

# Controlled Growth of CdS Quantum Dots

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The role of 3-mercaptopropionic acid as a surface anchoring group and the reaction temperature for the controlled growth of CdS crystals was investigated from a one-step aqueous synthesis carried out both at room temperature and using a hydrothermal route. The thiol group of 3-mercaptopropionic acid forms a relatively strong bond with the cadmium atoms found at the particle surface reducing the crystal growth rate. This leads to the formation of monodisperse crystals of about 2 nm diameter. For a low thermal activation, at room temperature, for instance, the crystal growth is mainly determined by the nucleation process without evidence of a large contribution from Ostwald ripening. When the thermal activation competes with the binding energy for the thiol group to the cadmium atom, the surface shell becomes unstable and the crystals growth involves the coarsening mechanism. Under hydrothermal conditions the radius ( $r$ ) for the obtained crystals follows a linear dependence for  $r^3$  versus  $t$  (reaction time). The crystal growing process is halted when the colloidal suspension is cooled. An appropriate control for the time and temperature of heating allows crystals of a tailored size to be obtained. The obtained colloidal suspensions of CdS nanocrystals were characterized from optical absorption, high-resolution transmission electron microscopy, and photoluminescence data.

## Keywords:

## 1. INTRODUCTION

Semiconductor nanocrystals have received considerable attention in the last decades from both basic and applied research. The changes in the physical properties related to the crystal size reduction, in the nanometric domain, are easily visible for semiconductors as pronounced variations in their optical properties.<sup>1,2</sup> For semiconductors such size dependence for the physical properties is attributed to the quantum confinement related to a crystal size smaller than the bulk exciton (electron–hole pair) Bohr radius. These small crystals are known as quantum dots (QDs). For many semiconductors, e.g., II–VI metal chalcogenides, the gap of energy between the valence and conduction bands can be tuned, modifying the crystal size, to absorb and emit light in the visible region of the electromagnetic spectrum. Within the visible region, a precise control for the crystal size during the preparative process allows a fine tuning for the gap energy, and, of course, for the photoluminescence (PL) spectra. Additionally, certain QDs can be excited by a single wavelength to emit in a relatively wide spectral range at higher wavelengths. These features, together with

a symmetric emission spectra, a relatively high quantum efficiency, and a higher stability against photobleaching, relative to organic dyes, make QDs promising fluorescent labels for biotechnological and medical applications.<sup>3,4</sup> Such properties of QDs also find applications for optoelectronic and communication devices.<sup>5</sup>

In the last few years the preparation of semiconductor nanocrystals of tailored size and properties has reached significant progress in terms of simplicity and reproducibility. Within the preparative methods reported, probably the most suitable ones appear to be the chemical routes, which include the pyrolysis of organometallic precursors,<sup>6</sup> colloidal synthesis using organic solvents<sup>7</sup> and solvothermal synthesis.<sup>8</sup> The simplest solvent is water, which also is environmentally compatible, and some synthetic routes of QDs using water have been developed.<sup>9–12</sup> Biological and medical applications of QDs as fluorescent labels involve their conjugation to biological molecules.<sup>13</sup> The linking of biological molecules to the surface of a QD requires intermediates, usually thiol-containing compounds with terminal amino or carboxyl groups, which must be available as anchoring sites for the bioconjugation. The thiol groups link the metal atoms at the nanocrystal surface. For QDs of II–VI metal chalcogenide-type

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