Book of Abstracts

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SEMICONDUCTOR MATERIALS & DEVICE PHYSICS CONFERENCE

(SEMIMATER 2024)

Oludeniz, Turkey

APRIL 18-24, 2024

Invited Speakers

Yia-Chung Chang	National Cheng-Kung University, Taiwan
Hongwei Luo	China Electronic Product Reliability and Environmental Testing Research Institute, China
Max Zenghui Wang	University of Electronic Science and Technology of China, China
Roberto Termine	Institute of Nanotechnology CNR-NANOTEC, SS di Rende (CS), Italy
Tamara Basova	Siberian Branch of Russian Academy of Sciences, Russian Federation

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Ersin Kayahan	Kocaeli University, Turkey
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Andry Sedelnikov	Samara National Research University, Russia

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Ersin Kayahan	Kocaeli University, Turkey
Ahmad Shukri Bin Muhammad Noor	Universiti Putra Malaysia
Andry Sedelnikov	Samara National Research University, Russia

PLENARY PRESENTATION

Id-14

Photosensitizing Materials via Their Decoration with Pulsed-laser-deposited Nanoparticles

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Abstract: Photosensitive materials constitute a highly attractive class of materials that enables not only the effective absorption of light but also its subsequent conversion into electrical current and/or amplification of local electromagnetic fields. In addition to the classical photosensitive materials used in photocatalysis, photovoltaics (PV), or photodetection (PD), the ability to tailor the optoelectronic properties of thin films via the decoration of their surfaces with appropriately deposited nanoparticles (NPs) is very exciting. In comparison with chemical based nanodecoration routes, physical vapor deposition techniques stands out by the purity/crystallinity of the deposited nanoparticles and their strong anchoring to the surface (without resorting to bridging ligands). In this context, the KrF pulsed-laser-deposition (PLD) technique is one of the most appropriate approaches for surface decoration by NPs, owing to its energetic ablated species and to its large process latitude. PLD is well known as a powerful technique for the synthesis of a variety of materials under various forms, including nanoparticles, nanotubes or thin films, under non-equilibrium conditions. After highlighting the unique features of the PLD technique, we will present examples where the PLD-based decoration of materials by different NPs has led to the development of novel nanohybrid materials with unprecedented optoelectronic properties. Examples include: (i) metal or semiconducting NPs decoration of carbon nanotubes (CNTs) for PV applications; (ii) metal-catalyst NPs decoration of TiO2 nanotubes for hydrogen production; (iii) oxide-NPs decoration of electrode materials for Li-Batteries, and (iv) metal NPs decoration of GaAs-based photoconductive antennas for enhanced THz emission. Focus will be put on the PLD growth of highly-crystalline PbS-NPs onto various substrates with a fair control of their size in the (2-20) nm range, and hence optoelectronic properties. Thus, the appropriate decoration of CNTs by PbS-NPs yielded nanohybrids exhibiting unprecedented photoconductive properties. Indeed, CNTs/PbS-NPs based micro-photo-detectors were shown to exhibit not only a very high internal quantum efficiency and a responsivity as high as 230 A.W-1 (@ 5 V), but also the fastest response time (of 30 µs) ever reported for CNTs and/or NPs based photodetectors.

Keywords: Pulsed Laser Deposition, Nanomaterials, Nanoparticles, Nanohybrids, Photoconversion, Photodetection.

INVITED PRESENTATION

Id-3

Chemiresistive Gas Sensors based on Metal Phthalocyanines and Their Hybrid Structures with Metal Nanoparticles

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Abstract: The search for new materials to create active layers of sensors for the detection of toxicants in water and air is an urgent task. Metal phthalocyanine (MPc) films are widely studied as active layers of chemiresistive sensors for determining low concentrations of various gases (e.g. NH_3, H_2S, NO_x). Alternatively, chemiresistive sensors based on hybrid materials are also used. The interest in hybrid materials is due to the synergistic effect that occurs when combining the properties of two or more chemical compounds forming a hybrid material. Thus, it was shown in a number of papers that the use of semiconductor films modified with noble metal nanoparticles as active layers of chemiresistive sensors leads to an increase in their sensitivity several times. In this contribution, we summarize the results obtained by our research group in the field of applications of metal phthalocyanines (MPc and $MPcF_x$, M = Cu, Co, Zn, VO; x = 0, 4, 16) and their hybrids with noble metal nanoparticles (MNP, M = Au, Ir) as active layers of chemiresistive gas sensors, with a primary focus on the sensors for NH_3 and NO detection. Attention is paid to the study of new hybrid structures "MNP/phthalocyanine" obtained by gas-phase deposition methods. MPc films were prepared by physical vapor deposition, while MNPs were deposited by a metal–organic chemical vapor deposition (MOCVD) method. The dependence of the sensor characteristics of hybrid film structures on their composition and structural features (molecular structure of phthalocyanine, concentration and size of nanoparticles) has been studied. It was shown that the modification of MPc films with nanoparticles improved the sensor performance and the obtained hybrid structures could be used for selective detection of low (ppb-level) concentrations of NH_3 and NO in the presence of some reducing gases and volatile organic compounds, viz. carbon dioxide, acetone, dichloromethane, ethanol, and even at high humidity. The response of Au/CoPc heterostructures to NH_3 and NO gases increased with an increase in the concentration of gold. The sensor response of Au/CoPc heterostructures to NH_3 increased 2–3.3 times compared to CoPc film, whereas in the case of NO it increased up to 16 times. The detection limits of the Au/CoPc heterostructure with a gold content of ca. 2.1 μg/cm^2 for NH_3 and NO were 0.1 ppm and 4 ppb, respectively. In the case of Ir/CoPc hybrid structures, the sensor response to NO depended not only on the Ir concentration but also on the condition of the MOCVD process, e.g. the type of the gas-reactant (H_2 or O_2) and its ratio to the carrier gas (Ar/H_2 = 0.5-2). The prepared heterostructures exhibited a limit of NO detection up to 4 ppb.

Acknowledgment: This work was supported by the grant of the Russian Science Foundation (project № 21-73-10142).

Keywords: Chemiresistive Sensors, Metal Phthalocyanines, Metal Nanoparticles, Hybrid Structures, Gas Sensors.

INVITED PRESENTATION

Id-6

The Resonance Measurement Under DC Bias Electric Field for Electrostrictive Ceramic

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Abstract: Actuator device fabricated by electrostrictive material has gathered extensive attention. The bias electric field performance of electrostrictive material is of critical importance to evaluate the actuator. However, the expensive and complexity of the measurement has hindered the application and research of electrostrictive ceramic for actuator. Nevertheless, it has been reported that the resonance measurement under dc bias electric field would be an accurate predictor methodology for electrostrictive material. This paper presents an investigation of the resonance performance under dc bias electric field of lead lanthanum zirconate titanate (abbreviated as PLZT) electrostrictive ceramic. The elastic compliance and electromechanical coupling factor were measured, while the effective piezoelectric coefficient was calculated. For verification, inverse piezoelectric coefficient under dc bias electric field was also obtained. The results demonstrate that the resonance measurement under dc bias electric field should be a valid methodology to evaluate the electrostrictive material, which may facilitate the fabrication and design of electrostrictive actuator.

Keywords: Actuator Device, Electrostrictive Ceramic, Resonance Measurement, DC Bias.

INVITED PRESENTATION

Id-15

Modeling Carbon-based Nanostructures and Devices: A Comprehensive Approach

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Abstract: We present a comprehensive modeling study of various carbon-based nanostructures and related devices utilizing advanced computational methods, including Density Functional Theory (DFT), Semiempirical Pseudopotential Method (SEPM), and Empirical Tight-Binding Models. The investigated nanostructures encompass buckyballs, graphene nanoribbons, textured graphene quantum dots, and moiré structures. Leveraging the symmetry properties of these nanostructures through symmetrized basis functions enables efficient calculations. We simplify self-consistent potentials obtained from DFT, transforming them into analytical forms, significantly reducing computational effort.

Our SEPM accurately reproduces DFT band structures for graphene and nanoribbons within the relevant energy range for device applications. For novel nanostructure devices, such as studying contact effects on the thermoelectric properties of graphene quantum-dot superlattices, we employ a simple tight-binding model. Modeling the entanglement properties of graphene nanoribbon quantum dot qubits is approached using an envelope function method. As these nanostructure devices gain practical interest, advanced methods like SEPM can provide quantitative predictions for meaningful comparisons with experimental studies.

Future application prospects of SEPM in buckyball devices and moiré structures composed of graphene or other two-dimensional materials, such as transition-metal dichalcogenides will also be discussed.

Keywords: Carbon-based Materials, 2D Materials, Nanostructures, Quantum Dots, Semiempirical Pseudopotential Method.

INVITED PRESENTATION

Id-24

The Sound of Music at the Nanoscale–Exploring the Nanoscale World with NEMS Resonators based on Low Dimensional Nanomaterials

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Abstract: The advent of low-dimensional nanostructures has enabled a plethora of new devices and systems. Among them, nanoelectromechanical systems (NEMS) offers the unique capability of coupling the exquisite material properties found in these atomically-defined nanostructures with their mechanical degree of freedom, opening new opportunities for exploring exotic phenomena at the nanoscale. In particular, as these devices driven into mechanical vibration—just as musical instruments—they become essentially nanoscale guitars, drums, tuning folks, etc. By studying the infinitesimal mechanical vibrations in these nanoscale “music instruments”, i.e., listening to the “sound of music” at the nanoscale, researchers can study a number of fundamental physical processes such as absorption, phase transition, anisotropy, and nonlinear processes.

Keywords: NEMS, 2D Material, 1D Material, Nanomechanics, Nanomaterial.

Semiconductor Materials & Device Physics Conference

INVITED PRESENTATION

Id-26

Coexisting and Cooperating Light-Matter Interaction Regimes in Meta-Voltaic Systems

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Abstract: Usually in the quantum framework formed by light-matter coupling the interaction between an atom and a cavity follows a single feedback channel: the exciton relaxation is observed by the emission of a photon that will be stored in the cavity for several roundtrips. After that, another exciton can be created after the photon re-absorption and so on. Until now the possibility that the excited system could relax through other channels, belonging to different regimes has not been considered.

We prepared a photovoltaic cell specifically engineered to behave as an optical cavity tuned to the excitonic transition of the embedded active material (CH3NH3PbI3 perovskite) in order to study how the cooperation of the strong coupling regime and the photovoltaic effect can lead to the an enhancement of the External Quantum Efficiency (EQE), i.e the wavelength-dependent photocurrent conversion efficiency,

We studied the angular dispersion of such photovoltaic cell and observed that the strong coupling regime is achieved when the cavity mode approaches the energy of the exciton, as demonstrated from the significant enhancement of the EQE respect to a classic configuration serving as a benchmark.

This constitute a proof-of-principle experimental demonstration of how the generation of polaritons can positively influence the properties of a photovoltaic cell. Nonetheless, such a peculiar cooperating dual-light-matter interaction could be exploited in future polaritonic photovoltaic architectures.

Keywords: Exciton, Photovoltaic, Strong Coupling Regime.

ORAL PRESENTATION

Id-27

ZnO Powders Synthesized by Extracellular R. Pusillus Fungi

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Abstract: The use of natural materials for the synthesis of oxide semiconductors not only promotes sustainability and environmental protection, but also offers a promising avenue for extensive research. Although Rhizomucor pusillus (R. pusillus) is known as a thermophilic fungus that can cause infections in humans and animals, in this study we investigate its potential for the sustainable synthesis of zinc oxide (ZnO) powders without chemical additives by using sol-gel method. Characterization of the synthesized ZnO powders by X-ray diffraction (XRD) and scanning electron microscopy (SEM) revealed the formation of crystalline ZnO nanoparticles with a hexagonal wurtzite structure. In addition, the analysis of the particle size distribution and the measurement of the zeta potential provided valuable insights. The results demonstrate the efficient production of ZnO particles from the extra cellular matrix of different fungi species and highlight the promising potential of the method for sustainable semiconductor manufacturing.

Keywords: R.Puisllus, ZnO, Oxide Semiconductors, Sol-gel, Sustainability.

POSTER PRESENTATION

Id-20

Normally-off NiOx Based Hydrogen-terminated Diamond Metal Oxide Semiconductor Field-effect-transistor

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Abstract: Diamond is considered to be a superior material for high-power devices for its excellent electronic properties such as large band gap (5.46 eV), high thermal conductivity (20 W/cm.K), large breakdown voltage (10 MV/cm), and high carrier mobility (3800 cm^2/V.s for holes and 4500 cm^2/V.s for electrons. In this report, we have experimentally demonstrated the normally off behavior of hydrogen-terminated diamond Metal-Oxide Semiconductor Field-Effect-Transistor (MOSFET) with the gate dielectric formed by thermal oxidation of Ni at 90 ºC in the normal atmosphere. An undoped single crystal diamond (100) of dimension 8 mm x 8 mm x 0.5 mm is used to fabricate NiOx-based MOSFET. For the hydrogen termination of the sample, the sample is placed in a hydrogen plasma for 40 mins in microwave plasma chemical vapor deposition (MPCVD). Then the sample is kept in the normal atmosphere to get two-dimensional hole gas (2DHG) through the surface transfer mechanism. Then, an Au layer of thickness 100 nm, deposited using an electron beam evaporator, is used to protect the hydrogen-terminated diamond from the further fabrication process. The devices are fabricated in four photolithography steps. In the first step, device regions are isolated by etching out the Au using a potassium iodide (KI) solution. In the second step, drain and source regions are separated using the KI solution. In the third lithography step, 3 nm nickel is deposited between drain and source in an electron beam evaporator and heated in the normal atmosphere for 2 hours at 90 ºC to form nickel oxide (NiOx) as gate dielectric. In the fourth step, a gate contact is formed by depositing Ni/Au (30/100 nm) metal stack by an e-beam evaporator. Then the devices are characterized for parameter extraction to evaluate their performances. From the drain current versus drain voltage (ID-VDS) characteristic, the calculated value of the maximum ID current is 0.6 $mA.mm^{-1}$ which is measured at VGS = −5 V and VDS = −8 V. From drain current versus gate voltage (IDS-VGS), the measured value of subthreshold swing at VDS = −5 V is 162 $mV.dec^{-1}$ with the on/off ratio of ~ 10^4 and the threshold voltage is calculated to be –0.14 V which shows normally-off behavior of hydrogen-terminated NiOx based diamond MOSFET.

Keywords: Diamond, Normally-off, MPCVD, Hydrogen-terminated, Nickel Oxide.

Semiconductor Materials & Device Physics Conference

POSTER PRESENTATION

Id-21

High-performance Ta_2O_5-based Normally-off GaN Transistors

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Abstract: The remarkable characteristics of Gallium nitride (GaN) and its alloys such as $Al_xGa_{1-x}N$, exhibit considerable potential as semiconductor materials for applications demanding cutting-edge high-power and high- frequency devices. GaN devices commonly manifest an "ON" (normally-on) state behavior owing to the presence of a two-dimensional electron gas (2DEG) at the hetero-interface of AlGaN/GaN. But, in power electronics, it is imperative to employ devices that are normally in an "OFF" (normally-off) state and possess a positive threshold voltage. This stipulation guarantees safety and streamlines the design of the gate driver circuitry. In this work, we present the fabrication and characterization of enhancement mode GaN transistors with a partially recessed gate and a completely recessed gate structure with Ta_2O_5 as the gate dielectric. Due to higher bandgap, high-k value, and exceptional interface quality of Ta_2O_5 with AlGaN and GaN, we have achieved improved electric coupling, favorable subthreshold behavior, and effective suppression of gate leakage current of the fabricated devices. By employing the gate recess method in conjunction with the thermally grown Ta_2O_5 gate oxide, we were able to fabricate the devices that exhibited a threshold voltage of +2.1 V and +0.2 V for completely recessed gate and partially recessed gate with respect to -2.0 V of an un-recessed gate device. I_{ON}/I_{OFF} ratios for completely recessed, partially recessed, and un-recessed gate transistors with Ta_2O_5 gate oxide are 6.5×10^9, 2.8×10^{10}, and 1.2×10^{10} respectively. The ON resistance of the un-recessed gate, partially recessed, and completely recessed gate sample is 5.6 Ω mm, 6.3 Ω mm, and 20.8 Ω mm respectively. The respective saturation currents exhibited by the un-recessed gate, partially recessed, and completely recessed gate transistors are 669.4 mA/mm, 574.3 mA/mm, and 146 mA/mm. The recessed devices demonstrate a minimal hysteresis of 0.7 V, while the un-recessed devices exhibit even lower hysteresis of 0.04 V. The ON and OFF state breakdown voltages of the completely recessed gate transistor are 97.6 V and 117.2 V respectively. The device characterization is done by using a Keysight B1500A semiconductor device analyzer. The inclusion of Ta_2O_5 gate oxide significantly contributed to the enhanced device performance.

Acknowledgment: This work is partially supported by the Department of Science and Technology India, and Ministry of Electronics and Information Technology.

Keywords: AlGaN/GaN Hetero-interface, Recessed Gate, Normally-off, High-k, Hysteresis.

All Submissions & Topics

Topic	Submission
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2 - Oxide Semiconductors	27 - ZnO Powders Synthesized by Extracellular R. Pusillus Fungi
15 - III-V Semiconductors	21 - High-Performance Ta2O5-based Normally-off GaN Transistors
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