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Functional Metal-Oxide and Diamond-like Carbon Thin Films using Standard and High Power Impulse Magnetron Sputtering

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Plasma-assisted PVD processes for thin film growth allow for tailoring the film functionalities via controlling the plasma properties. Magnetron sputtering is a widely employed PVD method for preparing functional thin films that cover a wide range of applications from solar cells to hard coatings. An emerging magnetron sputtering based method is high power impulse magnetron sputtering (HiPIMS) which facilitates the generation of large ionized fluxes of film forming species. The high flux of ionized particles reaching the substrate and the possibility to tune their energy provide additional means for controlling film properties, differentiating the HiPIMS process from standard magnetron sputtering. The use of HiPIMS technology for a variety of thin film applications has expanded considerably in the last decade and from providing further insights into thin film growth at atomic level to facilitating high quality coatings, HiPIMS has opened up new avenues for novel technological applications of thin films.

This presentation covers the implementation of standard magnetron sputtering and HiPIMS for two industrially relevant classes of materials namely metal-oxides and diamond-like carbon (DLC) with a focus on process-property-performance relationship. First, use of standard magnetron sputtering as an industrially relevant alternative to atomic layer deposition (ALD) of hydrogen-doped indium oxide (In2O3:H) transparent conductive oxide (TCO) is discussed. It is shown that high quality In2O3:H TCO comparable in performance to ALD can be synthesized using standard magnetron sputtering. Upon integrating into CIGS solar cells, the resulting TCO paves the way for an increase in efficiency as compared to baseline Al-doped ZnO. A range of other metal-oxide thin films that include TiO2, yttria-stabilized zirconia (YSZ), thermochromic VO2 are discussed where it is shown that using HiPIMS, previously unachievable performance of these thin films can be realized. For TiO2 control over its phase formation and room temperature synthesis of anatase and rutile phases, for YSZ the implementation into solid-oxide fuel cells and for thermochromic VO2 the potential for next-generation foil-based energy efficient smart windows is demonstrated.

In the second part, the role of HiPIMS in synthesizing high quality hydrogen free and hydrogenated DLC coatings is discussed. First, a novel strategy for synthesizing dense DLC coatings is presented. The strategy is based on electron temperature enhancement using Ne instead of Ar that facilitates an increase in carbon ionization thereby resulting in films exhibiting mass density in the order of ˜ 2.8 g/cm3. It is also shown that the films exhibit a unique combination of high density, low compressive stress (˜ 2.5 GPa) and high thermal stability. An insight into stress relaxation and recent progress with regards to mechanical behavior of these coatings is also presented. Furthermore, high rate synthesis of DLC coatings by coupling C2H2 with Ar- and Ne-based HiPIMS processes is also demonstrated. It is shown that by appropriate control of gas phase composition and energy of the film forming species, a ten-fold increase in the deposition rate as compared to Ar-HiPIMS process is achieved. This is obtained without significant incorporation of H (< 10 %) into the films together with high hardness (> 25 GPa) and mass density (˜2.32 g/cm3). Based on the obtained results, it is concluded that: (i) dissociative reactions triggered by the interactions of energetic discharge electrons with hydrocarbon gas molecules is an important additional source of film forming species and (ii) film microstructure and film hydrogen content are primarily controlled by interactions of energetic plasma species with surface and sub-surface layers of the growing film.

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