Friday Morning, October 6, 2000

Thin Films
Room 203 - Session TF+NS-FrM

Nanostructured Thin Films

Moderator: A. Hosseini-Tehrani, Florida International University

8:20am **TF+NS-FrM1 Cluster Beam Synthesis of Nanostructured Thin Films**, ***P. Milani***, *P. Piseri, E. Barborini, A. Podesta', C. Lenardi,* Universita' Di Milano, Italy **INVITED**

We will present and discuss the use of supersonic cluster beam deposition (SCBD) for the production of nanostructured thin films. With this technique nanostructured films of refractory and semiconductor materials can be produced over large areas on various substrates at room temperature. Elemental building blocks are clusters with a number of atoms ranging from few tens up to few hundreds. These units organize in the film in hierarchical structures from the nanoscale to the mesoscale. By exploiting aerodynamical effects typical of supersonic beams it is possible to obtain very high deposition rates with a control on neutral cluster mass distribution, allowing the deposition of thin films with controlled nanostructure. Due to high deposition rates, high lateral resolution, low temperature processing SCBD can also be used for the micro and nanopattering of cluster-assembled films when little or no post-growth manipulation or assembly is required. As a practical example we will discuss the case of nanostructured carbon films. Surface morphologies, granularity and atomic structure of nanostructured carbon films grown with different precursors and under different conditions have been investigated by different techniques. The application of nanostructured carbon for the fabrication of supercapacitors and field emission devices will be discussed.

9:00am **TF+NS-FrM3 Growth of Regular Arrays of Pillars and Helices with Repeat Distance Below 100 nm**, ***M. Malac***, University of Alberta, Canada; *R. Egerton,* Portland State University

Oblique deposition onto a rotating substrate pre-patterned with suitable nuclei results in the growth of regular arrays of pillars or helices.@footnote 1@ The repeat distance of such arrays can be varied from below 20 nm to over one micrometer. To improve the control over the microstructure it is beneficial to understand the growth mechanism on a microscopic scale. We find that the helices and pillars (within regular or random-nucleated arrays) are composed of many fibers growing simultaneously. The helix-arm diameter is determined by the number of fibers it contains. The distribution of fiber diameters is very narrow and remains constant along the entire helix height. The fiber-diameter, which is characteristic for given material and ratio of substrate and melting point temperatures, is in the order of a few nanometers. The crystalline nature of the growing material has only a minor influence on the fiber diameter. Additionally, we find that the columns formed within a film deposited onto a stationary oblique substrate are also composed of many individual fibers. The helix- and pillar-size distribution is much narrower within a regular unpatterned (randomly nucleated) array. This can be attributed to regularity of the shadowing between structures within a regular array. Anisotropy of shadowing within a regular square array arises from the varying distance of shadow-providing neighbors as substrate is rotated. This anisotropy has only a minor influence on the final shape of the pillars or helices. The helices within a random array start growth from a single fiber and exhibit a very narrow size distribution before the onset of bifurcation. This narrow size-distribution was observed when the helix arm diameter (= fiber diameter) is below the lower limit of scaling of the thin-film microstructure.@footnote 2@ @FootnoteText@ @Footnote 1@Malac M, Egerton RF, Brett MJ, Dick B, J. Vac. Sci. Technol. B 17 (6), 1999 @Footnote 2@Bales GS, Bruinsma R, Eklund EA, Karunasiri RPU, Rudnick J, Zangwill A, Science 249 (1990).

9:20am **TF+NS-FrM4 Plasma Spray Deposition of Nanostructured Materials**, ***H.M. Meyer, III***, *R. White,* Oak Ridge National Laboratory; *T.T. Meek,* University of Tennessee

Minimum film thickness achieved with any thermal-spray deposition process is limited by the size of powder feedstock materials. However, nanosized feedstock powder materials can be problematic for current plasma spray gun technology because of agglomeration and gun clogging. Some successes with nanopowder feedstock have been achieved, but mainly using special hardware and low quantities of expensive powders. We report the formation of nanostructured (i.e. nanomaterials) thin films using a unique combination of thermal spray coating techniques and liquid feedstock injection. This advanced thermal spray coating technology is a new method of synthesizing materials tailored at the nanoscale level. Injection of liquids into an arc-plasma gun offers the possibility of forming ultra-thin films at high deposition rates, a long-standing technology goal for the plasma spray industry. The formation of alumina thin films via plasma spray deposition using an aqueous precursor is presented. We compare the properties of our films with films formed by conventional thermal spray deposition using standard commercial alumina powders. Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR2272.

9:40am **TF+NS-FrM5 Deposition of Nanoparticles on Metal Surfaces**, ***R.S. Averback***, University of Illinois at Urbana-Champaign; *J.M. Gibson,* Argonne National Laboratory; *K. Albe, C. Zimmermann, Y. Ashkenazy, M. Yeadon,* University of Illinois at Urbana-Champaign **INVITED**

The deposition of metallic nanoparticles on surfaces has been investigated by a combination of molecular dynamics computer simulations and in situ transmission electron microscopy. It was observed that the reaction kinetics were dominated by a combination of interfacial stresses associated with epitaxy and capillary forces deriving from surface roughness. For Cu and Ag nanoparticles, it was found that the interfacial stresses led to 'contact epitaxy,' whereby the first few layers of the nanoparticles came into registry with the Cu(100) surface. Below a critical size, about 4 nm, the entire nanoparticle became epitaxial. For Co nanoparticles, which are more refractory and do not wet Cu(100) and Ag(100), contact epitaxy was not observed, although for deposition at 500 K, the nanoparticles burrowed into the substrate to achieve smoothing and coherency. Additional work examined how nanoparticles and grains in thin films respond to applied stresses. It will be shown that small particles on surfaces slide with little friction when they form a high energy grain boundaries, but that they quickly reorient during sliding and become locked from additional motion.

10:20am **TF+NS-FrM7 Scanning Probe Investigations of Passivated and Bare Au Nanoclusters on H:Si(111)**, ***M.D.R. Taylor***, *P. Moriarty,* University of Nottingham, UK; *M. Brust,* University of Liverpool, UK

Non-contact atomic force microscopy (NC-AFM) and scanning tunnelling microscopy (STM) have been used to characterise the morphology of thin films of decanethiol-capped 6 nm Au clusters spin-coated onto hydrogen-passivated (HF/NH4F treated) Si(111). Prior to cluster deposition, NC-AFM images taken under ambient conditions reveal that the H:Si(111) surface is atomically flat, typically consisting of 30-50 nm wide terraces separated by a mixture of single and multiple atomic steps. Following deposition of passivated clusters onto H:Si(111), a network of branched, dendritic islands (6 nm high) is observed with NC-AFM. The clousters forming these islands are remarkably loosely bound and may be swept aside by the AFM tip to fom agglomerates of clusters via minor modification of the non-contact mode feedback parameters. The underlying layers consist of poorly ordered clusters which are stable under STM imaging conditions with tunnel currentsup to 5 nA. This stability faciltates photon emission STM investigations of the passivated clusters. The results of comparative studies of STM-induced light emission from passivated and bare clusters (and from evaporated Au films) will be presented.

10:40am **TF+NS-FrM8 Nanophase Metal - Metal Oxide Films Deposited from a High-rate, Nanoparticle Beam**, ***F.K. Urban III***, *A. Hosseini-Tehrani, P.D. Griffiths, A. Khabari,* Florida International University; *Y.-W. Kim, I. Petrov, L. Wei,* University of Illinois

While interest in nanophase films deposited in vacuum from nanoparticle beams dates back to the early 1970s, development of suitable sources for such beams has been difficult. A rapidly increasing number of different materials are now being used to deposit nanophase films, from a few tenths to a micrometer in thickness. The new method employs DC magnetron sputtering and condensation of a conductive target material into a helium and argon gas mixture in a flow rate ratio of up to 0.12 at total pressures between 0.7-0.8 Torr. A low velocity beam of the gas and nanoparticles is formed as they escape through a 3 mm-diameter converging-diverging exit nozzle consecutively into differentially pumped chambers maintained at pressures less than 10-3 and less than 10-4 Torr, respectively. Results to date confirm a typically oxygen-containing nanophase film structure. A set of new metal and doped semiconductor elements including Ag, Al, Au, Co, Cr, Cu, Fe, Mo, Nb, Ni, Pt, Si, Sn, Ta, W, and Zr have just been deposited. To our knowledge, some of these are deposited in vacuum for the first time and details on their nanostructure, composition, and materials properties are just now being learned and will be reported. To date, all films are nanocrystalline with grain sizes ranging from 1 to 20 nm and have a porous structure metallic densities,

determined from combined Rutherford backscattering and film thickness measurements, in the range of 15-80% of the bulk densities. The effects of synthesis chamber wall cooling and gas conditions as well as starting material vapor pressure, melting point, and condensation energies will be presented. New findings on material properties will also be presented.

11:00am **TF+NS-FrM9 Thin Film Growth on a Fullerene Molecule***, **T.P. Martin,*** Max Planck Institut FKF, Germany **INVITED**

Since the surface of a fullerene molecule is not unlike that of graphite, it might be expected that they have similar properties when acting as a substate for thin film growth. The film-substrate interaction is indeed similar. However, the fact that the fullerene surface is curved and closes on itself leads to interesting differences. Both the similarities and the differences will be discussed including wetting, atom-packing, and reaction between film and substrate.

11:40am **TF+NS-FrM11 Sputtered Fabrication of Periodic Sub-Micron Structures***, **B. Dick,** M.J. Brett,* University of Alberta, Canada

It is known that Glancing Angle Deposition (GLAD) utilizing extreme self-shadowing during film growth can produce periodic microstructures on a pre-defined seed layer with electron beam evaporation.@footnote 1@ This deposition process has been applied to the fabrication of periodic magnetic pillars and has proposed application in optical devices. However, because individual seed elements enforce adatom shadowing on the substrate surface, higher operating pressures, resulting in larger angular flux distributions, can be tolerated in the formation of GLAD microstructures when deposited on a seed lattice. In this presentation, we report the use of low-pressure sputter deposition to fabricate periodic GLAD microstructures of between 500nm and 1.5µm thickness on substrates patterned with a 500nm period seed layer. We have characterized the growth of the microstructures in terms of the target area, deposition pressure, throw-distance, and flux incidence angle. The use of sputtering for periodic GLAD simplifies the process control, and should enable deposition of a broader range of materials for diverse applications including magnetics, optics, and sensors. @FootnoteText@ @footnote 1@B. Dick, M.J. Brett, T.J. Smy, M.R. Freeman, M. Malac, R.F. Egerton. J. Vac. Sci. Technol. A. 18(4), 2000.

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