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Synthesis and characterisation of metal selenide nanocrystals for use in electronic devices

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Abstract

Advancements in nanotechnology and nanosystems promise to extend limits of sustainable development and environment remediation in an attempt to address some of the world most challenging problems. Specifically, nanotechnology has played an important role in the design, synthesis, and characterization of various new and novel functional nanomaterials possessing extremely unique properties. For example, low dimensional nanostructures such as semiconductor nanocrystals with well controlled sizes, shapes, porosities, crystalline phases, and structures have been prepared via various synthetic methods. In addition these semiconductor nanocrystals have attracted research attention because of their fundamental role in the comprehension of the quantum size effect and great potential applications to save resources and improve the environment.

Tremendous studies have established that morphological, optical, catalytic and electronic properties of semiconductor nanocrystals can be manipulated during synthesis by simply varying the growth parameters. Herein we establish the effect of different synthetic methods and several growth parameters on the properties of the as-synthesized semiconducting metal selenides nanocrystals (Ni_xSe_y and In_xSe_y) including structural, optical, electronic and catalytic properties. For example, reducing coordinating solvent oleylamine was seen to favour a particular morphologies and stoichiometries despite the duration of synthesis. In the case of In_xSe_y nanocrystals, oleylamine favoured indium monoselenide (InSe) nanosheet formation while addition of 1-DDT as a co-surfactant to oleylamine produces In_2Se_3 nanowires. For Ni_xSe_y nanocrystals, TOP as a co-surfactant to different ligands favoured the formation Ni_3Se_2 with different shapes including dots, plates, rods and wires in different solvents. Other parameters studied included the reaction time and temperature.

Besides the properties, we probe the potential applications of these materials in dye sensitized solar cells as counter electrodes as well in chemical sensor as the sensing material. Ni_xSe_y nanocrystals were employed as CE in DSSCs in an attempt to replace the noble expensive platinum conventionally used as CE in most DSSCs. It was established that different stoichiometry played a significant role in the catalytic reduction of I_3^-. Thus, different photovoltaic performance parameters were obtained with $NiSe_2$ giving a higher PCE of 1.5 % followed Ni_3Se_4 then Ni_3Se_2. These values were however very low compared to the ones reported in literature, something that was attributed to low electron mobility, enhanced recombination and reduced catalytic performance as a result of poor device assembly and the organic ligand layer encapsulating the nanocrystal.

In another scenerio, indium monoselenide nanocrystals were employed in chemiresistive sensors to detect the presence of a number of VOCs including formaldehyde, methanol, chloroform and acetone in the ambient. Indeed despite the well-known electrical, optical and structural properties previously reported in literature, metal selenides such as CdSe, PbSe and ZnSe among others present lack of investigation for gas sensing. The experimental results showed that different morphologies of InSe nanostructures interacted differently to the analyte gas suggesting difference in the electronic properties of different morphologies. The InSe nanoparticle based sensors gave a good response to HCHO and MeOH fumes and were more selective to HCHO fumes than chloroform and acetone. While those fabricated using the InSe nanosheets though responding well to HCHO recovered half way when exposed back in air and resulted in relatively high noise to signal ratio when exposed to MeOH. The operating temperature range for the InSe sensor devices were determined to be near room temperature. The sensors response was observed to decrease with increasing temperature from 30 °C to 90 °C. Evident from the results,

the surface capping molecule (oleylamine) employed to stabilize the nanostructures during synthesis was responsible for the poor sensing abilities of the nanostructures.