Advanced Surface Engineering
Room 2007 - Session SE1-WeA

Glancing Angle Deposition

Moderator: M.J. Brett, University of Alberta Edmonton

2:00pm **SE1-WeA1 Atomic Chaos and Emergent Phenomena in Glancing Deposition**, ***K. Robbie***, *T. Brown, C. Elliott, C. Buzea,* Queen's University, Canada **INVITED**

The atomic-scale porosity created in thin films by glancing angle deposition is the result of chaotic atomic competition. A so-called growth instability arises when atomic vapor arriving at glancing incidence condenses under conditions where the behavior of each atom strongly affects the condensation behavior of subsequent atoms - a sensitivity to initial conditions, or chaos - creating oriented dendritic structures that can be engineered on the scale of nanometers by varying the deposition geometry. The chaotic nature of this growth results in fractal morphologies, with scale-invariant self-similarity and power-law scaling in observable parameters such as the 'column' diameter. While the stochastic arrival of atoms clearly plays a role in the chaotic dynamics of this system, it appears that atomic-scale condensation dynamics also contribute - and perhaps constitute a form of quantum chaos. Examining the morphologies of films deposited at glancing incidence reveals a rich set of structures not well described by simple ballistic aggregation models. Particularly interesting are morphological rare-events that occur in some materials, and include self-organized pyramidal structures in several noble metals. These structures may be described as emergent phenomena, and suggest that there are quantum contributions to this chaotic condensation process. Experimental studies of this film growth process will be presented, including measurements of growth exponents and observations of material-dependent variation in film morphology. Existing theories of ballistic aggregation will be reviewed, followed by several proposals of directions that might be pursued to explain the formation mechanisms of the observed emergent phenomena. Finally, the potential of geometrically-controlled atomic self-assembly for technological applications will be presented.

2:40pm **SE1-WeA3 Fabrication and Characterization of Square Spiral Photonic Crystals Made by Glancing Angle Deposition**, ***M.A. Summers***, *M.O. Jensen, M.J. Brett,* University of Alberta, Canada

The square spiral architecture is a promising candidate for photonic band gap (PBG) materials due to its ease of fabrication. The silicon square spiral structure is predicted to yield an optimum PBG width of 15% relative to the gap center frequency and can be fabricated using the glancing angle deposition (GLAD) technique. The GLAD fabrication process uses controlled substrate motion and highly oblique deposition to engineer precise architectures on the nanometer size scale. These nanostructures are grown with lateral and longitudinal periodicity using a pre-patterned substrate consisting of a tetragonal array of relief structures that can be fabricated using a number of lithographic techniques. Photolithography offers the possibility of large-scale manufacturability, while techniques such as laser direct-write lithography and electron-beam lithography provide the significant advantage of easy parameter modification and defect inclusion since no master is required. The GLAD process enables the scaling down of photonic crystal dimensions throughout the near infra-red wavelength region. Additionally, the versatility of the GLAD process enables the fabrication of a 3D-2D-3D photonic crystal hetero-structure, providing a foundation for potential use in optical networking applications. We report the structural and optical characterization of various silicon square-spiral photonic crystal structures fabricated using the GLAD technique.

3:00pm **SE1-WeA4 Structurally-chiral Films Fabricated for DUV Wavelengths by Serial Bi-Deposition**, ***L. De Silva***, *I. Hodgkinson,* University of Otago, New Zealand

We report serial bi-deposition (SBD) of structurally-chiral films for deep ultraviolet (DUV) wavelengths. Scanning electron micrographs confirm that the films have a twisted-columnar nanostructure similar to a double-start screw. Observation of circular Bragg resonances in reflection and transmission at around 230 nm indicates a dielectric pitch of 65 nm, an average refractive index of 1.75 and local in-plane linear birefringence of 0.05. Possible applications of DUV chiral media include novel thin film polarizing devices for use in the DUV spectral region where the range of available devices is severely constrained by material properties.

3:20pm **SE1-WeA5 Nanoporous Thin Films for Optical Interference Coatings**, ***M.M. Hawkeye***, *M.J. Brett,* University of Alberta, Canada

Thin films with periodically varying refractive indices display photonic bandgap effects and are commonly used as optical interference filters for a variety of applications. Glancing angle deposition (GLAD) offers a straightforward method for depositing thin films with controlled nanoscale porosity gradients, allowing fabrication of inhomogeneous optical coatings. Thin films of titanium dioxide with sinsuoidal refractive index profiles were deposited by reactive e-beam evaporation and their applicability as optical filters was investigated. We found that a wide range of filter characteristics may be achieved using the GLAD process to control the film porosity. By introducing intentional defects in the sinusoidal index profile, narrow bandpass optical filters are realized. Through modification of the defect parameters, the optical properties of the narrow bandpass may be controlled. Tunability of the filter characteristics such as spectral location, bandwidth, and polarization dependence is demontrated through simulation and experimental results. Apodization of the refractive index profile to reduce the interference sidelobes characteristic of these optical filters is also discussed. The presented work shows the precision of the GLAD technique for fabricating optical interference filters for applications in the visible spectrum.

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