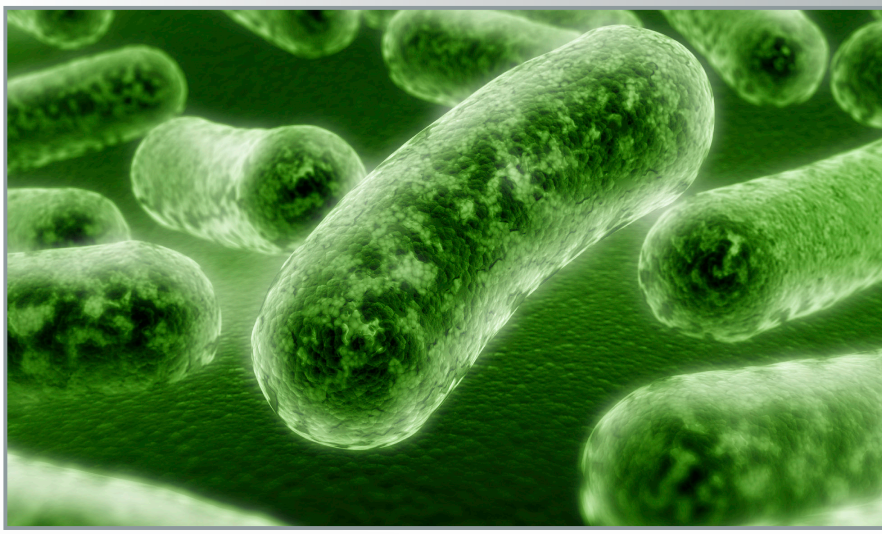
Bacterial Fermentation Improves Metallic, Semiconducting Nanoparticle Production

UT-B ID 200601686, 200701968



Technology Summary

A team of researchers at ORNL has successfully developed a method for producing inorganic nanoparticles, and controlling their size and shape, using a bacterial fermentation process that employs chemicals to control bacterial synthesis. They subsequently built on that research by producing in large quantities semiconducting quantum dots of high market value.

Nanoparticles may be metallic, inorganic oxides and sulfides, organic polymers, or lipids. Quantum dots are semiconducting nanoparticles structured for use in computing, tagging, electronics, LED displays, and photovoltaics. They currently have market values of thousands of dollars per gram. The high cost and limited available quantity of such nanomaterials discourage potential end users, who are not confident that the materials will ever be available in bulk. To date, ORNL researchers have successfully made samples of quantum dots ranging from tens of grams to kilograms in their bacterial fermentation runs.

In two consecutive projects, led by T. Phelps of the Biosciences Division, researchers first synthesized metallic nanoparticles using bacteria, with chemical reagents controlling the bacterial synthesis. Examples of metal-reducing bacteria have been known for years; these bacteria reduce iron(III) to iron(II) in the presence of an electron donor such as hydrogen, glucose, or organic acids. The ORNL project is among the first to integrate size and shape control into the biosynthesis of tailored, single-crystal metallic nanoparticles.

Particle size and shape are controlled by chemically modifying the fermentation broth. Size control is achieved by adding iron(II) acetylacetonate, a mild, water soluble and bacterially safe compound. The acetylacetonate binds to the surface of the nanoparticle, effectively capping its growth. When synthesis of the ferrite is complete, it can be separated magnetically from the precursor materials. When formation of the product is complete, the ferrite will no longer accept electrons from the bacteria.

The researchers then proceeded to experiment with the bacteria and synthesized mixed compounds that can be used as semiconductors in applications such as computing, LED displays, and a broad suite of electronics.

They used microbial fermentation (i.e., culturing the bacteria) in the presence of either several metals and one nonmetal, or one metal and several nonmetals. They successfully made nanoparticles containing Zn, Ag, Hg, Cd, Fe, and other chemical elements. The compounds are produced outside the bacteria, and after formation may be collected as nanometer-sized particles.

Advantages

The cost of producing metallic nanoparticles by microbial fermentation is low, often less than 1% of the cost of more traditional production methods. The method also makes possible the production of large quantities of structured semiconducting nanomaterials of high market value. Finally, the researchers have succeeded in tailoring these materials in size and shape.

Potential Applications

Metallic nanoparticles are of vital interest for a wide array of uses, including computers, LED displays, signs, photovoltaics, tagging equipment with lasers, biomedical treatments, fluorescents, and dyes.

Patent

Adam J. Rondinone, Ji Won Moon, Lonnie J. Love, Lucas W. Yeary, and Tommy J. Phelps, *Microbial Mediated Method for Metal Oxide Nanoparticle Formation,* U.S. Patent Application 12/357, 523, filed January 22, 2009.

Tommy J. Phelps and Robert J. Lauf, *Microbially-Mediated Method for Synthesis of Non-Oxide Semiconductor Nanoparticles,* U.S. Patent Application 12/364, 638, filed February 3, 2009.

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