Thin Films Division
Room: 20 - Session TF+MI-ThA

Control, Characterization, and Modeling of Thin Films II

Moderators: Subhadra Gupta, University of Alabama, Angel Yanguas, Argonne National Laboratory

2:20pm **TF+MI-ThA1 *In Situ* Monitoring of the Growth of Metallic, Nitride and Oxide Thin Films Prepared by Pulsed Laser Deposition**, ***Michal Novotny***, *J. Bulir, E. Maresova,* Institute of Physics ASCR, Czech Republic, *P. Fitl, J. Vlcek,* University of Chemistry and Technology Prague, Czech Republic, *M. Vondracek, L. Fekete, J. Lancok,* Institute of Physics ASCR, Czech Republic, *N. Abdellaoui, A. Pereira,* University of Lyon, Université Claude Bernard Lyon, France

Pulsed laser deposition (PLD) is a well-established technique in fabrication of thin films. PLD profits from its simplicity, modesty, versatility and flexibility. Varying deposition conditions, ie. fluence, laser repetition rate, ambient pressure, substrate and its temperature, one can easily influence nucleation and the growth of thin film and consequently its properties. The in-situ monitoring of electrical properties allows sophistically control such processes. We demonstrated the in-situ monitoring possibilities for aluminium and silver as metallic materials examples, titanium nitride and zirconium nitride as nitride materials examples, and zinc oxide and tin oxide as oxide materials examples. The films attract attention in eg. photonics, plasmonics, electronics, sensors and biophysics. Particular application requires the film of special morphology, ie. isolated nanoparticles, arrays, or smooth surface.

The targets of Al, Ag, TiN, ZrN, ZnO and SnO_2 were ablated by a Nd:YAG laser operating at wavelength of 266 nm and pulse length of 4 ns. The laser repetition rate was varied from 0.1 Hz to 10 Hz. Electrical conductivity and I-V curve were measured by four-wire technique.

The results of the in-situ monitoring are correlated with the AFM and SEM analyses of the surface morphology, optical properties characterized by spectral ellipsometry and composition studied by XPS. We are able to distinguish the growth mode in the real-time, estimate the point of coalescence as well as the subsequent evolution of the surface roughness and control it. The obtained results provide knowledge toward synthesis of novel functional materials for optoelectronics and sensors.

2:40pm **TF+MI-ThA2 Perpendicular Magnetic Anisotropy in CoxPd100-x Alloys for Perpendicular Magnetic Tunnel Junctions and Bit Patterned Media**, ***Subhadra Gupta***, *B.D. Clark, A.G. Owen,* University of Alabama

Materials with high Perpendicular Magnetic Anisotropy (PMA) have drawn intensive research interest in recent years. This is because they have applications in perpendicular magnetic tunnel junctions (p-MTJ) and perpendicular magnetic recording media. Often solutions to these problems require overly complicated multilayer structure or high temperature grown $L1_0$ alloy. We demonstrate a simple room temperature grown CoPd alloy that is characterized by Alternating Gradient Magnetometry (AGM), Energy-Dispersive X-ray Spectroscopy (EDS), and X-ray Diffraction (XRD). We have found that the PMA and coercivity is tunable based off thickness, composition, annealing, and seed layer. Current in-plane tunneling (CIPT) measurements were performed on the stack Si/ SiO_2/ MgO (13)/ CoxPd100-x (50) / Ta (0.3) / CoFeB (1) / MgO (1.6) / CoFeB (1) / Ta (5) / Ru (10), with the numbers in parenthesis being the layer thickness in nm. CIPT data shows the highest magnetoresistance measurements correlates with the samples with the highest PMA. The stack Si / SiO_2 / Ta (5) / Pd (5) / $Co_{25}Pd_{75}$ (20) / Ta (5), with the numbers in parenthesis being the layer thickness in nm, were patterned using block copolymer templating and show an increase in coercivity from 3.3 kOe to 3.6 kOe with a nanopillar diameter approaching 10 nm, indicating that it may be suitable for bit pattern media (BPM) development.

3:00pm **TF+MI-ThA3 Combining Dynamic Shadowing Growth and Colloidal Monolayer to Design Plasmonic Metamaterials**, ***Yiping Zhao***, University of Georgia **INVITED**

The past decade has witnessed a rapid development of plasmonic metamaterials, which have unique optical properties and promising applications. Here, we report a simple, versatile, and scalable method for plasmonic metamaterial fabrication, which combines dynamic shadowing growth and self-assembled nanosphere monolayers, referred to as nanosphere shadowing lithography. In this method, a physical vapor deposition creates regular nanostructure arrays on modified nanosphere monolayers due to shadowing effect. The nanostructure morphology can be controlled by tuning the vapor flux direction with respect to the monolayers. Benefited from its control in nanostructure morphology, we have designed and fabricated a series of plasmonic nanostructures, including discrete nanoparticle arrays, nanoholes, nanoparticle networks, graded nanostructures, and chiral metamaterials such as patchy particles, helically stacked plasmonic layers, and Swiss roll structures. These well designed plasmonic nanostructures show tunable localized plasmonic resonance property and large circular dichroism response. In addition, by combining a co-deposition growth method, alloy or mixed phase plasmonic structures can be designed and investigated systematically. Such a simple but scalable fabrication method has a great potential for plasmonic metamaterial and meta-device development.

4:00pm **TF+MI-ThA6 Physical Vapor Deposition of Emerging Resistive Memories**, *M. Pakala*, ***Lin Xue***, Applied Materials, Inc. **INVITED**

We are getting deeper into the memory centric computing era, with emerging non-volatile memories being rapidly developed to fill gaps in latency, density and functionality. Various types of resistive memories such as STT MRAM, ReRAM and PCRAM are being developed to augment characteristics of available charge based memories. This is driving new deposition process / equipment requirements for these materials, since many of these materials are non-standard materials for an existing semiconductor fab. In my presentation, I will cover the requirements for depositing such materials as well as factors that drive these requirements. Particular focus will be on depositing magnetic tunnel junction stacks for STT MRAM as well as other semiconductor/oxide materials for resistive memories and selectors that can enable high density cross point memory.

4:40pm **TF+MI-ThA8 Metal Oxide Nanostructure Growth by a Simple Hot Water Deposition (HWD) Method**, ***Nawzat Saadi***, *T. Karabacak,* University of Arkansas at Little Rock

We are presenting a new hot water deposition (HWD) method to grow metal oxide nanostructures (MONSTRs). The technique is simple, low cost, low temperature, scalable, high-throughput, and does not involve any chemical agents or surface activators. Moreover, HWD can be used to deposit a large variety MONSTR materials on almost any type of substrate material or geometry. The process simply involves a source metal and a target substrate that are both immersed into hot water. The water temperature during HWD is typically between 50-95 ºC. In this work, we demonstrate that zinc oxide (ZnO) MONSTRs can be deposited on different substrates including copper (Cu) plate, Cu mesh, Cu foam, and ITO coated glass. We used Zn plate and powder as the source. Temperature of the water was set to 75 ºC. We observed that ZnO nanowires with lengths of few hundreds of nanometers and hexagonal cross-sections of about 50-100 nm grew within about 3 hours. ZnO MONSTRs covered the target substrates uniformly including the 3D foam surface. Smooth facets observed in SEM images and XRD results indicate that ZnO nanostructures have a well-developed crystal structure. In addition, we present a growth mechanism that includes the main processes of "plugging" and surface diffusion. The plugging involves the steps of metal oxide formation on metal-source surface, release of metal oxide molecules from the source, migration trough water, and deposition on the target surface. This is followed by surface diffusion of metal oxide molecules that help forming MONSTRs with smooth crystal facets. We also claim that "shadowing" effect can play an important role and promotes MONSTR growth on taller hills of the target surface vs valleys. We performed experiments such as HWD at different substrate-target distances, target roughness, and deposition time in order to better understand the contribution of each step listed above.

5:00pm **TF+MI-ThA9 Microsphere-Based Disordered Coatings for Effective Radiative Cooling**, ***Sarun Atiganyanun***, *J. Plumley, K. Hsu,* University of New Mexico, *J. Cytrynbaum,* Williams College, *T. Peng,* Air Force Research Laboratory, *S.M. Han, S.E. Han,* University of New Mexico

Being able to cool the buildings below the ambient temperature under the sun in the middle of a summer without having to use air conditioning would result in tremendous energy savings. As a step towards this goal, we have investigated a facile application of coatings made of silica microspheres in disordered structures, using evaporation as well as spray-coating. For the evaporation coating, silica microspheres are dispersed in water, and the colloidal stability is disrupted by dissolving ionic salt into the solution. The colloidal solution is confined onto a substrate and is allowed to evaporate. For the spray-coating, much like commercial painting, the aqueous colloidal solution is forced through a spray nozzle and deposited onto a substrate. Scanning electron microscopy images and autocorrelation analyses show that the resulting structures are disordered without short- or long-range order.

Optical measurements also indicate that the coatings produced under optimal conditions have a short transport photon mean free path of approximately 4-8 μm in the solar spectral region. These coatings exhibit high emissivity above 95% in the atmospheric transparency window. These results suggest strong photon scattering properties in the visible region, while providing a strong thermal emission. Such films would enable effective radiative cooling. To estimate the theoretical limit, a computational model is first used to calculate the cooling power of the coatings under direct sunlight. The model predicts that the disordered coating with 200 μm thickness has a cooling power of ~250 W/m^2 at 27ºC and could reduce the temperature of the sample under the direct sunlight by approximately 37ºC below the ambient temperature. Our experimental measurements under direct sunlight show that our coatings perform better than commercial sunlight and heat reflective paints. We will further discuss how coatings of disordered, random, inverse structures can enhance the durability of our coating in a paint format, while maintaining radiative cooling properties.

5:20pm **TF+MI-ThA10 Sputter Beam Epitaxy: Innovation towards Spin Control in Intermetallic Thin Films**, ***Adam Hauser***, The University of Alabama **INVITED**

The vast array of interesting crystal structures and the wealth of elemental choices guarantee that we are never lacking for new opportunities in designing and making "custom-built" materials, if a method can be devised to build these complex materials systems. This talk will highlight our progress in thin film growth via Sputter Beam Epitaxy, an approach combining the fabrication strengths of off-axis magnetron sputtering and molecular beam epitaxy. We will focus on highly-ordered B2 alloys (including the Heusler sub-class) with an eye towards determination of the true properties of ideally ordered materials and tuning towards ideal spin damping properties.

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