Rods enhance superconductor performance

When it comes to synthesizing materials, not everyone strives for perfection. Superconductors are a case in point: The right kinds of defects, strategically incorporated into their crystal structure, can actually increase the electric current they can carry without resistance.

Peidong Yang and Charles M. Lieber of Harvard University have found a new way to introduce beneficial defects into superconductors. The chemists incorporate nanometer-scale rods of magnesium oxide into one type of superconducting material, they report in the Sept. 27 SCIENCE. The presence of the nanorods allows 10 times as much current to flow through the superconductor, Lieber says.

Theorists still do not fully understand why certain materials act as superconductors, let alone why defects should enhance their performance. The nanorods may boost current-carrying capacity by reducing the obstructive effect that magnetic fields have on superconductivity (SN: 2/10/90, p. 95).

The Harvard researchers have improved upon previous methods of adding defects. One such approach has been to bombard superconductors with heavy ions, such as lead or gold, at very high energies. The ions tunnel through the material, knocking atoms out of place as they go.

Ions, however, can't penetrate materials to a depth of more than a tenth of a millimeter, says Masaki Suenaga, a metallurgist at Brookhaven National Laboratory in Upton, N.Y. This limitation would be a problem in manufacturing thicker superconducting wires. Besides, making large quantities of superconductor in a particle accelerator just isn't practical. "It's scientifically very interesting," he says, "but I don't have any hope for commercial applications of heavy ion radiation."

Another method of adding imperfections uses high-energy protons as the blasting agent. The protons induce nuclear fission in the superconductor's bismuth atoms, says Lieber. "Fission fragments go bombing out of the material and create defect tracks." Although protons penetrate much farther than ions, they tend to make the material radioactive.

The drawbacks to ion and proton irradiation prompted researchers to find other ways of incorporating defects. One group tried adding carbon nanotubes to superconductors in the manufacturing stage, but the nanotubes reacted chemically with the superconducting material.

Magnesium oxide, however, seemed like a good choice for the nanorods, Lieber says. "People grow [superconductor] crystals in magnesium oxide containers, so they know that it's inert and won't introduce impurities into the crystals." Previous work had also showed that magnesium oxide "whiskers" improve the mechanical properties of superconductors, but those rods were much larger—micrometers in diameter—and tended to impair current-carrying capability.

"The main technical hurdle was developing a synthetic approach to making magnesium oxide whiskers with nanometer-scale diameters," Lieber says. After they overcame that obstacle, the scientists incorporated nanorods into the superconductor in two different ways. They either grew "a forest of little whiskers" in a fixed orientation on a surface and deposited superconductor around them or mixed a few nanorods into melted superconductor and allowed the material to crystallize.

The second technique worked because, Lieber says, "It turns out that these rods actually self-organize within this superconductor matrix."

The group used a superconductor known as BSCCO-2212 in the experiments; the name represents the proportions of bismuth, strontium, calcium, and copper in the material. However, Suenaga says he'd like to see nanorods added to another form, BSCCO-2223.

This variation interests many researchers because it remains a superconductor all the way up to a temperature of about 110 kelvins. On the other hand, BSCCO-2212 is easier to make, Suenaga says, which could facilitate large-scale synthesis.

Lieber says the next step is to reduce the size of the nanorods in order to increase their density. Demonstrating that the process can be scaled up to industrial production is important too, Suenaga says. "If they can make a tape out of it and actually test it, that would be very interesting." —*C. Wu*

How many genes does a bacterium need?

Take a look at today's bacteria. If push came to shove, how many of their genes could the microbes do without? Or to pose the query another way, what is the minimum number of genes sufficient for a modern bacterial cell?

In years past, such questions would have elicited replies no more scientific than calculations of how many angels can dance on the head of a pin. Yet in the last 15 months, researchers have unveiled the complete genetic complements of several single-celled organisms, including two bacteria. This new information has allowed investigators to take a serious stab at what were previously fanciful inquiries.

Relying largely upon a comparison of the bacteria whose full gene sets, or genomes, have been laid bare, two scientists now conclude that a mere 256 or so genes may be necessary and sufficient for the modern cell. Arcady R. Mushegian and Eugene V. Koonin, both of the National Center for Biotechnology Information in Bethesda, Md., report their analysis in the Sept. 17 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

The researchers propose that determining the minimal genetic requirements of a modern single-celled organism may aid attempts to reconstruct the genome of the ancestral microorganism from which all current life presumably evolved.

"Eventually, backwards extrapolation from the minimal gene set may lead close to the origin of life itself," Mushegian and Koonin write.

The two investigators constructed their minimal genome after examining the genes of *Haemophilus influenzae* and *Mycoplasma genitalium*, whose genomes were described last year (SN: 6/10/95, p. 367). *H. influenzae* relies on some 1,700 genes, while *M. genitalium*, the smallest known genome, has about 470.

Koonin notes that the two microorganisms represent branches of bacterial evolution that diverged at least 1.5 billion years ago. Yet the bacteria possess many genes that remain similar in DNA sequence and in function. Those conserved genes, 240 in total, are probably essential for cellular function, says Koonin.

That set of genes lacked some enzyme functions crucial to a cell, however. To fill the gaps, the researchers added 22 genes from *M. genitalium's* genome. (*H. influenzae* has genes whose proteins perform similar functions as the proteins of these *M. genitalium* genes, but their DNA sequences do not appear to be related.) Finally, they eliminated six conserved genes that appeared to be either redundant or needed only to interact with the hosts of these particular bacteria.

Jack Maniloff, a microbiologist at the University of Rochester (N.Y.) Medical Center, cautions that the 256 genes identified by Mushegian and Koonin may bear little resemblance to the genetic repertoire of a presumed ancestral organism. Maniloff notes that such an ancestor, unlike the two modern bacteria, probably lived at high temperatures, had little oxygen available to it, and drew energy from sulfur.

Still, Maniloff suggests that seriously investigating the size of the minimal genome is in itself an important advance. "I'm pretty pleased our species can address the question. I think it marks a stage where we can gauge the essential components of a living cell." —*J. Travis*