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TOPIC: OPTICAL CHARACTERIZATION OF SILICON NANOSTRUCTURE

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ABSTRACT

Silicon (Si) is most dominating material in microelectronic industry due to ideal band-gap (1.12 eV) for room temperature operation, low temperature sensitivity, ease of processibility and ease of availability. However, considering its indirect band gap nature, Si is an inefficient light emitter. In addition, competitive non-radiative recombination rates are much higher in standard bulk Si than the radiative ones and most of the excited e-h pairs recombine non-radiatively resulting in yield of very low internal quantum efficiency. Recently it has been discovered that nanostructuring of silicon is an effective way to turn silicon into a photonic material. It was found by Canham that when silicon was made nanoporous, its luminescence efficiency was greatly enhanced and photoluminescence obtained in visible range at room temperature. Since this observation optical properties of silicon nanostructures have been area of attraction among researchers. The optical properties of photoluminescent silicon could be harnessed in area of optoelectronics to develop light-emitting components for optical signal processing.

Present thesis deals with synthesis of silicon nanostructures and study of the effect of variations on processing parameters on the structural and optical properties on resulting structure. Nanoporous silicon (PS) was selected for study for this purpose. In order to study processing parameter dependent optical and vibrational properties of PS, characterization techniques like atomic force microscopy (AFM), scanning electron microscopy (SEM), Raman scattering and photoluminescence spectroscopy (PL) were selected.

In literature various methods of fabrication of PS are mentioned like stain etching, electrochemical anodization, laser induced etching (LIE), reactive ion etching, lithography etc. However electrochemical anodization is adapted for our sample fabrication considering simplicity, cost effectiveness and quality of the sample produced by this method. Moreover, this process does provide better possibilities for controlling the sample characteristics due to convenient control of the etching parameters. The light emission properties like the peak wavelength and the spectral distribution of photoluminescence (PL) from the porous silicon layer prepared by this method can be tailored by choosing suitable parameters for etching conditions and wafer type. Therefore, the electrochemical etching process offers promise for a better control of features of nanoporous silicon (PS) samples.

SEM and AFM are used to study electrolyte dependent variations in surface morphology of our PS samples in detail. Utilization of electron beam in SEM results in very high magnification. To view the morphological features of PS samples in more detail, AFM is

used. SEM and AFM images of PS samples have revealed that processing parameters affect pore morphology in PS significantly

It is expected that reduced dimensionality of PS could lead to confinement of electron and phonons which could subsequently result in major modification in its optical and viberational properties in comparison to that of bulk. In the work presented, photoluminescence and Raman spectroscopy techniques were used to study modification of optical and viberational properties of PS by variation in etching parameter. For variation in anodization condition, five different parameters- electrolyte concentration, current density, anodization time, electrolyte type and laser intensity were chosen. During preparation of samples any one of the parameter was varied while keeping other parameters constant.

Using the PL spectroscopy, it is also found that when PS sample when left in ambient for ageing, its photoluminescent properties are affected considerably. Remarkable blueshift and variations in the luminescence maximum observed when PS samples stored in the air for several days. This instability in PL spectrum could hinder its possible applications in various areas. Several authors have suggested that in addition to confinement of electrons, surface nature of PS also play an important role in origin and modification of photoluminescence.
The PL properties of PS could be stabilized if its surface could be modified in such a way that it would be least affected by environment. For this purpose intentional oxidation of PS is done by two different methods in our lab in order to passivate its surface. PL emission property of passivated PS surface and their stability upon exposure to ambient were studied in our lab also by PL spectroscopy.

Raman spectroscopy is used in this work to study, variations in viberational properties of PS and estimation of nanocrystalline sizes. *C*-Si displays a narrow optical-phonon band at 520 cm^{-1}. Raman spectra from PS appear to be red shifted and asymmetrically broadened relative to that of Raman line for bulk silicon. This shift has been attributed to quantum confinement of the electronic wave function in the nanocrystals. The Raman line-shape broadening and shifts have been correlated with the crystallite sizes in a phenomenological phonon confinement model (PCM). Experimentally observed Raman data fitted theoretically within the framework of PCM and size distribution of silicon nanoparticles are estimated.