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Gail Gallessich

Marine Sponges Provide Model for Environmentally Friendly Nanoscale Materials Production, Report Scientists at UC Santa Barbara

Nature was nano before nano was cool, stated Henry Fountain in a recent New York Times article on the proliferation of nanotechnology research projects. No one is more aware of this fact of nature than Dan Morse of the University of California, Santa Barbara. His research groups have been studying the ways that nature builds ocean organisms at the nanoscale for over ten years.

For example, they have studied the abalone shell for its high-performance, super-resistant, composite mineral structure.

Now they are now looking to learn new biotechnological routes to make high performance electronic and optical materials.

"We are now learning how to harness the biomolecular mechanism that directs the nanofabrication of silica in living organisms," says Morse. "This is to learn to direct the synthesis of photovoltaic and semiconductor nanocrystals of titanium dioxide, gallium oxide and other semiconductors – materials with which nature has never built structures before."

Most recently, Morse and his students have made advances in copying the way marine sponges construct skeletal glass needles at the nanoscale. The research group is using nature's example to produce semiconductors and photovoltaic materials in an environmentally benign way – as they report in a recent issue of the journal Chemistry of Materials.

"Sponges are abundant right here off-shore and they provide a uniquely tractable model system that opens the paths to the discovery of the molecular mechanism that governs biological synthesis from silicon," says Morse. "This sponge produces copious quantities of fiberglass needles made from silicon and oxygen."

Morse directs the new Institute for Collaborative Biotechnologies, a UCSB-led initiative funded by a grant of $50 million from the Army Research Office, which operates in partnership with MIT and Caltech. He also directs the Marine Biotechnology Center of UCSB's Marine Science Institute.

The work is particularly exciting, according to Morse, because silicon has been called the most important element on the planet technologically – silicon chips are fundamental components of computers, telecommunications devices, and in combination with oxygen forms fiber optics and drives other high-tech applications.

He explains that his research group discovered that the center of the sponge's fine glass needles contains a filament of protein that controls the synthesis of the needles. By cloning and sequencing the DNA of the gene that codes for this protein, they discovered that the protein is an enzyme that acts as a catalyst, a surprising discovery. Never before had a protein been found to serve as a catalyst to promote chemical reactions to form the glass or a rock-like material of a biomineral. From that discovery, the research group learned that this enzyme actively promotes the formation of the glass while simultaneously serving as a template to guide the shape of the growing mineral (glass) that it produces.

"Most recently in this research, which is supported by the National Oceanic and Atmospheric Administration's Sea Grant Program and the Department of Energy, we've discovered that these activities can be applied to the synthesis of valuable semiconductors, metal oxides such as titanium and gallium that have photovoltaic and semiconductor properties," says Morse. The group is using a synthetic mimic of the enzymes found in marine sponges.

These discoveries are significant because they represent a low temperature, biotechnological, catalytic route to the nanostructural fabrication of valuable materials. The research group is now translating these discoveries into practical engineering.

Currently these materials are produced at very high temperatures in high vacuums, using caustic chemicals. With these latest discoveries, scientists have found that nanotechnology can copy nature and produce materials in a much more environmentally friendly way than the current state-of-the-art.

About UC Santa Barbara

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