

Synthesis of Biocompatible Polymer Capped Quantum Dots for Cancer Detecting Applications

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Introduction

Semiconductor quantum dots have several optical properties, such as excellent photostability, broad excitation spectra, and narrow emission spectra, which make them attractive alternatives to organic dyes for biological labeling and cellular imaging. However, due to the toxic nature of semiconductor materials, particularly cadmium, quantum dots must be coated with a biocompatible material before they can be used as biological tools¹. In attempts to reduce toxicity, quantum dots have been encapsulated in phospholipids micelles, coated with amphiphilic polymers, and passivated with a shell of ZnS. Quantum dots have also been functionalized with antibodies so that they can be targeted to cancer cells for detection and diagnostic purposes. Despite these advances, improvements still need to be made to the coating process to ensure that quantum dots are thoroughly encapsulated and therefore completely nontoxic to live cells.

The objective of this research is to develop a coating process to coat nanoparticles, which can be applied to reducing the toxicity of quantum dots. The biocompatible polymer polycaprolactone was used to coat silver nanoparticles using the “graft to” and the “graft from” technique. In the “graft to” technique, the biocompatible polymer was first synthesized and then grafted to the nanoparticle surface. In the “graft from” technique, silver nanoparticles were synthesized with a surfactant, one end of which can be attached to the particle surface and the other end of which acts as a co-initiator for the living ring polymerization of the monomer ϵ -caprolactone. Thus, this technique allows the polymer chain to grow from the particle surface, thereby encapsulating the nanoparticle.

Procedure

“Graft to” technique. After purifying the monomer solution, the living polymerization of ϵ -caprolactone was initiated by distilled aluminum isopropoxide and terminated by mercaptoacetic acid after reacting for 1 to 2 hours. The purified polymer was then combined with silver nitrate in solution, and sodium borohydride was then added as a reducing agent. The thiol terminal group on the polymer has a strong affinity for the silver particle surface, which allows the polymer to graft to the particle surface, coating the particles while preventing agglomeration.

“Graft from” technique. Silver nanoparticles were first synthesized using silver nitrate as the precursor and 6-mercapto-1-hexanol as the surfactant. Once synthesized,

the nanoparticles were washed, dissolved in distilled toluene, and combined with distilled aluminum isopropoxide. This mixture was then distilled twice in order to drive the formation of the Al-complex catalyst, which was then added to ϵ -caprolactone monomer solution to catalyze the polymerization reaction.

Results and Discussion

Both the “graft to” and “graft from” polymer coated silver nanoparticles were characterized using UV-vis spectrometry, thermogravimetric analysis (TGA), Fourier Transform Infrared Radiation (FTIR), and transmission electron microscopy (TEM). UV-vis spectra showed the characteristic absorption peak for silver nanoparticles (400nm). The absorption peak for the silver nanoparticles was blue-shifted (350nm) for some of the samples due to the small particle size (5-10 nm). TGA curves showed that the samples ranged from 15% to 50% by weight of polymer coating. The FTIR spectra showed $-\text{OH}$ (3245.3 cm^{-1}), $-\text{CH}_2-$ (2934.2 cm^{-1}), and $\text{C}=\text{O}$ (1734.6 cm^{-1}) groups, confirming the presence of polymer. The TEM images (Figure 1) show that the nanoparticles are embedded in a polymer matrix. However, the desired core-shell structure cannot be confirmed because a higher resolution microscope is needed (HRTEM).

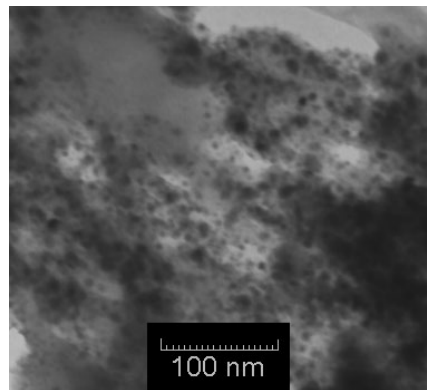


Figure 1 TEM image of “graft from” particles

Conclusion

The coating process described above was indeed successful in encapsulating nanoparticles. However, improvements must be made to the process to ensure that individual nanoparticles are indeed coated with a layer with biocompatible polymer.

¹ Derfus, A. M. *et al.* Probing the cytotoxicity of semiconductor quantum dots. *Nano Letters* 4(1), 11-18 (2004).