Title of the Thesis

Synthesis of Silicon-Nitride Nano-Structures and Quantum-Dots by Inductively Coupled Plasma CVD and their Characterization for Applications in Devices

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Abstract

This thesis deals with the single step growth of thin film of nanocrystalline silicon/silicon quantum dots (nc–Si/nc–Si–QDs) of varying size embedded in a-SiNₓ:H matrix, a new kind of material with novel functional and structural properties, by using low temperature and low pressure inductively coupled (13.56 MHz) plasma originated from silane (SiH₄) and ammonia (NH₃) with or without hydrogen (H₂) dilution. Different characterizations like, structural, morphological, compositional, optical, and electrical of the film make it convenient for its applications in photovoltaics, optoelectronics and photonics devices. A brief introduction of the dissertation is being presented in Chapter 1 whereas; growth and characterization techniques are described in chapter 2. Chapter 3 describes a comprehensive structural and optical investigation of nc-Si/a-SiNₓ:H thin films using various spectroscopic and microscopic tools. The increase of relative intensity ratio, I(220)/I(111) on XRD spectra has been studied, as best values of open-circuit voltage (V_{OC}) in solar cells identifies low recombination losses in (220) textures. The material exhibited strong blue emission band composed of a double peak (~413 nm and ~438 nm) and two shoulders (~467 nm and ~498 nm). In Chapter 4, a comprehensive analysis of the electrical transport phenomena, using different hopping conduction models, in undoped nc-Si/a-SiNₓ:H thin films has been described. Nature of variations of conductivity within 450–110 K, demonstrates specific transport mechanisms correlated to its complex microstructure and morphology. Chapter 5 demonstrates visible PL (1.66–2.47 eV) from nc-Si/a-SiNₓ:H QDs thin films developed by spontaneous (SiH₄ + NH₃ + H₂) plasma processing with the variation of substrate temperature within 400–150 °C. The Quasi-direct band-to-band recombination due to quantum confinement effect (QCE) has been assigned as responsible for the origin of the dominant component of luminescence; however, some defect related origins co-existing with band-to-band recombination have also been considered for their contribution in PL. In view of potential applications in third generation nc-Si solar cells, the nc-Si/a-SiNₓ:H QDs thin films with preferred (220) orientation have been produced. By decreasing the deposition temperature over 400–100 °C, the undoped nc-Si/a-SiNₓ:H QDs thin films of varying crystallinity (82–37%) are obtained with Si-ncs of average size ~5.7–1.3 nm and number density ~10¹¹–10¹² cm⁻², providing a significantly wide range of band gap and high optical absorption (>10⁵ cm⁻¹) with associated very high electrical conductivity, σₓ ~5.6x10⁻³–2.7x10⁻⁷ S cm⁻¹ along with high carrier concentration, n_c ~9x10¹³–1.8x10¹⁰ cm⁻³, significantly high electron mobility, μ_e ~426–103 cm²V⁻¹s⁻¹ and photosensitivity varying within ~1x10⁻¹–3x10³. These are being presented in Chapter 6. In Chapter 7, a tunable wide range (1.67–3.02 eV) visible PL from nc-Si/a-SiNₓ:H QDs thin films by varying the low deposition pressure in a narrow range at low substrate temperature ~250 °C, has been demonstrated. Quantum confinement effect has been assigned to be mostly responsible for the light emission. Chapter 8 describes rapid synthesis of photoluminescent nc-Si/a-SiNₓ:H QDs thin films without H₂ dilution through spontaneous (SiH₄ + NH₃)-plasma processing at ~250 °C with very low gas flow rates, making the material commercially viable. Finally, in Chapter 9, summary and conclusion of this thesis and future scope for some new possible studies have been presented.