The bacteria churn out methanobactin molecules in large numbers and send them into the environment to fetch copper. When the compound returns with copper, it is thought that the copper is incorporated into molecules of a key enzyme that converts methane to methyl alcohol. Due to its high reactivity, copper would be an appropriate atom to metabolize methane. Their reactivity also makes copper atoms toxic to the bacteria. Thus, methanobactin serves to keep copper under control and protect the bacterial cells from it, said the researchers.

One piece of the story still to be learned is how the methanobactin is retrieved by bacterial cells, Kim said. The cells apparently latch onto copper-bearing methanobactin molecules, but what happens next is unknown. Methanobactin has no tether to its mother cell. Therefore, when bacterial cells release their methanobactin molecules, they probably never see them again; instead, they take delivery of copper from methanobactin released by other cells of the same species, the researchers said

"Synthesized compounds analogous to some parts of the methanobactin molecule have been shown to be antibacterial," said Kim.

SnO_2 Nanoribbons Channel Light at the Nanoscale

In photonics technology, the use of electrons moving through semiconductors as information carriers is replaced with the movement of photons. For the promise of photonics to be delivered, however, scientists need to manipulate and route photons with the same dexterity as they do electrons. Peidong Yang's research team at Lawrence Berkeley National Laboratory and the University of California at Berkeley have demonstrated that semiconductor nanoribbons can serve as waveguides for channeling and directing the movement of light through circuitry.

"Not only have we shown that semiconductor nanoribbons can be used as low-loss and highly flexible, optical waveguides, we've also shown that they have the potential to be integrated within other active optical components to make photonic circuits," said Yang.

"Chemically synthesized nanowires and nanoribbons have several features that make them good photonic building blocks," Yang said. "They offer inherent one-dimensionality, a diversity of optical and electrical properties, good size control, low surface roughness, and, in principle, the ability to operate above and below light diffraction limits."

As reported in the August 27 issue of *Science* (p. 1269), Yang and his colleagues synthesized their nanoribbon waveguides from tin oxide. The single-crystalline nanoribbons measured ~1500 µm in length and featured a variety of widths and thicknesses. Yang said ribbons measuring 100–400 nm in width and thickness proved to be ideal for guiding visible and ultraviolet light.

"To steer visible and ultraviolet light within dielectric waveguides such as the tin oxide crystals we were synthesizing, we needed to make sure that a sufficient portion of the light's electromagnetic field was confined within the nanostructures so there would be minimal optical transmission loss," Yang said. "Considering the dielectric constant of the tin oxide, it follows that the diameter of 100 to 400 nanometers would be ideal for waveguiding light that measures from 300 to 800 nanometers in wavelengths." In their tests, Yang and his colleagues attached nanowire light sources and optical detectors to opposite ends of their tin oxide nanoribbons, then demonstrated that light could be propagated and modulated through subwavelength optical cavities within the nanoribbons. The nanoribbons were long and strong enough to be pushed, bent, and shaped with the use of a commercial micromanipulator under an optical microscope. Freestanding ribbons were also extremely flexible and could be curved through tight S-turns and twisted into a variety of shapes, which Yang said is "remarkable for a crystal that is brittle in its bulk form."

According to the researchers, while the nanoribbon waveguides can be coupled together to create optical networks that could serve as the basis of miniaturized photonic circuitry, the ribbons need to be in close proximity, preferably in direct physical contact, to enable an efficient transfer of light between them (see Figure 1).

Yang said, "We tested various coupling geometries and found that a staggered side-by-side arrangement, in which two ribbons interact over a distance of several micrometers, outperforms direct end-to-end coupling."

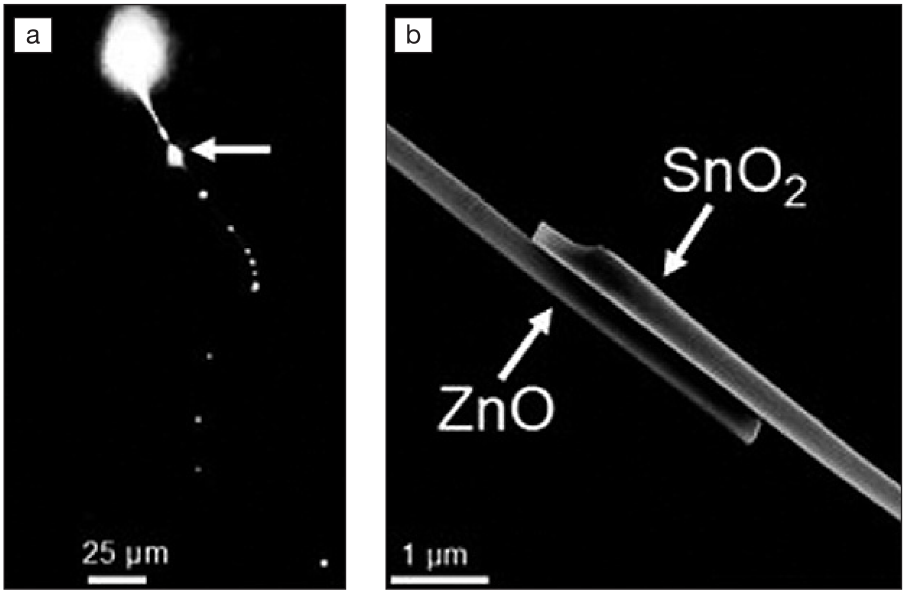

Figure 1. (a) A zinc-oxide nanowire laser is pumped with light, which is channeled into a tin-oxide nanoribbon at a junction between the two materials and guided through the rest of the ribbon's length; (b) an electron microscope image of the junction between wire and ribbon.