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Transport Properties Characterization of Thermoelectric Materials

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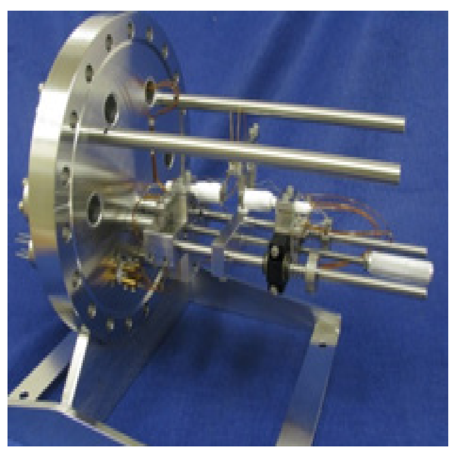

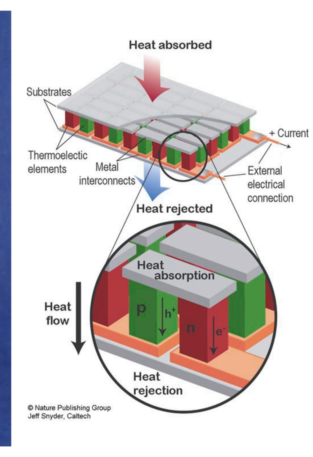

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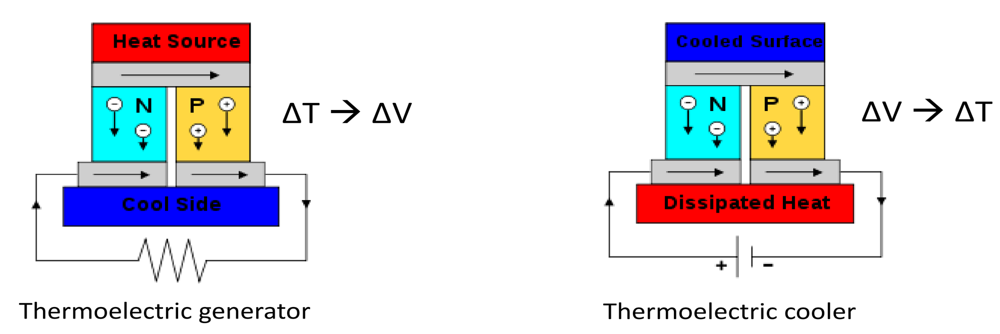
Abstract

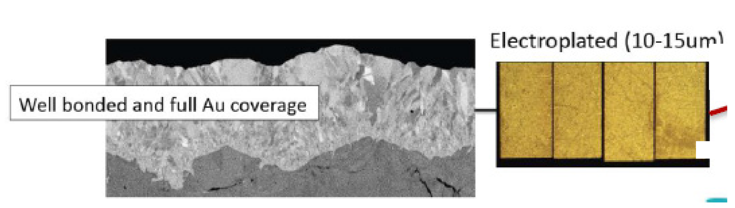
Thermoelectrics (TE) describe materials that either change temperature from an electric potential or generate electrical current from a temperature difference. They have potential applications for power generation, refrigeration, and generating electricity from processes with waste heat. However, TE materials suffer from stability issues at high temperatures and long time periods. This project analyzes the transport properties of Bi_2Te_3 alloys that have been aged for varying time periods. The thermoelectric figure of merit (ZT), which describes the efficiency of a TE system, was found by measuring the seebeck coefficient, thermal conductivity, and resistivity of the samples. The contact resistance was also measured to determine the materials' resistances. The relationship between ZT and aging time was determined. This relationship provides information on how these materials can maintain their transport properties over time and reveal if these formulations are fit for long-term use at elevated temperatures.

Introduction

Thermoelectric (TE) materials are currently used for niche applications in heating and cooling, but have the potential to be used in other systems as a way to increase efficiency by taking advantage of waste heat to generate electricity.



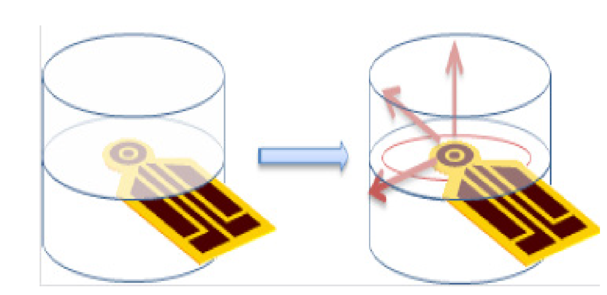
Gold, a good electrical conductor, was electroplated to reduce contact resistance and improve the efficiency. However, the gold tends to diffuse into the Bi_2Te_3 alloys and the transport property effect has been investigated. This effect is seen at elevated temperatures and extended time periods, leading to a loss in stability in TE devices.



The transport properties after aging will be studied to determine how gold diffusion affects the efficiency of TE devices. The results of this investigation will be used to determine the design and material specifications needed to create TE modules that will function at elevated temperatures for long periods of time.

Methods

Thermal Conductivity: a sensor generates heat and measures the change in temperature as a function of time to measure the thermal transport properties of the material.



Seebeck Coefficient & Electrical Resistivity: Seebeck measured by applying a temperature gradient across the material and measuring the voltage generated. Resistivity is measured by applying a voltage and recording the current.

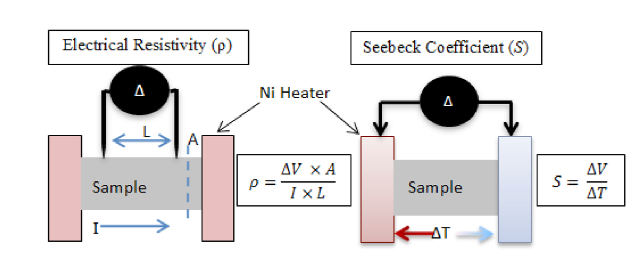
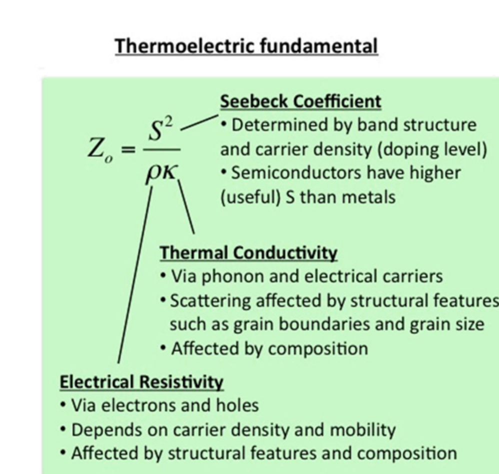
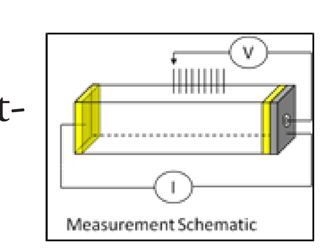
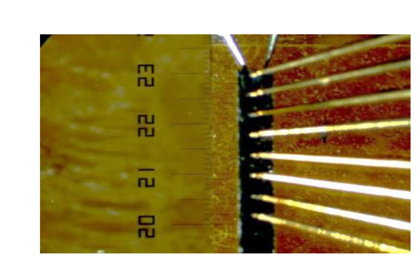


Figure of Merit (Z): S is the Seebeck Coefficient, κ is thermal conductivity, and ρ is electrical resistivity. The thermoelectric figure of merit can then be solved using the right eqn. Z evaluates material's efficiency. Changes in these transport properties and the ZT were compared across different aging periods.



Contact Resistance: current is injected through the metalized ends and the voltage is measured along several points on the top of the sample.

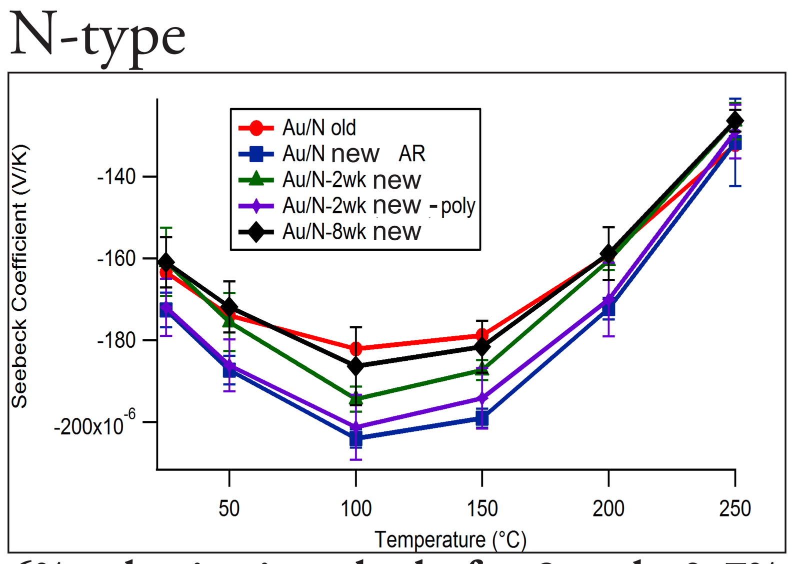




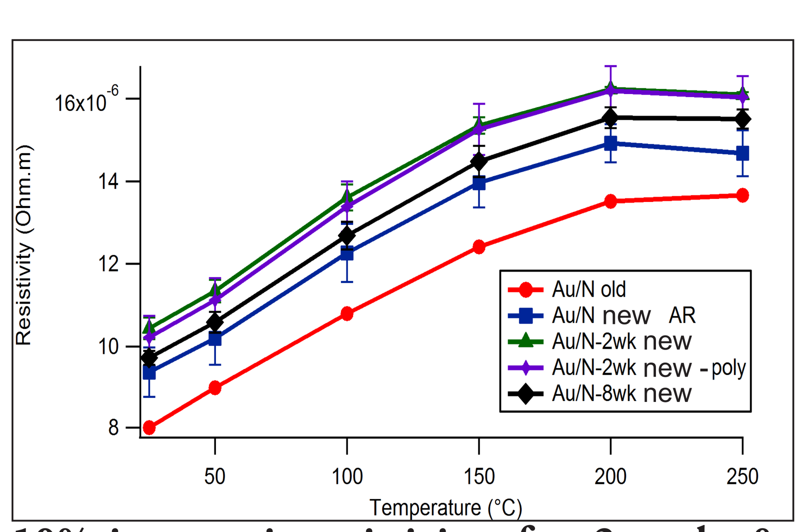
Results

EXPLANATION OF LEGEND
"Au/N-2wk new-poly"
Au = what element is diffusion barrier
N = what type of alloy is it (P or N)
2wk = how long it was aged
AR = as received (no aging)
old/new = un/modified with diffusion barrier
poly = polymer b/twn P and N legs

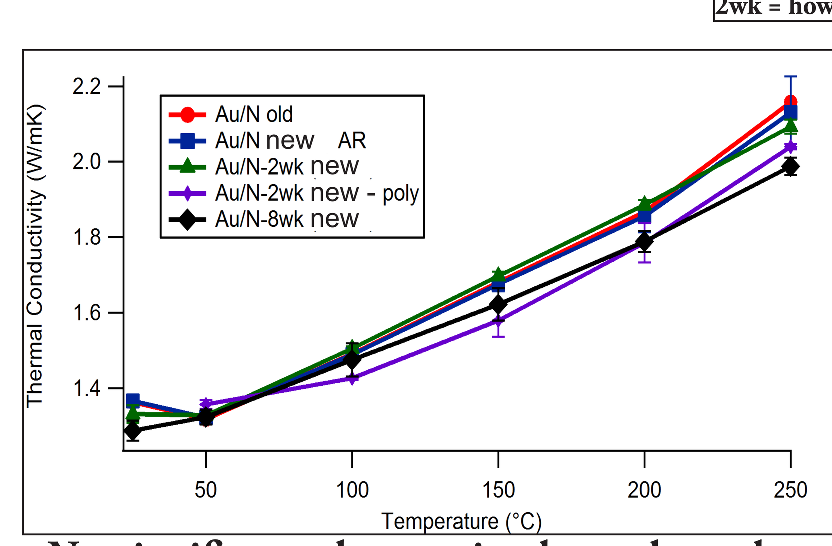
N-type



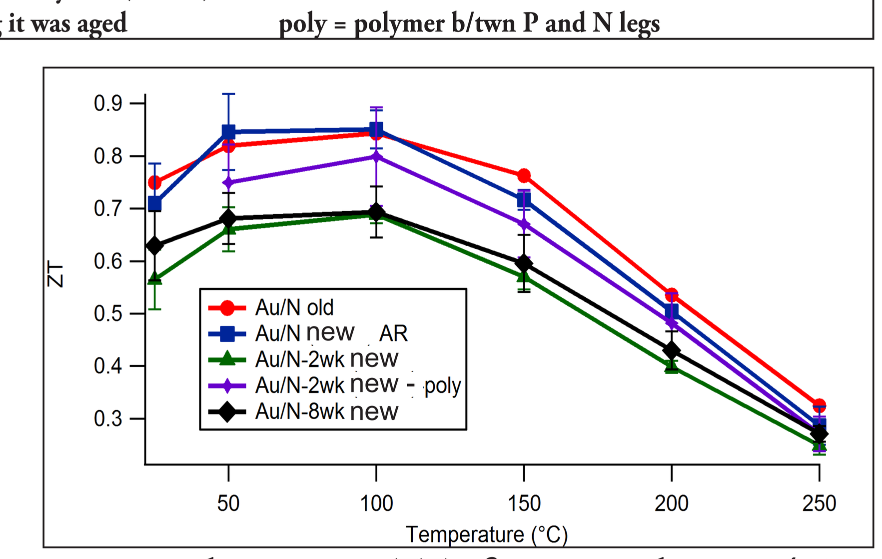
6% reduction in seebeck after 2 weeks & 7% reduction after 8 weeks compared to AR



10% increase in resistivity after 2 weeks & 7% increase after 8 weeks compared to AR

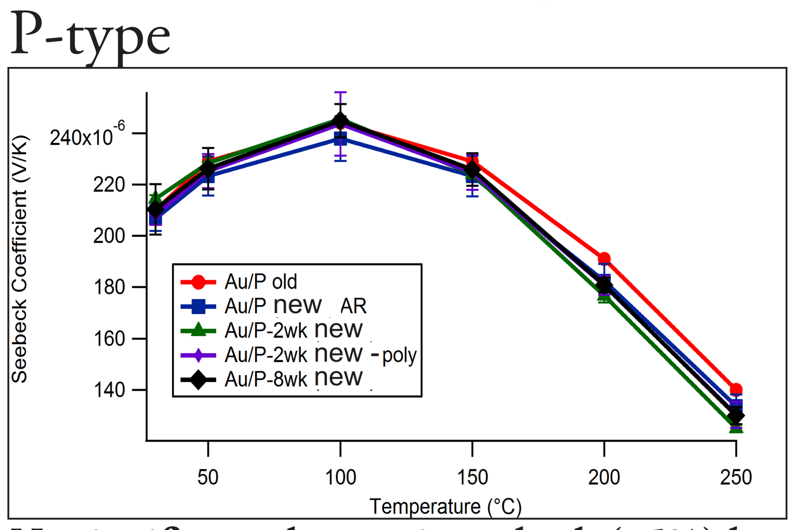


No significant changes in thermal conductivity (<5%) between aged and AR

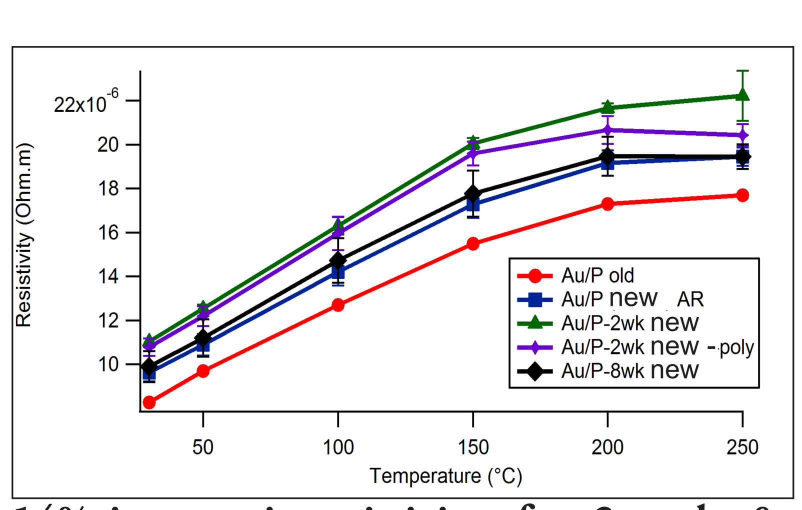


20% reduction in ZT after 2 weeks & 14% reduction after 8 weeks compared to AR

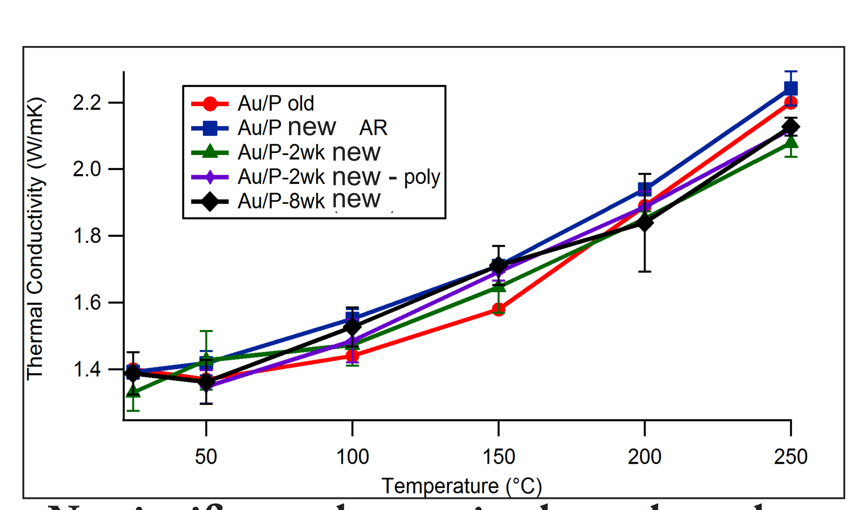
P-type



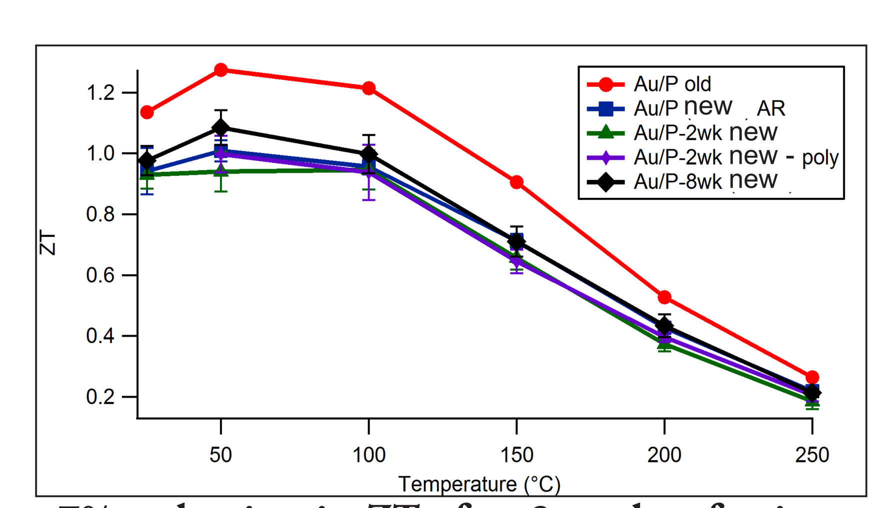
No significant changes in seebeck (<5%) between aged and AR



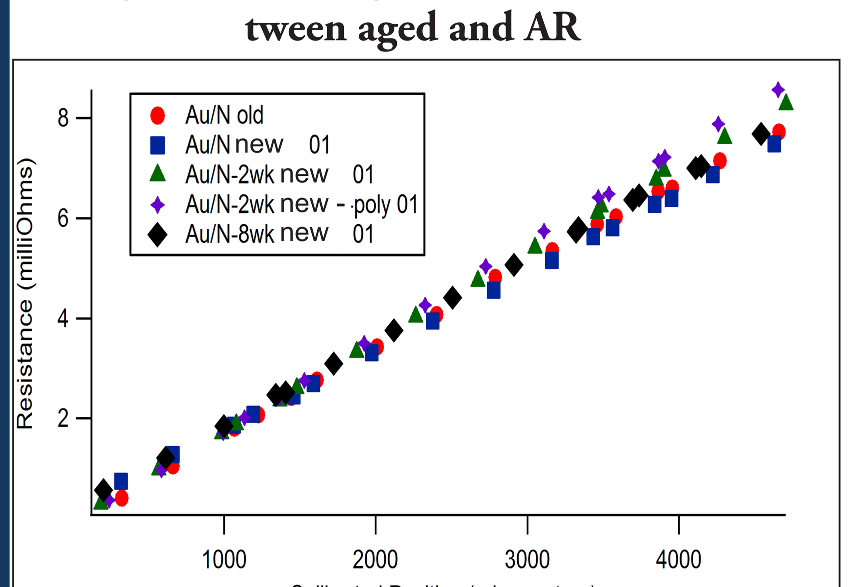
14% increase in resistivity after 2 weeks & 6% increase after 8 weeks compared to AR

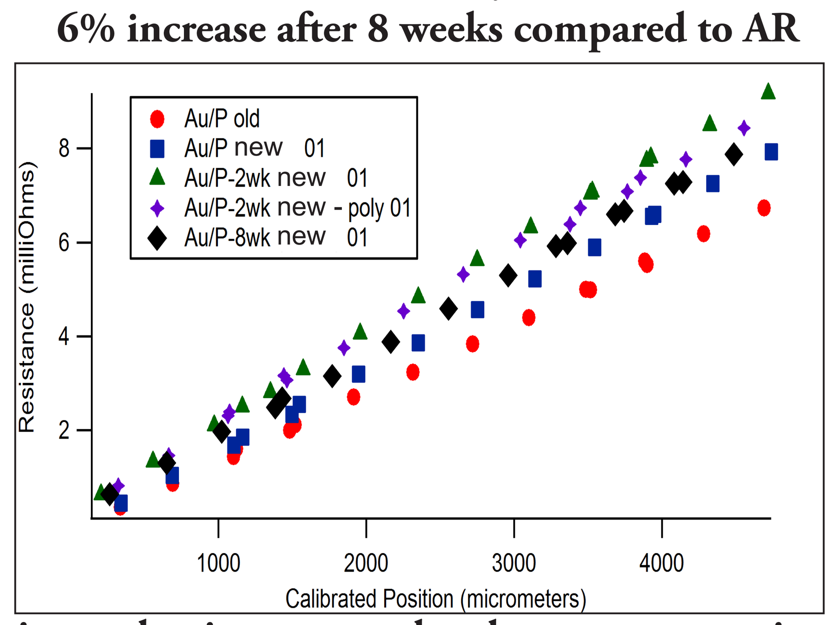


No significant changes in thermal conductivity (<5%) between aged and AR



7% reduction in ZT after 2 weeks of aging compared to AR





Slope of resistance mapping related to resistivity and y-intercept related to contact resistance of samples. Verifies the resistivity values determined from custom instrumentation.

Discussion

- General decrease in ZT after aging
- Change in transport properties mostly from resistivity
- Hypothesis: grain size increases with aging and causes increase in resistivity

Currently in Progress:

- Using microscopy to interpret changes in TE performance
- Measuring transport properties of TE materials with temperature gradient
- Cross section microscopy to measure grain sizes to test hypothesis
- Currently aging TE material for longer period of time

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