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Short-wavelength visible light emission from silicon nanocrystals¹ XIAODONG PI, Department of Mechanical Engineering, University of Minnesota, Minneapolis 55455, RICK LIPTAK, STEPHEN CAMPBELL, Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis 55455, UWE KORTSHAGEN, Department of Mechanical Engineering, University of Minnesota, Minneapolis 55455 — Si is the material of choice for modern microelectronics but, as an indirect-bandgap semiconductor, it is not an efficient light emitter. An electrically pumped Si laser would present a breakthrough for optoelectronic integration that may enable optical interconnect to make computers faster. Si light emitting diodes may revolutionize solid-state lighting and displays because of the low cost and environmental friendliness of Si. One of the most challenging problems of Si-based lighting and displays is the lack of a reliable and efficient full visible spectrum emission. Si nanocrystals (Si-NCs) have so far been the most promising form of Si to emit light. Most of the synthesis approaches of Si-NCs, however, only lead to red light emission. Our recent work on Si-NCs synthesized by non-thermal plasmas has focused on extending their light emission into the short-wavelength range. Firstly, the process of oxidation-etching-oxidation of Si-NCs is investigated. This process causes the size of Si-NCs to decrease, leading to shorter wavelength light emission from Si-NCs. Yellow or green photoluminescence (PL) has been observed from initially oxidized red light emitting Si-NCs after HF vapour etching and atmospheric oxidation. The intensity of PL from Si-NCs, however, decreases by a factor up to 100. It is found that HF etching restructures the surface of Si-NCs. This leads to a decrease in the incorporation of O during subsequent oxidation, which finally results in silicon suboxide $SiO_{1,9}$. Such an understoichiometry indicates a high density of defects such as Si dangling bonds at the Si-NC/oxide interface. Therefore, the PL efficiency is extremely low for short-wavelength light emitting Si-NCs obtained Xiaodong Pi by the process of oxidation-etching-oxidation. Secondly, an integrated two-stage Department of Mechanical Engineering, University of Minnesota, Minneapolis, 55455 plasma system is employed to achieve the light emission from Si-NCs in the full visible spectrum range. Red-light-emitting Si-NCs are produced in the first stage by Date submitted: 20 Nov 2006 the plasma decomposition of SiH₄. In the second stage a tetrafluoromethane (CF₄)based plasma etches Si-NCs and at the same time passivates them with carbon and fluorine. After the two-stage process Si-NCs emit light in the short-wavelength region from yellow to blue. We find that a self-limited oxidation process blueshifts the light emission until saturation is reached. Significantly, relatively high quantum yields of short-wavelength light emission from Si-NCs are obtained in spite of oxidation. It is interesting to note that Si-NCs treated by CF₄-based plasma are hydrophilic while those without CF_4 -based plasma treatment are hydrophobic.

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