Master degree project description in SCI School for HT/18

Title: Mass-fabrication of silicon nanoparticles from solid-state precursors

Nano-Silicon Group, Applied Physics Department, SCI School

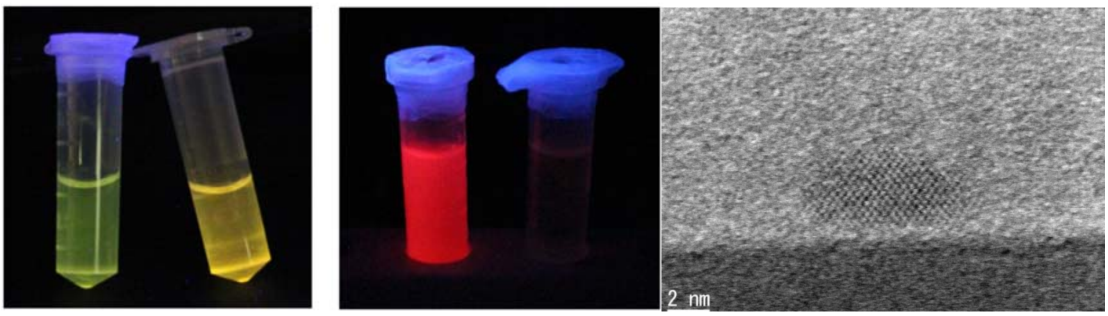
Background: Silicon nanoparticles find applications in different fields. For nanocrystals below 10 nm quantum size effect makes their emission wavelength varying[1]. This fact makes them attractive in light converting applications, such as phosphors in light emitting diodes or in photovoltaics (Figure below). Larger particles are useful for anodes in lithium ion batteries, because they allow repeatable accumulation of large quantities of lithium without mechanical failures[2]. In all these cases mass-fabrication of nanoparticles with a controlled size and dispersion are pre-requisites for successful implementation. While most nanoparticles are produced by colloidal synthesis, this method cannot be applied for silicon. Indeed, the strong covalent bonding in silicon requires high synthesis temperatures, in excess of 400 ^{o}C, which is well above evaporation temperatures of most organic solvents. So the synthesis is solid-phase using silicon-rich precursors in an alternative pathway. In this project different commercial and home-made precursor materials will be investigated for their applicability. They all will rely on disproportionation reaction from non-stoichiometric silica glass[3].

Task and expected results:
Using our in-house annealing furnace and electron microscopes the task is to investigate nanoparticle formation mechanism by thermal treatments of different durations and at various temperatures. The nanoparticles should be extracted by HF etching and obtained size-dispersions analyzed. Additional characterization techniques, such as dynamic light scattering, maybe used to independently confirm findings and trends. Insights into the phase separation mechanism of nanoparticle formation should be obtained from the analysis of experimental data.

Plan for project: Key activities for this full time master project include:

- Thermal treatment of silicon monoxide, hydrogen silsesquioxane, etc. powders
- Characterization of obtained particle morphology by electron and light-related techniques
- Analysis of the results and development of the synthesis model

Applications: Please contact Associate Professor Dr. Ilya Sychugov, ilyas@kth.se; project can be started at any time in 2018.



(left) Colloids of silicon nanocrystals under UV-lamp. Different emission colors originate from quantum size effect for nanoparticles less than 10 nm in size. (right) Electron microscope image of a silicon nanocrystal.

1. Sychugov, I.; Valenta, J.; Linnros, J., Probing Silicon Quantum Dots by Single-dot Techniques. *Nanotechnology* **2017,** *28*, 072002.
2. Ashuri, M.; He, Q. R.; Shaw, L. L., Silicon as a potential anode material for Li-ion batteries: where size, geometry and structure matter. *Nanoscale* **2016,** *8*, 74-103.
3. Hertl, W.; Pultz, W. W., Disproportionation and Vaporization of Solid Silicon Monoxide. *J. Am. Ceram. Soc.* **1967,** *50*, 378-381.