Self Assembly of CdSe Nanorods by Electrophoretic Deposition

**EXECUTIVE SUMMARY**

CdSe Nanospheres of about 5-7 nm diameter were synthesized by direct chemical reaction process. From these nanospherical particles, nanorods of about 20 nm in thickness were deposited on ITO substrates by electrophoretic deposition technique. Unambiguous HRSEM evidence of electric field driven self assembly of the nanospherical CdSe particles leading eventually to the formation of nanorods was observed. The alignment of the nanoparticles takes place in a direction perpendicular to the plane of the substrate due to the electric field gradient, even without using any templates. The size, crystallinity, composition and shape of the particles were analyzed by XRD, TEM, AFM, HRSEM and EDAX analysis. These findings demonstrate a convenient and simple template-less technique for the formation of nanorods and its assembly.

**OUTLINE**

CdSe is an important semi conducting material with unique optical and electrical properties, which makes it a promising material in the field of opto-electronic devices, biosensors etc. Growth of nanostructures having different morphologies can result in the modification of its physical properties and improvement in performance characteristics. By tuning the aspect ratio of nanorods one can follow the transition from zero to one dimensional quantum confinement systems. From the application point of view, semiconductor nanorods have already been demonstrated to possess considerable advantages over their quantum dots (QD) counterparts in various fields. These, include improved performance in photo enhanced optical gain as compared to spherical dots while providing polarized lasing. Nanorods and nanowires offer a larger surface area compared to that of films or bulk material in the field of application such as photo electrochemical cells, catalysts and sensors, where the sensitivity or efficiency is proportional to surface area.

Nano particles of CdSe were chemically synthesized by the direct reaction of an alkaline selenium solution with an aqueous solution of CdSe complex. XRD studies confirm the formation of nanocrystalline CdSe particles with cubic structure. TEM micrographs indicated that the as synthesized nanoparticles were spherical in shape and no nanorods were found in the chemically synthesized powders(Fig. 1). The particle size was found to be 5-7 nm matching closely with the estimate from XRD peak broadening calculated using Scherer formula. EDAX studies indicated the formation of compound with nearly equiatomic composition (CdSe type).

The CdSe nano particles were then dispersed in propylene carbonate by ultrasonication and the same was used for electrophoretic deposition (EPD) (Fig.2). HRSEM images are in agreement with GIXRD results confirming the formation of nanorods of CdSe synthesized by electrophoretic deposition on ITO substrates. It could be seen that the nucleation of rods of about 20 nm diameter always occurs at protrusions at the boundaries of an embryo structure. The formation of such embryos with rough corrugated edges is an important prelude before nucleation of nanorods. This nucleus is an island typically with nearly the same composition, but without any orderly arrangement of the nanospherical particles. The protrusions formed on the boundary of the nucleus due to interface instabilities, will be locations of concentrated electric field, leading to self assembly of the charged CdSe nanoparticles. AFM studies clearly identified that each nano rod infact consists of three individual fine strips of ~7nm width, matching well with the distribution of individual nanoparticles of CdSe synthesized by chemical route. Also very clear evidences of particle to particle coagulation leading to rod shaped growth were evident from AFM and HRSEM studies.

**Fig. 1:** Nucleation of rods can be seen to be taking place at asperities, which are expected to be points of high electric field, providing the driving force for alignment of nanoparticles of CdSe

**Fig. 2:** Electric field driven interaction of the charged nanoparticles during electrophoretic deposition can be seen to result in growth of nanorods. The primary rod growing from the nucleus and plenty of secondary rods nucleating from the primary arm can be seen. The secondary arms are also nearly parallel to each other, suggesting the strong inter-particle interactions during the growth process.
Growth of CdSe nanorods of well defined shape and size without any template by electrophoretic deposition has been achieved.

CdSe Nanoparticles behave like a tunable fluorophore. It can emit any color across the visible part of the spectrum (Fig. 3). At a size of around 7nm, it emits deep red but is still brown looking. At smaller nanosizes, it can emit photons ranging across the visible part of the spectrum. In cadmium selenide, crystallites of ~1.5 nm gives yellow color, 4 nm gives red and larger the particle, output color is black.

CdSe nanorods were deposited on ITO substrates by electrophoretic deposition process. A characteristic feature of electrophoretic process is that colloidal particles suspended in a liquid medium migrate under the influence of an electric field (20-1000 V/cm) and are deposited onto an electrode. All colloidal particles that can be used to form stable suspensions and that can carry a charge can be used in electrophoretic deposition. This includes material classes such as polymers, pigments, dyes, ceramics and metals. The process is useful for applying materials to any electrically conductive surface.

Semiconductor nano-crystallites have been the subject of intense studies over the last decade primarily due to their interesting size dependent electronic and optical properties. The fabrication of CdE (E = S, Se, Te) semiconductor nanocrystals has interested researchers, since its optical properties can be tuned by varying its size, resulting in the phenomenon of quantum confinement.

Electrophoretic deposition (EPD) is essentially a two-step process, involving the application of an electric field to the suspension (electrophoresis). In this case the particle motion is motivated by electro-hydrodynamic forces. The self-organization mechanism dictates the morphogenesis of fractal architecture. The fractal morphology however depends on the charge and mass of electro-pheretically deposited particle and hence morphology would vary for each system. Such self-organization phenomenon on solid surface is a culmination of non-linear competitive interactions. The surface energy as well as adhesion forces acts against the steric repulsive forces causing manifestation of steady state morphology.

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