Functional Thin Films and Surfaces
Room Pacific F-G - Session C1-2-WeA

Optical Materials and Thin Films II

Moderators: Dr. Silvia Schwyn-Theony, Evatec AG, Switzerland, **Dr. Juan Antonio Zapien**, City University of Hong Kong

2:00pm **C1-2-WeA-1 Perovskite Stannate $BaSnO_3$ Films for Near- and Mid-Infrared Plasmonic Applications**, ***Heungsoo Kim***, *A. Piqué,* Naval Research Laboratory, USA

Recently, ternary perovskite oxides have attracted great attention as alternative transparent conducting oxides (TCOs) because their structures are compatible with many other perovskite oxides that allow devices to be fabricated comprised entirely of perovskite oxides. Among these perovskite oxides, $BaSnO_3$ has gained considerable attention as a promising TCO because of its high mobility at room temperature (~320 $cm^2V^{-1}s^{-1}$ in bulk single crystals and ~100 $cm^2V^{-1}s^{-1}$ in epitaxial thin films) and high temperature stability in oxygen atmospheres compared to other TCOs, such as Sn-doped In_2O_3, Al-doped ZnO, and F-doped SnO_2. We have grown epitaxial La-doped $BaSnO_3$ (LBSO) thin films on (001) $SrTiO_3$ and (001) MgO substrates by pulsed laser deposition and investigated their structural, electrical, and optical properties as a function of the oxygen pressure and substrate temperature during deposition. By adjusting the oxygen pressure and substrate temperature during deposition, we were able to control the film crystallinity and strain, which modified the electrical and optical properties. The LBSO films grown at the optimum conditions (780 °C and 100 mTorr of oxygen) show the highest conductivity (3.6 x 10^3 S cm^{-1}) with a carrier concentration of 3.5 x 10^{20} cm^{-3} and a carrier mobility of 65 $cm^2V^{-1}s^{-1}$. This observed high conductivity corresponds to the film with the best crystallinity and the lowest strain state. The permittivity of the LBSO films can also be modified as a function of the oxygen pressure and temperature during deposition allowing tuning of their epsilon-near-zero (ENZ) wavelength from 2 µm to 6 µm. We will present details of the deposition conditions on the properties of LBSO films and the ability to tune the permittivity in infrared range.

This work was supported by the Office of Naval Research (ONR) through the Naval Research Laboratory basic research program.

2:20pm **C1-2-WeA-2 2-Dimensional Growth of GaS_x Crystal by Low-Pressure Vapor Phase Deposition**, ***Yijia Chen***, National DOng Hwa University, Taiwan; *C. Huang,* National Dong Hwa University, Taiwan

GaS_x is a promising material with band gap of less than 3 eV, which could be used for novel 2-dimensional nano-electronics and nano-photoelectronics. We successfully prepared GaS_x thin film on silicon substrate by low-pressure vapor phase deposition. The examination of the microstructure reveals the evolution of the 2-dimensional GaS_x crystal growth. We found that the GaS_x platelets are just sprouting out of the substrate from those dots coincidently aligned along some crystallographic direction of the Si substrate. The edges of the platelets show preferred directions, confirming the occurrence of preferred-orientation growth of GaS_x from the substrate. It is very interesting to find that the edges of the platelets are accumulated with the dots similar to those found further downstream on the substrate as the nucleation sites for GaS_x. Apparently, the dots not only signify the remnant for GaS_x nucleation, but also reveal their involvement of the lateral growth of GaS_x crystals. Recall that the dots are where GaS_x is abundant. It is most likely that sulfur is first dissolved in the Ga liquid, then reacts with Ga and precipitates as GaS_x on the existing edge of GaS_x platelets to expand the crystal size. These crystals were later exfoliated into GaS sheets, as evidenced by x-ray diffraction analysis. From this study, a major leap forward is provided toward the realization of 2-D GaS preparation.

2:40pm **C1-2-WeA-3 Hysteresises on Voltage-Current Characteristics and Optical Responses of PEDOT:PSS/ZnO Nanorods/ZnO:Ga Heterojunctions**, ***Tomoaki Terasako***, Graduate School of Science and Engineering, Ehime University, Japan; *M. Yagi,* National Institute of Technology, Kagawa College, Japan; *T. Yamaoto,* Materials Design Center, Research Institute, Kochi University of Technology, Japan

Zinc oxide (ZnO) with a wide bandgap energy of ~3.37 eV is expected to be applied to ultraviolet (UV) detectors. In general, ZnO exhibits *n*-type conduction because unintentionally doped native defects and/or residual hydrogen (H) atoms act as donors. On the other hand, it is difficult to obtain *p*-type conduction with good reproducibility by intentional impurity doping. Therefore, we have fabricated the UV detectors composed of the heterojunctions between the ZnO nanorods (NRs) and poly(3,4-ethylenedioxythiophne) poly(styrenesulfonate) (PEDOT:PSS) instead of those of ZnO *pn* homojunctions. In this paper, generation mechanisms of both hysteresises on the voltage-current (V-I) curves and optical responses of the PEDOT:PSS/ZnO NRs/ZnO:Ga (GZO) heterojunctions will be discussed.

The GZO seed layers were deposited on alkali-free glass substrates by ion-plating (IP) with a DC arc discharge using a sintered ZnO pellet containing Ga_2O_3 powder of 4.0 wt.%. Preparations of ZnO NRs layers were done by chemical bath deposition (CBD) using the mixed aqueous solution of zinc nitrate hexahydrate and hexamethylenetetramine. The PEDOT:PSS layer was spin-coated on the surface of the ZnO NRs layer at 3000 rpm for 30 s, followed by thermal annealing in air at 80 °C.

The V-I curves of the PEDOT:PSS/ZnO NRs/GZO heterojunctions exhibited a rectification behavior with hysteresis loops both in forward and reverse voltage regions. Under the irradiation of the ultraviolet (UV) light of 360 nm, the hysteresis loop area in the forward voltage region decreased, but that in the reverse voltage region increased. Both the ln V vs. ln I plots and Fowler-Nordheim (F-N) plots, 1/V vs. ln (I/V^2) plots, for the voltage increase in the forward voltage region in a dark state can be clearly divided into three characteristic regions. The V-I curve showed an ohmic characteristic in the low voltage region, whereas the current was approximately proportional to the fourth power of the forward voltage in the high voltage region. Therefore, the possible transport mechanisms in the low and high voltage regions are direct tunneling and F-N tunneling, respectively. In the medium forward voltages, the current was approximately proportional to the square of the forward voltage, which is characteristic of space-charge-limited conduction. The increase in repetition number of V-I measurement under the forward voltage (0→3→0 V) in a dark state led to the increase in maximum forward current.

This work was supported by JSPS KAKENHI Grant Number JP22K04220.

3:00pm **C1-2-WeA-4 Effective Ways to Enhance the Performance of n-MoS_2/p-CuO Heterojunction Based Self-Powered Photodetectors**, ***Krishan Kumar***, *D. Kaur,* Indian Institute of Technology Roorkee, India

In the present study, two effective routes to improve the response time and the detection range have been investigated for the n-MoS_2/p-CuO (a conventional p-n heterojunction). Initially, an insulating Aluminium nitride (AlN) layer was inserted in between the Molybdenum disulfide (MoS_2)and Cupric Oxide (CuO) layer, which eventually converted the conventional p-n heterojunction to Semiconductor-Insulator-Semiconductor (SIS) with a superior carrier tunneling mechanism. Here, the n-MoS2/p-CuO and n-MoS2/AlN/p-CuO (SIS) heterojunctions have been fabricated using the dc magnetron sputtering technique. The responsivities of the n-MoS_2/p-CuO and n-MoS_2/AlN/p-CuO (SIS) heterojunction are found to be 3.88 mA/W and 20.22 mA/W for the visible radiations (532 nm) and 4.47 mA/W and 26.28 mA/W and NIR radiations (1064 nm), respectively. The response time (rise time and decay time) of the fabricated n-MoS_2/p-CuO heterojunction decreases from 93.35 ms and 102.68 ms to 11.31 ms and 12.73 ms with the insertion of ultrathin insulating AlN Layer. The higher current and ultrafast photoresponse in n-MoS_2/AlN/p-CuO (SIS) heterojunction can be ascribed to the carrier tunneling mechanism through the ultrathin insulating layer. Furthermore, the range of detection of the photodetection can be enhanced up to the UV region with the addition of a layer of MoS_2 quantum dots on the surface of the MoS_2 layer in the fabricated heterostructure. The fabricated n-MoS_2 QDs/n-MoS_2-/AlN/p-CuO heterostructure shows photoresponse in a broad range from UV to NIR radiations. The recorded values of responsivity for the fabricated n-MoS_2 QDs/n-MoS_2-/AlN/p-CuO heterostructure are 4.97 mA/W, 20.22 mA/W and 26.28 mA/W for the incident of UV (376 nm), visible (532 nm) and NIR (1064 nm) radiations, respectively. The obtained results demonstrate the n-MoS_2-/AlN/p-CuO (SIS) heterostructure with the addition of MoS_2 QDs shows excellent potential for next-generation ultrafast optoelectronics applications.

3:20pm **C1-2-WeA-5 Femtosecond Laser Ablation (FESLA) XPS – A Novel XPS Depth Profiling Technique for Optical/Electrical Thin Films and Multi-Layered Structures**, ***Mark Baker***, *S. Bacon, S. Sweeney,* University of Surrey, UK; *A. Bushell, T. Nunney, R. White,* Thermo Fisher Scientific, UK

XPS depth profiling is a widely employed analytical technique to determine the chemical composition of thin films, coatings and multi-layered structures, due to its ease of quantification, good sensitivity and chemical

state information. Since the introduction of XPS as a surface analytical technique more than 50 years ago, depth profiles have been performed using ion beam sputtering. However, many organic and inorganic materials suffer from ion beam damage, resulting in incorrect chemical compositions to be recorded during the depth profile. This problem has been resolved for most polymers through the use of argon gas cluster ion beams (GCIBs), but the use of GCIBs does not solve the issue for inorganics. A prototype XPS depth profiling instrument has been constructed which employs a femtosecond laser rather than an ion beam for XPS depth profiling purposes. This novel technique has shown the capability of eradicating chemical damage during XPS depth profiling for all initial inorganic, compound semiconductor and organic materials examined. The technique is also capable of profiling to much greater depths (10s - 100s microns) and is much faster than sputter XPS sputter depth profiling. FESLA XPS results will be shown for selected bulk, thin film and multi-layered materials employed in optical and electrical applications.

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