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# Synthesis and Optical Properties of Si-Rich Nitride Containing Silicon Quantum Dots

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Hydrogenated silicon-rich nitride films were deposited by plasma-enhanced chemical vapor deposition using $NH_3$ and $SiH_4$. As-deposited samples were thermally annealed under different conditions in argon ambient. Fourier-transform infrared spectroscopy was carried out to investigate the bonding configurations, and Raman scattering spectroscopy was used to study the microstructures and confirm the presence of Si quantum dots (QDs). We found that a near-stoichiometric silicon nitride matrix was formed after high-temperature processing. When the annealing temperature reached 1100°C, the degree of crystallinity ($X_c$) increased to 51.6% for the 60-min sample compared with 46.1% for the 30-min sample. Red-light and yellow-light emission were obtained from the samples annealed at 1100°C for 30 min and 60 min, respectively. The emission mechanism is dominated by excitons confined within the Si QDs. The ultra-nanocrystals play an important role in the luminescence blue-shift. We measured the bandgap values from optical absorption studies. The increase of the optical bandgap from 1.80 eV to 1.90 eV with increase of the annealing temperature from 950°C to 1100°C is ascribed to the silicon clusters and nitride matrix.

**Key words:** Silicon quantum dots, silicon nitride, thermal annealing, photoluminescence, optical properties

## INTRODUCTION

Due to the indirect nature of its bandgap, bulk silicon is unsuitable for optoelectronic devices. However, the observation of strong photoluminescence (PL) from porous silicon structures reveals that silicon nanostructures can be promising materials for optoelectronics.[1] Recently, efficient PL and electroluminescence (EL) have been realized in different dielectric materials including silicon nanometer-sized clusters or silicon quantum dots (Si QDs).[2–4] Si QDs embedded in silicon oxide and silicon nitride are being intensively investigated. Lin et al.[5,6] obtained near-infrared EL from a Si-rich $SiO_x$-based metal–oxide–semiconductor (MOS) diode and attributed the EL mainly to the transfer of cold carriers by direct tunneling between adjacent silicon nanocrystallites. They also compared the EL of $SiN_x$- and $SiO_x$-based light-emitting diodes (LEDs).[7] Compared with silicon oxide, silicon nitride as a dielectric matrix offers lower barrier height and higher carrier mobility.[8] Thus, silicon nitride containing Si QDs can be a better choice for solar cells or LEDs.[9] For these optoelectronic devices, silicon nitride can also provide high-quality surface passivation.[10] However, there are many questions to be solved about this useful nitride containing Si QDs. On the one hand, although visible PL at room temperature has already been obtained from silicon nitride films containing Si QDs, the origin of this PL is not completely understood. Some attribute the PL to the quantum confinement effects (QCE) of excitons in the Si QDs,[11,12] while others hold the view that surface passivation and/or localized

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