Workshop on Sputtering
Room Constellation C, Hyatt Regency - Session WS-SuA

Workshop on Sputtering (Afternoon Session)

Moderator: W.D. Sproul, Advanced Energy Industries, Inc.

1:30pm **WS-SuA1 Control of Microstructural Evolution during Film Growth*, I. Petrov,*** University of Illinois at Urbana-Champaign **INVITED**

Microstructure is critical for polycrystalline thin film applications and its control during kinetically-limited, low-temperature deposition has been an important goal of materials science in the past decades. In this part of the workshop we will review the fundamental film growth processes - nucleation, coalescence, competitive growth, and recrystallization - and their role in thin film microstructure evolution as a function of substrate temperature. We discuss, further, atomistic mechanisms through which reactive deposition and low-energy ion/surface interactions modify growth kinetics and, thus, allow to controllably manipulate microstructural evolution. Special attention will paid to in-situ substrate treatment by ion-irradiation and its effect on film microstructure and adhesion.

2:30pm **WS-SuA3 Advances in Sputtering Power Supply Technology*, R. Scholl,*** Advanced Energy Industries, Inc. **INVITED**

Plasma power supplies display a marked interaction with the plasma and other elements of the system, and a clear understanding of the important parameters and characteristics of the power supply is a considerable aid in designing and operating a plasma system. In this presentation the basic characteristics of DC, midfrequency, and high frequency (RF) supplies will be outlined, and the key parameters vis-à-vis plasma interactions presented. Instrumentation and matching issues in RF systems will be discussed; in particular a presentation will be made on forward, reflected and load power and their significance in plasma systems. Finally, special and emerging power technology will be covered in a special section, including balancing systems for dual magnetron sputtering, multiple anode sputtering, and ultrahigh power pulsed DC, among others.

3:30pm **WS-SuA6 Cathodic Arcs and High Power Pulsed Magnetron Sputtering: A Comparison of Plasma Formation and Thin Film Deposition*, A. Anders,*** Lawrence Berkeley Laboratory **INVITED**

Film formation by energetic condensation has been shown to lead to well-adherent, dense films. Films are often under high compressive stress, but stress control is possible by pulsed high-voltage biasing, for example. Control of film growth via tuning the kinetic energy of condensing species is most efficient when the condensing species are ions, and when the degree of ionization of the plasma is high. Cathodic arc plasmas are fully ionized; they even contain multiply charged ions. The streaming plasma is supersonic, with kinetic ion energies in the range 20-150 eV, and additional energy can be provided via substrate bias. Ion formation at cathode spots and the dependence of plasma properties on the cathode material will be discussed. Along with ions, macroparticles are produced at cathode spots. This highly undesirable feature can be mitigated by plasma filters and other approaches, however, there is strong motivation to find alternative ways of producing fully ionized plasmas of condensing species. High power pulsed magnetron sputtering (HPPMS) may be one possible way of achieving this goal, at least for some target materials. In HPPMS, the power density at the magnetron target is pulsed to power levels exceeding the average power by about two orders of magnitude. Thermalization of sputtered atoms appears to be needed to accomplish ionization, and self-sputtering during each power pulse may be an important feature of HPPMS.

4:30pm **WS-SuA8 Progress and Prospects for Ionized Physical Vapor Deposition*, J. Hopwood,*** Northeastern University **INVITED**

For somewhat more than a decade, the intentional ionization of sputtered neutral atoms has been exploited to improve the directionality of sputter deposition. In addition to directional control, once a sputtered atom is ionized it is relatively easy to control its energy of deposition. Ionized sputtering is a subclass of the deposition technique commonly known as ionized physical vapor deposition (IPVD). The common characteristic of the many various IPVD techniques is that a neutral vapor, created by physical means including evaporation, sputtering, and ablation, is partially ionized using an intense secondary plasma. As the neutral vapor traverses this secondary discharge, the atoms are ionized by collisions with energetic electrons and metastable atoms. Due to the low ionization potential of most metals, the ionizing discharge need only have about 10@super 12@ electrons per cm@super 3@ with an electron temperature of ~ 2 eV. Atoms with high ionization potentials and small ionization cross sections, however, require significantly more intense secondary discharges. For this reason, reactive sputtering using IPVD may produce a high flux of oxygen or nitrogen atoms, but IPVD typically does not significantly ionize the reactive gas flow. Nonetheless, the depositing flux of metal may be as much as 80-90% ionized using IPVD. The physical mechanisms responsible for ionization will be briefly reviewed in the context of reactor design and process development. A primary user of IPVD is the semiconductor industry. The driving force for adopting IPVD was the need to deposit thin films into the high aspect ratio microstructures commonly found on modern integrated circuits. Conventional sputtering exhibits a cosine angular distribution of sputtered atoms that makes deposition of material into the bottom of deep submicron trenches and vias impossible. By simply applying a negative bias voltage to the wafer, however, ionized sputtered material can be accelerated perpendicular to the wafer surface such that the depositing flux provides adequate bottom coverage of microstructures. The common applications of IPVD include the deposition of copper seed layers used for the subsequent electroplating of copper interconnects, as well as the deposition of adhesion layers and barrier layers using reactively sputtered metal-nitrides. Examples of successful semiconductor processes that use IPVD will be discussed. Because many IPVD process tools require a complete sputtering system plus additional hardware for producing the secondary ionizing plasma, IPVD is a more complex and expensive process than conventional PVD. The secondary ionizing plasma may be produced by inductively coupled plasma, helicon resonators, or ECR plasma - all of which add cost and complexity. Recent advances, however, exploit single power source sputtering in which the secondary plasma is produced by the sputtering source. These simple techniques may allow for the broader use of IPVD in cost-sensitive applications.

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