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Energy deposition modeling and design of plasmas processes for synthesis of nano-structured film materials

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Understanding the science and engineering of thin films with controlled growth and microstructure is a key issue in modern nanotechnology, impacting both fundamental research and technological applications. Several investigations have been focused on understanding nucleation phenomena and their subsequent coalescence forming nanostructures. The over layer morphology produced by growth on a given surface reflects the local chemical bonding and the balance between the kinetics and thermodynamics of film formation. Recently, non-thermal plasma processes have been shown to be a viable technology for many industrial applications. Different plasma parameters like electrons, ions, radical species and neutrals play a critical role in nucleation and growth and corresponding film microstructure as well as plasma-induced surface chemistry. The film microstructure is also closely associated with deposition energy/flux which is controlled by electrons, ions, radical species and activated neutrals. Further, the integrated studies on the fundamental physical properties that govern the plasmas seek to determine their surface structure and modification capabilities under specific experimental conditions. This requires identification, determination and quantification of the surface activity of the species in the plasma. The purpose of this work is to extend process modeling to analyze and optimize design of Si-based thin films using a fluid model. Plasma enhanced chemical vapour deposition (PECVD) technique using radio frequency (RF) and ultra-high frequency (UHF) dual frequency power is utilized for the single step deposition of crystalline Si (c-Si) and Si quantum dot (QD) embedded in amorphous hydrogenated amorphous Silicon nitride (a-SiN_x: H). Plasma treatment process using PECVD involves complex chemical and physical phenomena, such as gas phase reactions, radiation heat transfer, dissociation-excitation-ionization reactions, etc. The comprehensive modeling of these phenomena is an unreachable target. So, key approximations, based on experimental observations using dedicated plasma diagnostics, are made in developing the process model. The overall goal of this work is to gain an increased understanding of the process fundamentals as well as process optimization and control on the basis of deposition energy/flux model and plasma diagnostics. Apart from this, C-based thin film nucleation and growth by magnetron sputtering, are also investigated and discussed.