Functional Thin Films and Surfaces
Room Palm 5-6 - Session MB2-1-MoM

Thin Films for Electronic Devices I

Moderators: Jiri Houska, University of West Bohemia, Czechia, **Spyros Kassavetis**, Aristotle University of Thessaloniki, Greece

10:20am **MB2-1-MoM-2 Enhanced Etching Resistance of Y2O3 Films Through Microstructure Control via Thermal Annealing***, Shiao Wang, Qiuming Fu, Hongyang Zhao,* Wuhan Institute of Technology, China*; **Tomasz Liskiewicz [t.liskiewicz@mmu.ac.uk]**,* Manchester Metropolitan University, UK*; Ben Beake,* Micro Materials Ltd, UK*; Yanwen Zhou,* Wuhan Pudi Vacuum Technology Co., China

Yttrium oxide (Y2O3) is a promising material for etch-resistant coatings in semiconductor manufacturing due to its high hardness, high melting point, and excellent chemical stability. This study investigates the effect of thermal annealing on the microstructure and etching resistance of Y2O3 thin films, aiming to improve their performance without introducing additional phases. Current methods for improving Y2O3 etching resistance involve costly phase introductions, and the effect of annealing temperature on the etching resistance of Y2O3 thin films has been understudied.

Y2O3 films were deposited on P-type Si substrates using RF magnetron sputtering. The films were then annealed in a vacuum at 300℃, 600℃, and 900℃. The crystal structure was characterised using XRD, and surface morphology was observed with FESEM. Etching tests were conducted using inductively coupled plasma with two different environments, chemical etching (CF4 and O2) and mixed etching (CF4, Ar, and O2). The etching rates and surface roughness were determined using a step profiler and AFM respectively. Chemical bond analysis was performed using XPS.

XRD analysis revealed that the Y2O3 films exhibited a polycrystalline cubic structure. The sharpness of the diffraction peaks increased and then decreased with increasing annealing temperature, indicating grain size changes. FESEM images showed that the film annealed at 900℃ had a dense, laminated structure with no pores or defects, while films annealed at 600℃ and 300℃ displayed rod-shaped grain structures with noticeable gaps. The etching rates of Y2O3 films were significantly lower than those of Al2O3, Si, and other materials. The 900℃ annealed film exhibited the lowest etch rates. AFM analysis showed the roughness of Y2O3 thin films decreased after both chemical and mix etching. XPS analysis confirmed the formation of Y-F compounds during etching, with deeper F penetration in mix etching due to Ar+ sputtering.

The enhanced etching resistance of the 900℃ annealed Y2O3 film is attributed to its high density and low surface roughness. In chemical etching, F radicals react with Y2O3, forming a Y-F protective layer, which reduces further etching. In mix etching, the additional Ar plasma facilitates the detachment of the formed Y-F compounds, increasing the etching rate compared to chemical etching.

This study demonstrates that thermal annealing is a cost-effective method to improve the etching resistance of Y2O3 films. The 900℃ annealing resulted in a dense film with superior etching resistance, making it a promising material for protective coatings in semiconductor manufacturing.

10:40am **MB2-1-MoM-3 Integration of Pzt with Transparent Conductive Layers for Enhanced Piezoelectric Applications***, **Nicoleta Nedelcu [nnedelcu@mtroyal.ca]**, Fred Harford, Dylan Webb,* Mount Royal University, Canada*; Cristian Rugina, Ana Maria Mitu,* Institute of Solid Mechanics Romanian Academy, Romania*; Arcadie Sobetkii,* MGM Star Construct Ltd, Romania

Lead zirconate titanate (PZT, Pb(Zr,Ti)O_3) is widely recognized for its superior piezoelectric properties, making it a key material in micro-actuator applications. PZT technology is extensively utilized in MEMS-based devices, including inkjet printheads, micro-speakers, and autofocus cameras. Quartz crystal resonators (QCRs), another essential component in communication systems, leverage the piezoelectric properties of quartz to generate stable oscillation frequencies. This study explores the integration of PZT with a transparent conductive layer to develop high-performance piezoelectric sensors and actuators. Specifically, we investigate the deposition of a conductive layer on PZT, QCRs, and quartz glass using DC sputtering. Optical characterization via UV-VIS spectrophotometry assesses transparency and optical properties, while dielectric constants are determined through mathematical modeling. X-ray diffraction (XRD) confirms the preservation of the pure perovskite phase in PZT, and surface morphology analysis using SEM and AFM reveals a uniform superficial layer with dispersed indium tin oxide (ITO) particles (10–30 nm). The electromechanical impedance (EMI) method is employed to evaluate PZT/Ag, PZT/ITO, QCR/Ag, and QCR/ITO structures, with minor variations attributed to temperature fluctuations, electrode thickness, and device positioning.

The successful integration of PZT with a transparent conductive layer on ceramic substrates demonstrates promising applications in transparent piezoelectric sensors, interactive displays, and touch-sensitive interfaces. These findings provide a foundation for developing high-transparency, piezoelectric-based touch sensors with improved electrical and optical performance.

11:00am **MB2-1-MoM-4 High-Quality C-Textured Sc0.36Al0.67N Thin Films on 200 Mm Si Wafers for Piezoelectric Applications***, **Sanjay Nayak [sanjay.nayak@silicon-austria.com]**,* Silicon Austria Labs GmbH, Austria

Sc-alloyed AlN (ScAlN) has emerged as a promising candidate for next-generation piezoelectric materials, offering superior piezoelectric properties and thermal stability compared to traditional perovskite-based materials. However, the metastable nature of ScAlN and the challenges associated with achieving high-quality, phase-pure films, especially in multilayer stacks, have limited its practical applications. This work presents a significant advancement in ScAlN thin-film technology. By employing a carefully optimized process and a suitable buffer layer, we have successfully fabricated high-quality $Sc_{0.36}Al_{0.67}N$ films with excellent piezoelectric properties. The bilayer films exhibit comparable crystalline quality to single-layer films, demonstrating the potential for scaling up the fabrication of complex ScAlN-based devices. We demonstrate the microstructural and stress tunability of ScAlN thin films by tuning the process parameters. The average piezoelectric coefficient ($e_{31,f}$) measured over a 200 mm wafer was found to be -2.9 C/m^2, highlighting the exceptional performance of these films. This achievement opens new possibilities for the development of high-performance MEMS devices, including energy harvesters, resonators, sensors, and actuators, that leverage the unique properties of ScAlN.

11:20am **MB2-1-MoM-5 Patterned Silver Nanowire Network for CdSe@CdZnS/ZnS Green Quantum Dot Light-Emitting Diodes***, Chia-Yu Lin, Tzu-Hsu Wen, **Chun-Yuan Huang [cyhuang2004@gm.nttu.edu.tw]**,* National Taitung University, Taiwan

Silver nanowire (AgNW) network possesses excellent conductivity and flexibility, making it an ideal material for electrodes of flexible optoelectronic devices. However, their high surface roughness can negatively impact device performance. To address this issue, the roughness of the patterned AgNW network electrode was reduced using a transparent photopolymer. To fabricate the patterned AgNW films, firstly, the polydimethylsiloxane (PDMS) substrates with proper size (18×18 mm^2)were covered with the stainless-steel shadow mask and then treated with UV ozone for 30 minutes. A 2 wt % AgNWs-ethanol solution was spin-coated, annealed, and then covered with UV-curable polyurethane (Norland Optical Adhesive 63, Edmund Optics). After UV curing, the composite of AgNW/polyurethane was then peeled off from the PDMS, allowing the AgNWs/polyurethane composite conductive film to adhere to the poly(ethylene terephthalate)(PET) substrate. Accordingly, with high transparency of 77% and low sheet resistance of 7~9 Ω/sq, the patterned AgNW network embedded in the polyurethane matrix was obtained for the subsequent fabrication of quantum dot light-emitting diodes (QLEDs). The electrode was applied as the anode in green CdSe/CdZnS/ZnS QLEDs. With the device structure of AgNW network/PEDOT:PSS/TFB/QD/MgZnO/Al, the QLED emitting pure green light centered at 536 nm resulted in a turn-on voltage of 2.4 V, a maximum brightness of 72,922 cd/m^2, and a current efficiency of 27.8 cd/A.

11:40am **MB2-1-MoM-6 Effects of Room Temperature Sputtered Nano-Interfaced WxMoyO_3 Nanograins on Highly Responsive NO Sensing***, **Somdatta Singh [somdatta@ic.iitr.ac.in]**,* Indian Institute of Technology Roorkee, India*; Ravikant Adalati,* University of Mons, Belgium, India*; Prachi Gurawal, Raman Devi,* Indian Institute of Technology Roorkee, India*; Gaurav Malik,* Jeonbuk National University, Republic of Korea, India*; Davinder Kaur, Ramesh Chandra,* Indian Institute of Technology Roorkee, India

This work demonstrates a heterostructure of monoclinic molybdenum trioxide (n-MoO_3) and tungsten trioxide (n-WO_3) with nano-interfaced (n-i@WxMoyO3) based NO gas sensing material. The nanocrystalline n-i@$W_xMo_yO_3$ thin film was coated using a single-step magnetron sputtering technique on an n-type (100) silicon substrate. Within the temperature range of approximately ambient temperature (50℃) to 350℃, this sensing material, $W_xMo_yO_3$ (where x = 0.71 and y = 0.29), detects NO gas and investigates the impact of crystal structure and nanointerfaces on sensing performance. A heterostructure composed of several materials can enhance the interaction between the gas molecules and the sensor surface by producing interfaces that promote charge transfer. With a response/recovery time of around 300 seconds/125 seconds at 300°C, the n-i@$W_xMo_yO_3$ has a low limit of detection (DL) of about 39 ppb and an excellent sensor response (SR = R_g/R_a) of about 44.15 for 50 ppm NO gas. Even at 50°C, the enhanced sensitivity of the sensing material with the nanointerface shows a strong affinity for NO molecules. It provides around 1.03 SR with response/recovery times of 53 and 71 seconds, respectively. The robustness of the n-i@$W_xMo_yO_3$ thin film sensor was established by its excellent selectivity (SR = ~44.15) and long-term stability (60 days) towards 50 ppm NO at 300°C. The remarkable sensing properties of MoO_3 functionalized WO_3 nanograins indicate an exciting potential for NO gas sensors that operate close to ambient temperature (50°C).

12:00pm **MB2-1-MoM-7 Study on the Effect of Different Oxygen Flow Rates on Vanadium-Doped Zinc Oxide Thin Film Piezoelectric Pressure Sensors***, **Cheng Han Hsu [e204242271@gmail.com]**,* National Cheng Kung University (NCKU), Taiwan

The piezoelectric effect is a phenomenon where certain materials generate an electric charge when subjected to mechanical stress.This property is widely utilized in sensors,and energy-harvesting devices because it converts mechanical energy into electrical energy.ZnO is a promising material for energy-harvesting devices due to its piezoelectric and semiconductor properties,along with good biocompatibility and low environmental impact.However,its relatively low piezoelectric coefficient (12.4 pC/N) limits its potential in these applications.To enhance the piezoelectric coefficient,vanadium was doped into ZnO thin films.Vanadium ions have a higher valence than zinc ions,which improves electric polarization and increases the piezoelectric coefficient.Additionally,V^{5+}ions,having a higher positive charge than V^{3+}ions,create stronger polarity,further boosting the piezoelectric properties.By adjusting the oxygen flow rate during the sputtering process,the V^{5+}content in the films is increased,enhancing the piezoelectric coefficient.In this study,we utilized an RF sputtering system with varying oxygen flow rates to prepare vanadium-doped zinc oxide thin films, which were then used to fabricate piezoelectric pressure sensor devices.The results show that as the oxygen flow rate increases,the grain shape of the thin films changes,and the grain size decreases. SEM reveal significant changes in the grain structure.XRD shows that the intensity of the 002 peak weakens as the oxygen flow rate increases,indicating structural changes in the thin films.XPS reveals that the content of pentavalent vanadium increases with higher oxygen flow rates, but decreases after reaching a critical value,which correlates with the trend observed in piezoelectric coefficient measurements.Further analysis of the O1s XPS shows that the lattice oxygen content in the films is higher than the surface adsorbed oxygen,with the lowest number of oxygen vacancies at a certain oxygen flow rate,which then increases as the oxygen flow rate rises.UV-visible spectra indicate that,due to the Burstein-Moss effect,the energy band structure of the thin films initially decreases and then increases with increasing oxygen flow rates.Finally,piezoelectric pressure sensors were fabricated from these thin films,and the stress sensitivity at different oxygen flow rates was measured.This study provides a comprehensive investigation of the structural,optical,piezoelectric properties of V-doped zinc oxide thin films at varying oxygen flow rates and explores their application as piezoelectric pressure sensors.The findings offer insights for optimizing thin film performancein piezoelectric sensing devices.

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