PCSI

Room Keahou I - Session PCSI-WeA1

Semiconductor Heterostructures: Growth, Nanostructures, & Interfaces II

Moderator: Karen Kavanagh, Simon Fraser University, Canada

1:35pm **PCSI-WeA1-2 Atomic Layer Deposition: Surface Processes Unlocking Advanced Materials in the Semiconductor Industry**, ***Erwin Kessels***, *Adrie Mackus, B. Macco,* Eindhoven University of Technology, Netherlands **INVITED**

Atomic Layer Deposition (ALD) has emerged as a critical technique in the precise fabrication of materials employed in advanced semiconductor devices. ALD offers unparalleled control over film thickness, uniformity, and composition at the atomic scale, also on complex 3D structured surfaces that have become commonplace in the semiconductor industry. Understanding of the surface processes that govern ALD, including the intricate interplay of surface reactions, is fundamental to achieving high-performance materials for next-generation semiconductor devices in the so-called Ångstrom era. This presentation will delve into the fundamental aspects of the physics and chemistry at the surface during ALD and explore how surface processes dictate film growth and material properties. Focus will be given to emerging materials under ALD investigation, such as ferroelectric oxides, 2D transition metal dichalcogenides (TMDs), and amorphous oxide semiconductors, along with how advances in surface process understanding can address challenges in controlling the material properties and their scaling behavior.

2:15pm **PCSI-WeA1-10 Low Temperature Ge/Si Heterojunction by DC Sputtering**, ***Yi-Jhen Wang***, *Hsin-Han Huang, Yu-Wen Lai, Chiung-Wei Lin,* Tatung University, Taiwan

This study investigates the fabrication and optimization of germanium (Ge) films on silicon (Si) substrates for high-sensitivity optical sensing applications. Ge with its small bandgap of 0.67 eV [1], effectively absorbs long-wavelength red light, making it suitable for photodetectors. This research used DC magnetron sputtering, rapid thermal annealing, and filament evaporation.

This research examined the influence of various process parameters, including deposition time, power, and substrate type on the properties of the Ge thin films. The results revealed that Ge thin films with an illuminated area of 113 mm2 deposited on n-type Si substrates at 13.26 W/cm2 showed good performance. After RTA treatment, there is a 180 times increase in carrier mobility and a 50 times reduction in resistivity compared with the pre-annealed condition. X-ray diffraction (XRD) analysis confirmed a preferential (400) similar to orientation [2]. The experiment further investigated the impact of various light sources on the illumination current-voltage (I-V) characteristics. As the illumination power and light absorption increased, the base temperature of the Ge/Si substrate also increased. The illumination gain is defined as $|Ilight|/|Idark|$ | at v=−1.45 V. The illumination Gain was stable even illumination the power reached a maximum of 1.2W. The Gain was 300 times under the illumination of 800 nm wavelength and 250 times for 700 nm wavelength. To conclude, the study provides insights into the optimal fabrication processes and the impact of rapid thermal annealing on the performance of Ge thin films.

[1] Dr. Vinay Kumar Singh, Band Gap Aan Resistivity Measurement of Semiconductor Materials for Thin Films, Phys. D. Volume 4, Issue 12 1202(2017)

[2] Park, M. I., Kim, C. S., Park, C. O., and Jeoung, S. C. XRD Studies on the Femtosecond Laser Ablated Single-Crystal Germanium in Air, Optic and Laser in Engineering. Volume 43, Issue 12 1326(2005)

2:20pm **PCSI-WeA1-11 Optical and Structural Properties of Group-IV Oxides Produced by Rapid Thermal Oxidation**, *Danissa Ortega,* ***Danissa Ortega***, *Haley Woolf, Atlantis Moses, Carlos Armenta, Jaden Love, Sonam Yadav, Stefan Zollner,* New Mexico State University*; Matthew Mircovich,* Arizona State University

There is great interest in germanium and germanium-tin alloys as optical sensors, especially short-wave infrared detectors, but little is known about thermal oxidation of thin Ge-Sn alloy layers on a bulk semiconductor substrate. We report a comparative study of the rapid thermal oxidation of bulk Ge, thick relaxed epitaxial Ge on Si, and Ge-Sn alloys on Si produced by chemical vapor deposition. Layer thickness, roughness, composition and strain, optical constants, and infrared-active molecular vibrations were characterized using spectroscopic ellipsometry, high-resolution x-ray diffraction, atomic force microscopy, and Fourier-transform infrared spectroscopy.

Before oxidation, the surfaces were ultrasonically cleaned in deionized water at room temperature and dried with nitrogen to achieve a low native oxide layer with less than 1 nm thickness. The ellipsometric angles ψ and Δ were acquired on a J.A. Woollam vertical angle spectroscopic ellipsometer (VASE) from 0.5 to 6.5 eV and on a J.A. Woollam Fourier-transform infrared spectroscopic ellipsometer (FTIR-VASE) from 0.03 to 0.6 eV at incidence angles ranging from 60-80°. The ellipsometric angles were then modeled with a three-layer model: Si substrate, pure Ge (or Ge-Sn) layer, and GeO_2, to obtain initial conditions. The initial strain was determined using high-resolution x-ray diffraction (HRXRD), including symmetric (004) and asymmetric (224) reciprocal space maps and rocking curves.

The samples were then rapidly thermally annealed in pure oxygen at temperatures ranging from 525-575°C in 40 psi pressure for up to 2 hours to create a range of thermal oxide layers on different types of surfaces. After oxidation, HRXRD and ellipsometric angles are measured again and compared to pre-oxidation results.

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2:25pm **PCSI-WeA1-12 Growth Evaluation and Electrochemical Properties of Lab6 Thin Films Deposited by HiPIMS**, ***César D. Rivera Tello***, *Jonatan Pérez Alvarez, Martin Flores, Lazaro Huerta,* Universidad de Guadalajara, Mexico

Lanthanum hexaboride (LaB_6) thin films are widely used due to their exceptional electron emission, thermionic and interesting mechanical properties. The LaB_6 has a crystal structure, increasing the hardness and improving the mechanical properties. Besides, the LaB6 films can promote a scavenger effect, that decreases surface impurities that could contribute to the corrosion increments, and the high reactivity with oxygen also helps to increase the corrosion resistance. However, the obtention of these properties can also present challenges in thin films' physical vapor deposition processes. In this sense, the High Impulse Magnetron Sputtering (HiPIMS) deposition parameters such as the pulse width can influence the morphology, and density of the films. In the present study, we analyze the influence of duty cycle of the deposition processes on the ionization, bonding, structural, and electrochemical properties of the films. Two films were deposited on silicon 001 and 52100 metallic alloy, varying the pulse width (50 and 60 µs). The ion energy distribution function (IEDF) of the LaB_6 species in the plasma deposition was evaluated by the IEDF curves obtained by a quadrupole mass spectrometer detector. The morphology and thickness of the LaB_6 thin films were analyzed from cross-sectional images using a field-emission scattering electronic microscope (FESEM). Electrochemical Impedance Spectroscopy (EIS) was made of the two films deposited on the metallic alloy. Raman spectroscopy and X-ray diffraction revealed higher crystallinity in the 50-film. Furthermore, this film showed better corrosion resistance. These results demonstrated how the pulse width and duty cycle in the HiPIMS process can significantly influence the crystallinity and overall quality of LaB_6 thin films.

2:30pm **PCSI-WeA1-13 Facile and Inexpensive Development of Nano-Structured Polymer Layers for Surface Enhanced Raman Spectroscopy Applications**, ***L. Jiang***, Tuskegee University*; Naga Korivi,* Oregon Institute of Technology

Surface-enhanced Raman scattering (SERS) is a spectroscopic method for label-free detection of trace analytes, providing insights into the chemical bonds of molecules on nano-structured metal surfaces known as SERS substrates. Since its discovery with pyridine on silver, advancements in nanotechnology have led to various substrate fabrication methods, primarily using colloidal metal nanoparticles or electron beam lithography for nanostructured surfaces [1,2]. However, colloidal substrates can be unstable and prone to contamination, while electron beam lithography is costly and yields small active areas. This limits the mass production of large-area SERS substrates, hindering their widespread use [3]. Recent efforts have focused on low-cost, thin-film substrates, such as metal nanoparticle layers on flower petals or eggshell membranes [4, 5]. We report the development of low-cost nano-structured polymer surfaces for use as SERS substrates. This method involves molding a silicone elastomer (PDMS) over treated chicken eggshells. The eggshells are cleaned and etched in hydrochloric acid to create a nano-scale texture. A PDMS pre-polymer mixed with toluene is poured over the eggshell, which is then cured at room temperature for 24 hours. After dissolving the eggshell in

hydrochloric acid, a PDMS layer with complementary nano-features remains. This layer is coated with a thin gold layer, which is expected to enhance Raman signals through localized surface plasmon resonance. Current efforts are focused on evaluating the nanostructured surface for SERS applications, with the thinning of the pre-polymer improving the interface by filling gaps in the eggshell mold.

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