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Study of the Permanent Deformation and Resistivity Changes in Bi_2Te_2 Thermoelectric Alloys

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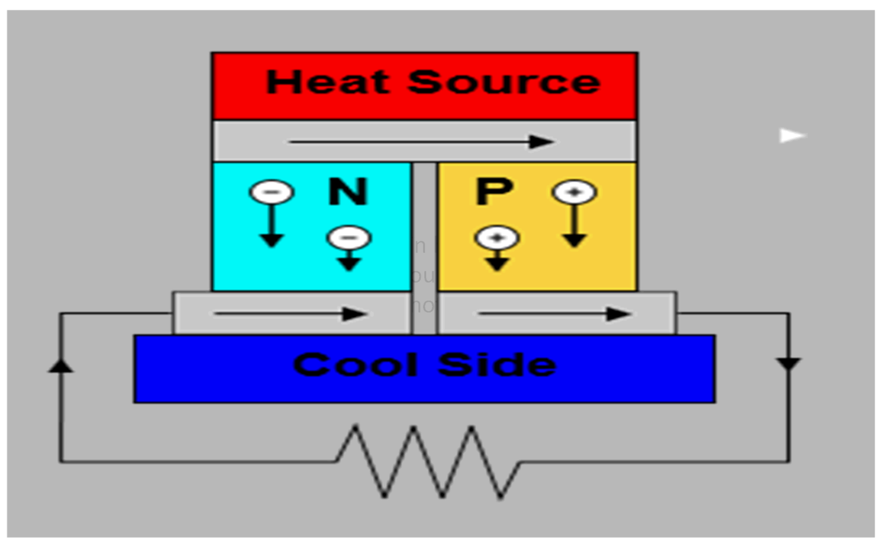

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Abstract

Before Bi_2Te_3 can be used in an industrial setting as a thermoelectric, how it ages must be understood, because previous results (see right side) show that thermally aging the material changes the figure of merit and permanently deforms it. The goal of this project is to determine why they occur, and if they are related or not. This will be done by doing a series of tests before and after a thermal aging process. This will at the very least determine if the phenomena are related.

Introduction

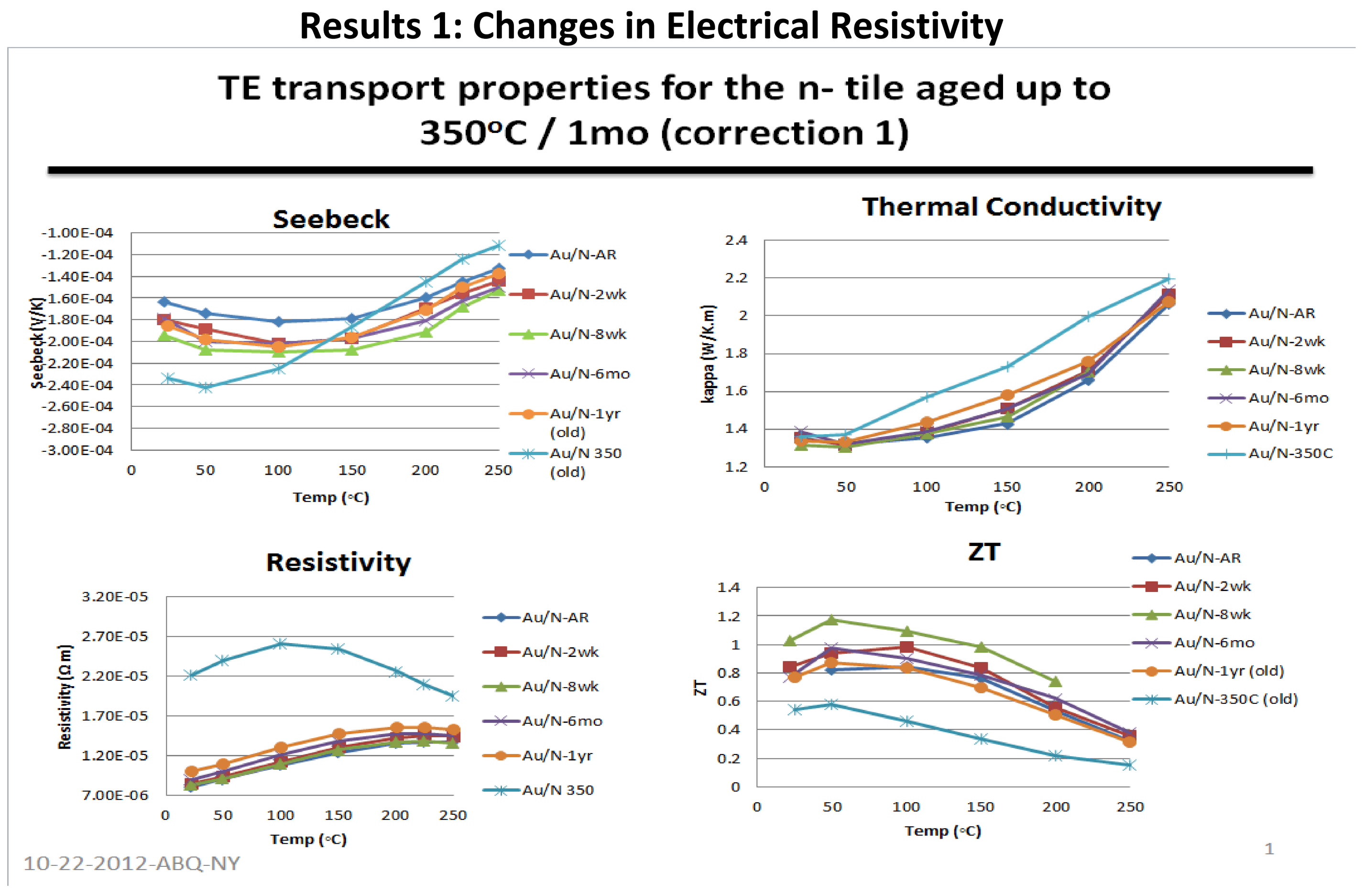
When a temperature gradient is applied to a thermoelectric material, a net migration of charges is induced. This direct conversion of heat into electrical energy without any moving parts could be used to reliably recover lost or wasted heat from chemical processes and automobiles. Currently, Bi_2Te_3 is the most efficient thermoelectric material between 25°C and 150°C.

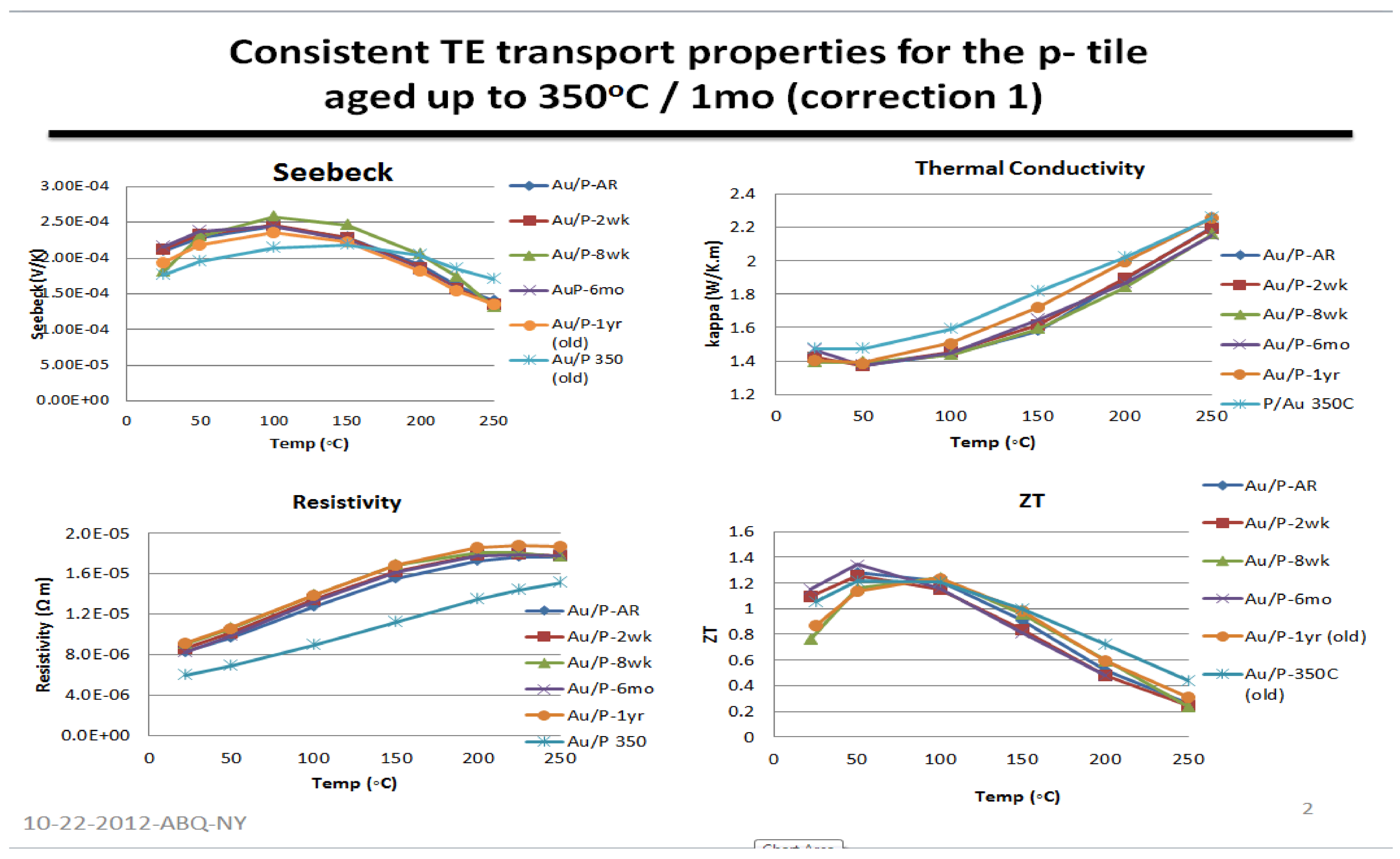
The efficiency of a thermoelectric material is determined by the figure of merit:

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

Where S is the Seebeck coefficient, κ is the thermal conductivity, σ is the electric conductivity, and T is the temperature.

Results 1: Changes in Electrical Resistivity





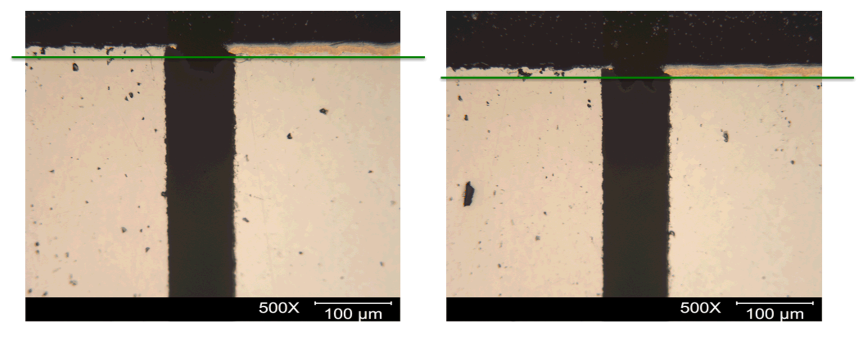
Transport Properties collected by Josh Whaley and Karla R. Reyes.
Thermal aging performed by Jeff Chames and Ryan Nishimoto lead by Nancy Yang.

Discussion 1

The properties of this material did not significantly change below 240°C, even when it was aged at this temperature for several years. However, when the sample was aged above 240°C for 2 months, the electrical resistivity was the only property that changed dramatically, which in turn affected the figure of merit. What is unusual about the electrical resistivity is that it decreases for the p-type, and increases for the n-type.

Observations

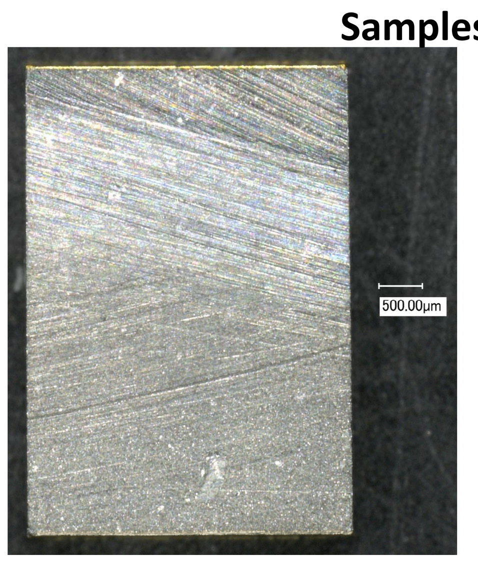
The height of the n-pile appeared to be taller in JPL #10

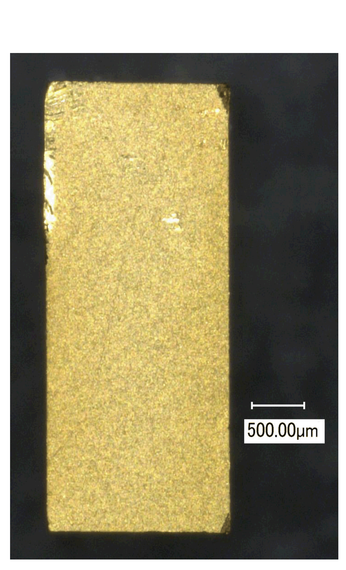


n-type → 399.8 ±0.8 p-type→387.9 ±0.6 difference of 11 microns

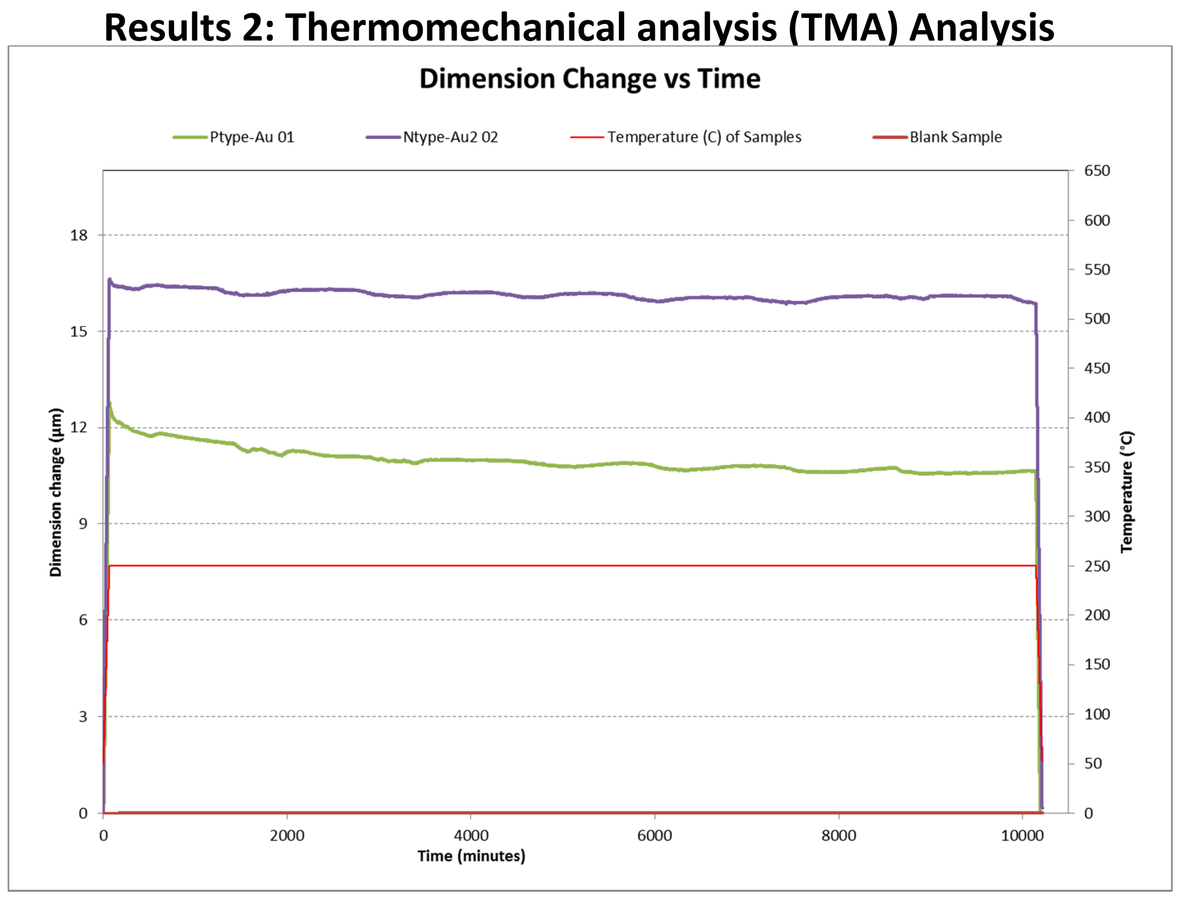
Microscopy study performed by Nancy Yang's team

Samples





Results 2: Thermomechanical analysis (TMA) Analysis



Data collected by April Nissen and Karla R. Reyes

Table 1: Mass, Height and Density Before and After Thermal Analysis

	p-type			n-type		
	Before	After	Difference	Before	After	Difference
Mass (g)	0.2171	0.2171	0	0.2483	0.2483	0
Height (µm)	4848.2	4842	-6.2	4834.9	4834.2	-0.7
Density (g/cm^3)	6.7593	6.773	0.0141043	7.751	7.759	0.007365

Discussion 2

These materials permanently deform after thermal aging, as evidenced by the data above and by the observation photos below. When the samples are initially isothermally aged, they expand, as expected. But as time goes on, they began to shrink in all dimensions. The p-type shrinks more than the n-type. The mass does not change.

Remaining Questions

A lot of different factors affect the electrical resistivity, such as the temperature, the number of defects, the amount of doping, stress, porosity, and phase changes. The Seebeck coefficient is dependent only on the chemical composition and crystal structure of the material, and since it does not change drastically, a phase change or a chemical reaction cannot explain the change in electrical resistivity or the permanent deformation. Current XRD data supports this claim.

The fact that the mass remains constant during the permanent deformation suggests a rearrangement of the matter in the sample: either via a phase change or due to the changes in the number of defects present. Since a phase change has been ruled out via measurements of the Seebeck coefficient, a change in porosity is the most likely explanation. The literature has suggested that there are differences in porosity between the p-type and the n-type, which would explain why one shrinks more than the other. Optical microscopy images (see left), seem to suggest this hypothesis as well.

Of course, this is assuming that the permanent deformation is independent of the electrical resistivity changes. Upcoming experiments will determine whether or not the problems are coupled.

On-going Experiments

A p-type and a n-type sample will have the following measured/performed on them:

- Electrical resistivity
- Porosity
- Contact resistivity
- Seebeck Coefficient
- X-Ray diffraction (XRD)
- Optical Microscopy

They both will then be thermally aged for a week at 250°C during thermomechanical analysis, and then undergo the same tests and measurements that were listed above.

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