_{3ij} \) are the first and second order hyperpolarizabilities and \( \hat{b}_j \) s are the unit vectors in the directions of the atomic bonds; whereas \( \vec{E}(\omega) \) is the incident electric field with either s- or p- polarization and even a DC field can be modeled for example for describing electric field induced second harmonic (EFISH) generation [4]. However, we are going to focus our discussion about the tensorial nature of the susceptibility.

For a second-order nonlinear phenomena, there is a third-rank tensor which corresponds with the susceptibility denoted by \( \chi^{(2)} \), with 27 elements in general and it can be represented by a column matrix with 3 rows, each row a \( 3 \times 3 \) matrix too. In the same way, a general fourth-rank tensor (\( \chi^{(3)} \)),

\[
\chi^{(3)} = \chi^{(3)} \vec{E} \vec{E} \rightarrow \chi^{(3)} \vec{E} \vec{E} \vec{E}
\]
can be represented as a $3 \times 3$ matrix which also has a $3 \times 3$ matrices as elements. Thus, there are 81 elements.

**RESULTS AND DISCUSSION**

The (susceptibility) third-rank tensor can be transformer by a point operation

$$\chi'_{ijk} = R_{im}R_{jn}R_{ko}\chi_{mnq},$$

where the $R_{ab}$ is a matrix defining a symmetry operation or could be a general rotation around a certain axis through an arbitrary angle $\theta$. For a general rotation $\chi'_{ijkl} = \chi'_{ijkl}(\theta)$, and then it can be separated into isotropic and anisotropic part. Isotropic part is invariant under rotations and the anisotropic part should have all the information about the azimuthal dependence. A specific example of the anisotropic part of the SBHM susceptibility tensor for facet (001) of silicon is

$$\tilde{\chi}^{[2]}_{ANM} = \begin{pmatrix}
0 & 0 & 2S[\alpha_u \cos^2 \phi + \alpha_d \sin^2 \phi] \\
0 & 0 & 2(\alpha_u - \alpha_d)S \sin 2\phi \\
2S[\alpha_u \cos^2 \phi + \alpha_d \sin^2 \phi] & 0 & 0 \\
0 & 0 & 2(\alpha_u - \alpha_d)S \sin 2\phi \\
2(\alpha_u - \alpha_d)S \sin 2\phi & 2S[\alpha_u \sin^2 \phi + \alpha_d \cos^2 \phi] & 0 \\
2S[\alpha_u \cos^2 \phi + \alpha_d \sin^2 \phi] & 2(\alpha_u - \alpha_d)S \sin 2\phi & 0 \\
0 & 2S[\alpha_u \sin^2 \phi + \alpha_d \cos^2 \phi] & 0 \\
0 & 0 & 2(\alpha_u + \alpha_d)\cos^2(\beta / 2)
\end{pmatrix},$$

whereas the isotropic part is

$$\tilde{\chi}^{[2]}_{ISO} = (\alpha_u - \alpha_d)S \sin (2\phi)\tilde{\varepsilon}$$

where $\tilde{\varepsilon}$ is the Levi-Civita tensor and $\phi$ is an arbitrary angle due to the choose of the $\hat{b}_j$s.

**Keywords:** Generation, Harmonic, Isotropic, Nonlinear, Optics, Tensor.

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**References**
The MoS₂ Saturable Absorber for Eye-safe Mode-locked Fiber Laser Generation

A. A. Latiff*, S. W. Harun², H. Ahmad³ and M. C. Paul⁴

1, 3 Photonics Research Centre, University of Malaya, Malaysia. (E-mail: anasabdullatif@utem.edu.my, harith@um.edu.my)
2 Photonics Engineering Laboratory, Faculty of Engineering, University of Malaya, Malaysia. (E-mail: swharun@um.edu.my)
4 Fiber Optics and Photonics Division, CSIR-Central Glass and Ceramic Research Institute, India. (E-mail: paulmukul@hotmail.com)

Stable mode-locked fiber laser operating at 2-micron region is experimentally demonstrated based on molybdenum disulfide (MoS₂) saturable absorber (SA). The MoS₂ was mechanically exfoliated from the commercial available MoS₂ crystal by using clear scotch tape to form a MoS₂ tape. The MoS₂ tape is integrated into the thulium-holmium co-doped fiber laser THDFL cavity. **Figure 1** illustrates the schematic diagram for THDFL cavity. The 5 m long single-clad thulium-holmium co-doped fiber (THDF) (CorActive, TH550) with 11.5 µm core diameter was used as a gain medium. This THDF is expected to generate effective lasing between 1960 nm to 2160 nm by 1552 nm wavelength pumping. The GVD parameter for THDF is about -72.8 ps²/km. This THDF has a core NA and absorption of 0.14 and 100 dB/m at 790 nm, respectively. The nonlinear absorption properties of the MoS₂ tape is shown in inset graph of **Figure 1**. The saturable absorption, non-saturable absorption, and saturation intensity are obtained to be 10 %, 12 %, and 100 MW/cm², respectively. This large saturable absorption of 10 % is expected to be able to suppress a wave breaking effect in the mode-locked fiber laser, and thus improves the attainable pulse energy. For this configuration, the rest of the cavity is connected by 6.4 m long SMF-28. Thus, contributing to the total cavity length of 21.4 m which also includes a scandium doped fiber (ScDF). The total net GDD in the cavity is operated in anomalous dispersion condition of -2.146 ps². The 10 m long ScDF was added in the cavity to gain sufficient nonlinearity effects for a mode-locked generation. The ScDF has a core composition of SiO₂-GeO₂-Sc₂O₃ with core diameter and NA of 7.5 µm and 0.12, respectively.

Once the MoS₂ tape is integrated into the THDFL cavity, the occurrence of mode-locking operation can be observed from 775 mW to 852 mW pump power. The peak lasing is observed to operate at a wavelength of 1979 nm with a 3-dB spectral bandwidth of 2.1 nm (160 GHz). Under the mode-locking regime, the obtained output power increases from 13 mW - 20 mW. This gives the optical-to-optical efficiency of 8.9 % with a maximum pulse energy of 2.2 nJ. A stable pulse train of mode-locked THDFL with a pulse period of 109.74 ns is obtained. The measured repetition rate of 9.12 MHz is corresponding to the total cavity length and also the obtained pulse period. Through the time-bandwidth product of sech² pulse profile, the minimum possible pulse width size is relatively determined about 1.97 ps. A pulse stability can be confirmed through the investigation on RF spectrum. **Figure 2** shows the RF spectrum of the mode-locked THDFL with the existence of two harmonics at 9.12 MHz and 18.6 MHz. The fundamental frequency of repetition rate has a signal-to-noise ratio (SNR) of 45 dB, validates this generation of mode-locked THDL is stable.

**Keywords:** Fiber laser; mode-locking operation; real saturable absorber; 2-micron region
Figure 1. Schematic diagram of THDFL. Inset graph is nonlinear absorption properties of MoS$_2$ tape.

Figure 2. RF spectrum with 30 MHz span.

References
CP-4

$k$-space analysis of photonic crystal slab resonator bonded on a high index substrate, with small mode-volume and low optical-loss

Indra Karnadi*1,2, Putu E. Pramudita2, Hoon Jang2 and Yong-Hee Lee2

1 Department of Electrical Engineering, Universitas Kristen Krida Wacana (UKRIDA), Jakarta Barat 11470, Indonesia.
2 Department of Physics, Korea Advanced Institute of Science and Technology (KAIST), Daejeon 34141, South Korea.
*indra.karnadi@ukrida.ac.id

In this report, we present a wave-vector ($k$)-space analysis of a small mode-volume photonic crystal (PC) slab resonator bonded on a high index substrate. In general, mechanical and thermal stability of PC slab resonator can be improved by bonding it on a high index substrate such as SiO$_2$ or sapphire. However, the presence of substrate reduces the index contrast which increases the radiation loss from the PC resonator or cavity to the bottom cladding. In addition, the presence of substrate also breaks the vertical symmetry of the structure that allows the transverse-electric (TE)-like cavity mode to couple with the transverse-magnetic (TM)-like slab mode. As a result, it is difficult to realize a small mode-volume cavity on a substrate with low optical loss at the same time.

Figure 1. The electric field intensity profile of a) 2D and b) 1D PC bonded on sapphire substrate ($n = 1.77$) calculated by 3D finite-difference-time-domain simulation.

Here, we show that by employing 1D instead of 2D structure as a PC platform, a small mode-volume cavity with low optical loss on substrate can be realized. By applying lattice tapering to make a cavity in 1D PC slab, the substrate loss can be suppressed significantly while keeping the cavity mode volume small. Moreover, the inhibition of TE-TM coupling due to parity mismatch in this structure further reduces the optical loss. Figure 2 shows the $k$-space profile of the cavity mode of the 2D and 1D PC bonded on a high index substrate (in this case sapphire). Fig. 2b shows that there is a negligible cavity components inside the
leaky zone that explains the origin of low optical loss in this structure.

Figure 2. k-space profile of the cavity mode of a) 2D and b) 1D PC bonded on sapphire substrate (n = 1.77). The solid white circles indicate to the equifrequency contours of the TM-like mode whereas the dash white circle indicates the sapphire light-cone.

Keywords: k-space analysis, low-loss, small mode-volume, photonic crystal resonator, TE-TM coupling.

References
Nickel Oxide film saturable absorber for mode-locking operation at 1.55-micron region

Sulaiman W. Harun*1, A. A. Latiff2 and H. Ahmad2

1Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
(E-mail: swharun@um.edu.my)
2Photonics Research Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia, Country.

INTRODUCTION

Ultrafast mode-locked fiber lasers have obtained many attentions in recent years due to their potential applications in many areas including medicine, optical sensing, material processing, telecommunication, etc. [1]. The laser can be realized by inserting a saturable absorber (SA) device inside the laser cavity. To date, there are many types of SAs that have been employed in passively mode-locked fiber lasers [2]. The interests on transition metal oxides such as zinc oxide (ZnO) [3] and titanium dioxide (TiO2) [4] are also increasing. However, up to now, a Nickel Oxide (NiO) based SA for mode-locked EDFL has yet to be reported.

Here, we demonstrate the generation of mode-locking pulse train in Erbium-doped fiber laser (EDFL) cavity using Nickel Oxide (NiO) based saturable absorber (SA) as a mode-locker. NiO was synthesized by using sonochemical method before it is embedded into poly ethylene oxide (PEO) film through solution casting technique. A small piece of the fabricated NiO film was sandwiched between two ferrules in the EDFL cavity. By adding 180 m single mode fiber (SMF) in the ring cavity, a stable 1 MHz repetition rate of mode-locked operation at 1558 nm is achieved. At 197.5 mW pump power, the proposed mode-locked EDFL has output power and pulse energy of 3.35 mW and 3.36 nJ, respectively. This study may be the first demonstration of mode-locked EDFL using NiO-based SA. The results indicate that NiO is the promising material used in ultrafast photonic applications.

RESULTS AND DISCUSSION

The nanostructure NiO was synthesized by a facile sonochemical method. It was then used to fabricate NiO/poly ethylene oxide (PEO) composite film based on solution casting technique. The thickness of the prepared composite film was measured to be 0.196 mm. The saturation intensity and modulation depth of the NiO are obtained to be 0.018 MW/cm2 and 39 %, respectively (Fig. 1(a)). The NiO based SA was integrated into the fiber laser cavity (Fig. 1(b)) by sandwiching a 1mm x 1 mm piece of the NiO/PEO film between two standard FC/PC fiber ferrules via a fiber connector after depositing with index matching gel onto the fiber ends. The net cavity length of the proposed EDFL is approximately 197 m and it operates in anomalous dispersion region of ~4.3 ps2. The additional SMF was added in the cavity to increase cavity length and thus promote mode-locking action.
**Figure 1.** (a) Nonlinear transmission of absorption profile (b) laser configuration (c) film image (d) output spectrum (e) temporal characteristics

**Keywords:** Mode-locked lasers, Metal oxide polymer film, passive saturable absorber

**References**

Non-Iterative Model Based Image Reconstruction of Diffuse Optical Tomography Based on the DE and RTE in Quality Control on Agricultural Produce Studies

Vebi Nadhira¹, Agah D. Garnadi², E. Juliastuti³, Deddy Kurniadi⁴, and Yoko Hoshi⁵

¹,²,³,⁴ Instrumentation and Control Research Group, Institute Technology of Bandung, Indonesia
(E-mail: vebi@tf.itb.ac.id, yuliast@tf.itb.ac.id, kurniadi@tf.itb.ac.id)
² Departemen of Mathematics, Bogor Agricultural University, Indonesia
(E-mail: agah.garnadi@gmail.com)
⁵ Department of Biomedical Optics, Hamamatsu University School of Medicine, Japan
(E-mail: yhoshi@hama-med.ac.jp)

INTRODUCTION
Several researchers have been developing the reconstruction methods to reduce the computation time in optical tomography (OT) with the regularization parameter selection method, a fast forward solver of radiative transfer equation (RTE), non-iterative algorithm, hardware development, and signal processing approach. In this paper, we focused on study of the non-iterative image reconstruction based on diffusion equation (DE) and RTE. To avoid the iterative step, we used L-curve-based algorithm for selection k optimal automatically to obtain truncated singular value decomposition (TSVD) matrix. This matrix will derive a new well-posed problem. In forward solving, the continuous wave signal processing approach was applied in order to get a faster boundary data calculation. Furthermore, we applied a fast RTE solver that has been developed by H. Gao and H. Zhao to solve the forward problem in OT based on RTE.

Usually, the development of non-destructive evaluation (NDE) based on optical tomography (OT) method has been focused for medical application. Nevertheless, NDE OT development on other application is also interesting and promising part as described by some researcher on this field [1, 2]. This paper as well as our previous papers mainly study NDE based on OT method for agricultural product quality control [3, 4, 5]. Therefore, the experiment of internal defects monitoring on agricultural produce using OT is described on this paper to validate our proposed non-iterative model based image reconstruction (NIMoBIR) algorithm.

RESULTS AND DISCUSSION
Basically, the NIMoBIR was a development of model based image reconstruction that implemented truncated singular value decomposition and L-curve analysis to solve the ill-posed problem. These algorithm reduces the computation time to reconstruct the cross sectional area. As part of the continuing development of agricultural produce quality control based on optical tomography, potato experiment was conducted to evaluate these two non-iterative algorithms. The object was illuminated by the near infrared source from 8 positions on object’s boundary as shown in Figure 1.

Figure 1. Experimental configuration
In this experiment, we vary the position and amount of epoxy as targets on the object then we analyze the residual value between measurement and reconstructed boundary data. The experiment objects with various target positions and the reconstructed images are shown in Figure 2. The reconstructions were performed with continuous-wave domain. Based on visual analysis, in general, we can conclude that the NIMoBIR algorithm using DE is succeeded to represent the position and size of the objects. However, there are several white spots on reconstructed images that are difficult to distinguish from the presence of the target. Furthermore, this method is unable to show the separation between two targets on object. Meanwhile, as shown in Figure 2, the NIMoBIR using RTE has a better ability to separate two targets on object than the NIMoBIR using DE. However, this method still has weakness to reconstruct the target position. Furthermore, we compare the residual value from NIMoBIR DE and RTE are \( 2.52 \times 10^{-6} \) and \( 1.13 \times 10^{-9} \) respectively. These averages are relatively low, so we can conclude that both algorithms are able to reconstruct the boundary data of the real object. The result of this study indicated that these algorithms have shown promising to detect the presence of epoxy on potato which is significant for agricultural produce quality control.

**Figure 2.** The results of CW-NIMoBIR reconstruction (a) the depiction of object condition (b) The reconstructed image using RTE (c) The reconstructed image using DE.

**Keywords:** diffuse equation, non-iterative, optical tomography, potato, radiative transfer equation.

**References**


Plenary Oral Presentation Abstracts

Wednesday, 9 August 2017
IP-6

High-resolution, Label-free Tissue Imaging: Angiography, Lymphangiography, Elastography, and Polarisation Contrast Extensions of Optical Coherence Tomography and Their Applications

David D. Sampson*1,2, P. Gong1, Q. Li1, and K. Karnowski1

1 Optical+Biomedical Engineering Laboratory, School of Electrical, Electronic & Computer Engineering, The University of Western Australia, Perth, Australia
(*E-mail: David.Sampson@uwa.edu.au)
2 Centre for Microscopy, Characterisation & Analysis, The University of Western Australia, Perth, Australia

INTRODUCTION

Optical coherence tomography (OCT) strikes the balance between resolution and field of view in imaging of biological tissue. Whilst it is often not possible to resolve individual cells, it is possible to image over multiple millimeters to centimeter-scale fields of view that are critical to many applications. Relaxing the resolution scale also relaxes the demands on the stability of imaging, which is often an important advantage. Overall, it is extremely challenging to have both multiple millimeter-scale fields of view and cellular scale resolution, accepting lower resolution has disadvantage, e.g., reducing the scattering contrast that OCT relies on for imaging without labelling. In part, this tradeoff has been the motivation for examining options for other sources of contrast in OCT, but additionally such sources convey additional information not available from morphological imaging. Many sources of contrast have been examined, such as detection of the vascular and lymphatic systems, as well as assessment of the associated flow parameters of blood and lymph. As well, tissue micro-scale mechanical properties are important in understanding function and revealing pathology – imaging these properties is often referred to as elastography. Another interesting source of contrast is polarization – modification to the polarization state of the OCT signal can reveal tissue birefringence and orientation of fibrous structures, or disruption of such structures caused by disease.

In the Optical+Biomedical Engineering Laboratory, we have been interested in the development of these methods, in the development of imaging systems using them, and in their biological and medical applications. Our main themes of application include intraoperative surgical guidance for breast cancer removal, airway physiology and asthma, wound healing and, more recently, glaucoma surgery.

RESULTS AND DISCUSSION

Figure 1 shows recent examples of the main methods we have been examining [1-3]. Figure 1A) shows lymphatic vessels superimposed on blood vessels, presented in a projection en face image of the first 400 µm of the scar shown at left [1]. Such images can be used to track progression of healing versus time over many months. Figure 1B) shows an elastogram of an involved lymph node excised from the axilla, demonstrating enhanced heterogeneity of strain in the vicinity of malignant tissue [2]. Figure 1C) shows OCT (left), birefringence (middle) and histology (right) of two freshly excised breast cancer specimens, demonstrating reduced birefringence in the vicinity of malignant tissue [3]. Many more examples will be presented in the talk.
Figure 1. A) OCT angiography and lymphangiography of burn scar [1]; B) OCT elastogram of lymph node ex vivo [2]; C) OCT, birefringence and histology of two breast cancer samples captured with polarisation-sensitive OCT Microscope-in-a-Needle [3].

Keywords: angiography, biomedical optics, elastography, optical coherence tomography, polarization, wound healing

References


IP-7

LSPR-mediated high axial and temporal resolution fluorescence imaging on metal nanonanoparticle sheet

Kaoru Tamada
Institute for Materials Chemistry and Engineering, Kyushu University
(E-mail: tamada@ms.ifoc.kyushu-u.ac.jp)

Recently, the demand of super-resolution fluorescence microscopies is increasing in the field of cell biology, because of the requirement to investigate molecular-level of dynamic reactions in/near the cells [1]. These super-resolution microscope techniques exhibit an advantage in lateral resolution, but not so superior in axial resolution, and rather weak in temporal resolution because of scanning property. Total internal reflection fluorescence (TIRF) microscopy is known to provide highest axial-temporal resolution and suitable for real-time imaging the cell/substrate contact regions. However, the problem of these state-of-the-art technologies are the cost of apparatus, which prevents them to be a standard equipment in basic laboratories.

Our latest paper reports our original technique for visualizing cell-attached nanointerfaces with extremely high axial resolution using homogeneously excited localized surface plasmon resonance (LSPR) on a self-assembled metal nanoparticle sheet [2]. This LSPR sheet can confine and enhance the fluorescence at the nanointerface, which provides high signal-to-noise ratio images of focal adhesion at the cell-attached interface. The advantage of this LSPR-assisted imaging technique is, not only the high axial and temporal resolutions, but also its usability, which provides comparable or better quality of images to TIRF microscopy even under a conventional epifluorescence microscope.

Homogeneous silver (AgMy; \(d = 5\) nm) and gold (AuOA; \(d = 10\) nm) nanoparticles were synthesized as described in our previous study [3]. The metal nanoparticle 2D sheet (monolayer) were fabricated by self-assembly at air-water interface [4]. The sheet was transferred onto hydrophobized cover glass by Langmuir-Schaefer method.

Fig. 1a presents a schematic drawing of the confined optical field at the AuOA sheet/water interface and at the TIR interface to show the difference in the visualization depth against fluorescence imaging. Fig. 1b shows the fluorescence images of PE-labeled actin filaments in the rat basophilic leukemia (RBL-2H3) cells in water. In the images, the top half surfaces were covered by the AuOA sheet, and the bottom half surfaces were bare glass. The effect of confined light due to the AuOA sheet was obvious in the images. Fluorophores close to the AuOA sheets were selectively excited, and the detailed structure of cell-attached interface (focal adhesion) was clearly visualized on the AuOA sheet, whereas these features were screened by the sheet-like actin layer

![Fig. 1a Schematic drawing of the depth of the LSPR and evanescent fields on the AuOA and under regular TIRF microscopy.](image)

![Fig. 1b Fluorescence images of actin filaments in RBL-2H3 cells in aqueous media.](image)
and blurred on glass (regular TIRF image). Although the illumination depth must be shorter on the AuOA sheet than on glass (~1/10 in calculation), the emission intensity was eventually comparable with the aid of LSPR-enhanced fluorescence.

**Fig. 2** shows the image taken under an epifluorescence microscope for the FITC-labeled cells on the AuOA sheet covered with 10 nm SiO$_2$ layer. We obtained the fluorescence image of cells that show elongated morphology, which is identical to that observed on glass but is highly sensitive to the cell-contacting nanointerfacial structure. Because the lateral resolution of the original image appeared to exceed the TIRF camera resolution (160 nm/pixel), we switched to a super-resolution digital CMOS camera (ORCA-Flash 4.0, Hamamatsu, Japan), which delivers 65 nm/pixel lateral resolution.

This technique provides a chance of high-resolution imaging even under conventional epifluorescence microscopy, which will open a great chance for all biochemist and medical scientist to start a state-of-art molecular imaging by use of their own microscope.

**Keywords:** metal nanoparticle, self-assembly, localized surface plasmon, bio-imaging, adhesive cells

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**References**
Optical properties and dynamics of excitons in self-assembled tubular molecular aggregates

Jasper Knoester*1

1 University of Groningen, Zernike Institute for Advanced Materials, The Netherlands. (E-mail: j.knoester@rug.nl)

INTRODUCTION
Self-assembly is widely recognized as an attractive route to prepare nanoscale functional materials. Many examples of self-assembled molecular aggregates occur in nature or have been prepared synthetically. Aggregates consisting of natural or synthetic dye molecules exhibit intriguing optical functionalities, such as efficient light harvesting, optical bistability, ultrafast emission (superradiance), and efficient excitation energy transport. These properties are caused by collective optical excitations, Frenkel excitons. In this talk, I will present recent results on nano-tubular molecular aggregates [1], which are self-assembled aggregates with a cylindrical shape, typically of diameters in the order of 10 nm and lengths up to 100’s of nanometers or microns. I will first address the basic theory of Frenkel excitons in molecular assemblies and their localization behavior and dynamic properties. I will then consider several examples of tubular aggregates that we recently have studied together with experimental groups and discuss our new insights into the optical properties and exciton dynamics of these particular systems. Throughout the talk, connections between theory and experiment are made.

RESULTS AND DISCUSSION
An important effect in molecular aggregates concerns the localization of the Frenkel excitons as a consequence of environment induced disorder. This may be detrimental to optical properties. I will discuss, as we have recently shown [2], that in tubular aggregates, the excitons are much more robust against the effects of disorder as compared to often studied chain-like molecular aggregates. This explains many experimental observations, especially with regard to strong polarization properties of the optics of tubular aggregates. Next, I will address a specific class of tubular aggregates, namely double-walled nanotubes of carbocyanine molecules (Fig. 1, left) [3,4,5]. Their optical properties may be understood by assuming a herring-bone type packing the molecules within the cylindrical walls. Most recently, together with synthetic chemists and spectroscopists, we have shown that by substitution of just four halogen atoms in each molecule it is possible to change the diameter of the tube, opening new perspectives to intriguing studies and applications of these type of systems [6]. Finally, I will address our studies of single-walled nanotubular aggregates of TPPS4 molecules, which are porphyrin derivatives (Fig. 1, right) [7,8,9]. Specifically, I will address our most recent work where together with the experimental group of Libai Huang at Purdue University we have directly probed the exciton diffusion constant in single nanotubular aggregates [10]. The results indicate that delocalization effects enhance the exciton transport. The combined possibilities to probe exciton transport in a single tube and to control the diameter of tubular aggregates is interesting in the light of recent predictions that the diffusion constant in tubular aggregates shows a universal scaling with the ratio of the diameter and the exciton delocalization size [11].
Figure 1. Left: Self-assembled double-walled tubular aggregate of cyanine dye molecules, with fluorescence spectrum [2]. Right: Self-assembled single-walled aggregate of porphyrin molecules with transient absorption spectroscopy image used to probe exciton transport [10].

Keywords: -

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References
Nonlinear Acousto-optical Interaction in Optical Waveguides

B. M. A. Rahman*1, and M. M. Rahman2

1, 2 Dept. Electrical & Electronic Engineering, City, University of London, U.K.  
(E-mail: b.m.a.rahman@city.ac.uk)

INTRODUCTION

Optical waveguides are designed to guide light by introducing materials with different refractive indices. However, as these materials also have different acoustic indices, these waveguides can also guide sound waves. The nonlinear interactions between light and sound waves is an interesting features for such waveguides and Stimulated Brillouin scattering (SBS) is such a nonlinear process. This can inhibit delivery of power above a threshold by producing an optical grating due to the electrostriction effect, which modulates the density profile of the waveguide. This is a major limiting issue in delivering high power through an optical fibre, such as fibre amplifier or laser. On the other hand, such light-sound intercations can also be exploited to develop exotic distributed temperature and strain sensors. The wavelength of reflecting light can be monitored and such a sensor is naturally distributed, unlike fibre Bragg grating based sensors. We have developed one of the best optical mode solver using H-field based finite element method [1]. However, analysis of sound wave is more complex then solving the Maxwell’s equations for electromagnetic light wave, as acoustic index is mostly anisotropic. Recently, we have also developed a full-vectorial acoustic code [2] and here we report light-sound interactions in a planar silica guide. A full-vectorial finite element based approach, exploiting structural symmetry, is used to find light-sound interactions between the fundamental quasi-TE optical mode and fundamental and higher order transverse acoustic modes in a Ge-doped planar silica waveguide [3].

RESULTS AND DISCUSSION

The height and width of the core are taken as 3 μm and 6 μm, respectively and core is doped with 10% Ge to increase both the optical and acoustic indices to ensure that optical mode is guided at the operating wavelength of $\lambda_0 = 1550$ nm. This waveguide also supports higher order longitudinal and shear acoustic modes. Variations of the phase velocities with the acoustic frequency for the several shear modes are shown in Fig. 1. Here, only shear or transverse modes are shown. It can be observed that as the operating frequency is reduced the acoustic velocity is increased, which reduces the effective acoustic index and so the mode approaches its cutoff. It can also be noted that for higher order modes, their cutoff acoustic frequencies are higher. The dominant $U_X$ vector profile of the $U_{X11}$ acoustic mode is similar to the dominant $H_Y$ field profile of the quasi-TE mode, and their overlap was significantly high as shown by a blue curve in Fig.2 (left hand scale). On the other hand, overlap of this $H_Y$ profile with the non-dominant profiles of the fundamental acoustic modes, with odd symmetry will cancel out and the acousto-optical interactions would be negligible. The overlap of the optical field with the higher order transverse $U_{X31}$ mode is also carried out and found to be below 5%, shown by the green curve (right hand scale). However, it should be noted that although overlap of $U_X$ profile for the $U_{X21}$ mode with the optical field is zero as the former has odd symmetry, but its non-dominant $U_Z$ profile may have a considerable overlap, as this have an even symmetry. It is observed to have near 20% overlap, shown by a red curve (right-hand scale).
However, mode profiles in a waveguide with strong acoustic index contrast are more complex, often higher displacement vectors exists at the material interfaces. Besides that, magnitude of the non-dominant displacement vectors can also be high. So, to study such complex light-sound interaction in sub-wavelength optical waveguides, as to exploit such exotic nonlinear processes, the non-dominant components should also be considered by using full-vectorial acoustic and optical modal approaches, as presented here.

**Fig. 1.** Variations of the phase velocities with acoustic frequencies for the shear modes

**Fig. 2.** Variations of overlap of the $H^Y_{11}$ mode with the $U^{X}_{11}$, $U^{X}_{21}$ and $U^{X}_{31}$ modes with the guide width

**Keywords:** Optical waveguides, Acoustic modes, SBS, Finite element method.

**Acknowledgment**

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**References**

Application of 2D Materials in Generating Q-Switched Linear Pulses

Harith Ahmad, Kavintheran Thambiratnam and Sulaiman Wadi Harun

University of Malaya, Malaysia

INTRODUCTION

The emergence of graphene has pushed significant research efforts to explore the application of various 2-dimensional (2D) materials for various photonic applications. Of particular interest is the use of these materials as saturable absorbers (SAs) to control light transmission in an optical cavity. Lately however, research interest have now expanded beyond graphene and other carbon derivative 2D materials such as graphene oxide and carbon nanotubes. New research efforts have focused on transition-metal dichalcogenides (TMDs), a large family that includes 2D materials such as MoS$_2$, WS$_2$ and MoSSe$_2$ among others, all of which exhibit characteristics comparable to graphene and other carbon derived 2D materials. In this talk, a brief introduction will be given on the principles of Q-switching and how these materials behave in cavities with various doped fibers such as erbium, thulium and praseodymium doped fibers as linear gain media. Q-switched outputs have many interesting applications in areas such as machining, the fabrication of new materials and spectroscopy.

References

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Wireless Terra-Hertz Detection Using Metamaterial Antenna on Optical Modulator

Yusuf N. Wijayanto¹, Ashif A. Fathan¹, Robeth V. Manurung¹, Atsushi Kanno², Hiroshi Murata³, Dadin Mahmudin¹, Tetsuya Kawanishi⁴, and Purwoko Adhi¹

¹ Research Center for Electronics and Telecommunication, Indonesian Institute of Sciences (LIPI), Indonesia
² National Institute of Information and Communications Technology (NICT), Japan
³ Graduate School of Engineering Sciences, Osaka University, Japan
⁴ Waseda University, Japan
(E-mail: yusuf.nur.wijayanto@lipi.go.id)

INTRODUCTION

Recently, wireless signal are commonly used for communication and sensing. High operational frequency in terra-hertz (THz) band is promising for broadband wireless communication and high resolution sensing [1]. However, THz wireless signal has relatively large loss of about 1dB/km in air [2]. In order to compensate the drawback, optical fiber link can support the THz wireless link by adopting radio-over-fiber (ROF) technology since the optical fiber has extremely low lightwave propagation loss of 0.2dB/km [3]. In the ROF technology, a conversion device between wireless THz and optical signals is required. We have proposed and reported several devices using patch antennas on optical modulator for operating in microwave band [4,5].

In here, we propose a metamaterial antenna on optical modulator for wireless THz detection through ROF technology. The proposed device is shown in Figure 1 by consist of a planar metal metamaterial structure as an antenna on electro optic (EO) crystal as the substrate and an optical waveguide locate under the antenna. As the basic principle operation as following: when wireless THz signal is detected by the metamaterial antenna. The received THz electric fields are induced along the metamaterial antenna as shown in Figure 2. In the same time, laser is propagated to the optical waveguide. As a result, the lightwave can changed its phase due to effect of THz electric fields and EO effect of the substrate. Therefore, the wireless THz signal can be modulated to the lightwave signal using the proposed device.

RESULTS AND DISCUSSION

When lightwave propagate in the optical waveguides, the THz electric fields along the gap in the metamaterial antenna can be collected through EO modulation using the Pockels effects of the EO crystal. Therefore, the collected THz electric fields by lightwave signals through EO modulation along the optical waveguide as the modulation index can be formulated as following equation when wireless THz signal is irradiated normally to the proposed device,

$$\Delta \phi = \frac{\pi r_{33} n_e^3}{\lambda} \Gamma \sum_{h=1}^{N} \int_{(h-1)D}^{(h-1)D+L_g} P(y) E_0 \sin(k_{THz} n_g y + \zeta) \, dy$$

where $P(y)$ is the THz electric field polarity, $h$ is the $h$-th resonator electrodes, $\lambda$ is a lightwave wavelength, $r_{33}$ is the EO coefficient, $n_e$ is the refractive index of the EO crystal, $\Gamma$ is an overlapping factor between the THz and lightwave electric fields, $k_{THz}$ is the Thz-wave number in vacuum, $n_g$ is the group index of the
lightwave, $\phi$ is an initial phase of the lightwave, and $N$ is the number of the metamaterial resonator electrodes. Since the EO phase modulation index of the proposed device is below unity, it can be represented for conversion efficiency from wireless THz to lightwave signals.

Conversion efficiency was calculated for 0.1THz wireless irradiation with periodically meandering gap along the optical waveguide ($P$) of 0.69mm. The calculated conversion efficiency is shown by dotted in Fig. 4. Therefore, the metamaterial antenna fabricated on an optical modulator can be used for conversion from wireless THz to optical signal for supporting ROF technology.

**Figure 1.** Basic structure of the proposed metamaterial resonators on an EO modulator, (a) whole view, (b) a unit cell, and (c) cross-sectional view.

**Figure 2.** Ez distribution at 0.1THz. **Figure 3.** THz Ez magnitude and conversion efficiency.

**Keywords:** Terra-hertz band, metamaterial antenna, optical modulator, radio-over-fiber

**Acknowledgment:** supported financially by Thematic Project from LIPI and ASEAN-IVO Project from NICT

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An SMS fiber structure for respiratory monitoring

A. M. Hatta, S. Syafrani, A. Kusumawardhani and Sekartedjo

Department of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.
(E-mail: amhatta@ep.its.ac.id)

INTRODUCTION

Monitoring human physiological conditions such as the respiratory rate is becoming an important and common practice for taking care of the person health. Respiration monitoring can be used to recognize the breathing pattern in a person and it can be used to detect hyperventilation [1]. The use of fiber optics for respiratory monitoring has been reported earlier. In general, there are three categories of respiratory sensors application depending on the sensor’s placement: (i) sensors placed in a nostril or oxygen mask, (ii) sensors embedded into expandable belts or special garments, and (iii) sensors attached to the back of chair or placed on a bed mattress [1].

For the sensors placed in oxygen mask, the sensors detect the breathing parameters consisting of temperature or humidity or the force of inhaled/exhaled air flow. Some proposed configurations employ an intensity-modulated fiber-optic, a fiber-optic Michelson interferometer, a system with a photonic crystal fiber segment, or Fabry-Perot-based breathing sensor [2-5].

A multimode interference (MMI) in a singlemode-multimode-singlemode (SMS) fiber structure has been implemented for many sensing applications [6]. In this work, we proposed the use of SMS fiber structure as a sensor placed in oxygen mask for respiratory monitoring.

RESULTS AND DISCUSSION

The SMS fiber was fabricated by splicing a coreless multimode fiber (MMF) section with the two singlemode fibers with its two ends. The MMI takes place at the MMF section. The breathing parameters (temperature, humidity, and air pressure) change the refractive index of surrounding air of the MMF section. The variation of refractive index of surrounding air leads to the variation of MMI pattern and thus the output power fluctuation. A laser source of 1550 nm and an optical power meter were used in the intensity measurement scheme.

The breathing parameters in this experiment were found to vary in the following ranges. The temperature, humidity and air pressure variation due to inhaled-exhaled air flow were 29 – 32.5 C, 80 – 84% of relative humidity, and 0 – 1.8 Pa, respectively. In this work, the SMS fiber sensors fabricated with MMF of different lengths were tested in a chamber working according to the breathing parameters cited above. It was found that for a typical sensor with the MMF length of 22.3 mm, it produced the output power variation of -17.2 to -16.6 dB, -17.2 to -17.4 dB, and -17.2 to -17.3 dB, for the temperature, humidity, and air pressure variations, respectively. The most significant breathing parameters in this typical sensor is the temperature variation.
A computerized monitoring system was developed and the respiratory monitoring was demonstrated. It is shown in Fig. 1(a) a typical signal of respiration pattern using the SMS fiber sensor while the subject was breathing normally. The same subject’s breathing was monitored using a standard tool of spinometer and the result is shown in Fig. 1(b). It is seen that the response of the proposed sensor has a good agreement with the spinometer. The proposed SMS fiber structure can be used for continuous respiratory monitoring at hospitals or other clinical applications [1]. It offers cost-effective and simple fabrication sensor.

Figure 1. Monitoring response of normal breathing using (a) a sensor based on SMS fiber structure, (b) a spinometer

Keywords: respiratory, SMS fiber structure, monitoring system

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References
CP-9

Optical Properties of Toluene Soluble Carbon Dot from Laser Ablated Coconut Fiber

Isnaeni*1 and Maria Margaretha Suliyanti2 and Yong-Hoon Cho3

1, 2 Research Center for Physics, Indonesian Institute of Sciences, Indonesia. (E-mail: isnaeni@lipi.go.id, yantirw2015@gmail.com)
3 Department of Physics, Korea Advanced Institute of Science and Technology, Republic of Korea. (E-mail: yhc@kaist.ac.kr)

INTRODUCTION

Carbon-based nanoparticles also have excellent electrical properties and have promising applications, such as photocatalysis, luminescent devices, chemical sensing, biosensor, bio imaging and drug delivery [1,2]. In general, there are several types of carbon-based nanoparticles, such as fullerene, carbon nanotubes, carbon nanowires, graphene dot and carbon dot [2,3]. Each of them has its own unique optical and electrical properties. In some cases, carbon-based nanoparticles are luminescent. The most common emitted color is cyan or bluish green color [2]. Several researches have shown that different size of carbon-based nanoparticles emit blue to red colors [1,4]. Furthermore, different functional surface significantly affect emission color of carbon-based nanoparticles. Carbon-based nanoparticles can be synthesized using hydrothermal, metal-graphite intercalation, arc discharge, nanolithography and laser ablation.

In this work, we focus on carbon dot, which is a spherical shape carbon-based nanoparticles. Carbon dot has a solid structure of carbon, unlike other types of carbon-based nanoparticles. The synthesis of carbon dot usually utilizes chemical process that uses high purity chemicals. The use of high purity chemicals is to ensure that the fabricated carbon dot has controllable structural properties. Since carbon is the main element in nature, it is very useful to synthesize carbon dot made of natural resources. The main purposes of this work are (1) to synthesize carbon dot made of coconut fiber using laser ablation technique and (2) to optically characterize fabricated carbon dot in order to reveal the origin of its fluorescence.

RESULTS AND DISCUSSION

After centrifuge cleaning process, the synthesized carbon dot in toluene solution has good solubility. There was no agglomeration or carbon deposition after several months. This result indicates that fabricated carbon dot has excellent solubility in toluene solvent. As comparison, the toluene solution containing carbon power (before laser ablation) and toluene solvent containing carbon dot (after ablation) are shown in Figure 1. The samples are illuminated by a blue laser pointer (wavelength 405 nm) in ambient condition. A clear cyan color is emitted from the carbon dot (after ablation) sample. This indicates that size of carbon nanoparticles is very small and can be called as carbon dot. The estimated size of cyan color carbon dot is approximately 2 nm until 5 nm. The cyan emission emitted from carbon dot sample is not very strong. This is probably due to low concentration of carbon dot.
Furthermore, we investigated emission spectra of carbon dot emission under different excitation wavelength. We used excitation wavelength 260 nm, 340 nm, 400 nm and 440 nm. When the carbon dot solution was excited by 260 nm wavelength, we found that the main emission peak is at around 300 nm, and there is a small peak at around 500 nm (green color emission). When the carbon dot solution is excited by 340 nm wavelength, there is a nice emission spectrum around 440 nm wavelength. Moreover, the emission peak shifted smoothly when the carbon dot was excited using 440 nm wavelength. A clear emission spectrum at 540 nm wavelength occurs. There is a clear different of emission spectrum between the carbon dot excited using 340 nm and 440 nm wavelength. These two spectra seem unrelated one to another. These two independent spectra are clearly observed when the carbon dot was excited by 400 nm wavelength. We found a distinctive superposition of two spectra. This is a superposition spectra from two individual spectra mentioned earlier. Therefore, it is assumed that there are three separate emission peaks in our carbon dot sample. In order to confirm these finding, we have conducted further excitation wavelength dependence photoluminescence of carbon dot sample using excitation wavelength from 250 nm until 550 nm, with wavelength interval 1 nm. The result is shown in Figure 2.

Keywords: up carbon dot, molecular states, surface states, photoluminescence.

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References
CP-10

Non-linear Performance of Al$_{0.3}$Ga$_{0.7}$As/InP/Ge Multijunction Solar Cells Upon Multiplication of Solar Irradiance

T. Sumaryada*1, S. Rohaeni1, N.E Damayanti1, H. Syafutra1, H. Hardhienata1

1Department of Physics, Bogor Agricultural University, Jalan Meranti Kampus IPB Dramaga Bogor 16680, Indonesia.
(E-mail: tsumaryada@apps.ipb.ac.id)

INTRODUCTION

The combination of the III-V based solar cells like GaInP, AlGaAs, InP, and GaAs in the form of multijunction solar cells and their exposure to several hundreds times of solar radiation had produced the highest efficiency rate and approaching the 50% psychological limit [1]. Most of the experiments related to high efficiency multijunction solar cells were done using a small prototype specimen and their realization to industrial scale manufacturing and commercial energy market is still far from the required condition. More researches related to multijunction solar cells are needed, including the simulation and modeling aspect of multijunction solar cells [2-3].

In this paper we report our investigation on the performance of Al$_{0.3}$Ga$_{0.7}$As/InP/Ge multijunction solar cells under the variation (multiplication) of solar irradiance by using a simulation approach. The study consist of simulation spectrum simulation and performance simulation for each subcell. Simulations were intended to gain the highest possible efficiency in each subcell (parallel stack) in the multijunction solar cells. The temperature variation is also considered, since the efficiency of solar cell depend on the surface temperature of the subcells.

The solar radiation used in this simulation is the AM1.5G spectrum. Simulations were performed at Solar Irradiance Multiplication Factor (SIMF) of 1, 5, 10, 50, 100 and 200 suns. Each set of simulations were done at 25 $^\circ$C, 50 $^\circ$C, 75 $^\circ$C and 100 $^\circ$C. The solar cell’s performance reported in this paper including the Power-Voltage curve and the efficiency versus SIMF curve. The intensity of solar radiation transmitted from one subcell to next adjacent cell ($I_n$) and the absorption coefficient ($\alpha(\lambda)$) of each subcell were calculated by using [2]:

$$I_n = I_{n-1}e^{-\alpha_s(x_n)} \quad \text{and} \quad \alpha(\lambda) = 5.5 \sqrt{E(\lambda) - E_g} + 1.5 \sqrt{E(\lambda) - (E_g + 0.1)}$$

(1)

and the total efficiency of multijunction solar cell was calculated by

$$\eta = \frac{P_1 + P_2 + P_3}{P_0}$$

(2)

The power producing simulation were performed using a freely available PC1D program from Basore et al [4].

RESULTS AND DISCUSSION

The results of our simulation show a non-linear performance variation of solar cell with respect to increasing solar irradiance. The feature of our results (see Figure 1) is in agreement with the
experimental results of another III-V solar cells reported by other research groups [5]. The efficiency is almost two fold of the experimental results, but this is expected due to the difference model applied in this simulation. As mentioned in our previous works [3], the series arrangement of subcells in the multijunction solar cell will reduced the efficiency by almost 40% as compared to a parallel stack, so we expect to gain a maximum of 48% (60% of 80% is 48%) for a realistic simulation (series stack of subcell with enforced identical current) which is comparable to a current record of 44.7% efficiency by Dimroth et al [1]. Based on our finding, we suggest that the non-linearity behavior mostly come from the first subcell which is directly exposed to the high intensity and temperature of a concentrated solar radiation.

Figure 1. The non-linear performance of Al0.3Ga0.7As/InP/Ge multijunction solar cells as shown by

The efficiency vs SIMF (Solar Irradiance Multiplication Factor).

Keywords: multijunction solar cells, PC1D, solar cells simulation, solar irradiance multiplication

Acknowledgment

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References

Nanoscale Surface Characterization using the Bond Model in Nonlinear Optics

Hendradi Hardhienata¹, Ignu Priyadi¹, Mulyaninsih¹, Adalberto-Alejo Molina², and Husin Alatas¹

¹Theoretical Physics Division, Department of Physics, Bogor Agricultural University, Jl. Meranti, Gedung Wing S, Kampus IPB Darmaga, Bogor 16680, Jawa Barat, INDONESIA

²CONACYT Research Fellow - Center for Research in Engineering and Applied Science (CIICAp), Institute for Research in Pure and Applied Science (IICBA), UAEM Cuernavaca, Mor. 62209, Mexico

E-mail: hendradi@ipb.ac.id

INTRODUCTION

The demand and ability to create thin film devices has triggered interest in understanding physical processes at the very surface of a material. Although much of the physics inside the material bulk has been well understood, the surface properties such as molecular orientation is still not fully explored and often differ than those of the bulk due to symmetry breaking caused by the absence of an upper layer. Optical techniques to characterize surface processes have gained increase in interest among other methods due to several advantages: it is nondestructive, monitoring can be performed in real time, and can be performed at room temperature without requiring vacuum condition. However, when performing spectroscopical measurement using linear optics on important semiconductors such as Silicon, several shortcomings arises: the output radiation from the surfaces and bulk mixes and requires separation. Furthermore, the linear susceptibility is isotropic producing no changes when rotating the sample and thus cannot be applied to detect the molecular orientation at the surface. Nonlinear techniques offers a way out. Because of parity symmetry, centrosymmetric materials such as Silicon produce zero response from the bulk when probed for second harmonic generation (SHG) but not at the surface. In addition the nonlinear susceptibility tensor of the surface such as the case of Si is now anisotropic hence NLO have great potential to understand the physics at the surface.

Despite many progresses that have been made in theoretical NLO, interpreting experimental spectroscopic data such as Rotational Anisotropy Second Harmonic Generation (RASHG) by NLO using ab initio quantum models has proven to be difficult and a physical picture is often hard to obtain. Phenomenological models are therefore still utilized in such cases where recently significant progress in understanding NLO at surfaces has been made using the Simplified Bond Hyperpolarized Model (SBHM) first introduced in 2002. SBHM has opened the possibility to derive a connection between polarizability models and group theory, identifying various nonlinear sources such as separation of bulk quadrupoles and surface dipoles, bulk dipolar SHG in zincblende structures, and recently understanding electric field induced SHG in Si.
RESULTS AND DISCUSSION

We will explain the recent progress in NLO surface characterization using the bond model and in addition explain several new result of this model in explaining RASHG experiments e.g. nonlinear ellysymmetry of SHG and third harmonic generation using arbitrary polarization incidences (Fig 1a), electric field induced SHG, modelling surface molecular orientation such as determination of twin boundaries in wurzite structures e.g. ZnO (Fig. 1b). A group theoretical analysis and calculation of NLO far fields are also provided for a rigorous analysis. Brief remarks about future potentials of this model is also explained.

Figure 1. Bond model analysis of (a) THG in Si structures for arbitrary polarization (b) RASHG modelling in wurzite structures with twin boundaries. (Selected pictures, more will be presented)

Keywords: Surface characterization, nonlinear bond model, harmonic generation, rotational anisotropy.

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References
CP-12

Preferences and characterization of brightness enhancement film for OLED-based SPR sensor

Briliant Adhi Prabowo*1, Yu-Ying Lee2, and Kou-Chen Liu3

1 Research Center for Informatics, Indonesian Institute of Sciences, Bandung 40135, Indonesia. (E-mail: briliant.adhi.prabowo@lipi.go.id)
2 Graduate Institute of Optoelectronics, Chang Gung University, Taoyuan 33302, Taiwan. (E-mail: thehappyday@msn.com)
3 Department of Electronics Engineering, Chang Gung University, Taoyuan 33302, Taiwan. (E-mail: jacobliu@mail.cgu.edu.tw)

INTRODUCTION

The specific incident angle of the light source is a critical factor in the surface plasmon resonance sensor (SPR) configuration. Particularly, the utilization of the polychromatic light source, such as an organic light-emitting diode (OLED). The basic purpose of OLED which is fabricated in the large and flat substrate leads to the wide viewing angle of the light incident. This drawback should be overcome to obtain the advantageous features of the OLED in SPR sensor. Therefore, the microstructure films for brightness enhancement and incident light polarization are employed in the simple alignment method in the portable system of SPR sensor.

The preferences of particular brightness enhancement film is an important factor to obtain the optimum SPR coupling in the interface of metal sensing and dielectric medium sample. There are several types of brightness enhancement film which is determined by its surface microstructure design, such as a linear prismatic array with various sizes and cone hexagonal array. Five types of the brightness enhancement film are characterized by its brightness level in the presence and absence of the polarization film.

RESULTS AND DISCUSSION

In the ideal SPR sensor configuration, the required incident angle for SPR coupling is described by:

\[ \sin \alpha = n_p^{-1} \left( \frac{\varepsilon_m \varepsilon_d}{\varepsilon_m + \varepsilon_d} \right)^{0.5} \]

(1)

Where, \( \alpha \), \( n_p \), \( \varepsilon_m \), and \( \varepsilon_d \) are an incident angle of light, the refractive index value of prism, the dielectric constant of metal sensing, and dielectric constant of the medium sample, respectively. In the OLED-based portable SPR sensor in our group, the incident angle \( \alpha \) is determined by the 0° viewing angle which is perpendicular from the OLED substrate. The brightness enhancement mechanism of the BEF is described in previous report.

The types of brightness enhancement film and its size are listed in Table 1. Where the measured brightness of the microstructure types are presented in Fig. 1. The BEF type E shows the highest luminescence, however it seems not suitable for the polarized light due to the random direction of the output light from the cone array surface. The highest gain of the luminescence after polarizer film was achieved around 0.774 by utilizing the BEF type D.
Table 1. The various type of BEFs comparison and its measured brightness gain.

<table>
<thead>
<tr>
<th>Film type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>s (µm)</td>
<td>188</td>
<td>125</td>
<td>125</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>t (µm)</td>
<td>22</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>p (µm)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>n/a</td>
</tr>
<tr>
<td>BG</td>
<td>1.105</td>
<td>1.156</td>
<td>1.109</td>
<td>1.163</td>
<td>1.323</td>
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<tr>
<td>BGP</td>
<td>0.635</td>
<td>0.698</td>
<td>0.692</td>
<td>0.774</td>
<td>0.638</td>
</tr>
</tbody>
</table>

Gain = Measured out brightness / original OLED brightness

*a*) Brightness gain; *b*) Brightness gain after polarizer film.

Figure 1. Luminance measurement of different BEFs on OLED device.

Keywords: SPR, sensor, brightness enhancement film, microstructure

Acknowledgment

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References

CP-13

Refractive Index Sensing with Ultra–High Figures of Merit using Core-Multishells Silver Nanotube

Azrul Azwar*1,2, Agoes Soehianie1 and Alexander A. Iskandar*1

1 Physics of Magnetism and Photonics Research Group, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia. (*iskandar@fi.itb.ac.id)

2 Physics Department, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Pontianak, Indonesia. (*a.azwar@physics.untan.ac.id)

INTRODUCTION

Localized surface plasmon resonances (LSPRs) are optical phenomena that occur in metallic nanostructures in which collective charge motions confined at metal-dielectric interfaces. The unique properties of LSPRs such as enhanced absorption or scattering cross section make them suitable in a wide range of applications. One of the most important application of LSPRs is the refractive index sensing, which utilizes the peak shift in the scattering or absorption spectrum of metal nanostructure due to the refractive index change of the surrounding environment [1]. A widely used parameter that characterizes the sensing performance is Figure of merit (FOM), defined by [2]

\[
FOM = S \frac{\Delta \lambda}{\Delta n} = \frac{1}{\Delta \lambda} \left( \frac{d \lambda_p}{dn} \right)
\]

where \( S \) is the sensitivity, \( \Delta \lambda \) is the width of resonance spectrum which defined as FWHM (Full width at half maximum), \( \lambda_p \) and \( n \) are the resonance wavelength and refractive index of the surrounding medium, respectively.

In this report, the refractive index sensing performance of nanotube consists of Ag core and Ag shell separated by a dielectric spacer layer are theoretically investigated by calculating the spectral dependence of absorption efficiency (\( Q_{abs} \)) with respect to the variation of spacer layer or background refractive index. It is found that compared to the variation of background refractive index, the absorption spectra are much more sensitive to the refractive index change of spacer layer. This results show that the inner sensing (sense the refractive index variation of spacer layer) offers higher FOM than outer sensing (sense the refractive index variation of background medium). The calculated FOM for various geometrical parameters of the structure shows that the highest FOMs of less than 10 and more than 200 for outer and inner sensing, respectively.

RESULTS AND DISCUSSION

It is shown in Fig.1.a, the linear dependences of resonances wavelength variation with respect to the change of background refractive index (dash line) and to the change of spacer layer refractive index (solid line) for silver nanotube with 50 nm core radius, 25 nm thickness of the dielectric spacer layer and 15 nm thickness of Ag shell. One observes that the sensitivity of inner sensing is higher than the outer sensing. This high sensitivity related to the high localized field within the dielectric spacer layer inside the nanotube which indicate the effective coupling between surface plasmons of Ag core and
inner surface of Ag (outer) shell as shown in the inset. By varying the geometrical parameters, one found that the maximum value of FOM is more than 200 for inner sensing as given in Fig 1.b.

**Keywords:** Absorption efficiency, Figure of merit, LSPRs, Nanotube, Plasmonics, sensing.

**Acknowledgment**
The authors thank M.O. Tjia for the valuable discussions throughout the work. This work was supported by Program Unggulan Perguruan Tinggi DIKTI 2017 form the Indonesian Ministry of Research, Technology and Higher Education.

**References**
Detection of Dye Molecules Adsorbed inside a Mesoporous Layer by Surface Plasmon Resonance and its Comparison to Simulation Results

Siti Chalimah, Jalu Setiya Pradana and Rahmat Hidayat
Physics of Magnetism and Photonics Research Division, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology, Indonesia
(E-mail: sitichalimah31@gmail.com, rahmat@fi.itb.ac.id)

INTRODUCTION

Surface Plasmon Resonance (SPR) has interesting prospect to be applied for surface sensing due to its highly sensitivity, such as in optical bio-chemical and bio-medical sensors. [1] The ability to sense biomolecular interaction is an important key in designing such sensors. In this presentation, we report our work on the application of SPR spectroscopy with Kretschmann configuration to identify the adsorption of dye molecules into mesoporous metal oxide layer. We can find that some devices, such as gas sensors and solar cells, are built with a mesoporous layer. While some microscopy imaging techniques are able to see the mesoporous appearance on the surface, it is still difficult to confirm the adsorption of dye molecules inside a mesoporous layer. In the present work, we use an Aluminum-doped Zinc (AZO) layer with porous size of about tens of nanometer and thickness of a few tens of nanometer. The change of the measured SPR spectra are then compared to the spectra obtained from simulation work calculated by using the transfer-matrix method. The main problem in analyzing the measured spectra is to distinct whether the dye molecules penetrate deep into the inner side of the layer or just deposited on the layer surface.

RESULTS AND DISCUSSION

![Figure 1](image.jpg)

**Figure 1.** The SPR spectra measured from a) prism|Au|AZO|air, and b) The SPR spectra measured from prism|Au|AZO+dye|air in which the AZO layer was immersed in AZO layer for 0.25 hour.

Figure 1 shows the measured SPR spectra from a prism|Au|AZO|air and prism|Au|AZO+dye|air. The AZO layer was prepared by sol-gel technique with a thickness of a few
tens of nanometers in order to keep the resonance frequency was still in the visible light region, which is determined by a relationship:

\[ k_x = k_{s}\rho = \frac{2\pi}{\lambda} \sqrt{\epsilon_m \epsilon_d} \]  

(1)

As indicated in Fig. 1(a), the SPR dip was still observed in the visible light region.

Figure 2 and 3 show the simulation results calculated by transfer matrix theory. In this simulation, we assume that the SPR structure is similar to multilayer with N layer. The total reflectance is then calculated through a recursive formula given by [2]

\[ R = |r| = \left| \prod_{i=1}^{N} r_i \right| \]  

(2)

where \( r_i \) is the reflectance at each layer

\[ r_i = \frac{E_i^+}{E_i^-} \left[ \frac{\rho_i e^{\delta_{i}}} {\tau_i e^{\delta_{i}}} + e^{-\delta_{i}} \right] \]  

(3)

where \( \rho \) and \( \tau \) are Fresnell coefficient for each layer. The simulation results show that shifting trend of these simulation spectra is similar to the measured spectra, which may indicate the adsorption of dye molecules into the mesoporous layer.

Fig. 2. Simulated SPR spectra with the superstrat \( n_d = 1.5 \) and thickness of 15 nm, imitating AZO layer.

Fig. 3. Simulated SPR spectra with the superstrat \( n_d = 2.8 - i*0.04 \) and thickness of 30 nm, imitating AZO layer with dye molecules.

**Keywords:** Surface Plasmon Resonance, transfer-matrix method, mesoporous layer

**Acknowledgment**

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**References**


Laser-Induced Gas Plasma Spectroscopy for the Analysis of Carbon in Soil

Ali Khumaeni1*, Zener Sukra Lie2, Koo Hendrik Kurniawan2, and Kiichiro Kagawa3

1 Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Jl. Prof. Soedharto, SH, Tembalang, Semarang 50275, Indonesia
(E-mail: khumaeni@fisika.undip.ac.id)
2 Research Center of Maju Makmur Mandiri Foundation, 40/80 Srengseng Raya, Kambangan RT 02 RW 06, Jakarta Barat 11630, Indonesia
(E-mail: zener_lie@yahoo.com; kurnia18@cbn.net.id)
3 Fukui Science Education Academy, Takagi Chuou 2 Choume, Fukui 910-0804, Japan
(E-mail: k-kagawa@fukuikagakugakuen.com)

INTRODUCTION

Recently, carbon inventories in soils have gradually increased due to the serious global climate change [1]. Soil carbon is fundamental determinant of many soil chemical and physical properties such as nutrient availability, soil structure, and water holding capacity, which directly influence ecosystem quality and soil quality [2]. This increment of the temperature influences the soil carbon dynamics and reduces the annual change of soil organic carbon. Thus, an efficient technique of measuring soil carbon is required to estimate and monitor the terrestrial carbon inventories.

Laser-induced breakdown spectroscopy (LIBS) has recently become very popular technique for rapid qualitative and quantitative elemental analysis [3]. In this method, a pulsed neodymium yttrium aluminum garnet (Nd:YAG) laser is usually employed as an ablation source. However, the standard LIBS cannot be used for direct analysis on soil sample because the soil target will be blown off by the arrival of the focused laser beam.

In this study, we proposed a unique technique for the direct analysis of carbon in soils by means of the specific characteristics of a pulse CO2 laser. The laser employed for radiation source was a pulsed transversely excited atmospheric (TEA) CO2 laser. The laser energy was fixed at 1.5 J by setting an aperture in the path of laser beam and focused through a ZnSe window on a sample using ZnSe lens of 100 mm in focal length. The sample applied in this study was a carbon soil sample collected from the garden. For semi-quantitative analysis, a standard soil samples containing various concentrations of carbon (200, 500, and 1000 mg/kg) were used. Prior to the analysis, a small amount of moist soil was painted on a nickel plate (dimension of 20 mm x 20 mm), which serves as a metal subtarget, as illustrated in Fig. 1(a).

RESULTS AND DISCUSSION

Figure 1(b) shows the emission spectrum obtained from the soil. It is seen that a strong emission intensity of C I 247.8 nm clearly appears with low background intensity. Furthermore, many typical atomic lines of Si showing characteristics of the soil sample can readily be observed in the right side of the carbon line.

The method described above was adopted for a study on semi-quantitative analysis of the company soil sample containing various concentrations of C. Taking advantages of the fact that the ratio intensity between C I 247.8 nm and Si I 251.9 nm is almost constant, the Si emission line was employed as a standard. An excellent linear calibration curve with a zero intercept was successfully made for the soil sample, as
presented in Fig. 2. It should be noted that the use of silicon (Si) for standardization should be evaluated with regard to soil mineralogy because the Si content in soils varies with the mineralogy of soils. This technique has high possibility to be applied for carbon analysis in soil to measure the dynamics of carbon due to the global climate change.

Figure 1. (a) New device used in this study, (b) Emission spectrum of C obtained from the garden soil

Figure 3. Calibration curve of C content in the soil containing various concentration of C

Keywords: Laser-induced breakdown spectroscopy; LiBS; Laser-induced gas plasma spectroscopy; Carbon analysis; Soil sample

Acknowledgment
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References
Study of Charge Generation in Hybrid Polymer-Inorganic Solar Cell and the Effect of Incorporated Metal Nanoparticles

Priastuti Wulandari*, Yolla S. Handayani², Rahmat Hidayat³, Koichi Okamoto⁴, Kaoru Tamada⁵

1, 2, 3 Physic of Magnetism and Photonic Group, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia.
(E-mail: wulan@fi.itb.ac.id, yollasukmahandayani2@gmail.com, rahmat@fi.itb.ac.id)

4, 5 Institute for Material Chemistry and Engineering, Division of Fundamental Chemistry, Nanomaterial and Interfaces, Kyushu University, Japan.
(E-mail: okamoto@ms.ifoc.kyushu-u.ac.jp, tamada@ms.ifoc.kyushu-u.ac.jp)

INTRODUCTION

Solar cells are an intensively research subject in the last few decades. Various architectures of solar cells have been proposed by using inorganic, organic or hybrid materials in order to improve the solar energy conversion efficiency [1,2]. It has been demonstrated by some researches that the hybrid solar cell having junction structure with a ZnO layer shows relatively good energy conversion efficiency within the class of organic or hybrid solar cells. Improvement of the cell structure by incorporating ZnO nanorods/wires has been also reported, but the conversion efficiency is still low. In such structure, we may consider very effective charge dissociation at the ZnO/polymer junction. However, the whole process is supposed to be a complicated mechanism involving other electronic process, such as back-transfer, charge accumulation and charge trapping. All of these consecutive processes determine the working performance and their energy conversion efficiency. In particular, those processes will be limited by the effective lengths of exciton diffusion and charge carrier transport, which are extremely small in order of a ten to a hundred nanometer for both materials [3,4].

In this study, we investigate the mechanism and kinetics of charge carrier generation and transport in those types of hybrid solar cells and the investigation is focused on the play role of surface plasmon generated by incorporated metal nanoparticles on charge generation kinetics. It has been known that metal nanoparticles exhibit strong localized surface plasmon resonance wave, where it is believed to be able to promote exciton dissociation or charge transfer generation. This is expected from the facts that the generation of SPR wave would both enhance the photon absorption and improve the efficiency of charge separation. In this work, metal nanoparticles are being incorporated in the active layers of hybrid solar cell device for those reasons.

Synthesis of silver nanoparticle capped by myristates (AgMy) is conducted by direct thermolysis method.[5] Next, we exchange the myristate ligand of silver nanoparticle into thiol system by used of 1-Octanethiols (AgSC8). Characterization of AgSC8 is done by used of UV-Vis spectrometer and Transmission Electron Microscope (TEM). Fabrication of hybrid solar cell incorporated AgSC8 inside active layer of poly (3-hexyl thiophene-2, 5-diyl) (P3HT) and phenyl-C61-butyric acid methyl ester (PCBM) is done by spin-coating technique. Active layer (P3HT:PCBM) with 1:1 of ratio and AgSC8 solution with various volume (25μL, 50μL and 100 μL) are mixed together to form homogenous solution without any color change. The solution is stirred in room temperature for 30 minutes before used in fabrication process. For static measurement, the J-V characterizations including the determination of the Filling Factor (FF) and the power conversion efficiency under standard conditions (simulated sunlight AM1.5) are carried out.
RESULTS AND DISCUSSION

It has been known that thiolate is used as capping material on nanoparticles because of the strong coordination between sulphur from thiolate to gold or silver. Exchange capping material of myristate into thiolate on AgNP has been successfully done as indicated from UV-Vis spectra. Plasmonic peaks is found at $\lambda_{\text{max}} = 414$ nm for AgMy and it is shifted to high frequency (red shift) when it changes into thiolate capping (AgSC8) to the position of $\lambda_{\text{max}} = 419$ nm. TEM image of AgSC8 with diameter size similar to AgMy is about 5 nm. UV-Vis spectra of active layer’s thin film show higher absorbance spectra when AgSC8 embedded inside active layer compare to the thin film without AgSC8 which is indicated the strong photon absorbance from AgSC8.

J-V measurement under simulated light reveals that the incorporation of 5 $\mu$L of AgSC8 inside the active layer increases $V_{oc}$ of the device together with the improvement of filling factor and energy conversion energy efficiency from 1.01% to 1.92% as shown in figure 1 and the insert table shows corresponding J-V data for each device. The results indicate the enhancement of charge carrier generation and also charge transport inside the device structure and these suggest promising enhancement of device performance by incorporating metal nanoparticles (specifically AgSC8) inside active layer of the hybrid solar cells.

**Keywords:** hybrid solar cells, metal nanoparticles, localized surface plasmon resonance

**Acknowledgment**
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**References**

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Sol-gel deposition of TiO$_2$/PMMA bilayer, and Its Optical Properties for Antireflection Application

Gatut Yudoyono$^1$, Sudarsono$^2$, Yono Hadi Pramono$^3$, Mochamad Zainuri$^4$, and Darminto$^5$

Department of Physics, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya 60111, Indonesia
E-mail: 1. gyudoyono@physics.its.ac.id; 2. sudars29@gmail.com; 3. yonohadirpramono@gmail.com; 4. mochamadzainuri1964@gmail.com; 5. darminto@physics.its.ac.id

INTRODUCTION

Nanomaterials TiO$_2$ are synthesized by the co-precipitation method using TiCl$_3$ precursor. The resulted TiO$_2$ powder has the crystal morphology of nanoparticles and nanorods. TiO$_2$/PMMA bilayer film is prepared by a sol-gel method using spin-coating technique, with PMMA layer used as the first layer for anti-reflection function and deposited on microscope slide glass (MSG) substrate. The TiO$_2$ layer is deposited on top of the PMMA layer from a TiO$_2$ solution prepared by mixing TiO$_2$ powder, a binder of ethyl cellulose, and solvent of terpineol with a mass ratio of 1: 1: 28. The optical properties are measured in terms of the absorbances using UV-VIS spectrometer on the multilayer systems with single TiO$_2$ layers deposited at various spinning speeds. The antireflection coating properties of TiO$_2$/PMMA bilayer are investigated using transmittance measurement.

RESULTS AND DISCUSSION

Based on the absorption spectra of the system with TiO$_2$ single-layer the calculation are performed on the amount of gap energy using Tauc model and the Urbach energy using Urbach's equation, as shown in Table 1. The absorption intensities of all samples are very small on the visible range of wavelength (> 350 nm) the intensities are larger in the UV range (<350 nm). Based on these spectra we get the range of the energy gaps for the system. The values of energy gaps of all systems are greater than the energy gap of TiO$_2$ in the form of powder (E$_g$ = 3.0-3.2 eV). This difference maybe attributed to the presence of the binder material (ethyl cellulose) which leads to enlarge energy gap.

Table 1. Optical Energy gap and Urbach energy for TiO$_2$ single layer

<table>
<thead>
<tr>
<th>Material TiO$_2$</th>
<th>Sample</th>
<th>Spin rate(rpm)</th>
<th>Energy gap (E$_g$, eV)</th>
<th>Urbach energy (E$_u$, meV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanoparticle rutile</td>
<td>Pr2</td>
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<td>255</td>
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<tr>
<td></td>
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<td>3.54</td>
<td>255</td>
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<tr>
<td></td>
<td>Pr4</td>
<td>4000</td>
<td>3.58</td>
<td>204</td>
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<td>5000</td>
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<td>Nanorods rutile</td>
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<td>1000</td>
<td>3.65</td>
<td>255</td>
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<tr>
<td></td>
<td>Rr2</td>
<td>2000</td>
<td>3.68</td>
<td>255</td>
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<tr>
<td></td>
<td>Rr3</td>
<td>3000</td>
<td>3.68</td>
<td>255</td>
</tr>
<tr>
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<td>Rr4</td>
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<tr>
<td></td>
<td>Rr5</td>
<td>5000</td>
<td>3.70</td>
<td>221</td>
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</table>

Figure 1 shows the transmittance for TiO$_2$/PMMA bilayer, with the structures is g/T/M/A; g = glass; T = TiO$_2$; M = PMMA; a = air; Pa = nanoparticle anatase; Pr = nano-particle rutile; Ra = nanorods
anatase; Rr = nanorods rutile. It is shown in the figure that the TiO$_2$ nanorods layer has a higher transmittance than the structure of TiO$_2$ nanoparticles. Transmittance bilayer with nanorod TiO$_2$, rutile phase is higher than anatase phase, but with reversed TiO$_2$ nanoparticles. The PMMA layer with a refractive index smaller than the refractive index of TiO$_2$ can be increased the transmittance of the TiO$_2$ layer, so it is likely that the bilayer TiO$_2$/PMMA structure can be used as a bilayer coating acting as the antireflection layer.

Figure 1. Transmittance spectra of TiO$_2$/PMMA bilayer.

**Keywords:** antireflection, bilayer, sol-gel, titania.

**References**
An alternating current sensor based on SMS fiber structure and Ferrofluids

H.H. Saputra¹, Sekartedjo¹ and A.M. Hatta¹

¹Department of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.
(E-mail: hadrian13@mhs.ep.its.ac.id, sekar@ep.its.ac.id, amhatta@ep.its.ac.id)

INTRODUCTION

Optical fiber current sensors have attracted much attention on account of their merits such as its safety aspects and portability compared to the traditional current sensors. One of the common measuring techniques employs the Faraday effect which measures the magnetic field generated by the electric current [1]. Recently, fiber current sensor with ferrofluids was proposed. The refractive index and absorption coefficient of ferrofluids vary with a magnetic field created by the applied electric current [2].

Li et.al. [3] proposed a direct current sensor based on ferrofluids and multimode interference (MMI) in a singlemode-multimode-singlemode (SMS) fiber structure [4]. A segment of no core fiber (NCF) was employed as a multimode section in the SMS fiber structure. In this scheme, magnetic fields generated by the electric current induces the absorption effect of the ferrofluids in the multimode section of the SMS fiber structure [3]. In this work, we presented an alternating current sensor based on the ferrofluids and the SMS fiber structure. A ratiometric measurement system which is low cost and simpler than wavelength scanning method was demonstrated experimentally.

RESULTS AND DISCUSSION

The alternating current measurement set-up using the ratiometric scheme is shown in Fig. 1. The laser beam of 1550 nm is split by a fiber coupler into two arms, one serves as the reference, and the other used for sensing. Both arms are connected to the optical power meters. In the sensing arm, a polarizer is employed and it is connected to the SMS fiber structure. The ratiometric measurement system can reduce power fluctuations of the input light source and thus reduce the measurement error and improve the accuracy. The NCF segment of SMS fiber structure is immersed in the ferrofluids filling a thin plastic container. A home made ferrofluids is used by mixing the Fe₃O₄ powder and oleic acid as surfactant.

A solenoid wire is used to produce the magnetic fields generated by the electric current. The alternating current measurement from 0 to 10 A with 50 Hz frequency is carried out. A current sensitivity of 0.616 dB/A is achieved for the SMS fiber structure with the NCF of 125 µm core diameter and total length of 7.7 cm. The proposed sensor has advantages of low cost, easy of fabrication and implementation. This study is useful for the development of alternating current monitoring system in many applications.
Figure 1. An alternating current measurement set-up: the sms fiber structure attached to the solenoid wire

**Keywords:** alternating current sensor, SMS fiber structure, ferrofluids

**Acknowledgment**
This work was supported by “Penelitian LBE Dana Lokal ITS 2017”.

**References**
Electrical, Optical, and Crystal Structural Properties of Lithium Niobate (LiNbO$_3$) Thin Films Fabricated by Chemical Solution Deposition

Irzaman$^{*}$, Aminullah$^2$, B. Yuliarto$^3$, K. A. Hamam$^4$, and H. Alatas$^1$

$^1$ Department of Physics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia. (E-mail: irzaman@apps.ipb.ac.id, alatas@apps.ipb.ac.id)

$^2$ Department of Food Technology and Nutrition, Djuanda University, Bogor, Indonesia. (E-mail: aminullah@unida.ac.id)

$^3$ Advanced Functional Materials Laboratory, Department of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung, Indonesia. (E-mail: brian@tf.itb.ac.id)

$^4$ Department of Physics, Faculty of Science, King Abdul Aziz University, Saudi Arabia. (E-mail: khamam@kau.edu.sa)

INTRODUCTION
Lithium niobate (LiNbO$_3$) thin film has attracted much attention due to its ability for potential electrical, optical and acoustic applications. LiNbO$_3$ is an important ferroelectric material because it has piezoelectric, electrooptical, pyroelectrical and photorefractive properties [1, 2].

There are different methods used in the manufacture of thin films, which include film deposition techniques such as sputtering, pulsed laser deposition (PLD), chemical solution deposition (CSD) and chemical vapor deposition (CVD) [3 - 5]. The method used in this research is the CSD method, because it has good stoichiometric control, easy to make, and its synthesis can occur at low temperatures. This research is aimed to characterize the current-voltage (I-V), the film conductivity, the reflectance and absorbance, structure of films, and to test the properties of ferroelectric and dielectric constant. The substrate is p-type silicon at annealing temperature of 900°C for 1, 8, 15 and 22 hours.

RESULTS AND DISCUSSION
Structural characterization of the resulted films was performed by XRD measurement which showed that the highest diffraction intensity was LiNbO$_3$ film prepared with annealing time of 1 hour, while the lowest intensity was obtained from the film prepared with 22 hours of annealing time which has rhombohedral structure (Figure 1).

![X-ray diffraction pattern](image)

**Figure 1.** X-ray diffraction pattern of LiNbO$_3$ film

The absorbance curve in Figure 2 showed that the most absorbed and reflected wavelengths are in the range of 400-500 nm and 570-600 nm, respectively. Data of reflectance can be used to calculate the
refractive index (n) and the energy gap (Eg) of the films and it was found that the refractive indexes are in the range of 1.31 – 1.93 and the energy gaps are 2.54 – 3.19 eV.

![Graph showing absorbance of LiNbO3 films with various molarity and annealing time.](image)

**Figure 2.** Absorbance of LiNbO₃ films with various molarity and annealing time

The I-V characterization which was performed in dark and illuminated conditions showed that the films have photodiode characteristics. In addition, the results showed that the higher molarity has led to the good quality diode thin film and the best result was showed by the molarity of 2 M with annealing time of 22 hours.

The electrical conductivities (σ) of films which were annealed for 1, 8, 15, and 22 hours were $1.49 \times 10^{-5}$, $2.05 \times 10^{-5}$, $2.27 \times 10^{-5}$, and $6.66 \times 10^{-5}$ S/cm, respectively. These values are in the range of semiconductor conductivity.

**Keywords:** crystal structural property; electrical property; lithium niobate; optical property; thin films.

**Acknowledgment**

This work was funded by the Grant of International Research Collaboration and Scientific Publication from the Ministry of Research, Technology and Higher Education, Republic of Indonesia under contract No. 082/SP2H/UPL/DIT.LITABMAS/II/2015.

**References**

Twin Table Ladder Modulation Outperforms Pure Bert Lambert Method on Recognising Non Invasive Blood Glucose Level Measurement Optical Device Spectral Responses

Renan P. Jenie¹,², Evy Damayanti², Irzaman³, Rimbawan², Dadang Sukandar³, and Husin Alatas³

¹ Community Nutrition Department, Bogor Agricultural University, Indonesia (E-mail: qwerty_user1983@outlook.com, evyimam@yahoo.com, rimbawan62@yahoo.com)
² Physics Department, Bogor Agricultural University, Indonesia (E-mail: qwerty_user1983@outlook.com, irzaman@apps.ipb.ac.id, alatas@apps.ipb.ac.id)

INTRODUCTION

A comparative trial conducted between January 2017 and March 2017, at Electronic Material Physics Laboratory, Department of Physics, Bogor Agricultural University, West Java, Indonesia. The objective is to compare accuracy of Twin Table Ladder (TTL) [1] and Pure Bert Lambert (BL) [2] optical spectral parser engine for prototype compared to veni for fasting normo glucose participants. Main outcome measure: accuracy as rooted means squared error (RMSE) of either TTL and BL inference method, smaller is better. Clarke error grid analysis (ega) and Parker ega, and sensitivity and specificity are calculated from the outcomes, larger is better.

Figure 1. Clarke Error Grid Analysis for Twin Table Ladder (reader’s left) compared to Pure Bert Lambert (right) methods.

Blood spectral data from participant older than 17 years were assigned to single measurement group. Blood spectral data previously taken from All participant modulated using either TTL and BL methods, and inferred using Fast Artificial Neural Network. The data contained blood glucose level measurement using both prototype of non invasive blood glucose level measurement optical device (prototype) and veni puncture spectrophotometry (veni). No randomization of records. The same data was inferred using either TTL and BL method. Analyser are not blinded for either measurement methods. 120 blood spectrum data from volunteered included in measurement group. The trial is completed for current prototype version, and shall be reopened for future versions. Document generated according to CONSORT 2010 standard for clinical trial.
RESULTS AND DISCUSSION

110 datums were included in the analysis of the primary outcome. RMSE of TTL 5.27 mg / dl is smaller than BL 5.91 mg / dl, which imply that TTL more accurate than BL. No difference between Parkes ega of TTL and BL, but there is slight decrease in Clarke ega, 99.3 % group A in TTL compared to 100 % group A in BL ( Figure). There large increase of sensitivity using TTL (0.72) compared to BL (0.57), and slight decrease of specificity (TTL 0.68 compared to BL 0.72). Diagnostic accuracy, diagnostics odd ratio, and Youden index all increased in TTL (0.70, 5.53, 0.40) compared to BL (0.65, 3.40, 0.29). Usage of TTL decrease minimum sample needed (2.49) compared to BL (3.44) ( Table). No apparent possible case for adverse effect for either methods.

Table 1. Sensitivity and specificity comparison of Twin Table Ladder and Bert Lambert Methods. Desirable values are highlighted.

<table>
<thead>
<tr>
<th></th>
<th>Twin Table Ladder</th>
<th>Bert Lambert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Prevalence</td>
<td>0.51 (0.46, 0.55)</td>
<td>0.42 (0.38, 0.46)</td>
</tr>
<tr>
<td>True Prevalence</td>
<td>0.47 (0.43, 0.52)</td>
<td>0.47 (0.43, 0.52)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.72 (0.66, 0.78)</td>
<td>0.57 (0.51, 0.63)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.67 (0.62, 0.73)</td>
<td>0.71 (0.66, 0.77)</td>
</tr>
<tr>
<td>Diagnostic Accuracy</td>
<td>0.70 (0.66, 0.74)</td>
<td>0.65 (0.61, 0.69)</td>
</tr>
<tr>
<td>Diagnostic Odd Ratio</td>
<td>5.53 (3.83, 7.98)</td>
<td>3.40 (2.39, 4.85)</td>
</tr>
<tr>
<td>Number Needed to Diagnose</td>
<td>2.49 (1.96, 3.49)</td>
<td>3.44 (2.49, 5.81)</td>
</tr>
<tr>
<td>Youden's Index</td>
<td>0.40 (0.29, 0.51)</td>
<td>0.29 (0.17, 0.40)</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>0.67 (0.61, 0.72)</td>
<td>0.65 (0.58, 0.71)</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>0.73 (0.68, 0.78)</td>
<td>0.65 (0.60, 0.70)</td>
</tr>
<tr>
<td>Positive Likelihood Ratio</td>
<td>2.25 (1.88, 2.71)</td>
<td>2.02 (1.64, 2.50)</td>
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<tr>
<td>Negative Likelihood Ratio</td>
<td>0.41 (0.33, 0.50)</td>
<td>0.60 (0.51, 0.70)</td>
</tr>
</tbody>
</table>

Keywords: Bert Lambert Methods, Non Invasive Blood Glucose Level Measurement Optical Device, Spectral Responses, Twin Table Ladder Modulation

Acknowledgment

Clinical Trial are registered on Database of Komisi Etik Penelitian Kesehatan, Badan Litbang Kesehatan, no LB.02.01/5.2/KE.493/2016, which also grants the ethical clearance. This works supported by IPTEK 2015 no 079/SP2H/LT/DRPM/II/2016. We would like to thanks Non Invasive Bio-marking Working Group, Bogor Agricultural University, for Their indispensable support for this research.

References

Critical properties of the six-state clock model on rewired square lattices

Muhammad Yusuf *1 and Tasrief Surungan2

1Department of Physics Gorontalo State University, Gorontalo, Gorontalo 96128, INDONESIA. (E-mail: my@ung.ac.id)
2Department of Physics, Hasanuddin University, Makassar, South Sulawesi, 90245, INDONESIA. (E-mail: tasrief@unhas.ac.id)

Abstract

The symmetry of spins, lattice dimension and the type coupling interaction are all important for the existence of phase transition, firmly exemplified by the two dimensional (2D) six-state clock model[1]. This is the discrete counterpart of of continuous XY model which is the native host of a unique type of phase transition called Kosterlitz-Thouless (KT) transition, separating the quasi-long range order (QLRO) and the higher temperature paramagnetic phase. Due to the discrete symmetry of spins, the six-state clock model experiences an additional KT transition at low temperature, separating the QLRO and the lower temperature ordered phase. In probing the role played by the spatial dimension on the existing KT transition, here we study the six-state clock model on rewired square lattice. The lattice is obtained by adding an extra link to each site of square lattice, connecting each spin to one of its next-nearest neighbors [2]. The average number of nearest links increases from two to three, which corresponds to increase in spatial dimension. We used Wang-Landau algorithm of Monte Carlo simulation[3] and calculated the correlation ratio in probing the properties of the native KT transition. We observed two KT transitions which shifted to higher temperatures. This indicates that the existing lower temperature ordered phase is more robust compared to that observed in the native square lattice[4].

References
Low-loss ARROW Waveguide with Square Hollow Core and Square Polyethylene/Air Reflectors for Terahertz Waves

Henri P. Uranus*1 and B. M. A. Rahman2

1 Department of Electrical Engineering, Universitas Pelita Harapan, Indonesia. (E-mail: henri.uranus@uph.edu)
2 Department of Electrical & Electronic Engineering, School of Mathematics, Computer Science & Engineering, City, University of London, United Kingdom. (E-mail: b.m.a.rahman@city.ac.uk)

INTRODUCTION

One major problem in developing guided-wave devices, particularly waveguides for terahertz (THz) band, is that most materials are lossy in this frequency band. Polymers, metals, and semiconductors are all lossy in this THz regime (0.1 – 10 THz). In order to circumvent this problem, most scientists considered guiding the waves through the low-loss air within their devices, leading to hollow-core structures. However, such scheme has its own difficulties, as air has low refractive index, hence index-based wave guiding scheme is not possible, and absorption loss, leakage loss also present (a serious problem). To deal with this, several schemes have been proposed, e.g. by putting metal wires or metal coatings as reflectors, by simply having the reflection from dielectric interfaces, photonic crystal fiber (PCF)-like holey cladding, anti-resonant reflection [1], or using the legacy microwave structures like microstrip structures and hollow-core metallic tube, etc.

As a close neighbour, devices working in THz regime can also be modelled using the same modelling techniques usually used in optics. In this work, we used a finite element-based leaky mode solver with Bayliss-Gunzburger-Turkel-like transparent boundary conditions [2] for studying THz waveguides of a hollow-core structure designed with ARROW (anti-resonant reflecting optical waveguide) principles [3] with square core and square polyethylene/Air reflectors. The result shows promising application as it gives low attenuation.

RESULTS AND DISCUSSION

Figure 1 shows the proposed structural cross-section which has been optimized by using the ARROW principles [3] for resonant condition in the hollow core and anti-resonant condition in the reflectors for q-TE polarization with \( w_1=1500\mu m, \ h_c=750\mu m, \ h_1=h_3=h_5=63\mu m, \ h_2=h_4=376\mu m, \ w_1=w_3=190\mu m, \ w_2=1130\mu m, \) and \( w_4=4520\mu m. \) In the simulations using the FEM mode solver, the refractive index of air is taken as 1, while that of the polyethylene (PE) is taken as \( 1.54-i*0.00066845, \) at the 1 THz operating frequency. Figure 2 shows the q-TE\(_{00}\) mode, which is the lowest loss mode in this leaky and lossy structure. The loss of this mode is only 0.05 dB/cm which is much lower than a solid core waveguide with photonic crystal fiber holey cladding using the same material (PE/Air). The longitudinal component of the time-averaged Poynting vector \( <S_z(x,y)> \) is shown in Fig.2, which clearly shows that the near-Gaussian shaped modal field is well confined inside the hollow core.
Figure 1. The proposed low-loss THz waveguide.

Figure 2. The longitudinal component of time-averaged Poynting vector of q-TE\textsubscript{00} mode (a) a 3-D profile with waveguide inset on top, (b) its 2-D profile.

**Keywords:** Terahertz waveguides, ARROW structure, finite element method, leaky mode solver, hollow core structure.

**Acknowledgment**
This work was supported by Erasmus Mundus LEADERS mobility project financed by European Commission grant number 2014-0855.

**References**
Directional Sensing Using Nonconcentric Silver Nanotube

Suhandoko D. Isro and Alexander A. Iskandar*

Physics of Magnetism and Photonics Research Division, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesha 10, Bandung 40132, Indonesia.
(E-mail: suhandokodwi7@gmail.com, iskandar@fi.itb.ac.id)

INTRODUCTION

The Au and Ag based metal nanoparticles of core-shell structures have been intensively studied and reported to have highly desirable applications for refractive index sensing [1]. The nonconcentric core related symmetry breaking structure has been further shown using the plasmon hybridization method [2] to have the possibility of generating multiple fano resonances in a single layer core-shell structures that also offer enhanced optical sensing [3]. More recently, nanowire of Ag shell with axial offset of the glass core was calculated using the theory of transformation optics to exhibit the possible appearance of multiple Fano resonances that offer very high figures of merit (FOM) for refractive index sensing at near UV frequencies [3]. We further show in this report that the nanotube with dielectric core-metal-shell structure also offer the possibility for directional sensing of incoming optical wave.

The nanostructure considered in this study comprises a dielectric cylinder with silver coating arranged in a way such that it forms a non-concentric core-shell system. An incoming plane wave with transverse electric (TE) polarization is incident on the nanostructure, resulting in scattered and standing waves within the system. The emerging fields in all regions can thus be expressed mathematically in the following way [4]

\[
H_{z1}(\rho_2, \phi_2) = \sum_{m=-\infty}^{\infty} [(i)^m J_m(k_3\rho_2) + B_3(m) H_m(k_3\rho_2)] e^{im\phi_2} \tag{1}
\]

\[
H_{z2}(\rho_1, \phi_1) = \sum_{n=-\infty}^{\infty} [A_2(n) J_n(k_2\rho_1) + B_2(n) H_n(k_2\rho_1)] e^{in\phi_1} \tag{2}
\]

\[
H_{z1}(\rho_1, \phi_1) = \sum_{n=-\infty}^{\infty} [A_1(n) J_n(k_1\rho_1)] e^{in\phi_1} \tag{3}
\]

where \(H_{z1}, H_{z2}\) and \(H_{z3}\) denote the magnetic field solutions in the dielectric core, silver coating and background region, respectively. \(H_{m/n}(k_i\rho_j)\) represents the \(n/m^{th}\) order Hankel function of the first kind while \(J_{m/n}(k_i\rho_j)\) describes the \(n/m^{th}\) order Bessel function. The wave number for each region is given by \(k_i = k_f \sqrt{\varepsilon_i}\) with \(k_f = \omega/c\). Two coordinate systems have been introduced, \((\rho_1, \phi_1)\) and \((\rho_2, \phi_2)\), the former has its origin at the center of the core cylinder while the latter is fixed at the axis of the cylindrical Ag layer. The unknown field coefficients \(A_1(n), A_2(n), B_2(n),\) and \(B_3(m)\) can be determined from the boundary conditions at the two interfaces with the help of Graf’s addition theorem given below

\[
J/H_n(k_2\rho_1) e^{in\phi_1} = \sum_{m=-\infty}^{\infty} J_{m-n}(k_2\rho_1) e^{-(m-n)\phi} J/H_m(k_2\rho_2) e^{im\phi_2} \tag{4}
\]
in which \((\rho, \phi)\) are the core offset parameters representing the relative position between the two coordinate origins. The standard definition of directivity is used to characterize the radiation of the nanostructure.

RESULTS AND DISCUSSION

The radiation intensities of the scattered waves were calculated for various geometrical parameters such as the core offset parameter and the core cylinder radius \((R_{in})\), whereas the radius of the silver coating was fixed at \(R_{out} = 50\) nm. The Ag nanotube has a dielectric core of \(\varepsilon_1 = 4\) with vacuum background. The radiation pattern of the scattered wave is illustrated in figure 1(a). The variation of directivity with respect to \(R_{in}\) was calculated and the result is displayed in figure 1(b). It can be seen that the best result is obtained for the case of \(R_{in} = 27.5\) nm and \((\rho, \phi) = (20.5\) nm, \(0^\circ)\) with directivity \(D = 12.27\) as shown in figure 1(b).

![Figure 1](image)

**Figure 1.** (a) The radiation pattern obtained for the case of \(R_{in} = 27.5\) nm and \((\rho, \phi) = (20.5\) nm, \(0^\circ)\), which exhibits the highest directivity of \(D = 12.27\) (large lobe), along with the radiation pattern obtained from the case of \(R_{in} = 12.5\) nm and \((\rho, \phi) = (35.5\) nm, \(0^\circ)\) (small lobe). (b) The calculated directivity for some variations of inner core radius. The core cylinder for each structure is shifted toward the outer surface so that the narrowest distance between the two surfaces is 2 nm.

**Keywords:** directional sensing, nonconcentric nanotube, plasmonics

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PP-8

Transmission Profile of a One Dimensional Photonic Crystal Embedded by two Graphene Layers

Angga Ismi Aziz¹, Dwi Rahmawati¹, Husin Alatas¹, and Hendradi Hardhienata¹

¹Theoretical Physics Division, Department of Physics, Bogor Agricultural University, Jl. Meranti, Gedung Wing S, Kampus IPB Darmaga, Bogor 16680, Jawa Barat, INDONESIA

E-mail: hendradi@ipb.ac.id

INTRODUCTION

In this work we report the simulation results of the electric field transmission profiles of a propagating monochromatic wave inside a 1D Photonic Crystal (consisting of arrays of dielectric slabs with index $n_1$, $n_2$) with the insertion of two graphene layers on both ends. It has long been understood that 1D photonic crystal when shined by light exhibit several interesting features such as the occurrence of bandgaps and the possibility to modify its properties by changing the refractive index and width of the slab length. It is also well known that insertion of single defect layer can produce a pass band inside the bandgap which can also be modified by changing the properties of the defect slab. With the availability of graphene which have many interesting properties such as very high electron mobility and mechanical strength¹, there exists the opportunity to insert very thin graphene layers into photonic crystals. Earlier results indicate that insertion of such graphene layers can produce interesting result e.g. attenuation properties of the electric field inside the slab² and ability to control the passband properties for a dual defect³. However, other features may arise from various combinations of inserted graphene layers.

Figure 1. Model of the two graphene layer insertion into a 1D photonic crystal

In this research, we present a simulation study of multi-layer graphene inserted into a 1D photonic crystal and measure the field transmittance profile output and analyze their dispersion relations. We use the rigid and well known transfer matrix methods (TMM) obtained using the field periodicity and continuity condition between the slab boundary, which proved to be effective in calculating electromagnetics field profile and offers high flexibility in simulating the transmission profiles for
different dielectric index and graphene conductivity values. In our model we insert two very thin graphene layers at both ends as given in Figure 1.

RESULTS AND DISCUSSION

Applying the TMM for our model we found that the dispersion relation is given by

\[
\cos K\Lambda = \frac{(M_{11} + M_{22})}{2}
\]

where \( M_{11} \) and \( M_{22} \) are the components of the final 2x2 transfer matrix and explicitly contains the graphene conductivity \( \sigma \). Interestingly, we found that the dispersion relation is independent of the graphene conductivity value due to cancellation when adding \( M_{11} + M_{22} \) as long as its thickness is very thin e.g. comprising of only single atomic layer so that it is negligible. However, because the transmittance is obtained via

\[
t = \left[ \frac{1}{M_{11}} \right]
\]

thus containing the graphene conductivity it will produce attenuation effect due to field absorption by the graphene layer thus decreasing its transmittance as can be seen in Fig. 2.

![Graph](image)

**Figure 2.** Field transmittance variation due to changes in the graphene conductivity of (a) zero, (b) \( \sigma = 10 \) (c) \( \sigma = 20 \).

**Keywords:** Photonic crystal, graphene, transfer matrix, dispersion relation.

**References**

Effect of Laser Pulse Repetition Rate on the Size of Gold Nanoparticles Produced by Laser Ablation Method

Ali Khumaeni\textsuperscript{1*}, Heri Sutanto\textsuperscript{1}, and Wahyu Setia Budi\textsuperscript{1}

\textsuperscript{1}Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Jl. Prof. Soedharto, SH, Tembalang, Semarang 50275, Indonesia

(E-mail: *khumaeni@fisika.undip.ac.id; herisutanto@gmail.com; wahyu.sb@undip.ac.id)

INTRODUCTION

Synthesis of nanoparticles (NPs) has attracted increasing attention due to interesting applications of nanoparticles in various fields. NPs are fine particles with a dimension less than 100 nm. NPs have been applied for photonics devices, catalysts, sensors, and biomedical applications [1]. The particles have specific characteristics compared to their bulk materials in optic, chemical, and electronic properties. Gold nanoparticles (GNPs) is one of NPs, which are recently studied, due to their appealing applications for biomedical sensing and biophotonics [2].

Various techniques have been applied to produce GNPs. The techniques include chemical and physical techniques [3]. However, by using chemical technique, high-purity NPs cannot be produced because of impurity from stabilizer and agent during the synthesis. Furthermore, the techniques need delicate sample preparation and time consuming.

The other technique for synthesis GNPs is pulse laser ablation (PLA) technique. The technique can be used to synthesize GNPs with very high purity compared to chemical and other physical techniques. In PLA, high-power pulse laser is focused on high-purity gold metal placed in the pure liquid to produce gold nanoparticles. The laser usually use as an energy source is nanosecond or femtosecond laser. However, high-power laser (more than 50 mJ in laser energy) is commonly used to ablate the material.

In this study, GNPs was produced by using PLA technique utilizing pulse neodymium yttrium aluminum garnet (Nd:YAG) laser with low power (less than 50 mJ). The effect of laser pulse repetition rate on the size of produced GNPs was examined. The GNPs was characterized morphologically by scanning electron microscope (SEM). Size distribution and emission absorbance were obtained by particle size analyzer (PSA) and ultraviolet visible spectroscopy.

The setup used in this study is shown in Fig. 1(a). A Nd:YAG laser beam (New Polaris II at fundamental wavelength of 1064 nm, 50 mJ) was focused on the surface of sheet gold metal (99.9\%) by convex lens to ablate the sheet to produce GNPs. The repetition rates of laser beam were set at 15 and 10 Hz. The laser beam was bombarded on the sample surface for duration of 20 minutes. It should be pressurized that during laser bombardment, the gold sheet and solution were periodically moved to achieve a homogeneous GNPs colloid and new-sheet position.

RESULTS AND DISCUSSION

GNPs colloids produced by using PLA method with different repetition rate of pulse laser are shown in Fig. 1(b). Dark-red (left-hand side) and light-red (right-hand side) color GNPs were produced by using PLA technique with repetition rates of 15 and 10 Hz, respectively. The laser energy was 30 mJ.
and duration of laser bombardment onto the pure gold sample was 20 minutes. During the synthesis process, gold metal and solution were periodically moved to obtain homogeneous GNPs colloid. The averaged diameters of GNPs produced in this study was 25.8 nm with standard deviation of 7.3 nm for the laser repetition rate of 15 Hz, while for the case of 10 Hz repetition rate, the diameter of GNPs was 9.8 nm with standard deviation of 2.5 nm as shown in Figs. 2(a) and 2(b), respectively. It should be mentioned that the spectrum of GNPs taken by using ultraviolet visible (UV-Vis) spectroscopy shows clear single absorbance line at the center wavelength of 520 nm, which certifies that the GNPs produced by using the present method has spherical shape. Detail explanation on the effect of laser repetition rate on the size of GNPs will be discussed in the paper.

Figure 1. (a) Experimental setup used in this study, (b) GNPs colloid

Figure 2. Sizes of GNPs obtained by using PSA for laser repetition rate of (a) 15 Hz and (b) 10 Hz

Keywords: Gold nanoparticles; pulse laser ablation technique; Nd:YAG laser; laser repetition rate; biophotonics

Acknowledgment
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References
The Influence of MoO\textsubscript{3} Addition on Photovoltaic Performance of Natural Dye-Sensitized TiO\textsubscript{2} Photoanode in Photoelectrochemical Cell

Akhiruddin Maddu\textsuperscript{*1}, Astuti Alawiyah\textsuperscript{2} and Sidikrubadi Pramudito\textsuperscript{3}

\textsuperscript{1,2,3} Department of Physics, Bogor Agricultural University, Indonesia.
(E-mail: akhiruddin@apps.ipb.ac.id, sdpramudito@yahoo.com)

INTRODUCTION

The photoelectrochemical solar cell is a type of solar cell based on the semiconductor-electrolyte junction, where the semiconductor (type-n or p) acts as photoelectrode which interacts with photon energy to generate the free electrons [1,2]. In the depletion region of the semiconductor-electrolyte junction a double layer is formed with different charge polarities that give rise to the potential difference and internal electric field. When free electrons are generated with appropriate photon energy in the deflection region, they will be driven by electrostatic forces in the depletion region to the outer circuit that produces electrical power.

In this research, we developed photoelectrochemical cell using photoanode made of TiO\textsubscript{2}/MoO\textsubscript{3} composite coated onto ITO glass substrate. The MoO\textsubscript{3} nanopowder was synthesized by sonochemical precipitation. Photoanode was made by mixing TiO\textsubscript{2} powder (P25 Degussa) with MoO\textsubscript{3} nanopowder to form a composite film. To enhance visible light absorption, the resulted film photoanode was sensitized by the natural dye (anthocyanins) extracted from a plant (Melastoma malabathricum L.). The performance of photovoltaic was measured in the photoelectrochemical cell with kalium iodide (KI) electrolyte.

![Figure 1. I-V characteristic of solar cell without MoO3 addition](image-url)
RESULTS AND DISCUSSION

Figure 1 show the current-voltage (I-V) curve of photoelectrochemical cells each using photoanode TiO$_2$ without and with the addition of MoO$_3$. The resulting I-V curves show the ideal characteristics of solar cell diode. Based on the obtained I-V curve it is known that that the addition of MoO$_3$ to the TiO$_2$ photoanoda significantly increases the photocurrent but the voltage decreases. The increased photocurrent due to electron transfer that is generated by photon energy from the dye increases as the position of the higher conduction band of MoO$_3$ from the TiO$_2$ conduction band (as shown at Fig. 2) makes it easier for the electrons to transport to the external circuit. On the other hand, the open circuit potential ($V_{OC}$) becomes lower because of the position of the photoanode conduction band became closer to the redox potential position of the electrolyte (see Fig. 2). But overall the performance of photoelectrochemical cells increased, i.e the value of its conversion efficiency increased with the addition of MoO$_3$ compared with that without the addition of MoO$_3$. This enhancement is largely determined by the increase in short-circuit current ($I_{SC}$) which increases by six times higher for a photoanode (TiO$_2$) added MoO$_3$ compared to that without the addition of MoO$_3$.

![Energy diagram of TiO$_2$/MoO$_3$ heterstructure electrode](image)

**Figure 2.** Energy diagram of TiO$_2$/MoO$_3$ heterstructure electrode

**Keywords:** MoO$_3$, natural dye, photoelectrochemical cell, photoelectrode, photanode

**References**

PP-11

Photonic Crystal Grating Based on Perovskite Organometallic using Finite Difference Frequency Domain Methods

Adli¹, T.P. Negara², H. Hardhienata³, and H. Alatas³

¹,²,³Theoretical Physics Division, Department of Physics, Bogor Agricultural University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, Indonesia
(E-mail: adlyms@gmail.com, teguhpujanegara@yahoo.com)
²Department of Computer Science, Pakuan University, Bogor, Indonesia
(E-mail: teguhpujanegara@yahoo.com)

INTRODUCTION

It is well known that the optical response of a material can be numerically analyzed using the Finite Difference Frequency Domain (FDFD) method [1]. This method can be applied to investigate field profiles of structures for any length and any frequency of electromagnetic radiation [2]. Discretization of Maxwell equation into linear equations using FDFD is conceptually more simple and more easy to implement than other methods such as Finite Element Method or the Method of Moments. [3]. Furthermore, compared to the Finite Difference Time Domain (FDTD), the FDFD method is more simple for steady state differential equation that are a function of time. However the FDFD is less popular than FDT because it has slower convergence when applied to 3D Maxwell equations.

In this work we apply FDFD methods to investigate the field profile of periodic structures that are composed of organometallic perovskite materials. Such a material has several interesting physical properties such as high flexibility, easy to fabricate, and low cost. Several research group have applied organometallic perovskite structure in solar cells and reported high efficiency [4] as well as electron transport absorption and resonance in the visible spectrum [5]. Our FDFD simulation on periodic grating structures made from organometallic perovskite showed a field amplification for certain frequency modes. By varying the refractive index of the analyte a change in the resonance peak is observed which has the potential application as sensor.

RESULTS AND DISCUSSION

Our structure is depicted in Figure 1 and consists of a 2.0332 x 0.156 μm Si substrate, deposed by a SrTiO₃ organometallic slab with the same dimension. On the top of it, a grating made from organometallic SrNbO₃ with dimension 0.1508 x 0.156 μm is installed. The grating can be filled with an analyte having an index range from 1 (air) – 1.5.
The simulation result of the spectral transmittance in the visible range is given in Figure 2. We observe electronic resonance mode for a wavelength of 402 nm, 415 nm, 430 nm, 461 nm, 499 nm, 547 nm, 559 nm, 670 nm, and 758 nm. The physical explanation will be presented in the full paper.

Keywords: Finite Difference Frequency Domain, Organometallic Perovskite, Grating Structure, References

PP-12

Fluorescence Spectroscopy Characteristic of Indonesia Local Citrus

Tika HS*, Usman A², Sutrisno² and Akhiruddin M³

¹,²Dept. of Mechanical and Biosystem Engineering, Bogor Agriculture University. Indonesia. (E-mail: tikahafzara@gmail.com, uahmad2010@gmail.com)
³Dept. of Physics, Bogor Agriculture University. Indonesia. (E-mail: akhiruddin@ipb.ac.id)

INTRODUCTION

Citrus experienced physical damage in peel will produced essential oil that can be detect by fluorescence spectroscopy. To developed mechanical damage detection system of Indonesia local citrus based on fluorescence spectroscopy, needs data of Indonesia local citrus on fluorescence spectroscopy characteristics. The aim of this study is to determine the characteristic of fluorescence spectroscopy such as absorbance, excitation, and fluorescence of Indonesia local citrus and the fluorescence substance that contain in citrus peel. From this experience, it was found absorbance and fluorescence wavelength of Indonesian local citrus are 320 nm to 365 nm and 536 nm to 552 nm. Fluorescence substance is Polymethoxylated flavone such as tangeretin and nobiletin.

RESULTS AND DISCUSSION

Absorbance Spectrum Analyze of Indonesia Local Citrus

The primary peak of absorbance wavelength from this citrus is almost the same. Fig 1. show absorbance spectrum of Indonesia citrus. The primary peak appear in 320 nm to 365 nm. Another peak appear in 420 nm and 450 nm. It means that there are three fluorescence substance contain in citrus peel extract. This information used to select the proper lamp to excitate the sample. From the absorbance wavelength, the proper lamp to excitate the sample was 365 nm.

![Figure 1. Absorbance spectrum of three Indonesia local citrus](image-url)
Characteristic of Fluorescence Spectroscopy from Indonesia Local Citrus

Same as the absorbance spectrum, there are three peak in fluorescence spectrum but the intensity is different. Fig 2. Show the fluorescence spectrum of three varieties Indonesia local citrus. The first peak appear in 536 nm 552 nm, second is in 650 nm to 680 nm and the last is in 720 to 800 nm. Kondo et al. (2009) state that mandarin citrus has fluorescence substance that excited with light from 320 nm to 390 nm and emit the fluorescence of 520 to 570 nm. The fluorescence substance in Mandarin citrus is Polymethoxylated flavone. From this literature, the fluorescence substance from Indonesia citrus supposed to be the same as the mandarin citrus. The first peak in 542 nm should be Polymethoxylated flavone. This substance will release in the citrus peel when citrus get damage. From this study, the fluorescence method can be apply to be detection method of Indonesia citrus. The other peak in 670 nm and 740 nm refer to chlorophyl substance. Belasque et al. (2008) state that chlorophyll fluorescence wavelength is 650 nm until 800 nm.

![Fluorescence spectrum of Indonesia local citrus](image)

**Figure 2.** Fluorescence spectrum of Indonesia local citrus

**Keywords:** absorbance spectrum, citrus, fluorescence spectrum, surface defect

**References**

High Sensitivity Integrated Sensor Based-on Multi-path Optical Ring Resonator for Environment Applications

Dadin Mahmudin*1, Yusuf N. Wijayanto1, Robeth V. Manurung2, Gandi Sugandi1, Ahmad Rifqi Md. Zain2, Pamungkas Daud1 and Sahbudin Shaari2

1 Research Center for Electronics and Telecommunication, Indonesian Institute of Sciences (LIPI), Indonesia
2 Institute of Microengineering and Nanoelectronics (IMEN), Universiti Kebangsaan Malaysia, Malaysia
(E-mail: dradrin@gmail.com)

INTRODUCTION

High sensitivity environmental sensors with simple and compact structures are required to monitor undesirable pollution. In this paper, integrated sensors (IS) based on the Multi-path Optical Ring Resonator (MpORR) are proposed. This device (IS) consists of several sensor components based on Microring Resonator, can be shown at Figure 1 and 2. This device has the ability to detect some unwanted substances that attach to sensitive layers of sensor components sensitively and selectively. The refractive index value of the layer sensitive will change if any unwanted substances are attached. This refractive index change is used as the basis for detecting these unwanted substances. It is designed on Silicon on Insulator (SOI) substrate. Silicon as the core of optical waveguides and Silicon Dioxide (SiO2) as a cladding. This paper also discusses the simulation results of the structure of the component sensor.

RESULTS AND DISCUSSION

Ring resonator with wide FSR is absolutely necessary for the design of the sensor with high sensitivity. Some papers show a wide Free Spectral Range (FSR) allowing the value of the Q-factor to increase so that the sensitivity of the sensor will increase [1,2,3].

FSR in MRR equation can be written:

\[ FSR = \Delta \nu = \frac{c}{n_{eff} 2\pi r} \]  \hspace{1cm} (1)

Where c is the speed of light, neff is the effective refractive index and r is the radius of the resonator. Based on the above equation, wide FSR can be generated by setting the value of r as small as possible. The smaller the value of r, the bending loss on the waveguide will increase. The vernier effect method
on the MpORR structure will widen the FSR without reducing the radius value [3,4]. Figure 5 shows the simulation results of the MpORR structure with $r = 3\mu m$ and the waveguide width is 100 nm. The color difference of the spectrum shows the measurement results of a different analyte. The value of FSR obtained is 3 THz.

Figure 3. Simulation results of MpORR for the transmittance characteristics

Figure 4 shows physical characterization of proposed component. Figure 5 can be seen that the difference between the design and the fabrication result is very small. It can be believed will not affect the performance of the sensor.

Figure 4. Physical characterization of the MpORR component

The proposed multi-path optical ring resonator can be realized with a wide free spectral range value (FSR) of 3 THz.

**Keywords:** multi-path optical ring resonator; Silicon on Insulator; Free Spectral Range

**Acknowledgment:** This work is part of the project entitled “Design of Smart Sensor Multimode Optical Waveguide Based on Polymer Substrate for Environmental Applications” funded by the “The Excellent Research Grant from Indonesian Institute of Sciences (LIPI”).

**References**


Ab-Initio Calculation of Electronic Structures of Methylammonium Lead Bromide/Iodide as Wide Band Gap Active Materials for Bulk Hetero Junction Perovskite Solar Cell Applications

Efi D. Indari¹, Triati D.K. Wungu¹ and Rahmat Hidayat¹

¹ Physics Department, Bandung Institute of Technology, Indonesia.
(E-mail: efidwiindari@gmail.com, triati@fi.itb.ac.id, rahmat@fi.itb.ac.id)

INTRODUCTION

A rapid success of perovskite solar cells has been achieved within these few last years. Inspired by more than 20 % efficiencies performed by the single layer architecture, researchers start working on tandem layer by combining low and wide bandgap active materials, to obtain even higher efficiencies. One of the most promising wide band gap active materials is methylammonium lead bromide/iodide (MAPbBr$_{3-x}$I$_x$) which complement the low bandgap of silicon. To the best of authors’ knowledge, the highest achieved efficiency was 13.7 %, which has not fulfilled the goal of the design yet. Hereby, a fundamental study about this particular active material, especially the electronic structures that influence the photo-absorption efficiencies (which in the end affects overall solar cells efficiencies is required) to be carried out. A number of experimental investigations in this particular issue had been conducted. However, a computational study has just been limitedly reported. Hereby we report our calculation results by varying the composition of bromide ions with density functional theory (DFT) method.

RESULTS AND DISCUSSION

The calculation results include the materials bandgap, density of states (DOS), and projected density of states (PDOS) of each system. The values of bandgaps including the structure of each crystal are shown in table 1. The trend of the obtained values follows an equation proposed by Noh et al shown below:

$$E_g(x) = 1.57 + 0.39x + 0.33x^2$$  \hspace{1cm} (1)

where x is the bromide ions proportion compared with iodide. Lower values obtained are due to the application of generalized gradient approximation (GGA) as the exchange correlation functionals.

<table>
<thead>
<tr>
<th>Crystal Structure</th>
<th>Lattice Parameter (Å)</th>
<th>Obtained Bandgap (eV)</th>
<th>Theoretical Bandgap (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAPI</td>
<td>Pseudocubic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a=6.2621, c=6.3275</td>
<td>1.232</td>
<td>1.57</td>
</tr>
<tr>
<td>MAPI$_2$Br(x=0.33)</td>
<td>Cubic</td>
<td>6.18</td>
<td>1.266</td>
</tr>
<tr>
<td>MAPIBr$_2$(x=0.67)</td>
<td>Cubic</td>
<td>6.07</td>
<td>1.428</td>
</tr>
<tr>
<td>MAPBr$_3$</td>
<td>Cubic</td>
<td>6.29</td>
<td>2.618</td>
</tr>
</tbody>
</table>

Exemplary results of DOS and PDOS are depicted in figure 1 (a) and (b) respectively. From figure 1 (a), it is known that the obtained bandgap of MAPI$_2$Br at R high symmetry point. Meanwhile, PDOS
graphs shows that the valence and conduction bands are dominated with outermost orbitals of halide ions (4p Br\(^{-}\) and 5p I\(^{-}\)) and 6p orbitals of Pb\(^{2+}\) respectively. It is also known that in valence band, 4p Br\(^{-}\) is more dominant than 5p I\(^{-}\).

![Graphs showing DOS and PDOS of MAPI\(_2\)Br](image)

**Figure 1.** (a) DOS and (b) PDOS of MAPI\(_2\)Br

**Keywords:** DFT, DOS, electronic structure, PDOS, perovskite, wide bandgap active material.

**Acknowledgment**
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**References**
PP-15

Preparation Organic Lead Halide Perovskite Layers in Relatively High Humidity Atmosphere and its Solar Cell Characteristics

Adhita Asma Nurunnizar¹, Muslihun¹, Tanti Dewinggih¹, Mhd. Ikhsan Alturisa², Mardiyati² and Rahmat Hidayat¹

¹ Physics of Magnetism and Photonics Research Division, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology, Indonesia
² Materials Engineering Program Study, Faculty of Mechanical and Aerospace Engineering, Bandung Institute of Technology, Indonesia
(E-mail:asmaannizar@gmail.com, rahmat@fi.itb.ac.id)

INTRODUCTION

Research on the application of organometal halide perovskite (hybrid perovskite) as an active layer in solar cells has significantly increased in the past 5 years [1,2]. This material exhibits photovoltaic characteristics with relatively small energy gap and therefore becomes a good active layer in solar cells. Despite its simplicity in its preparation, this hybrid perovskite material produced remarkable high solar cell efficiency. The key feature of this material is that it can be synthesized with the wet-chemical process at low temperature. This low-temperature process feature could reduce the cost of cell fabrication which leads to open a possibility of much cheaper solar cell among the third generation of solar cells. The formation of organometal halide perovskite crystal is simply based on stoichiometry reaction. However, the formation process seems to be sensitively affected by some process parameters such as concentration, temperature, and humidity. It is therefore interesting to explore the preparation of this crystal (CH₃NH₃PbI₃ (MAPbI₃) crystal) at relatively high humidity atmosphere, which is a common condition in tropical countries, and understanding its effect on the produced crystal perovskite layer and its solar cells characteristics.

RESULTS AND DISCUSSION

The MAPbI₃ perovskite layers were prepared by a one-step spin coating technique, where the substrate and precursor solution were pre-heated at certain temperature prior to the spin coating process. The resulted perovskite layers were characterized by XRD and compared to the reference XRD pattern with COD entry no. 96-433-5369. [4]. The XRD peaks are in good agreement with the literature, with the most intense peak is at 14.1°, which indicates the diffraction from (110) and (002) planes. The presence of small peaks at 23.5° and 30.1° indicates the diffraction from (211) and (213) planes, which belongs to β-MAPbI₃ phase. In addition to peaks originated from the perovskite crystal, there is also a peak which does not belong to perovskite crystal. A peak (denoted with letter “L”) observed at 2θ = 12.65° is the diffraction peak from (001) plane of PbI₂. The presence of this L-peak in all XRD patterns shows that there is a small amount of unconverted PbI₂ left in perovskite films depending on precursor solution temperature increasing from 40°C, 60°C to 80°C. The remaining PbI₂ contents in these perovskite layers are about 2-4%.

The presence of remaining PbI₂ seems critically affect the durability of the devices, particularly to the temperature effect. The J-V characteristics of the cells were measured under dark condition. Figure 3 clearly shows that the J-V characteristics significantly change with increasing temperature, although the J-V curve exhibits a good diode characteristic at room temperature. By fitting with a space charge limited current model, the change of the J-V curve can be caused by the increase of internal Ohmic resistance, which may
be due to the perovskite conversion back into the PbI\(_2\). However, such effect may be reduced with further improvement if we can reduce the thickness such that there is no formation perovskite layer on the top of mesoporous TiO\(_2\) layer.

![Figure 1. XRD patterns of MAPbI\(_3\) spin-coated at 40°C (PSX-40 sample), 60°C (PSX-60 sample), and 80°C (PSX-80 sample).](image1)

![Figure 2. The J-V curve of perovskite solar cell made in this work from 1.0 M precursor solutions with temperature at 60°C.](image2)

![Figure 3. J-V curves of PSC made in this work from](image3)

**Keywords:** organic metal halide perovskite, solar cells, perovskite crystal

**Acknowledgment**
The authors acknowledge the support from Hibah Kerjasama Luar Negeri, Ristekdikti.

**References**
Variations of Plasmon Coupling between Identical Au Nanospheres with Their Separation and Sizes Studied within a Hybridization Scheme

Margareta V. Stephanie*1 and Alexander A. Iskandar2

1, 2 Physics of Magnetism and Photonic Research Division, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia.
(E-mail: margavanstep@gmail.com, iskandar@fi.itb.ac.id)

INTRODUCTION

Metallic-nanosized particle is intriguing subject for light manipulating investigation due to its significant properties called particle plasmon. Localization of plasmon resonance depend not only size and shape of particle, but material and medium of particle as well. Another optical properties can be acquired by considering two identical nanospheres structure, or called dimer. Distance between spheres and size of them determine the resonance shift as the result of interparticle coupling. Plasmon coupling are known to play important roles in metal nano structure and metal nanoparticle system. Coupling of localized surface plasmon between two closely separated particles give high field enhancement in the gap that have variety applications in surfaced-enhanced Raman spectroscopy, high-precision measurement as plasmon ruler, and solar cell technology.

Two small identical nanospheres (radius \( \leq 20 \) nm) generate dipole mode interaction and yield energy shifts from isolated sphere. In this study, we use this parameter to develop plasmon hybridization formulation in modelling plasmon coupling supported by bonding and antibonding plasmon modes. Using the linear combination of atomic orbitals or LCAO method, plasmon hybridization of two identical spheres is found to be related to interconnectedly coupling and overlap function which both of them depend on parameter distance and radius.

RESULTS AND DISCUSSION

The multisphere scattering problem is governed by Mie theory1 using vector spherical harmonic function (VSHF). It is necessary to use addition thorem to combine all scattered wave from other spheres with original incoming waves so that VSHF that refer primary origin can be translated to another coordinate system located in the center of other sphere. This analytical approach show the multi-polar plasmons excitation corresponding to dipoles, quadrupoles and higher poles. Bonding energy of homodimer sphere can be achieved from resonance mode of extinction cross section which is defined as follow

\[
C_{\text{ext}} = \frac{2\pi}{k^2} Re \sum_{j=1}^{N_s} \sum_{n=1}^{\infty} \sum_{m=-n}^{n} \sum_{m=-n}^{(n+1)(n+m)!} \left( \alpha_{mn}^j p_{mn}^j + b_{mn}^j a_{mn}^j \right) (1)
\]

where

\[
\alpha_{mn}^j = a_n^j \left( p_{mn}^j - \sum_{l \neq j}^{(1,L)} \sum_{n=1}^{\infty} \sum_{\mu=-n}^{n} [a_{\mu n}^j A_{mn}^{\mu \nu}(l,j) + b_{\mu n}^j B_{mn}^{\mu \nu}(l,j)] \right) 
\]

\[
b_{mn}^j = b_n^j \left( q_{mn}^j - \sum_{l \neq j}^{(1,L)} \sum_{n=1}^{\infty} \sum_{\mu=-n}^{n} [a_{\mu n}^j A_{mn}^{\mu \nu}(l,j) + b_{\mu n}^j B_{mn}^{\mu \nu}(l,j)] \right) 
\]

\( a_{mn}^j \) and \( b_{mn}^j \) are total scattering coefficient of each sphere, \( a_n^j \) and \( b_n^j \) are Lorenz-Mie single sphere coefficients, \( p_{mn}^j \) and \( q_{mn}^j \) are incident coefficients, depend on the nature of propagation properties.
of incoming light, $A_{mn}^{\mu\nu}$ and $B_{mn}^{\mu\nu}$ are translation coefficient from $l$th coordinate system to $j$th coordinate system, associated to Gaunt coefficient $^2$.

Coupling interaction of two nanospheres can be considered as linear combination of each plasmon constituents $^3$. Bonding ($E_+$) and antibonding ($E_-$) of plasmon energy are expressed as

$$E_\pm = \frac{\alpha \pm \beta(x,r)}{1 \pm S(x,r)}$$  \hspace{1cm} (5)

where $\alpha$ can be considered as ground state energy or simply as energy of single sphere, $\beta$ is coupling function, and $S$ is overlap function. $\beta$ and $S$ are each a function of both distance ($x$) and radius ($r$) of spheres. The empirical plasmon hybridization of nanosphere dimer is found depending on interconnectedly coupling and overlap function as shown in the following formula

$$E_\pm(x,r) = \frac{2.333-0.1095 \exp(0.003994 x + 0.04356 r)}{1 + r \exp(-3.205 x + 1.417)}$$  \hspace{1cm} (6)

Equation above show that energy of two identical nanospheres differ exponentially interparticle distance and radius of sphere. From Figure 1, at fix radius, as the spheres are largely separated, the interparticle coupling becomes weak and toward vanishing of overlapping function and bonding energy approach to energy of single nanosphere.

![Figure 1. Bonding energy to separated distance center-to-center of dimer for various radius of spheres.](image)

In conclusion, hybridization scheme developed in this study has shown that interparticle distance and size of particle contributed to plasmon coupling of two identical particle and can be useful in investigation of measurement and sensing application of plasmonic devices.

**Keywords:** coupling, homodimer, nanospheres, plasmon hybridization

**Acknowledgment**

This work was supported by Program Unggul Perguruan Tinggi Dikti 2017 from the Indonesian Ministry of Research, Technology and Higher Education.

**References**

Study Characteristics of Current-Voltage Curves of DSSC with Reduced Graphene Oxide Thin Film as Counter Electrode

F. Yuliasari, Fitrilawati, N. Syakir, A. Aprilia*

Department of Physics University of Padjadjaran.
Jalan Raya Jatinangor Km 21 Sumedang 45363 West Java Indonesia
*a.aprilia@phys.unpad.ac.id

INTRODUCTION

Dye-sensitized solar cell (DSSC) is a promising alternative to conventional silicon or compound semiconductor solar cells. The basic DSSC structure consists of dye that adhered to nanocrystalline TiO$_2$ photoanode, an electrolyte solution, and Pt counter electrode. Recently, carbon materials such as graphene oxide (GO) obtain graphene-like that known as reduced graphene oxide (RGO) have been considered as candidates of counter electrode in DSSC. The important parameters of solar cells can be calculated from the current–voltage (I–V) characteristics and by analyzing their equivalent circuit. In this research, the characteristics of DSSC using RGO thin film as counter electrode was studied. The RGO thin film were deposited on FTO (Fluorine-doped Tin Oxide) substrate by using spin coating technique and followed by thermal reduction process at 200$^\circ$C. In this research, a simple and a straight-forward approach to derive the parameter s of DSSC in terms of single diode model were discussed. The electrical properties of interfacing between RGO counter electrode and electrolyte was investigated by Electrochemical impedance spectroscopy (EIS). We also tried to extracting the cell parameters such as series resistance (RS), shunt resistance (RSH), and ideality factor (n) by analysis of a current density-voltage (J–V).

RESULT AND DISCUSSION

We report characteristics of reduced graphene oxide (RGO) as a counter electrode in dye-sensitized solar cell (DSSC) with structure FTO/TiO$_2$/Ru-dye/Electrolyte/RGO/FTO. The device with GO (DSSC$_{GO}$) and commonly counter electrode (Pt) were also prepared. RGO film was characterized by Ultra-violet Visible spectroscopy. The absorbance spectrum of GO film was increased after thermal reduction process indicates the oxygen content was reduced in RGO film.

![Figure 1](image-url) Photocurrent density-voltage (J-V) curves of DSSC with varied counter electrode, GO (square), RGO (circle), and Pt (triangle)
Figure 1 shows J-V curves of DSSC with varied counter electrode (CE), namely DSSC_{Pt}, DSSC_{RGO} and DSSC_{GO}. The photovoltaic parameters such as $J_{sc}$, $V_{oc}$, $FF$ and $\eta$ were calculated from J-V curves. The device with RGO film as counter electrode shows a better performance compared to the GO film. The efficiency ($\eta$) of 3.43% was obtained by DSSC using RGO film as a counter electrode. The parameters series resistance ($R_s$), shunt resistance ($R_{sh}$), and ideality factor ($n$) was measured using diode model equation. For DSSC_{RGO}, $R_s$ value was obtained 3.5 $\Omega$cm$^2$, $R_{sh} = 300 $ $\Omega$cm$^2$, $n = 2.4$. Shunt resistance ($R_{sh}$) is related to the leakage current inside the cell, low $R_{sh}$ will produce power losses in solar cells. A high ideality factor ($n > 1$) correlated with charge recombination process that occurred inside the cell, leading to smaller value of $I_{sc}$. Figure 2 shows the electrochemical impedance spectroscopy measurement of the sample with structure FTO/Electrolyte/RGO/FTO. The result shows that the triiodide diffusion decreases in size and eventually merges with the growing charge-transfer semicircle.

![Figure 2. Nyquist plot of electrochemical impedance spectroscopy measurements, data A shows at 0.4 Volt condition, data B shows at 0.6 Volt condition, and inset picture shows at 0 Volt](image)

**Keywords**: Dye-sensitized solar cell, reduced graphene oxide, current density - voltage curves

**Acknowledgment**

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**References**

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Fabrication of surface Plasmon resonance (SPR) grating coupler with sub-wavelength periodicity and its reflectance spectrum simulation

Jalu Setiya Pradana*¹, Siti Chalimah² and Rahmat Hidayat³

Physics of Magnetism and Photonics Research Division, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology, Indonesia
(E-mail: jspradana@gmail.com, rahmat@fi.itb.ac.id)

INTRODUCTION

Surface Plasmon Resonance (SPR) is a resonance phenomenon between electrons oscillation on the metal surface and an incident electromagnetic wave causing quantized plasmon oscillations on metal surfaces. This SPR phenomenon produces an evanescent wave that has a very strong electric field, which is considered can be used for light excitation or light absorption of small amounts of adsorbed molecules on the metal surface. Therefore, this SPR phenomenon has been applied to bio-chemical or bio-medical sensors.

In this presentation, we show the fabrication of grating-coupled SPR element with sub-wavelength periodicity and its analysis on its reflectance and transmission spectra by performing spectrum simulation using Rigorous Coupled Wave Analysis (RCWA).

RESULTS AND DISCUSSION

The fabrications of sub-wavelength grating structures were performed by pulse laser interference technique and simple template technique. Figure 1 shows the scanning electron microscopy (SEM) image of the surface relief grating structure obtained by simple template technique with a periodicity of about 700 nm. Those structures were made from polymerizable hybrid polymer precursor based on organically modified siloxane monomers. The precursor was changed into those nano-structured polymer layers by photo-induced polymerization.

In order to get an insight on the possible reflectance and transmission spectra of those structures, RCWA calculation has been performed. RCWA calculation is different from coupled wave analysis (CWA) in which RCWA is a fully vectorial calculation based on the Maxwell equation and do not use an approximation as in CWA. In RCWA formulation, the waves and the medium are also transformed into their Fourier series representation. Therefore it will be useful for calculation for an object with periodic structure. The calculation results are then a representation of electric fields in each mode. Another benefit working in RCWA is that the differential equations of Maxwell equation are transformed into matrix forms where the wave equation (for two-dimensional structure) is given by

$$\frac{\partial^2}{\partial z^2} \begin{bmatrix} s_x \\ s_y \end{bmatrix} - \Omega^2 \begin{bmatrix} s_x \\ s_y \end{bmatrix} = 0$$

(1)

where $s_x$ and $s_y$ are the electric fields which can be found as the eigenvector solution of eq. (1) and $\Omega$ stands for wave propagation constants. All $s_x$, $s_y$ and $\Omega$ are in matrix form.
Figure 1. The SEM image of grating structure obtained by simple template technique with periodicity of about 700 nm

Figure 2. The reflection spectra calculated for different incident angles from a surface relief grating structure with 400 nm periodicity, 200 nm width, and 50 nm depth.

Figure 2 shows the reflection spectra calculated for different incident angles from a surface relief grating structure with 400 nm periodicity, 200 nm width, and 50 nm depth. It seems that there are two reflectance dips for incident angle larger than 0°. The right side dip shifts with increasing incident angle, indicating characteristics of propagating SPR wave. It should be noticed that the left side dip does not significantly shift. We suggest that this dip may be originated from a localized surface plasmon wave, which may happen due to sub-wavelength periodicity.

Keywords: surface relief grating, SPR, RCWA

Acknowledgment
Authors acknowledge the support from Desentralisasi research program from ITB-Ristekdikti.

References
PP-19

Preliminary Study on the Photovoltaic Characteristics of Dye-Sensitized Solar Cell (DSSC) using Aluminium and Titanium doped ZnO as the blocking layer

Wa Ode Sukmawati Arsyad¹, Ahmad Januari¹, Jumalia¹, Waode Sitti Ilmawati¹, Rahmat Hidayat²

¹Physics Department, Faculty of Mathematics and Natural Sciences, Halu Oleo University, South East Sulawesi, Kendari, Indonesia.
²Physics Department, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology, Bandung, West Java, Indonesia
(E-mail : wdsukmawati@gmail.com)

INTRODUCTION

In order to improve the power conversion efficiency of solar cells, it is important to improve the charge carrier extraction efficiency and reduce the charge carrier recombination at the electrode by introducing a blocking electron or hole layer. One of most studied electron blocking layer is undoped ZnO or doped ZnO layer such as Aluminium (Al) doped ZnO (AZO) and Titanium (Ti) doped ZnO (TiZO). It has been reported that, in the case of hybrid polymer solar cell, AZO may slightly improve the conversion efficiency. The introduction of Al dopants produces defect states which can improve charge carrier (electron) extraction from polymer active layer and reduce charge carrier recombination. [1,2] It is therefore interesting to verify the possibility on the use of AZO and TiZO layer for improving DSSC solar cells. We have recently succeeded to fabricate efficient solar cells using gel polymer electrolyte, which also indicates the presence of charge carrier recombination on TiO₂ layer. [3]

RESULTS AND DISCUSSION

We investigated the utilization of the Zinc Oxide nanocrystals as the blocking layer in the DSSC. The ZnO was synthesized by sol-gel method with various concentrations of Ti and Al dopant. The solar cell investigated in this research has a multilayer structure consisting of FTO/ZnO (or AZO or TiZO)/TiO₂/Indoline based dye/electrolyte/Pt on FTO, as shown in Fig. 1. We use LCR meter (Mastech) to measure the resistance of the AZO and TiZO thin film. It is found that for the AZO thin film, the ac resistance of the thin films decreases with increased concentration of the Al, yielding the values of 24.0x10³ Ohm, 23.3x10³ Ohm and 22.6x10³ Ohm for 1%, 1.5% and 2% of Al, respectively. While for the TiZO thin film, the ac resistance of the thin films increases with increased concentration of the Ti, yielding the values of 6.8x10³ Ohm, 7.5x10³ Ohm, 10.0x10³ Ohm, 12.9x10³ Ohm, and 14.1x10³ Ohm for 1%, 1.5%, 2%, 2.5% and 3% of Ti respectively. In general, the ac resistance of TiZO thin films are smaller than the ac resistance of the AZO thin films.

From the photovoltaic characteristics as shown in Fig. 2, the current density value ($J_{sc}$) for undoped ZnO blocking layer much more smaller compared to the reference cell (TiO₂ without blocking layer) which were 1.05 mA/cm² and 11.93 mA/cm² respectively. Through doping with Al, $J_{sc}$ value is increased from 1.05 mA/cm² for undoped ZnO blocking layer to 3.05 mA/cm² for 1% AZO blocking layer, however, further improvement of the Al concentration has led to the decreasing on the $J_{sc}$. Meanwhile, at the same concentration of 1%, the $J_{sc}$ only slightly increased from 1.05 mA/cm² for undoped ZnO blocking layer to 1.73 mA/cm² for TiZO blocking layer. Further improvement of the Ti concentration increased the $J_{sc}$.
reaching its maximum of 7.59 mA/cm$^2$ at 2% TiZO, however, the addition of Ti concentration up to 2.5% and 3% has also led to the decreasing of the $J_{sc}$. The exertion of TiZO seemed to have more effect on the open circuit voltage ($V_{oc}$) compared to the utilization of AZO, for which the $V_{oc}$ value is enhanced from 0.74V for the reference cell to 0.76V, and 0.78V for 1.5% and 2% TiZO respectively. Further increasing on the Ti concentration also reducing the $V_{oc}$ as well as the $J_{sc}$. The highest efficiency was obtained for the cell with 2% TiZO namely 2.92%. These characteristics may be interpreted due to the formation of dopant states that close to the lowest conduction band of TiZO, which assist the charge extraction into the FTO.

Keywords: Al-doped ZnO, Ti-doped ZnO, DSSC, J-V curve, photovoltaic characteristics, resistance, ZnO.

References

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INTRODUCTION

Photosynthesis is a process in which living organisms convert light energy into chemical energy in organic molecules. These processes exploit solar energy to provide energy for physical-chemical reactions in living organisms [1]. Photosynthesis consumes sunlight that falls to earth in the form of electromagnetic waves. Electromagnetic waves emitted radiation that varies. The molecules absorb visible light and are relatively stable to influence the transition from a low energy state to a higher energy state. In the process of photosynthesis, the dominant radiation is visible light. The process of light absorption involves photosynthesis pigment contained in chloroplasts, known as chlorophyll. Chlorophyll has a high efficiency, many photons are absorbed by the leaves and then converted into chemical energy [2].

RESULTS AND DISCUSSIONS

The optical properties of the solution can be observed using spectroscopic techniques to measure absorbance, transmittance and reflectance in the UV-VIS range (Svanberg 2004). In this study, the measurement includes value of absorbance against wavelength to determine the chlorophyll absorption region with the peaks of the plotted graph is observed. Optical absorbance of the sample extract solution chlorophyll scanned from 300nm to 800nm wavelengths are in the range of visible and ultraviolet light and the results can be observed as in Fig. 1.

Optical Absorbance

Fig 1 shows absorption curve with wavelength as a function of the absorption spectrum. It appears that some green and yellow light between 500nm to 600nm is absorbed by the solution. Chlorophyll a and b as well as compounds that are not detected by wavelengths are strongly absorbed by the purple, blue, orange and red. The curve shows that maximum absorption occurs in the blue and red ribbons.
Photovoltaic Effect.

Characterization of chlorophyll photovoltaic effect is done through current and voltage measurements in an electrochemical cell. Measurements were made on the condition irradiated using light bulbs (light source 24W 240V halogen bulbs) and filter. The intensity of the light used is 20 mW/cm$^2$ at a distance of 10 cm. The filter uses variable wavelength 404.656 nm (white), 434.75 nm (yellow), 546.074 nm (orange) and 576.959 nm (red). Measurements were performed by creating a layer of chlorophyll extracts first by immersion as described earlier. Samples were measured in terms of current and voltage at the moment by the light and the results can be seen in the Table 3.

Table 3. Data of Current, Voltage and IPCE

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Color</th>
<th>Current (uA)</th>
<th>Voltage (mV)</th>
<th>IPCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>404.656</td>
<td>White</td>
<td>0.035</td>
<td>7.51</td>
<td>0.00054</td>
</tr>
<tr>
<td>434.750</td>
<td>Yellow</td>
<td>0.039</td>
<td>8.02</td>
<td>0.00056</td>
</tr>
<tr>
<td>546.074</td>
<td>Orange</td>
<td>0.032</td>
<td>7.00</td>
<td>0.00036</td>
</tr>
<tr>
<td>576.959</td>
<td>Red</td>
<td>0.031</td>
<td>6.46</td>
<td>0.00033</td>
</tr>
</tbody>
</table>

**Keywords:** Spectroscopy, photo-voltage effect, chlorophyll, morinda citrifolia.

**References**


Optical Near Field Generated by Silver Equilateral Triangle Tip and Its Enhancement by Geometrical Optimization at Appropriate Wavelength

Nanda Perdana¹, Alexander. A. Iskandar¹

¹Department of Physics, Institut Teknologi Bandung, Jl. Ganesa 10 Bandung
(E-mail: nandaphysalis@gmail.com)
¹Department of Physics, Institut Teknologi Bandung, Jl. Ganesa 10 Bandung

INTRODUCTION

Interaction between electromagnetic waves (lights) with free electrons on nanosized metals produces localized plasmon oscillations with a resonant frequency that strongly depends on the composition, size, geometry, dielectric environment and particle-particle separation distance of nanoparticles [1]. These localized surface plasmon resonances (LSPR), associated with noble metal nanostructures, creating sharp absorption and scattering spectral peak as well as strong electromagnetic near-field enhancements. There are a lot of interesting applications of LSPR that have been explored, such as, nanomanipulators [2], near-field microscopy [3], surface enhanced Raman scattering (SERS) spectroscopy [4], and many other nonlinear optics applications. These LSPR applications used complex geometry variations of nanoparticles, including cylinders, cubes, prisms, tetrahedra, bipyramids, and even stars [5]. For this topic, triangular tip geometry is considered, because sharp-tipped geometries can generate relatively high electric near-field enhancement just outside a sharp corner of a scatterer, compared to unpointed geometries, such as spheres and ellipsoids.

Figure 1. Spatial field distribution of a regular triangular silver tip (left) and x-axis field spectrum (right) of the scatterer, illuminated by 393.6 nm x-polarized, z-propagated plane wave
This work uses a computational electromagnetic method, called surface integral equation (SIE) for simulating the optical responses, because SIE method yields reasonable errors with low computational requirements, rather than by FDTD and FEM method. Maximal near-field enhancement for a configuration of silver equilateral triangle tip is studied by finding its resonant frequency and optimal geometry configuration of a preferred scatterer.

RESULTS AND DISCUSSION

Consider a regular triangular silver tip with 50 nm side length and 25 nm height. The scatterer is illuminated by normalized x-polarized, z-directed incoming electric plane wave. Figure 1 presents the spatial electric field distribution near the scatterer.

Figure 1 shows that the magnitude of electric field just outside the tip is relatively high compared to the incoming electromagnetic plane wave. Therefore, sharp-tipped geometry can produce high near-field enhancement. These enhancement depends on the frequency of the incoming plane wave and the geometrical factor of the scatterer, such as tip angle and scatterer height. In this works, resonant frequency of the system is studied and the geometry configuration is also variated, by changing the tip angle and scatterer height of the geometry.

Keywords: Enhancement, Equilateral, Near-field, Tip, Triangle

Acknowledgment

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References

Optical Responses of Ag Nanosphere Formulated Using Green Tensor Method

Anna Fitriana and Alexander A. Iskandar

Department of Physics, Institut Teknologi Bandung, Jl. Ganeca 10 Bandung
(E-mail: annafphy@gmail.com), (E-mail: iskandar@fi.itb.ac.id)

INTRODUCTION

The optical responses of metal nanosphere have since the last couples of decades become a subject of growing research interest owing to the novel phenomena arising from the light matter interaction and their useful new application in a broad variety of fields. The classical complete treatment of Mie on light scattering is known to provide its simple and highly quasitstatic cross sections in terms of polarizability of the scatterer measuring much smaller than the wavelength of the incident light. This has further led to the Frölich rule for estimating the resonance frequency of the scattered light corresponding to localized surface plasmon resonance frequency of the metal nano scatterer.

It is understood that the bare polarizability $\alpha_0(\omega) = \frac{3V\varepsilon_b[\varepsilon(\omega) - \varepsilon_b]}{[\varepsilon(\omega) + 2\varepsilon_b]}$ does not take into account the effects of depolarization field and retardation phase that appear as we go beyond the quasitstatic approximation. These additional effects can be obtained from the Mie formula by including higher order terms in the multipole expansión. In a different direction, several studies have been undertaken by means of Green tensor formulation such as Coupled Dipole Method (CDM) and Method of Moments (MOM). It is the purpose of this report to present the first line of approach at various levels of approximation and corresponding results of the absorption cross section efficiency by silver nano spheres of various radii in surrounding médium of $\varepsilon_b = 1$.

RESULTS AND DISCUSSION

The complete and explicit expression for the power absorption efficiency of an incident plane wave by a very small metal nanosphere of radius R and dielectric function $\varepsilon(\omega)$ is obtained in terms of the dressed polarizability $\alpha(\omega)$ as given by

$$Q_{abs} = \frac{k_0 \text{Im}[\alpha_0(\omega)]}{\pi R^2} \frac{|\alpha(\omega)|^2}{|\alpha_0(\omega)|^2}$$

with $\alpha(\omega)$ given in term of the Green function $G$ by

$$\alpha(\omega) = \frac{\alpha_0(\omega)}{1 - \frac{\alpha_0(\omega)}{V} k_0^2 \int_V G \, dV}$$

where $G$ is the solution of inhomogeneus wave vector equation associated with dielectric background of permittivity $\varepsilon_b$. $G$ consists of singular part and contribution of the excluded volume, expressed by $\int_V G \, dV = S + M$ with $S = \lim_{\delta V \to 0} \int_{\delta V} G \, dV$ and $M = \lim_{\delta V \to 0} \int_{V-\delta V} G \, dV$ [2]. The excluded volume M is then treated at different levels of approximation yielding to the following expression for the dressed or effective
polarizability $\alpha(\omega)$.

1. $M \equiv G(r_0, r_0)V$, with $G(r_0, r_0) = \frac{ik_b}{6\pi}$ for uniform background of dielectric medium.

$$\alpha_1(\omega) = \frac{\alpha_0(\omega)}{1 - \frac{ik_b^3}{6\pi} \sqrt{\epsilon_0} \alpha_0(\omega)} \quad (3)$$

2. $M \equiv \lim_{\delta V \to 0} \int_{V - \delta V} G_0 dV = \frac{2}{3k_b^2} \left( (1 - ikR) e^{ik_b R} - 1 \right)$, and the corresponding polarizability:

$$\alpha_2(\omega) = \frac{\alpha_0(\omega)}{1 - \frac{\alpha_0(\omega)}{V} \frac{2k_b^2}{3k_b^2} \left( (1 - ikR) e^{ik_b R} - 1 \right)} \quad (4)$$

Given in Fig.1a are the $Q_{abs}$ spectra calculated using Mie theory, and equation (1) with $\alpha_0$, $\alpha_1$, $\alpha_2$ respectively. Fig.1b depicts the variations of corresponding $Q_{abs}$ spectral peak wavelengths with respect to increasing Ag nanosphere radius.

![Figure 1](image_url)

Figure 1.(a) $Q_{abs}$ spectral distribution for Ag nanosphere with $R = 12$ nm and $\epsilon_b = 1$ and (b) peak wavelengths for Ag nanosphere of various radii

It is shown in Figure 1 (a) that the $Q_{abs}$ spectral profile varies with the different polarizabilities used in the calculation. Figure 1 (b) further shows the comparison among the $Q_{abs}$ spectral shifts with respect to increasing the nanosphere radius attained by using equation (1) with different polarizabilities.

**Keywords:** absorption, dressed polarizability, optical response, quasistatic

**Acknowledgment**
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**References**
PP-23

Electric Field Assisted Deposition of Disperse Red 1 Molecules on ITO Substrate and Spectroscopic Characterization of Resulted Films

Herman, R.E. Siregar, M.O. Tjia

1Physics of Magnetism and Photonics Research Group Division, Faculty of Mathematics and Natural Sciences, Bandung Institute of Technology, Jl.Ganesa 10, Bandung, Indonesia 40132. 2Department of Physics, Padjadjaran University, Jl. Raya Bandung–Sumedang km.21 Sumedang, Bandung, Indonesia 45363
(*herman@fi.itb.ac.id, fismots@fi.itb.ac.id)

INTRODUCTION

A large number of experiments have been performed to produce free standing films of Disperse Red 1 (DR1) molecules for its functionalization in optical devices which are useful for various applications including second harmonic generation (SHG) of light. Most methods developed so far employ the process such as spin coating, sol-gel method, and Langmuir-Blodget (LB) method by using the cyclo (8+DR1] and cyclo [2+DR1] skeletons and group serving as the immobilizing planar scaffolds. The resulted films were shown to yield significant SHG effect. These methods generally require however tedious preparations or post deposition treatment or both.

The much more practical dry process of physical vapor deposition was successfully applied in 2001 for the deposition of a free standing DR1 film with regular head-tail stacking of the molecules perpendicular to the substrate. Recently an improvement of the deposition process is carried out by the application of external electric field for aligning the polar molecules in the antisymmetric molecular arrangement with the Hydroxyl molecular end groups anchored on the ITO substrate surface yielding H aggregate configuration, and may thus offer SHG application.

RESULTS AND DISCUSSION

Presented in Fig.1 are the XRD patterns of the DR1 films deposited with different applied electric fields.

Figure 1. XRD patterns of the DR1 films deposited on ITO substrates at various electric fields applied in the direction toward the substrate. The inset shows the XRD pattern of sample deposited with E=3.3 MV/m measured 3 months later.
The diffraction peaks reveal the periodic head-tail stacking of DR1 molecules, with Periodicity of 9.8 Å as deduced from the XRD data. This is roughly equal to the DR1 chain length in its fully stretched conformation. The XRD data also exhibit the increases of diffraction intensities implying the growth of molecular stacking length with increased applied field.

The results of UV-Vis spectroscopic measurement of the films detected in transmission mode are presented in Fig.2 for various applied fields during the deposition processes. The vanishing spectral peak around 400 nm signifies the growing formation of the desired molecular H aggregate. These results confirm the desired H aggregate molecular configuration in the films with appropriately increased electric field, which offer potential SHG application.

An additional spectroscopic study using IRRAS measurement provides the evidence of Hydrogen bonding between the Hydroxyl molecular end groups and the two different oxide compounds In_2O_3 and SnO_2 of the ITO substrate. The result suggests the anchoring mechanism for the DR1 molecules deposited on ITO substrate, which stabilizes the film and the molecules in the antisymmetric H aggregate configuration useful for SHG application.

**Key word:** DR1 aggregates, Molecular immobilization, Non-centosymmetric SHG

**Acknowledgment**
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Temperature Growth And Characteristics Of ZnO Nanorods And Its Optical Properties

Nandang Mufti1,2*, Ifa K R Laila1, Riris Idiawati1, abdulloh fuad1,2, Eni Latifah1, Ahmad taufiq1,2, Sunaryono1,2

1Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang (State University of Malang), Jl. Semarang No. 5, Malang 65145, Indonesia

2Central Laboratory for Mineral and Advance Materials, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang (State University of Malang), Jl. Semarang No. 5, Malang 65145, Indonesia

(*Corresponding author: nandang.mufti.fmipa@um.ac.id)

INTRODUCTION

Zinc oxide (ZnO) is one of semiconducting materials that have drawn the attention of researchers due to its many possible applications, such as light-emitting diodes, fluid sensor, photocatalyst, solar cell, nanogenerator, and so forth [1],[2], [3]. ZnO is a type-n semiconductor which is unique since it has a wide energy band gap at x (3.37 eV) and a large excitonic binding energy, namely 60 meV at room temperature [4]. The synthesis of ZnO in nanometric size offers better electronic and optical properties compared to ZnO in bulk such as nanorods. The synthesis of ZnO nanorods attracts many researchers since they can be used as resources of renewable energy for example in a solar cell or nanogenerator [2], [3].

This research aimed to identify the effects of growth temperature on the characteristics of ZnO nanorod synthesized by the sovothermal method. The Zinc oxide (ZnO) nanorods synthesis was carried out through two steps, i.e. ZnO seed layer deposition and the ZnO nanorods growth. The ZnO seed layer was synthesized via spin coating method using zinc acetate dehydrate and ethanol on ITO substrate. Meanwhile, the ZnO nanorods growth was done through the modified hydrothermal method by using hexamethylenetetramine (HMT) as a precursor and zinc nitrate with a molar ratio of 1:1 for 6 hours. A variation of ZnO nanorods growth temperatures of HMT 25 mM and 50 Mm was performed in this research. The ZnO nanorods were characterized by X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) to study their structures and morphology. Transform infrared spectroscopy (FTIR) and ultraviolet–visible spectroscopy (UV-Vis) were utilized to characterize the optical characteristics of ZnO nanorods.

RESULTS AND DISCUSSION

In general, the synthesized ZnO nanorods were oriented on the planes (100) and (101) with diameters ranging from 81 nm until 365 nm and rods lengths ranging from 1.4 and 5.1 μm. The HMT 50 mM concentration showed that the higher the growth temperature, the higher the sizes of diameter and length of the ZnO nanorods. The ZnO nanorods synthesized by using the 50 mM HMT concentration at 80 °C presented the most optimum result since it had a small size, diameter, and crystallite size with a high value of energy gap.
The energy gap (Eg) values were gathered by using the Tauc method from the characterization results of UV-Visible Spectroscopy. The identification of energy band-gap was performed by plotting the curve between (αhv)² and (hv) known as Touch graph. The energy band-gap values (E_g) of ZnO nanorods are summarized in Table 1, which resulted from the intercepts of linear equation in the transitional area. The ZnO nanorods grew from 50 mM precursor concentration showed that the higher the immersion temperature, the smaller the energy band-gap, namely the E_g changed from 3.24 eV to 3.15 eV at 80 °C and 100 °C, respectively. The E_g values of ZnO nanorods were commonly showing lower redshifts approximately ranged 0.15 eV until 0.22 eV than the E_g value of bulk ZnO, i.e. 3.37 eV. It related to the optical confinement effect in the formation of ZnO nanorods [4].

Table 1 Energy band-gap of ZnO nanorods

<table>
<thead>
<tr>
<th>Band-gap (eV)</th>
<th>Refractive index (n)</th>
<th>Optical Constant (ε)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed Layer ZnO</td>
<td>3.22</td>
<td>2.051</td>
</tr>
<tr>
<td>ZnO NRs 25 mM 80 °C</td>
<td>3.23</td>
<td>2.045</td>
</tr>
<tr>
<td>ZnO NRs 25 mM 90 °C</td>
<td>3.23</td>
<td>2.045</td>
</tr>
<tr>
<td>ZnO NRs 25 mM 100 °C</td>
<td>3.23</td>
<td>2.045</td>
</tr>
<tr>
<td>ZnO NRs 50 mM 80 °C</td>
<td>3.24</td>
<td>2.0392</td>
</tr>
<tr>
<td>ZnO NRs 50 mM 90 °C</td>
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<td>2.0702</td>
</tr>
<tr>
<td>ZnO NRs 50 mM 100 °C</td>
<td>3.15</td>
<td>2.095</td>
</tr>
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</table>

Keywords: ZnO nanorods, hydrothermal, band gap, Optical Properties,

Acknowledgment

The authors would like to thank DRPM, Kemenristekdikti, Republic of Indonesia, for supporting a “research grant 2017” for NM.

References


PP-25

Measurement of Curcumin Concentration in Herbal Medicines using Optical Fluorometric Method

Siti Nurma Nugraha¹, Husin Alatas², Irmanida Batubara³

¹) SMPN 2 Bogor, Dinas Pendidikan Kota Bogor, Indonesia
²) Department of Physics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia
³) Department of Chemistry, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia

INTRODUCTION

Fluorometric is a simple, rapid, and sensitive evaluated method to quantify curcumin in powder formulation of turmeric and temulawak extract. Both rhizomes are commonly used as the main ingredients in Indonesian herbal medicines. Numerous methods have been developed on curcumin determination in medicinal plants such as High Performance Liquid Chromatography (HPLC) [6]. An alternative fluorometric method [10] is proposed and used in this study. It can be applied for the analysis of herbal medicines containing a fluorescent component, such as curcumin, that exhibits strong fluorescence in organic solvents [10]. The fluorometric method has higher sensitivity and selectivity compared to the spectrophotometric technique and it is also simpler and less expensive compared to the chromatographic analysis [5]. The aim of the present work is to develop the corresponding simple procedure based on the corresponding fluorometric method for measuring curcumin concentration in two commercial herbal medicines, containing turmeric and temulawak.

RESULTS AND DISCUSSION

Fluorescence measurements were performed on a FLUOstar Omega fluorometer (BMG Labtech, USA) which uses a UV-vis spectrometer that instantaneously captures wavelengths in a range of 220-850 nm at 1 nm resolution. The excitation and emission wavelengths were set to 420 nm and 530 nm, respectively. All the measurements were carried out in triplicate (three repetitions). The fluorescence intensity of all curcumin standards was measured by four different experiments: (1) Bottom optic with Gain Adjustment (GA) equal to 500; (2) Bottom optic with GA = 1000, (3) Top optic with GA = 500, and (4) Top optic with GA = 1000. Calibration curve of curcumin was then plotted with fluorescence intensity on the x-axis and curcumin concentration on the y-axis and the linearity was determined using least-square regression analysis. The fluorescence intensity of curcumin is proportional to the concentration of curcumin in the range of 0.4-2.4 µg/mL.

Fluorescence intensity of the samples, as read out from the instrument, was put into the regression equation (obtained from previous step) to get a final estimate of curcumin concentration contained in sample. The result was in µg/mL unit which was then converted to mg/g according to the following formula

\[ y' = \frac{y}{c_{sample}} \times 1000 \]

where \( y' \) is the curcumin concentration in mg/g, \( y \) is the concentration in µg/mL, and \( c_{sample} \) is the sample concentration (1000 µg/mL for temulawak and 250 µg/mL for turmeric). The factor 1000 was used to
convert milligram to gram. The estimates from this method were evaluated through comparison with results from HPLC analysis. Percent difference ($P_d$) was computed using Equation 2 when comparing the two quantities.

$$P_d = \frac{c_{\text{fluorometer}} - c_{\text{HPLC}}}{c_{\text{HPLC}}} \times 100$$

with $c$ denoting curcumin concentration in mg/g. The determination of this concentration level plays a main role in estimating the percentage of difference ($P_d$) against HPLC measurement. The exemplified case given in Figures 1 present bar charts of $P_d$ for the evaluation of fluorometric analysis. For temulawak, curcumin concentration derived from the fluorometer differs by 0.32% to 51.74% with the concentration measured by HPLC (10.637 mg/g). The best estimates (indicated by smaller absolute $P_d$) are found in bottom optic at GA1000 experiment. For top optic, curcumin concentration tends to overestimate those from HPLC especially at GA1000. With regards to turmeric, curcumin content analyzed by the fluorometer tends to be higher than the one by HPLC (0.3387 mg/g). $P_d$ ranges from 11% to 768%, which is higher than the range found for temulawak. At GA500, better performance is seen in bottom optic experiments. At GA500, top optic yields curcumin content that is consistently larger than the HPLC and its performance is inferior to the corresponding bottom optic experiment. Through comparison with HPLC measurement, the results demonstrated that the current method has a potential to be used as an alternative quality standard for curcumin content determination in herbal medicines.

**Figure 1.** Percentage difference between curcumin concentration in temulawak from fluorometer and that from HPLC for (a) BO, GA500 (b) BO, GA1000 (c) TO, GA500 (d) TO, GA1000.

**Keywords:** commercial herbal medicine, curcumin, fluorescence, temulawak, turmeric

**References**
The Effect of CTAB addition in ZnO Nanorods Optical Properties

A H Ramelan¹, S Wahyuningsih², F N Aini³, L N M Z Saputri⁴

¹, ², ³, ⁴ Inorganic Materials Research Group, Universitas Sebelas Maret, Indonesia
(E-mail: aramelan@mipa.uns.ac.id, sayekti@mipa.uns.ac.id, fitrinurai@gmail.com, liya.nikmatul@gmail.com)

INTRODUCTION

ZnO material is a semiconductor material that has high transmittance and reflection[1], so it can be developed as Anti-Reflection Coating (ARC) material. The developed one-dimensional nanostructures such as nanorods result in improved optical, electronic compared to bulk structured materials. ZnO nanorods were synthesized from Zn(NO₃)₂.4H₂O precursors with variations cetyl trimethylammonium bromide (CTAB) addition using hydrothermal method. The rasio precusors : CTAB are 1:0; 1:1; 1:2; and 1:3. ZnO material was characterized by X-Ray Diffraction (XRD), Transmission electron microscopy (TEM) and UV-Vis Spectrophotometer. The presence of variations in CTAB addition causes an increase in crystal size. The TEM characterization results in the formation of homogeneous rods. Modified ZnO nanorods improves optical properties, the band gap energy value of ~ 2.9 eV. The value of transmittance increases and the reflectance value decreases with increasing CTAB.

RESULTS AND DISCUSSION

The characterization results using XRD shown in Figure 1, the XRD peak position shows that ZnO hexagonal wurzite with lattice constants a = 3.253Å and C = 5.215Å corresponding to the values in ICSD (No. 67848). Dominant peak is present at 2θ = 36.52°(101). Increased addition of CTAB surfactants showed sharp and clear peaks indicating the formation of materials with high crystallinity and intensity indicated that the addition of CTAB enhanced the alignment of nanorods [2].

![ZnO difactogram pattern with variations of addition CTAB surfactant](image)

Figure 1. ZnO difactogram pattern with variations of addition CTAB surfactant (a) ICSD Standard 67848; (b) ZnO without addition of surfactant; (c) 1: 1 surfactant addition; (d) 1:2 surfactant addition; (e) 1: 3 surfactant addition

TEM imaging results are shown in Fig. 2, indicating that rods have been formed. Nanorods form a rod with a tapered end or cone [3].
ZnO nanorods absorption peak ranges from 310-330 nm, with the band gap energy value ~2.9 eV. The increasing crystal size results in less bandgap energy. This is in accordance with the research Pellegrini et al[4], that this phenomenon is related to quantum confinement effect in nanomaterials. This decrease of bandgap energy becomes an indication of the increase in crystallinity caused by the gathering of ZnO nuclei to form a cluster and eventually become a solid and regular crystallite grain of larger size [5]. There is a decrease in % R and an increase of % T of ZnO nanorods material with increasing of CTAB due to the increasing number of CTAB that caused ZnO nanorods was distributed evenly to increase optical scattering (Figure 3).

![Figure 2. TEM morphology derived from CTAB precursor synthesis, 1:3](image)

**Keywords**: ZnO nanorods, optic, reflectance, transmittance

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