Advanced Surface Engineering
Room 205 ABCD W - Session SE-TuA

Smart Coatings and Responsive Surfaces: Engineering for Tomorrow

Moderator: Filippo Mangolini, The University of Texas at Austin

4:00pm **SE-TuA-8 Spatial Configurations in Magnetron Sputtering: A Comprehensive Review**, ***Esteban Broitman***, *Rickmer Kose,* SENTYS Inc.*; Sven Kelling,* SENTYS, Inc.

Magnetron sputtering stands at the forefront of thin-film deposition, with its efficacy intimately tied to how magnetron sources and substrates are arranged in space. In this review, we distill experimental results from across the literature into three core configurational categories: sputter-up versus sputter-down magnetron orientations, planar versus confocal magnetron arrays, and on-axis versus off-axis substrate alignments.

For each configuration, we explore how geometry shapes plasma confinement, steers the angular distribution of sputtered atoms, and dictates film characteristics—density, residual stress, microstructural evolution, and step coverage. By correlating specific geometric features with these critical film properties, we introduce a decision framework that guides researchers in selecting the optimal magnetron arrangement to achieve a targeted material performance.

To illustrate practical implementation, we showcase contemporary deposition chambers and magnetron source designs engineered for rapid, tool-free adjustment of magnetron–substrate geometry, empowering users to fine-tune film growth in situ.

4:15pm **SE-TuA-9 Wide-Bandgap Hybrid Metamaterials: Theory guided Advanced Surface Engineering for UV active Photonic Properties**, ***Ufuk Kilic***[12], *Shawn Wimer, Matthew Hilfiker, Raymond Smith,* University of Nebraska-Lincoln*; Christos Argyropoulos,* The Pennsylvania State University*; Eva Schubert, Mathias Schubert,* University of Nebraska-Lincoln

Metamaterials (MMs) -the artificially engineered surface structures with subwavelength scale features- are at the forefront of optoelectronic, quantum, and biomedical advancements [1-4]. Despite the critical importance, their effective operation in the ultraviolet (UV) spectral range by using wide-bandgap materials (WBGM) for aforementioned advancements is seldom discussed in the literature [1]. WBGMs provide exceptional transparency, high stability, corrosion resistance, and UV-active optical responses. These properties enable strong UV-active light-matter interactions, making them ideal for robust, tunable MMs in advanced photonic and quantum applications.

In this study, our methodology is framed over a theory-guided approach for fabricating and optimizing MM platforms from ultra-wide bandgap Zirconia (ZrO_2). While the finite element modeling provides insights on light-matter interaction at nanoscale [2-4], Monte Carlo ballistic simulation method unravels the particle flux dynamics and the structure growth process [5]. Utilizing electron beam assisted glancing angle deposition technique, that is particularly known for its capacity to produce various 3D morphologies over wafer-scale area, and free of masks [2-4], we fabricated highly ordered nano-columnar, and nano-helical MM platforms. Using Mueller Matrix generalized spectroscopic ellipsometry technique, we optically investigated the fabricated MM platforms within the spectral range covers near-IR (0.64 eV) to vacuum-UV (9.5 eV) and found that they exhibit strong optical anisotropies including circular dichroism and birefringence.

Here, we also present and discuss the subsequent depositions of dielectric (ZrO_2) and metallic (silver/Ag) materials leading to hybrid plasmonic MMs with a multiple number of subsegments that achieve enhanced and spectrally controlled optical anisotropies active in visible to UV spectral range. Performing complementary scanning electron microscopy, transmission electron microscopy, and energy-dispersive X-ray spectroscopy, we extracted the integrity, crystallinity, and stoichiometry of the fabricated MM platforms. This work advances photonic and quantum device design by integrating material fabrication, theoretical modeling, and experimental characterization, demonstrating how wide-bandgap ZrO_2 combined with plasmonic metals enables tunable MMs for high-power systems, UV photonic circuits, and chiral sensors.

[1]Duncan, M. A.,et al.,ACS Appl.Mater.Interfaces,14(50),55745-55752,(2022)

[2]Kilic, U.,et al.,Adv.Funct.Mater.31.20:2010329,(2021)

[3]Kilic, U.,et al.,Adv.Opt.Mat.2302767,(2024)

[4]Kilic, U.,et al.,Nat.Comm.15.1:3757,(2024)

[5]Wimer, S.,et al.,Vacuum,(under review 2025)

4:30pm **SE-TuA-10 On the Energy Efficiency of Sputtering of Elemental Targets by Inert Gas Ions Ne, Ar, Kr, and Xe**, ***Ivan Petrov,*** University of Illinois at Urbana Champaign*; Michal Fečík, Stanislav Mráz, Jochen Schneider,* RWTH Aachen University, Germany

Environmentally responsible surface engineering has emerged as an important topic in academic and industrial research. A recent review article[1] provides an extensive overview of sustainability aspects of physical vapor deposition (PVD) processes, focusing on magnetron sputtering and cathodic arc deposition. The authors point out that “energy and mass balances are an important sustainability-relevant aspect, constituting tremendous untapped potential for the surface engineering community”. Sputtering by particle bombardment produces energetic species which contribute to low-temperature growth of high-quality coatings and films. A large portion of the incoming energy is, however, converted to heat in the targets. Therefore, it is of interest to optimize the energy and the mass of the inert gas to make sputtering more energy efficient.Here we attempt to quantify the fraction of the incoming energy which is transferred to the sputtered atoms for elemental targets as a function of ion energy for four inert gases, Ne, Ar, Kr, and Xe. Previously, Carter et al[2] introduced the term erosion efficiency, $\eta^{er} = U.Y(E)/E$, where U is the sublimation energy of the metal target. This definition includes the potential energy required to remove the atom from the surface but does not consider the kinetic energy of the sputtered atoms. Petrov et al[3], using the Yamamura et al[4] expression for the sputtering yield Y(E), showed that the maximum value of the erosion efficiency, η^{er}_{max}, exhibit periodic fluctuations as a function of the atomic number of the target Z_2 in the interval 0.4-4%.Here we extend this approach to calculate the sputtering energy efficiency $\eta^{sp} = (U+E_{av})Y(E)/E$, where E_{av} is the average kinetic energy of the sputtered atoms, estimated using the Thompson formula. Values of η^{sp}_{max} are approximately factor of x4 higher in the range of 2-16%. Ar delivers close to optimal total energy efficiency for targets with atomic number $Z_2 < 50$, while for heavier targets Kr yields higher total efficiencies from approximately 20% to 80%, and Xe from 20% - 110%. The sputtering energy efficiency η^{sp} exhibits maximum values at ion energies approximately factor of 2 higher than the values for η^{er}_{max}. The ion energy interval within which $\eta^{sp} > 0.8\ \eta^{sp}_{max}$ for most targets is 100-1500 eV.

1. M. Hans, J.M. Schneider, A. Matthews, C. Mitterer, Surf. Coat. Technol. **494**(2024)131486
2. G. Carter, M.J. Nobes and D.G. Armour, Vacuum **32**(1982)509
3. I. Petrov, V. Orlinov, S. Grudeva, Bulg. J. Phys. **18**(1991)215
4. Y. Yamamura, N. Matsunami, N. Itoh, Rad. Eff. **71**(1983)65

[1] **ASED Young Investigator Award Finalist**

[2] **ASED Rising Star**

Author Index

Bold page numbers indicate presenter