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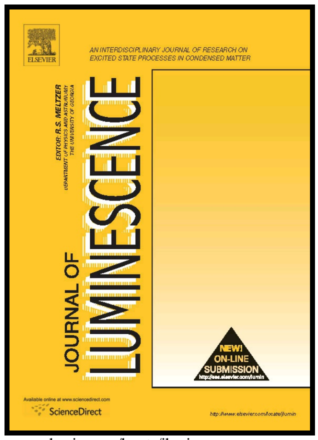

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Effect of phonon confinement on photoluminescence from colloidal silicon nanostructures☆

Ujjwal Ghanta[a], Mallar Ray[a], Susmita Biswas[b], Samim Sardar[c], Tuhin Kumar Maji[c], Samir Kumar Pal[c], Nil Ratan Bandyopadhyay[a], Bo Liu[d], Syed Minhaz Hossain[e,*]

[a]*School of Materials Science and Engineering, IIEST, Shibpur, Howrah-711103, India*
[b]*Centre of Excellence in Green Energy and Sensor Systems, IIEST, Shibpur, Howrah-711103, India*
[c]*Department of Chemical, Biological and Macromolecular Sciences, S. N. Bose National Centre for Basic Sciences, Block JD,Sector III, Salt Lake, Kolkata 700098, India*
[d]*Institute for Condensed Matter Physics, TU-Braunschweig Mendelssohnstrasse 3, 38106 Braunschweig, Germany*
[e]*Department of Physics, IIEST, Shibpur, Howrah-711103, India*

Abstract

Room temperature time-resolved photoluminescence (TRPL) of colloidal Si nanostructures prepared by repetitive oxidation-etching-oxidation of mechanically milled silicon, indicate towards phonon confinement in Si nanostructures. The Si nanocrystals have a well-defined Raman peak, which is asymmetrically broadened and red shifted, compared to bulk silicon. The PL intensities exhibit tri-exponential decay characteristics with decay times ranging between pico to nanosecond. For a fixed emission wavelength, the decay time is found to be strongly dependent on excitation wavelength. Steady state luminescence spectra reveal that PL peak positions and intensities are dependent of excitation energy. On the basis of these observations we show that phonon confinement plays a significant role in the non-radiative relaxation of excited carriers at the band edges of nanocrystalline Si core.

Keywords: Nanocrystalline Silicon, Photoluminescence, Phonon Confinement

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1. Introduction

Crystalline silicon (Si) in the bulk form is a classical indirect band gap semiconducting material which makes it an inefficient light emitter. Electronic transitions are invariably associated with phonons to conserve momentum, which eventually increases the non-radiative decay rates over the radiative ones. Relative enhancement of radiative transitions over non-radiative decay has been observed in various nanostructures of Si [1, 2, 3]. However, a clear understanding of the mechanisms and the processes leading to this interesting phenomenon is still awaited [4, 5, 6]. Presently, it is more-or-less accepted that quantum confinement of excitons and surface/interface defects and/or oxides play a combined role in the process of efficient light emission in nano Si.

Although it is expected that momentum conservation rules should be relaxed in nanometre sized Si crystallites due to uncertainty principle, leading to the formation of a quasi-direct band gap material - the role of this process in light emission is still controversial [7, 8, 9]. Most of the studies attempting to understand the contribution of such processes in luminescence from Si nanostructures have so far focussed on examining and explaining carrier confinement. However, the presence of phonon modes should also play a determining role in the exciton recombination process in such nano-systems. In nanostructures, not only the charge carriers become confined within the physical dimension of the system but also the phonons get confined resulting in discretization of lattice vibration modes along with reduced density of states [10]. The quantized phonon modes in low dimensional Si therefore, have their effect on the photo-generated carrier decay dynamics [11]. In this communication we show explicitly how these phonon modes play a significant role

*Corresponding author
Email address: `shminhaz@physics.iiests.ac.in` (Syed Minhaz Hossain)

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