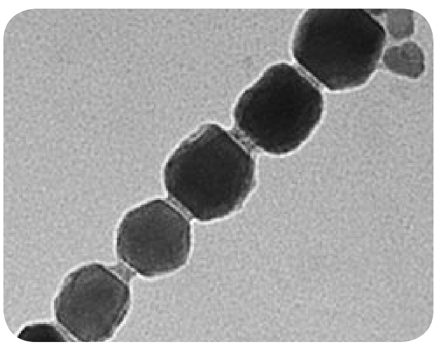
Nano-Scale Biomanufacturing

Ames Laboratory scientists create magnets from cloned DNA

Building nano machines as well as nano-scale electronic components and drug delivery devices will require sophisticated new manufacturing technologies. In cases where such products need to be mass produced, the methods used must be cost effective, easily replicable and capable of rendering end products of a consistent quality.

Biotech holds the promise of successfully meeting all of these requirements. By utilizing complex proteins as templates, researchers can fabricate unlimited quantities of nano-components customized to suit the most exacting needs. Researchers at the U.S. Department of Energy's Ames Laboratory recently demonstrated the versatility of nano-scale bio-manufacturing when they synthesized magnets derived from models produced naturally by certain bacteria.



Transmission electron micrograph of a nanocrystalline magnetite chain removed from lysed bacteria. A phospholipid membrane, located between the individual magnets, acts as an adhesive, allowing the chain to form.

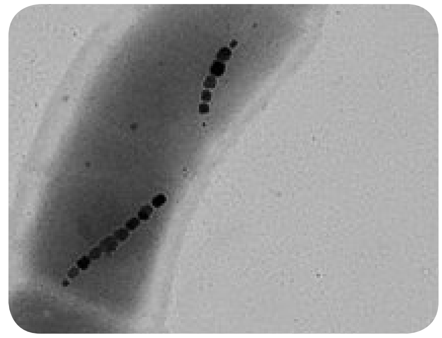
Natural and synthesized biomagnets

For decades, scientists have been aware that organisms known as magnetotactic bacteria naturally produce magnetite, an alloy consisting of iron and oxygen.

Theories differ as to why the bacteria make magnets. However, it is known that in marine environments, these bacteria can be found in areas between water that contains oxygen and water that lacks oxygen. This unique environment may be what prompts the organisms to absorb thousands of times more iron than other bacteria.

Some speculate that the tiny magnets the organisms produce allow them to navigate using the earth's magnetic field in order to locate areas that possess more ample oxygen supplies.

Drawing upon research from Japan, an interdisciplinary team of Ames Lab scientists chose to add cobalt to the bacteria's iron-oxide alloy. The resulting new ($CoFe_2O_4$) material has more desirable magnetic properties than magnetite. Also, importantly, it is not thought to be produced naturally by magnetotactic bacteria. Thus, evidence of $CoFe_2O_4$ would prove that the scientists had successfully synthesized it. The team began by isolating several promising strains of magnetotactic bacteria.



A naturally occurring bacteria species known as Magnetospirillum magneticum strain AMB-1, as seen via a transmission electron micrograph. The dark chains are the organism's naturally produced magnets, known as magnetosomes.

Next, they looked at several proteins also produced by the organisms that were known to bind with iron. One protein, known as Mms6, was eventually chosen. The protein was cloned from the bacteria. The Ames Lab researchers first tried synthesizing nano-scale magnetic crystals, using the proteins

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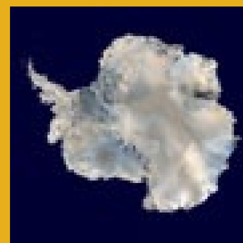
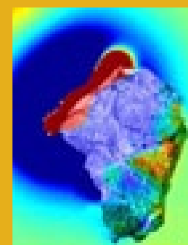
with various concentrations of reagents in a solution. However, the resulting particles formed too quickly, were small, and they lacked the desired crystal morphology.

Next, the team tried synthesizing the crystals with the help of polymers which were themselves developed at the Ames Laboratory. The Mms6 protein was attached to a polymer known to self-assemble and form a kind of gel. The molecular strands making up this polymer come together in a particular way, and thus they attached to the protein in a manner which gave the latter an alignment that allowed it to serve as an ideal template for the formation of cobalt-ferrite crystals.

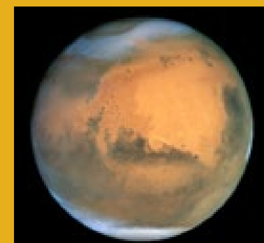
MARTIAN BACTERIA?



Antarctica viewed from space



A meteor fragment



The planet Mars

Perhaps the most intriguing study related to magnetotactic bacteria took place in the late '90s. That's when Dennis Bazylinski, one of the Ames Lab team members involved in synthesizing biomagnets, looked at tiny magnetite crystals — so-called magnetofossils — embedded in a 4.5-billion-year-old meteorite uncovered in Antarctica in 1984. Further research revealed the meteorite was from Mars. And astonishingly, the research team determined that many of the crystals were identical to those produced on earth by a particular strain of magnetotactic bacteria. No other known natural process is thought to be capable of producing crystals of the type made by these bacteria. Though not everyone agrees with this theory, the crystals studied by Bazylinski and his team might well be evidence of life elsewhere in our solar system.

Practical applications

While consumer-ready products resulting from the Ames Lab research may still be a few years off, the work demonstrates a potential way of mass producing nano magnets. Someday, it may be possible to create nano-magnets, measuring just 40-100 nanometers across in a room-temperature environment, simply by replicating the templates developed at the Ames Laboratory. Also, the nano magnets produced in this way would be superior to those created using other techniques, both in shape and the way in which their atoms align to form potent magnetic domains.

Nanomagnets produced using the Ames Lab method have one additional advantage that promises to open up vast potential uses in medicine and biotech. Namely, they are naturally coated with the Mms6 protein. Bioengineers could adhere many substances to this membrane, creating drugs and other devices which could be readily directed to where they are intended to go using simple magnetic attraction.

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- Surya Mallapragada, Ames Laboratory Materials, Chemistry and Biomolecular Materials program director
- Marit Nilsen-Hamilton, biochemist
- Paul Canfield, senior physicist
- Tanya Prozorov, chemist
- Ruslan Prozorov, physicist
- Balaji Narasimhan, scientist

Selected Publications

"Cobalt Ferrite Nanocrystals: Out-Performing Magnetotactic Bacteria," ACS Nano: Vol. 1, No. 3, pp. 228–233, 2007; http://pubs.acs.org/doi/pdf/10.1021/nn700194h.

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