In-Situ Passivation of Silicon Clusters

A. Brewer[1], K. von Haeften[1], C. Binns[1], O. Crisan[1,2], P. Howes[1], M. P. Lowe[3], C. Sibbley-Allen[1], S. C. Thornton[1]

[1] *Department of Physics & Astronomy, University of Leicester, United Kingdom*

[2] *National Inst. for Material Physics, Romania*

[3] *Department of Chemistry, University of Leicester, United Kingdom*

kvh6@le.ac.uk

Bulk silicon is a poor light emitter due to its indirect band gap and a viable method to achieve luminescence is confinement in nano-structures and passivation of the dangling bonds at the surface [1]. Here, we report on the production of clusters by high pressure magnetron sputtering of a silicon target and aggregation in a argon/helium gas mixture [2,3], their subsequent passivation with nitrogen in the gas phase and their deposition on a substrate at flux rates of 1Å per second. Our apparatus is equipped with an arrangement of cells to focus the cluster beam after the aggregation chamber [4]. One of the cells was filled with nitrogen so that the clusters were undergoing multiple collisions. The cell could be filled with up to 1 mbar nitrogen which guaranteed that the cluster surface was covered completely. Then, the clusters passed through differential pumping stages into ultra high vacuum where they were co-deposited with a gas beam of water onto a liquid nitrogen cooled surface. After the deposition had been completed we melted the ice and obtained a suspension of $\sim 1\ \mu l$ containing silicon clusters.

We characterised samples that were deposited on a carbon grid by transmission electron spectroscopy (TEM) and we also carried out photo luminescence spectroscopy (PLS). The TEM images show spherical clusters with diameters ranging from 2 to 100 nm depending on the growth conditions. For specific growth conditions we also observed flakes and nanowire-like structures. Un-passivated clusters in water suspension showed a yellowish-brownish colour whereas the suspension with nitrogen passivated clusters was clear giving evidence that a silicon nitride layer was formed during the gas phase reaction. The suspension with nitrogen-passivated clusters showed PL at room temperature with a strong peak at 421 nm (90 nm fwhm) when excited at 307 nm.

Our results show for the first time PL from silicon nanoparticles in aqueous suspension and demonstrate the relevance of our approach for applications in biology or nanotechnology, for instance, for jet-printing luminescent quantum dots into nano-structures. Likewise our results show the potential of the pick-up technique to produce alloyed clusters and to achieve radial structural control in the gas phase [5].

[1] L. T. Canham, Applied Physics Letters **57**, 1046 (1990).

[2] S. Pratontep *et al.*, Rev. Sci. Instr. **76**, 045103 (2005).

[3] M. Astruc Hoffmann *et al.*, Eur. Phys. J. D - At., Mol. Opt. Phys. **16**, 9 (2001).

[4] K. Wegner, P. Piseri, H. V. Tafreshi, and P. Milani, J. Phys. D **39**, R439 (2006).

[5] T. Laarmann, H. Wabnitz, K. von Haeften, and T. Möller, J. Chem. Phys. **128**, 014502 (2008).