Electrodeposited Thermoelectric Nanowires

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One-dimensional structured materials, such as nanowires and nanotubes (NTs), are the primary building materials for nano-electronics and sensors. During the past several years, approaches for fabricating thermoelectric devices on the micrometer scale have been studied for applications in cooling and for power generation [1].

Thermoelectric devices may be used both for generation of primary power from heat sources and by harvesting waste heat for additional power generation. In addition, as electronic devices become smaller and electronics are positioned in greater density, demand for increased cooling may develop.

Recent work in thermoelectric theory has predicted that the efficiency of a thermoelectric device can be increased by a factor of ~3 if the leg diameter can be decreased to a size at which quantum confinement effects will occur [2, 3]. Thermoelectric nanowire of ~ 10nm diameter will increase performance efficiency through enhanced charge carrier mobility by quantum confinement effects. In addition, the high aspect ratio of the wires (10 nm x 20-50 μm) will assist in maintaining a large ΔT at low heat flux.

Nanowires have been grown in alumina templates with pore diameters of 100 nm and 40 nm. In order to make high efficiency devices, templates with pore diameters of 5–15 nm are necessary. Templates can be made by anodizing aluminum; pore size can be controlled by adjusting the anodization conditions, including applied potential, current density, and electrolyte composition. Templates with pore sizes from 12 to 100 nm have been made, as shown in Figure 1.

For use in devices, the nanowires can be electrodeposited in templates as bundles of wires 10-50 μm in diameter, with each nanowire distinct, and contacted in parallel. Electrodeposition has many advantages over other deposition technologies, including precisely controlled room temperature operation open to the atmosphere, low energy requirements, fast deposition rates, and inexpensive materials. It is simple to scale-up with easily maintained equipment. Figure 2 shows a top view of 50 μm diameter bundle; the template was masked using parylene. Devices under study based on nanowire elements include thermoelectric generators and coolers and microcalorimeters.

This paper will discuss electrochemical deposition of nanowire semiconductors for thermoelectric applications, fabrication of alumina nanotemplates of 12-100 nm pore diameter, and electronic and thermoelectric properties of nanowires expected to exhibit enhanced properties induced by quantum confinement.

References:
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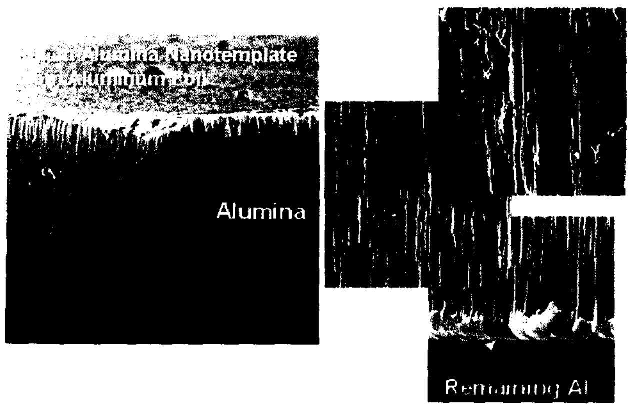

Figure 1. Alumina nanotemplate fabricated by anodizing a 50 μm thick layer of aluminum foil. Pore dimension is approximately 25 nm. Alumina nanotemplate with smaller pore diameter (down to 12 nm) were achieved using high

concentrated sulfuric acid at fixed current density of 100 mA cm^{-2} at room temperature.

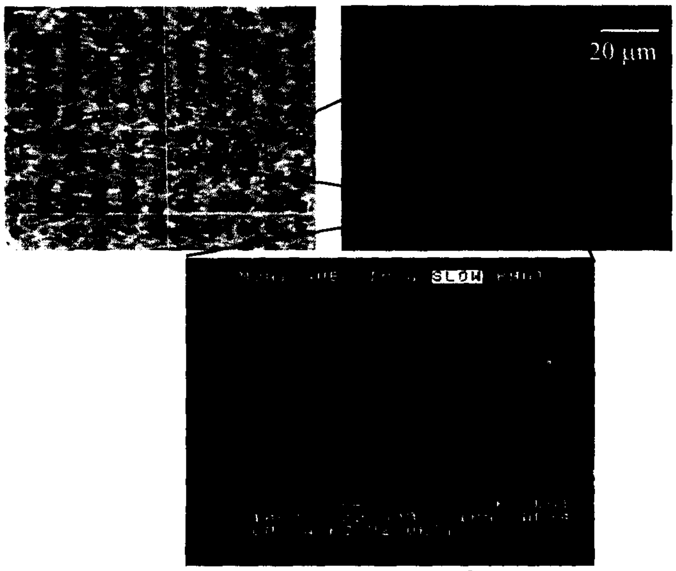

Figure 2. Patterned Electrodeposited Bi_2Te_3 nanowire bundles with pore diameter of 200 nm diameter. After electrodeposition of n-type Bi_2Te_3 nanowires, the sample will be polished to remove over-grown Bi_2Te_3. Then alumina nanotemplate will be patterned again to create opening followed by electrodeposition of p-type $Bi_{2-X}Sb_XTe_3$ nanowires.