

Emerging Materials

Room Event Hall - Session EM-TuP

Emerging Materials Poster Session

EM-TuP-1 A Novel Topological Semi-Metal: MoP Pathfinding for Future Interconnects at Nanoscale, Jeong-Seok Na, Kyle Blakeney, David Mandia, Jeremie Dalton, LAM Research

Metal interconnect resistance increases as devices continue to shrink, which poses challenges for metallization schemes in future device nodes.

Topological semi-metals (TSMs) were recently introduced and have demonstrated promising resistivity scaling performance at nanoscale. This is due to their unique properties related to topologically protected surface states and suppressed electron backscattering. MoP is considered one of promising candidates due to its high carrier concentration ($\sim 10^{23} \text{ cm}^{-3}$) and relatively low bulk resistivity ($\sim 9 \mu\Omega \cdot \text{cm}$) compared to other TSMs.

We describe the fundamental problem of metal resistivity increasing as interconnect dimensions shrink. Recently, some materials have been observed to show an unconventional resistivity decrease with decreasing dimensions. Among these topological semi-metals, MoP is a promising candidate. There have been few reports about MoP synthesis process that is compatible with interconnect applications.

In this study, we investigate the growth behavior and film properties of MoP using thermal ALD process. First, we compared different reducing agents in the ALD of MoP films. Second, comprehensive film characterization was conducted to evaluate resistivity and crystal phase/structure using 4-point probe, XPS depth profile, AR-XPS, GI-XRD and XRR analyses. The selective growth was tested to evaluate bottom-up gapfill in via structures over a wide temp range for both logic and memory applications. Finally, we discuss the need for thermal stability studies and nanoscale device characterization in order to prove the resistivity scaling benefits of MoP films.

EM-TuP-2 Vapor Phase Infiltration of Poly(1-Trimethylsilyl-1-Propyne) with Trimethylaluminum, Jonathan Jenderny, Applied Electroynamics and Plasma Technology, Ruhr-University Bochum, Germany; Nils Boysen, Fraunhofer Institute for Microelectronic Circuits and Systems, Duisburg, Germany; Florian Preischel, Inorganic Materials Chemistry, Ruhr-University Bochum, Germany; Teresa de los Arcos, Technical and Macromolecular Chemistry, Paderborn University, Germany; Aleksander Kostka, Center for Interface-Dominated High-Performance Materials, Ruhr-University Bochum, Germany; Peter Awakowicz, Applied Electroynamics and Plasma Technology, Ruhr-University Bochum, Germany; Jean-Pierre Glauber, Leibniz Institute for Solid State and Materials Research, Germany; Harish Parala, Institute for Materials Chemistry, Leibniz Institute for Solid State and Materials Research, IFW Dresden, Germany; Anjana Devi, Institute for Materials Chemistry, Leibniz Institute for Solid State and Materials Research, Germany

Inorganic-organic hybrid materials are gaining importance for different applications, combining the advantages of both organic and inorganic materials. Vapor phase infiltration (VPI) has emerged as a promising technology for the synthesis of hybrid materials. In the field of polymeric gas separation membranes, a common problem is long-term stability, as filtered gases can lead to material deterioration or swelling [1]. In addition to increasing the membrane stability, VPI has also been shown to beneficially impact the separation performance, e.g., when infiltrating polymer of intrinsic microporosity 1 (PIM-1) with trimethylaluminum (TMA) [2].

In this study, VPI of poly(1-trimethylsilyl-1-propyne) (PTMSP) with TMA is investigated. PTMSP was chosen due to its exceptionally high free volume and its organic nature, featuring a carbon-carbon double bond as functional group. Saturation of the precursor inside the polymer is attained after already 60 seconds of infiltration time inducing significant densification of the material as observed by transmission electron microscopy (TEM). Water contact angle measurements indicate a shift towards hydrophilic behaviour after infiltration. Depth profiling using time-of-flight secondary ion mass spectrometry (TOF-SIMS) shows accumulation of aluminium (Al) in the PTMSP polymer. The presence of Al was detected along the whole polymer, confirming that the VPI process affects the whole polymer and is not limited to the sub-surface or the gradient layer region. Depending on the infiltration time, a significant densification of the porous structure was observed that directly influences the selectivity of the gas permeation, up

to a complete blocking for long infiltration times. These results represent the first VPI process of a polymer featuring only a C-C double bond and outline the versatility of the VPI technique, being applicable for both gas-barrier and membrane applications in the future.

[1]: N. A. Ahmad, et. al., *Sep. Purif. Technol.*, 2019, 212, 941

[2]: E. K. McGuinness, et.al., *Chem. Mater.*, 2019, 31, 5509

[3] J. Jenderny, et.al., *Adv. Mater. Interfaces*, 2024, 11, 2400171

EM-TuP-3 Study of (TaN)_{1-x}C_x Electrode to Investigate Its Impact on OTS Selector Devices, Minkyu Lee, Taeyoon Lee, Yonsei University, Korea

Conventional transition metal nitrides (TMNs) have gained significant attention in the field of memory devices due to their low resistivity and high thermal & chemical stability. In particular, tantalum nitride (TaN) has been widely applied in various memory industries owing to its high melting point, uniform resistivity, and diffusion barrier properties. However, recent research in the direction of reducing the reset current in phase change memory (PCM) faces limitations with TaN due to its low resistivity. Therefore, it is essential to study materials that can control resistivity while having low roughness and good adhesion with the substrate. Carbon, an element with a small atomic size, can be incorporated into TMN materials to modulate their resistivity and control surface roughness through grain size variations. Here, we demonstrate novel (TaN)_{1-x}C_x electrodes that can adjust electrical resistivity depend on the compositions of carbon. X-ray diffraction (XRD) patterns were analyzed to confirm each crystal lattice and peak shift. Applying measured XRD patterns, full width half maximum (FWHM) and grain sizes were extracted using Debye-Scherrer equation. To visualize crystal structure and amorphous state of (TaN)_{1-x}C_x films, transmission electron microscope (TEM) was employed along with the diffraction pattern using fast fourier transform (FFT).

EM-TuP-4 Study for Deposition of CuI onto Indium-Gallium-Zinc-Oxide for Light Detection Application, Woosuk Sohn, Taeyoon Lee, Yonsei University, Korea

IGZO phototransistors have been recently paid attentions in various fields such as displays, image sensors, and wearable devices, owing to their high charge mobility and photosensitivity. Although the IGZO phototransistors are widely recognized, some improvements are required as they can detect a limited wavelength range of visible light due to the wide bandgap of IGZO (approximately 3.7–3.8 eV). Generally, the bandgap of IGZO can be adjusted by introducing impurities, however, such approaches often lead to performance degradation by decreasing the mobility of transistor and raising the threshold voltage and subthreshold swing. In this study, we developed a CuI/IGZO phototransistor capable of detecting light in the whole visible range by utilizing copper iodide (CuI), a p-type semiconductor material widely used in photodetectors, solar cells, and LEDs. As p-type CuI is spin-coated on the n-type IGZO layer, a pn junction and a type-II bandgap structure can be formed, which leads to an increase in the number of electrons and holes generated by light and enhances the photocurrent. Also, zinc (Zn) was additionally doped to prevent the degradation of performance of CuI TFTs due to the volatility of iodine, and enhance the on-off current ratio of the transistor. For the gate dielectric, spin-coated Al₂O₃ was employed instead of SiO₂, yielding better device stability. While the Al₂O₃ layer was not deposited by atomic layer deposition (ALD), it still provided sufficient insulating properties. Future work could incorporate ALD-based thin-film deposition to achieve improved thickness uniformity, interface control, and large-area process scalability. In fact, ALD has shown promise in uniformly doping IGZO and CuI thin films and controlling defects, suggesting that it can further enhance the responsivity and detectivity of CuI/IGZO phototransistors. The proposed device has great potential for applications in photo-memory and neuromorphic device, presenting innovative advancements in fields such as artificial intelligence, autonomous driving, and smart devices.

EM-TuP-5 Networking Density Effects on the Patterning Performance of Resists Deposited via Hybrid MLD, Long Viet Than, Giulio D'Acunto, Stacey F Bent, Stanford University

The implementation of extreme ultraviolet (EUV) lithography in semiconductor manufacturing promises to extend Moore's Law by enabling the patterning of sub-8 nm feature sizes. However, further device scaling is dependent on the implementation of EUV-tailored photoresists that meet requirements in sensitivity, resolution, and line edge roughness. With feature sizes approaching the nanometer scale, stochastic variation in the photoresist molecular structure also affects pattern quality, resulting in the need for new resist chemistries with uniform chemical distribution.

Tuesday Evening, June 24, 2025

Metal-organic thin films deposited via hybrid molecular layer deposition (MLD) are a promising class of materials to address the challenges of designing new EUV-compatible resist chemistries, by incorporating EUV-absorbing metal centers into the polymer network while exhibiting Å-level thickness control and atomic-scale homogeneity. In this work, we investigated a series of hybrid MLD-derived aluminum alkoxide (alucone) resists, deposited via trimethylaluminum (TMA) and a series of alcohol counter-reactants (glycerol, ethylene glycol, and sequential dosing of methanol/ethylene glycol). This process yielded thin films that are chemically akin, as demonstrated by X-ray photoelectron spectroscopy (XPS), but exhibit notable differences in networking/crosslinking density. Electron beam lithography, an established proxy for EUV, was used to evaluate how these structural differences affect their patterning performance. All three alucone resists exhibited negative-tone patterning, attributed to the loss of organic ligands and to the formation of inorganic alumina. We found that decreasing the crosslinking density improves the resolution limit, ultimately achieving 14 nm lines in 1:1 line/space patterns with alucone containing methanol/ethylene glycol linkers. The variation observed between these hybrid materials underscore the importance of structure-property relationships for the rational design of metal-organic EUV resists.

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