Wednesday, May 13

1:30 p.m. A-1 Fundamental Understanding of Pulsed PECVD Through Diagnostics and Modeling

C.A. Wolden, Colorado School of Mines, Golden, CO

Invited 40 min. Talk

Atomic layer deposition (ALD) is the leading technology for nanoscale synthesis of thin films, imparting digital control over thickness and composition, uniformity, and conformality. However, its low rates preclude its use for the practical synthesis of relatively thick mesoscale coatings (100 - 1000 nm). There are tremendous opportunities in this area, and some applications of interest include flexible electronics, precision optical components, thin film batteries, and solar cells. At CSM we have developed low frequency (~1 Hz) pulsed plasma-enhanced chemical vapor deposition (PECVD) as an alternative to ALD for self-limiting growth of metal oxides. Pulsed PECVD retains Angstrom level control over thickness and composition, but at significant net rates (> 30 nm/min). In this presentation will introduce the principles of the technique, highlighting a number of salient results. Pulsed PECVD appears to have widespread applicability, having been successfully used to synthesize a wide variety of oxides (ZnO, TiO_2, Al_2O_3, Ta_2O_5). Achievements include demonstration of high rates, exceptional quality, a high degree of conformality, and room temperature synthesis of crystalline semiconductors. The technology continues to expand and current efforts in the synthesis of nanolaminates, mixed metal oxides, and inorganic/organic hybrids will be described. To date, pulsed PECVD process development has been largely empirical. In order to continue to expand and refine this deposition technology for emerging markets it is clear that a more fundamental understanding of the process is necessary. We have embarked on a project that employs time-resolved diagnostics (Langmuir probe, optically emission spectroscopy (OES), electrical impedance spectroscopy (EIS)) to provide fundamental insights into the dynamics controlling the plasma chemistry in these systems. These *in situ* measurements are being used to validate state-of-the-art computational models of the process. In pulsed PECVD the role of both neutrals (fluid flow, transport phenomena, gas- and surface chemistry) and activated species (ion, electrons, metastables) are of comparable importance. As such, this system poses unique challenges to modeling that will be addressed through transformative approaches to accelerate computations for plasma simulations with large number of species and chemical reactions. In this talk we will describe the development of this integrated tool set, as we work to create a platform that will enable automated process development and provide strategies for real time control.

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2:10 p.m. A-2 Optimizing Sputter Processes via 3D Magnetic and Plasma Simulations

D. Monaghan, M. Holik, and V. Bellido-Gonzales, Gencoa Ltd., Liverpool, United Kingdom; and J. Bradley, Liverpool University, Liverpool, United Kingdom

The presentation will demonstrate how the performance of a magnetron sputter cathode in terms of target use, uniformity and coating quality, can be greatly enhanced by appropriate simulation tools. All geometries of magnetron sputter targets rely upon the nature of the magnetic field design to optimize the plasma distribution and hence the target erosion. Simple circular geometries can be solved by 2D simulations whereas rectangular geometrics require 3D solutions. Magnetic field solutions in 3D are readily available from a range of commercial packages. A 3D magnetic field simulation goes some way to providing the ability to create a good magnetic trap. To provide a replication of the resulting target erosion requires the collisional and anodic effects to be taken into account. This requires a 3D plasma simulation and calculation of the impact points of the particles on the target surface. It will be shown that 3D magnetic and plasma simulations can provide an accurate prediction of how a target erodes. This in turn leads to the ability to improve the sputter process without exhaustive plasma test and results in higher efficiencies. The plasma modeling also predicts the magnetic changes required to tune uniformity and the coating properties and a number of examples will be shown.

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2:30 p.m. A-3 Simulation Analysis of Plasma Discharge Anomalies in PVD and PECVD Processes

M. Siemers, A. Pflug, and B. Szyszka, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany

Developing industrial PVD and PECVD plasma sources within the framework of a model based simulation environment has been subject of large R&D efforts in the past decade. However, substantial progress has been possible only within the last few years due to the increasing availability and utilization of parallel hard- and software architectures. With the use of massive parallelization we realized a full featured 3D simulation environment for low temperature plasma discharges based on the Particle-in-Cell Monte Carlo (PIC-MC) approach. A finite element mesh model has been incorporated to enhance geometry mapping into the simulation domain. Within the simulation environment all relevant static and dynamic process parameters of a plasma discharge (e.g. pressure distribution, magnetic field and coater geometry) can be varied. This avoids costly touch ups and aberrations during the design phase of a coater and gives insights into the complexity of 3D plasma discharges which are hard to achieve using conventional experimental techniques. Also, the plasma simulation turns out to be a rather cost effective design tool since costly expenses for plasma diagnostics can be avoided using the process model. We are going to show simulation results regarding discharge anomalies in PVD and PECVD processes. The visualization of macroscopic and numerical process quantities helps us identifying the cause of unwanted plasma aggregations, e.g. from insufficient magnetron and compartment layout respectively.

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2:50 p.m. A-9 Advanced Radio Frequency Plasma Enhanced Evaporation and its Advantages

W. Schwärzler, Provac AG, Balzers Principality of Liechtenstein and D. Gary, Ricmar Sales snd Service Inc., Aptos, CA

Dielectric layers functionality, complexity, and stability demands are ever increasing. Efficient coating layers easily can be produced by using Advanced Radio Frequency Plasma Enhanced Evaporation techniques in high vacuum environments. This presentation gives a brief overview about enhancing conventional E-Beam evaporation with the Advanced Radio Frequency Plasma Techniques evolving from Taurion technology. Advanced Radio Frequency Plasma Enhanced-Electron Beam Evaporation (RFPE-EBE) is predominately used to produce absorption free and densified oxide layers such as SiO_2, TiO_2, Ta_2O5, Nb_2O_5, and nitrate metallic layers (possible to produce hard layers-nitride basis). The bombardment of the substrate with high-energy ions of the respective process gas can also be used for degassing of the substrate surface and increasing the cleaning effect. Advanced Radio Frequency Plasma Technology can directly be used in combination with existing coating processes. Advantages of RFPE-EBE include easier operations, maintenance, cleaning, and use of the basically neutral plasma of the high-frequency plasma sources that renders damage to the substrates by electrical discharges impossible right from the start. Additionally, the use of pure process gases expands new areas of applications, where the other processes are not suitable.

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3:30 p.m. A-7 The Modeling of Large and Distributed Vacuum Systems

J. Luby, Edwards Vacuum, Tewksbury, MA; A. Chew, Edwards Vacuum, Crawley, United Kingdom; and M. Galtry, Edwards Vacuum, Shoreham, United Kingdom

As the size and complexity of vacuum systems increases, the financial and technical challenges do so also. Accurate modeling allows system optimisation in advance of engineering efforts and negates the need for inefficient empirical iterations. This paper will describe a computational modeling technique which allows the modeling of vacuum systems incorporating any number of primary and secondary pumps and all other elements of a vacuum system. Real examples will be used to illustrate accuracy and efficacy.

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3:50 p.m. A-6 Differential Sputter Yield Measurements of Single- and Multi-Element Targets Due to Ion Beam Bombardment

A. Yalin, B. Rubin, J. Topper, and C. Farnell, Colorado State University, Fort Collins, CO

Detailed knowledge of differential sputter yield profiles could aid the optimization of coating processes based on ion beam etching. In this contribution we present an experimental setup and demonstrative results for measurement of differential sputter yield profiles (i.e. angular profiles of ejected particles). The facility employs a gridded ion source to provide an approximately mono-energetic and collimated beam. Sputter yields are measured using a quartz crystal microbalance (QCM) deposition monitor. We present measurements of differential sputter yield profiles for molybdenum targets, and boron nitride targets, due to bombardment by xenon ions in the energy range of 100-300 eV. Total sputter yields (found by integrating the differential profiles) are validated against weight-loss measurements and published values. The measured profiles are fit with Modified Zhang expressions to compactly describe the results using two fit parameters, a characteristic energy (E*) and total sputter yield (Y). We also present demonstrative modeling that uses the ion beam conditions and differential sputter yield profiles to model and optimize placement of targets and substrates in coating processes.

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4:10 p.m. A-8 Development of Me-DLC Films for Strain Gauge Applications

R. Bandorf, U. Heckmann, S. Schnabel, M. Luebke, and G. Braeuer, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany

In many industrial applications, strain gauges are commonly used for measurements of applied forces or the loading status of work pieces. While commercial strain gauges using polyimide foils can cause errors due to influence of humidity, thin film strain gauges are of interest for direct application on the work piece surface. Besides the improvement of the signal due to avoiding glue and polymer substrate, the gauge factor can be further improved by using new sensor materials. For diamond-like carbon films, a high gauge factor up to 1000 is published in literature. Unfortunately, a very high negative temperature coefficient of resistance TCR is also connected with those properties. By adding metal with typically positive TCR, thermal compensation in DLC can be realized. An investigation was conducted of suitable material for thermal compensated strain gauges with a gauge factor higher than two, as is typical for conventional NiCr. DLC films were doped with different metals (Ti, W, Ni) and the resulting sensing properties were measured. For Ni-DLC, the TCR showed a zero crossing. The gauge factor of those films was higher than ten, resulting in a significant increase in sensitivity with the potential for thermal compensation.