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Novel synthesis of nanocrystalline thin films by design and control of deposition energy and plasma

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Thin films synthesized by plasma processes have been widely applied in a variety of industrial sectors. The structure control of thin film is one of prime factor in most of these applications. It is well known that the structure of this film is closely associated with plasma parameters and species of plasma which are electrons, ions, radical and neutrals in plasma processes. However the precise control of structure by plasma process is still limited due to inherent complexity, reproducibility and control problems in practical implementation of plasma processing. Therefore the study on the fundamental physical properties that govern the plasmas becomes more crucial for molecular scale control of film structure and corresponding properties for new generation nano scale film materials development and application.

The thin films are formed through nucleation and growth stages during thin film depostion. Such stages involve adsorption, surface diffusion, chemical binding and other atomic processes at surfaces. This requires identification, determination and quantification of the surface activity of the species in the plasma. Specifically, the ions and neutrals have kinetic energies ranging from ~ thermal up to tens of eV, which are generated by electron impact of the polyatomic precursor, gas phase reaction, and interactions with the substrate and reactor walls. The present work highlights these aspects for the controlled and low-temperature plasma enhanced chemical vapour disposition (PECVD) of Si-based films like crystalline Si (c-Si), Si-quantum dot, and sputtered crystalline C by the design and control of radicals, plasmas and the deposition energy. Additionally, there is growing demand on the low-temperature deposition process with low hydrogen content by PECVD. The deposition temperature can be reduced significantly by utilizing alternative plasma concepts to lower the reaction activation energy. Evolution in this area continues and has recently produced solutions by increasing the plasma excitation frequency from radio frequency to ultra high frequency (UHF) and in the range of microwave. In this sense, the necessity of dedicated experimental studies, diagnostics and computer modelling of process plasmas to quantify the effect of the unique chemistry and structure of the growing film by radical and plasma control is realized. Different low-temperature PECVD processes using RF, UHF, and RF/UHF hybrid plasmas along with magnetron sputtering plasmas are investigated using numerous diagnostics and film analysis tools. The broad outlook of this work also outlines some of the ‘Grand Scientific Challenges’ to which significant contributions from plasma nanoscience-related research can be foreseen.

Keywords: Plasma, particle energy, nc-Si film, Si quantum dot, crystalline C film