Title of thesis : ***Fabrication of semiconductor nanostructures and its optical characterization.***

Name of scholar : ***Bipin Joshi***
Supervisor : ***Prof. S.S. Islam***

Department of Applied Sciences and Humanities

Faculty of Engineering and Technology

Jamia Millia Islamia, Delhi-110025

ABSTRACT

Morphological and spectroscopic investigations of semiconductor nanoparticles were carried out in the present thesis. Silicon (Si) and gallium arsenide (GaAs) nanostructures are under investigations in the present work. Nanostructures of both the semiconductors have been prepared using laser induced etching (LIE) technique. The LIE of these two semiconductors were done to clearly understand the process of LIE on indirect and direct band gap semiconductors like Si and GaAs respectively. Raman and photoluminescence (PL) spectroscopy were employed to investigate the optical properties of nanostructures of direct and indirect band gap semiconductors.

Surface morphological investigations of semiconductor nanostructures using (scanning electron microscope) SEM and atomic force microscope (AFM) show that sample morphologies get modified during the process of LIE. The SEM and AFM images reveal that the etching time and etching laser power density are the controlling parameters of LIE process. Etching of Si takes place only if the energy of excitation photon is higher than the band gap of crystalline Si (c-Si). Virtually no etching takes place if the energy of exciting photon is less than c-Si band gap energy. For LIE process in semi-insulating GaAs (100) in HF solution under both super- and sub-band gap illuminations were used. It is found that the bandgap photon illumination, though an essential criterion in case of semiconductor etching, is not so crucial to determine the etching rate in semi-insulating GaAs; rather the impurity and defect states in as-grown GaAs plays the key role. The reaction rate analysis at the semiconductor-electrolyte interface shows that the reaction rate is much faster in case of sub-bandgap illumination. The interpretation is given with suitable demonstration of excess carrier processes. The surface morphology studies by SEM and AFM also show the formation of qualitatively superior nanostructure under sub-bandgap photon illumination.

Spectroscopic characterization of laser etched semiconductor nanostructures has been carried out using Raman and PL spectroscopy. Raman scattering is employed to investigate phonon confinement effect whereas, PL is utilized to study electronic confinement effect in low dimensional semiconductors. The Raman spectra from laser-etched semiconductor nanostructures are found to be asymmetrically broadened and red- shifted from its corresponding crystalline counterpart. These differences in Raman line shape in semiconductor nanostructures have been assigned to the phonon confinement effect using a simple phonon confinement model (PCM). Experimentally observed Raman data have been fitted theoretically within the framework of PCM. Size and size distribution of nanoparticles have also been estimated by this type of theoretical fitting. The red- shift and broadening of Raman line shape have also been estimated using a simpler bond polarizability model (BPM). A good agreement between PCM and BPM further confirms the presence of confinement effect in Si and GaAs nanostructures prepared by LIE technique. PL is employed to complete the investigation of quantum confinement effect in Si and GaAs nanostructures. Efficient visible PL is observed at room temperature due to confinement of electrons. The appearance of PL bands and their blue-shift establishes the formation of nanoparticles in the porous layer. The shape of the PL and Raman spectra depends on the laser photon energy used for etching. Raman and PL spectroscopic results support each other and confirm the quantum confinement effect.

Investigation of any possibility of laser induced temperature rise during Raman measurement is also carried out experimentally and theoretically in the Si nanostructures. Theoretical temperature rise due to a laser beam is calculated as a function of the laser power density for a two layer system consisting of thin Si NSs layer on to a thick Si substrate. The calculated result shows that rise in the temperature is almost negligible for laser power density of 4 kW/cm^2 or less. A temperature rise of 100 K can be achieved for excitation laser power density of 135 kW/cm^2. Theoretically calculated sample temperatures are in consonance with the experimental temperature calculated by ratio of Stokes and anti-Stokes Raman scattering data. For excitation laser power densities in the range 0.2 kW/cm^2 - 4 kW/cm^2, Raman scattering results do not show an anharmonic effect. Asymmetric Raman line-shapes at low laser power densities (~ 0.2 kW/cm^2) are observed due to quantum confinement effect.

Bipin Joshi