Thin Films
Room 203 - Session TF-TuM
Thin Films in the 21st Century

Moderator: G.N. Parsons, North Carolina State University

8:20am **TF-TuM1 Atomic-Level Control of Microstructure, Morphological Evolution, and Physical Properties during Film Growth: The Golden Era of Materials Science*, J.E. Greene,*** University of Illinois, Urbana **INVITED**

A primary goal of research being carried out worldwide in the area of thin film crystal growth from the vapor phase is the development of the ability to understand, control, and quantitatively model - at the atomic scale - surface chemical reaction pathways, growth kinetics, and microstructural evolution. This typically involves operating far from thermodynamic equilibrium in order to selectively open new kinetically-limited reaction paths and has resulted in the development of hybrid growth techniques which combine the inherent advantages of CVD (choice of precursor chemistries for site-specific surface reactions, self-limiting surface terminations, surface-mediated reaction kinetics, surfactant reactions, and conformal coverage), MBE (clean UHV processing compatible with in-situ surface science techniques, and low deposition temperatures), and sputter deposition (the use of hyperthermal particles to overcome surface kinetic barriers). In-situ structural (e.g., RHEED, LEED, STM, AFM) and chemical (e.g., AES, XPS, EELS, STS, TPD) probes coupled with powerful post-deposition analytical techniques such as high-resolution TEM and synchrotron-XRD, RBS, SIMS, and PL have provided the primary tools for rapid experimental progress over the past few years. The corresponding development of efficient computational methods for molecular dynamics, kinetic Monte Carlo, and density functional theory, together with powerful analytical approaches such as level-set schemes which easily handle singularities and higher dimensions, allows robust predictive modeling to proceed in parallel with experiment. Examples of atomic-scale manipulation of film chemistry, surface morphology, epitaxy by driven assembly, and preferred orientation in polycrystalline layers will be discussed. Structure and chemistry can be manipulated at all length scales from nanometer to mesoscopic to continuum through increasingly complex organizational hierarchies.

9:00am **TF-TuM3 1D Nanostructures: Building Blocks for Nanotechnologies*, C.M. Lieber,*** Harvard University **INVITED**

One-dimensional (1D) nanostructures, such as nanowires and nanotubes, are critical building blocks that have the potential to impact many emerging and proposed areas of nanoscale science and technology. This presentation will focus on exploiting our fundamental understanding of growth and physical properties of these nanoscale materials to design and assemble rationally functional nanoscale tools and devices. First, the orthogonal assembly of semiconductor nanowires into integrated multi-terminal electronic and optoelectronic devices and the resulting properties of these structures will be described. Second, a new concept for a carbon nanotube based molecular scale computer will be discussed together with proof of concept experiments. Third, critical tools for imaging, sensing and manipulation at the single molecule scale, which are based on the unique mechanical and electromechanical properties of nanotubes, will be discussed.

9:40am **TF-TuM5 Challenges for Thin Films in Communications*, W.D. Westwood,*** THINK Films, Canada, Ontario **INVITED**

Considering the growth rate in both the demand for thin films and the capability to fabricate them over the past 40 years, it is a daunting task to predict the future of thin film technology, even over the next decade. Apart from Zn evaporation for paper capacitors, the main application of thin films for telecommunications prior to 1960 were electroplated Au relay contacts. Sputtering Ta based resistors and capacitors for tone touch telephone frequency generators was the first of a new range of applicatio ns. Today, there are many very demanding applications in integrated circuits and optical components for communication systems; e.g wavelength separation in high speed fiber systems utilizes over 100 oxide layers in interference coatings with a precision of better than 0.1%. The number of deposition methods has greatly increased in the past 40 years; a whole range of techniques involving combinations of physical, chemical and plasma processes are now used to deposit films for specialized applications. In parallel, sophisticated analytical techniques have provided better understanding of the composition and structure of films and the growth processes. Despite these advances, the requirements for control of films remains ahead of the capability and even better methods are required. Will improvements in PVD or CVD methods meet the requirements or will new techniques provide the high yield, high precision processes which are required?

10:20am **TF-TuM7 The Transition from Thermally-grown SiO@sub 2@ to Deposited Thin Film Alternative Gate Dielectrics*, G. Lucovsky,*** North Carolina State University **INVITED**

This continued scaling of lateral dimensions of Si field effect transistors to increase device packing densities, and to improve high frequency performance requires proportional decreases in the effective thickness of the gate dielectric. When this equivalent oxide thickness, EOT, is reduced to < 2.5 to 3 nm, direct tunneling emerges as an important factor in device performance and reliability. Direct tunneling at bias voltages for channel inversion exceeds 1A-cm-2 at EOT ~1.5 to1.6 nm, and defines a limitation for thermally-grown SiO@sub 2@ for high power devices. Limitations for portable devices are much more restrictive. The obvious solution for extending EOT to significantly smaller values ~0.5-0.6 nm is to introduce deposited thin film alternative gate dielectrics with higher dielectric constants. This is a formidable task, since the performance and reliability of devices with thermally-grown SiO@sub 2@ derives from i) the low density of defects, trapping sites and fixed charge, at the Si-SiO@sub 2@ interface, and the ii) the low density of electrically-active defects in the SiO@sub 2@ film. Deposited gate dielectrics will then require separate and independent control of the properties of Si-dielectric interface, and the thin film alternative dielectric generally in stacked configurations. Introduction of alternative gate dielectrics will proceed in two steps, i) replacement of SiO@sub 2@ with deposited silicon oxynitride alloys and silicon nitride, extending EOT to ~ 1.1 nm, and then iii) replacement of the dielectrics of i) with metal-oxide and silicate thin films with dielectrics constants in excess of 10. This paper will address issues relevant to single layer and composite structures for both groups of replacement dielectrics identified above.

11:00am **TF-TuM9 Porous Coatings with Engineered Microstructure*, M.J. Brett,*** University of Alberta, Canada **INVITED**

Traditional thin film coatings are often optimized for durability, density and uniformity. However, recent opportunities for porous thin films have led to development of new techniques for fabrication of extremely porous coatings with precisely controlled microstructure. One such process is Glancing Angle deposition (GLAD), which combines the features of glancing incidence flux at the substrate with controlled substrate motion. Whereas "normal" evaporated or sputtered thin films usually possess a columnar structure that is densely packed, in the GLAD process extreme self shadowing from nuclei leads to greatly increased separation of columns and growth of isolated microstuctures. Microstructural shape may be tailored by substrate motion to produce, for example, helices, pillars, chevrons, and S-curves with feature sizes from 10 nm to 20 µm. In this manner GLAD has been utilized for simple one-step fabrication of films of high surface area and controlled porosity and structure from dielectric, semiconductor, metal, and alloy materials by sputtering, evaporation, and pulsed laser deposition. Although the stochastic nature of the deposition normally leads to random column nucleation, large area periodically arranged micropost or microhelix arrays may be easily created by deposition over patterned seeds on the substrate. This talk will present details of oblique deposition processes, characterization and description of film microstructures, and results of investigations or of opportunities for the use of engineered porous films in optics, thermal barriers, sensors, magnetics, and as high surface area devices.

11:40am **TF-TuM11 Thin Film Technology in the 21st Century*, F. Jansen,*** BOC Edwards **INVITED**

A century of technology development and materials engineering has provided us with deposition processes for nearly every imaginable material. Interactions between process parameters and materials properties are generally well understood. Today, this allows the controlled deposition and crafting of complicated devices of which thin-ness and small-ness is a fundamental attribute. As the technology of thin films progressed from optical to electronic applications, the definition of 'thin' moved from the 100 nm scale into the <10 nm domain where atomic scale effects start to become important design considerations. The opening of the 21st century brings us to a convergence of thin film deposition with atomic scale engineering. Atomic layer deposition is aimed at nanoscale process control. Self-assembled monolayers provide surfaces with unique and useful properties. Microelectronic mechanical sensors require a broad spectrum of nanoscale engineered materials all based on thin film techniques. Approaching device applications from the opposite direction of the thickness scale, will challenge the thin film technologist to develop new methods to control the process and achieve practicality. The shift from inorganic to organic electronic materials is predicted to continue with concomitant changes in process technology. With microelectronics now reaching fundamental limits of miniaturization, thin film technologists will be forced to return to their beginnings, optical device technology, be it this time on a scale and with a required degree of control that was unthinkable in the last century.

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