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Material science and thermoelectric characterization of Bi2Te3-based TE module

Nancy Yang, R. Nishimoto, J. Chames, A. Gardea, and M. Clift
Sandia National Laboratories, CA

Abstract

Thermoelectric (TE) materials are viable alternatives for power generation and cooling. Skutterudutes, Zintl, SiGe and Bi_2Te_3-based alloys are promising TE materials due to their low thermal conductivity. These TE systems effectively mine power from low level heat sources with minimum moving parts and minimum pollution. TE performance is expressed by figure of merit (ZT) that can be calculated from measured electrical resistivity (ρ), thermal conductivity (κ), Seebeck coefficient (S) and Temperature (T) using the following equation:

$$ZT = \frac{S^2}{\rho\kappa}T$$

At SNL, CA, we are interested in Bi_2Te_3-based alloys for power generation. In order to design a reliable long-lived TE system we have focused on gaining a better insight into the process-structure-TE performance relationship for Bi_2Te_3 based TE alloys. Progress has been made in understanding the mechanical properties of Bi_2Te_3-based alloys, as well as the metallization design/construction, and its effect on material compatibility and integrity of TE module. In addition, the material anisotropy and its implication to TE transport are also being studied.

The study found that the Bi_2Te_3 are extremely weak, $\boldsymbol{\sigma_y}$<200 MPa and brittle. Fracture is often seen initiated at the inter-particle pores, with cracks propagated parallel to the extrusion direction, following the basal plane, and/or the inerparticle boundary (Fig.1). In commercial TE modules, constructed with multiple metallized layers and solder (Fig.2-upper), the Sn-rich solder reacted with Bi_2Te_3 alloys at $\geq 160^oC$ (Fig. 2-lower). In addition, the extruded Bi_2Te_3-based alloys exhibit strong (01-10) texture parallel to the extrusion direction, as evidenced by inverse pole figures from electron backscattered diffraction (Fig. 3). The TE measurements show that electrical resistivity (ρ) increases with texture and decreases with porosity of Bi_2Te_3–based alloy (Fig. 4).

In this talk, we will present and discuss the experimental activities and findings related to material properties, TE transport, and system integrity and compatibility of Bi_2Te_3-based TE modules.

Mechanical behavior

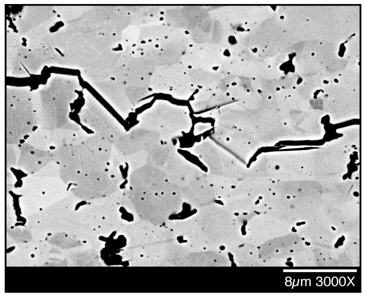

Figure 1: Fracture of the Bi_2Te_3-based TE module is microstructure dependent.

Material-device interaction

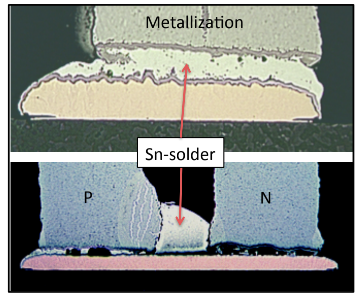

Figure 2: Material compatibility is essential for system integrity and reliability of TE module.

Material anisotropy

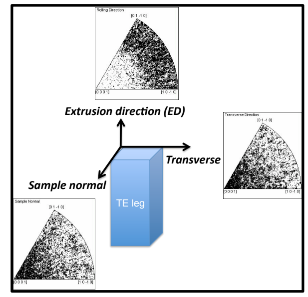

Figure 3: TE transport property of Bi_2Te_3 is texture dependent.

TE property

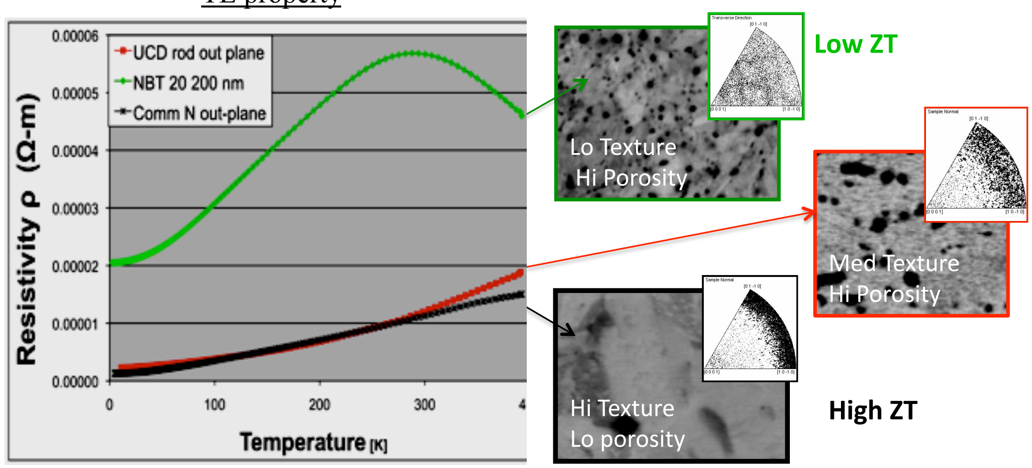

Figure 4: Electrical resistivity is highly dependent of process-induced porosity and texture of Bi_2Te_3-based alloys.