Bacterium *E. coli*-Templated Synthesis of Cadmium Sulfide Nanostructures

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Abstract

A simple sonochemical method has been used to synthesize nanoporous hollow structures of semiconducting cadmium sulfide (CdS) using *E. coli* bacteria as templates. To enable adsorption and reaction throughout the *E. coli* cell envelope, the cell permeability is enhanced by suitable ethanol treatment while preserving the morphology. CdS nanostructures in the form of monodisperse quantum dots, near monodisperse nanocrystals, and nanoporous hollow microrods are controllably formed on ethanol-treated *E. coli* with increasing reaction time. Additionally, nanorod antennas have been fabricated by utilizing the pili formed during the growth phase of the bacteria. The bacterial template route has been extended to the synthesis and assembly of other chalcogenide nanostructures including PbS and ZnS.

Motivation

Bio-templated synthesis and assembly routes:

- DNA, RNA, and organisms from microbes to complex multicellular systems.
- Controllable size, from nano- to macroscopic scales.
- Precisely controlled shape, structure, and functionality.
- Bottom-up nanofabrication of complex functional assemblies and devices.

Nanoporous Hollow Structures:

- Large surface area.
- Strong ability to interact with reactants throughout the structure.
- A variety of possible applications in catalysis, biomedicine, novel materials, etc.

Challenges

- Understanding nucleation and growth of inorganic species on bio-templates.
- Control over material properties such as phase structure, composition, etc.
- Synthesis of non-biocompatible materials.

Present Work

Development of novel bacterial template route for the synthesis and assembly of hollow chalcogenide nanostructures, including CdS, PbS, ZnS, etc.

Experimental

- Growth of *E. coli* cell culture under ambient conditions until stationary growth phase. The cell concentration is ~10^8 CFU/mL.
- Ethanol treatment of cells with 95% ethanol for 3 minutes to increase the permeability of cell outer membrane.
- Synthesis of CdS nanostructures: 0.5 mmol of cadmium acetate dehydrate was first added to 50 mL of ethanol-treated ER2738 solution, and 0.5 mmol of thiourea was then added after 30 min. The reaction was conducted for up to 4 h in an ultrasonic bath with the temperature maintained at around 28°C.
- Investigation of the time-dependence of size, shape, and structure of the bacteria *E. coli*-templated CdS structures.
- Fabrication of nanorod antennas by utilizing the pili formed during the growth phase of the bacteria.

Conclusion

We have used ethanol-treated *E. coli* bacteria as a template to promote controllable growth of nanoporous hollow CdS microrods via a simple sonochemical synthetic method. The morphology, micro/nanostructure, and optical absorption properties of the CdS nanomaterials have been tailored over a wide range by simply changing the synthetic conditions, including the sulfur/cadmium molar ratio of the reactants, the reaction time, and the growth condition of *E. coli* bacteria. The facile synthesis procedure can be extended to the fabrication of other sulfides and core-shell nanostructures.