Nanowire Thermoelectric Devices

Efficiencies would be considerably greater than those of conventional thermoelectric devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

Nanowire thermoelectric devices, now under development, are intended to take miniaturization a step beyond the prior state of the art to exploit the potential advantages afforded by shrinking some device features to approximately molecular dimensions (of the order of 10 nm). The development of nanowire-based thermoelectric devices could lead to novel power-generating, cooling, and sensing devices that operate at relatively low currents and high voltages.

Recent work on the theory of thermoelectric devices has led to the expectation that the performance of such a device could be enhanced if the diameter of the wires could be reduced to a point where quantum confinement effects increase charge-carrier mobility (thereby increasing the Seebeck coefficient) and reduce thermal conductivity. In addition, even in the absence of these effects, the large aspect ratios (length of the order of tens of microns ÷ diameter of the order of tens of nanometers) of nanowires would be conducive to the maintenance of large temperature differences at small heat fluxes. The predicted net effect of reducing diameters to the order of tens of nanometers would be to increase its efficiency by a factor of ≈3.

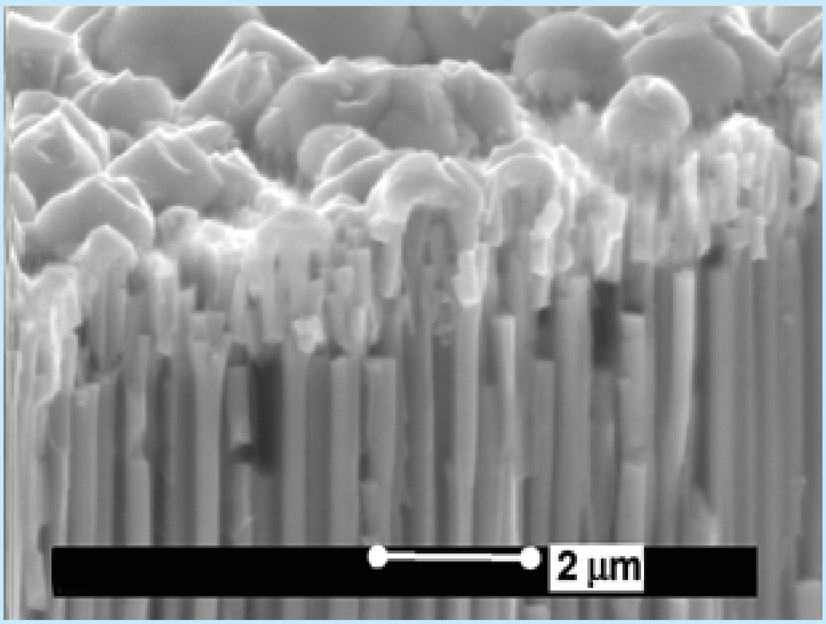

Figure 1. **Thermoelectric Nanowires of n-Type Bi_2Te_3** with a diameter of 10 nm and length of 40 µm were grown in an alumina template. The thermoelectric material was allowed to grow onto the top of the template, forming caps that make contact with each other. In a production version, the overgrowth and part of the template would be polished away and metal contacts deposited as in Figure 2.

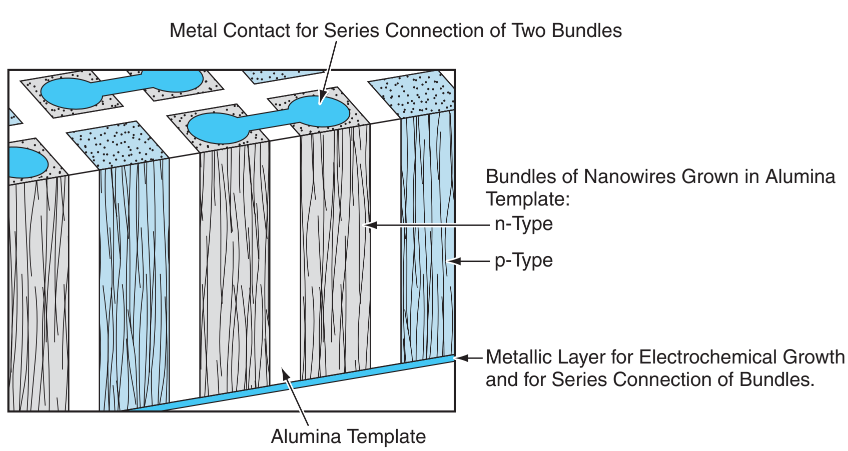

Figure 2. **Bundles of Nanowires** would be grown electrochemically in an alumina template. The nanowires in each bundle would be electrically connected in parallel and the bundles electrically connected in series by metal contacts grown electrochemically on the ends of the bundles.

Nanowires made of thermoelectric materials and devices that comprise arrays of such nanowires can be fabricated by electrochemical growth of the thermoelectric materials in templates that contain suitably dimensioned pores (10 to 100 nm in diameter and 1 to 100 µm long). The nanowires can then be contacted in bundles to form devices that look similar to conventional thermoelectric devices, except that a production version may contain nearly a billion elements (wires) per square centimeter, instead of fewer than a hundred as in a conventional bulk thermoelectric device or fewer than 100,000 as in a microdevice.

It is not yet possible to form contacts with individual nanowires. Therefore, in fabricating a nanowire thermoelectric device, one forms contacts on nanowires in bundles of the order of 10-µm wide. The fill factor for the cross-section of a typical bundle is about 1/2. Nanowires have been grown in alumina templates with pore diameters of 100 and 40 nm. To ensure that every pore in a template is filled with a nanowire, one allows the thermoelectric material to grow onto the top of the template (see Figure 1), then polishes the template back to a level where every pore is filled.

After polishing, contacts on bundles of nanowires can be made by electrochemical deposition of nickel or another suitable metal. Figure 2 depicts a proposed configuration for growing bundles of n- and p-type nanowires, electrically connecting the wires of each bundle in parallel, and electrically connecting successive bundles in series to make a thermoelectric device. The bundles would be suitably masked to allow electrochemical growth only in the desired areas. For a given bundle, the metal caps would be made to electrochemically grow out from the exposed ends of the nanowires, eventually merging to form one metal contact.

This work was done by Alexander Borshchevsky, Jean-Pierre Fleurial, Jennifer Herman, and Margaret Ryan of Caltech for **NASA's Jet Propulsion Laboratory**. *FFurther information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-30210, volume and number of this NASA Tech Briefs *issue, and the page number.*