Synthesis of CdSe/CdS core/shell quantum dots for biological sensing applications

Yang Xu*a, Poojitha Mariamb, Varun Sethia, Mason Jonesa, Kathleen Meehan

aThe Bradley Dept. of Electrical and Computer Engineering
Virginia Tech, Blacksburg, VA USA 24061
bDept. of Electrical and Computer Engineering, Univ. of Virginia, Charlottesville, VA USA 22904

ABSTRACT

A simple, room temperature, one-pot method to produce biocompatible CdSe/CdS quantum dots (QDs) in aqueous solution is presented. CdCl₂ and NaSeSO₃ are the precursors for the CdSe core where gelatin is used as an inhibitor. A CdS shell is grown by injecting H₂S gas, generated by a reaction between sulfuric and sodium sulfide, into the solution. This fast, low cost synthesis approach is simple for scale-up production of QDs. Transmission electron microscopy shows that the bare CdSe quantum dots were 2-3 nm in diameter. The emission peak from the CdSe can be tuned over most of the visible wavelength (from 520 nm to 600 nm) as the diameter of the QDs is allowed to increase before growth of the CdS shell. The core/shell structure was confirmed via UV-Vis absorption spectroscopy, PL studies, and structural characterization (XRD). The higher band gap CdS coatings significantly enhanced the photoluminescence (PL) of CdSe quantum dots by a factor of 2-3. However, the large lattice mismatch between the CdS coating and the CdSe core results in eventually quenched luminescence from CdSe with thicker CdS coatings. To increase the photochemical stability and biocompatibility of the CdSe/CdS QDs, a silica coating is grown directly on the QDs. Preliminary data indicates that the PL from CdSe/CdS QDs post-growth is affected as the applied electric field is altered. Efforts to functionalize the QDs with DNA and antibodies have begun. Studies have been initiated to demonstrate the feasibility of microinjecting the QDs into Xenopus embryo with minimal post-synthesis processing.

Keywords: CdSe, CdS, quantum dot

1. INTRODUCTION

Since common cells are almost transparent, they can hardly be seen by human eyes under optical microscope. Researchers often rely on certain fluorescence material, which attach to the interested biological component, in order to detect cell activities. Although organic fluorescent dye has been widely used to label the cells, their drawbacks, such as narrow absorption band and high chemical reactivity ¹, are obvious compared to the nanomaterial counterparts ², ³, quantum dots (QDs), especially CdSe, whose emission spectra spread most of the visible wavelengths. Both biocompatibility and aqueous solubility are required for QDs to be used in biological system. Because CdSe QDs synthesized through metal-organic approach are hydrophobic, ligands exchange or extra coatings are needed for those dots to use in aqueous environment. In addition, highly toxic metal-organic precursors make this complex process much less desirable than the method under development in this study, which offers an easy and user-friendly way to prepare high quality CdSe QDs. CdSe/CdS core/shell structure QDs were developed to enhance the photoluminescence (PL) intensity of CdSe. Due to its chemical stability and biocompatibility, a silica coating was grown on the core/shell structure QDs. The effect on the QDs PL intensity and wavelength under an applied electric field, known as quantum confined Stark effect, was studied to give a preliminary understanding of the PL change when a binding event occurs on the QD surface.

2. EXPERIMENTAL PROCEDURE

All the chemicals used were of analytical grade and deionized (DI) water (18.3 MΩ) was used in all the experiments. CdSe QDs were synthesized by mixing 4 ml of 40 mM of CdCl₂ (99%, Acros) solution with type A gelatin at pH 7.2, which was achieved by adding ammonium hydroxide, and 2 ml of 20 mM of sodium selenosulfate solution, prepared by heating appropriate amounts of selenium (99.999%, Cerac) and sodium sulfite (98+%, Acros) in deionized water.