New High Efficiency Thermoelectric Materials for Thermal Energy Harvesting

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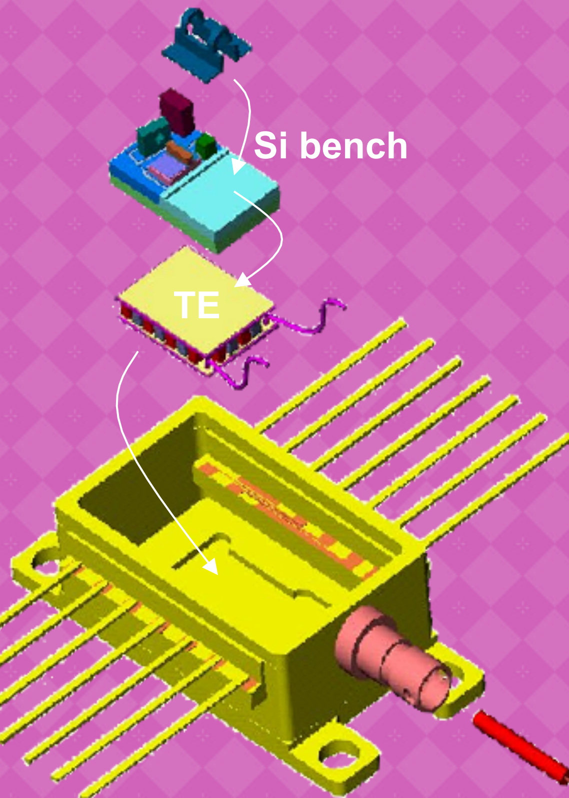
OUTLINE

- Thermoelectric Effects
- Thermoelectric Refrigeration
- Figure of Merit (ZT)
- Direct Thermal to Electric Power Generation

APPLICATIONS

Water/Beer Cooler

Cryogenic IR Night Vision



Laser/OE Cooling

Electronic Cooling

Cooled
Car Seat

THERMOELECTRIC APPLICATIONS

- Power Generation
  - Radioisotope Thermal Generators (RTGs)
    - Cassini, Voyager missions
    - Lifespan of more than 14 years
  - Waste Heat Recovery
    - Large scale – Power Plants
    - Small scale - Automobiles

THERMOELECTRIC APPLICATIONS

- Active Cooling/Warming
- Localized cooling
  - CPUs
  - Biological specimens
- Commercial Coolers/Warmers
- Luxury Vehicles – Cool/Warm Seats

THERMOELECTRIC (TE) EFFECTS

- Figure of Merit:

$$ZT = \frac{\alpha^2 T}{\rho(\kappa_e + \kappa_g)}$$

α– Seebeck Coefficient

ρ– Electrical Resistivity

κ– Thermal Conductivity

κe – Electronic ≈ L_0T/ρ (W-F relation)

κg – Lattice

EXPERIMENTAL SET UP AND PROCEDURES

- To begin the experiment, we first had to sandpaper the metal that held the samples in place. This eliminated the amount of impurities that could be found within the sample. Our sample was a bulk nanograined bismuth antimony telluride powder. Then the following steps were taken:
- Nanopowders were created using ball milling of bulk p-type bismuth,antimony,telluride (BiSbTe) alloys.They were placed in a jar with balls inside of an argon filled glove box to prevent oxidation.
- The jar of nanopowders was loaded into the ball mill machine and processed for 18 runs at 90 minutes each.

HYDROGEN REDUCTION

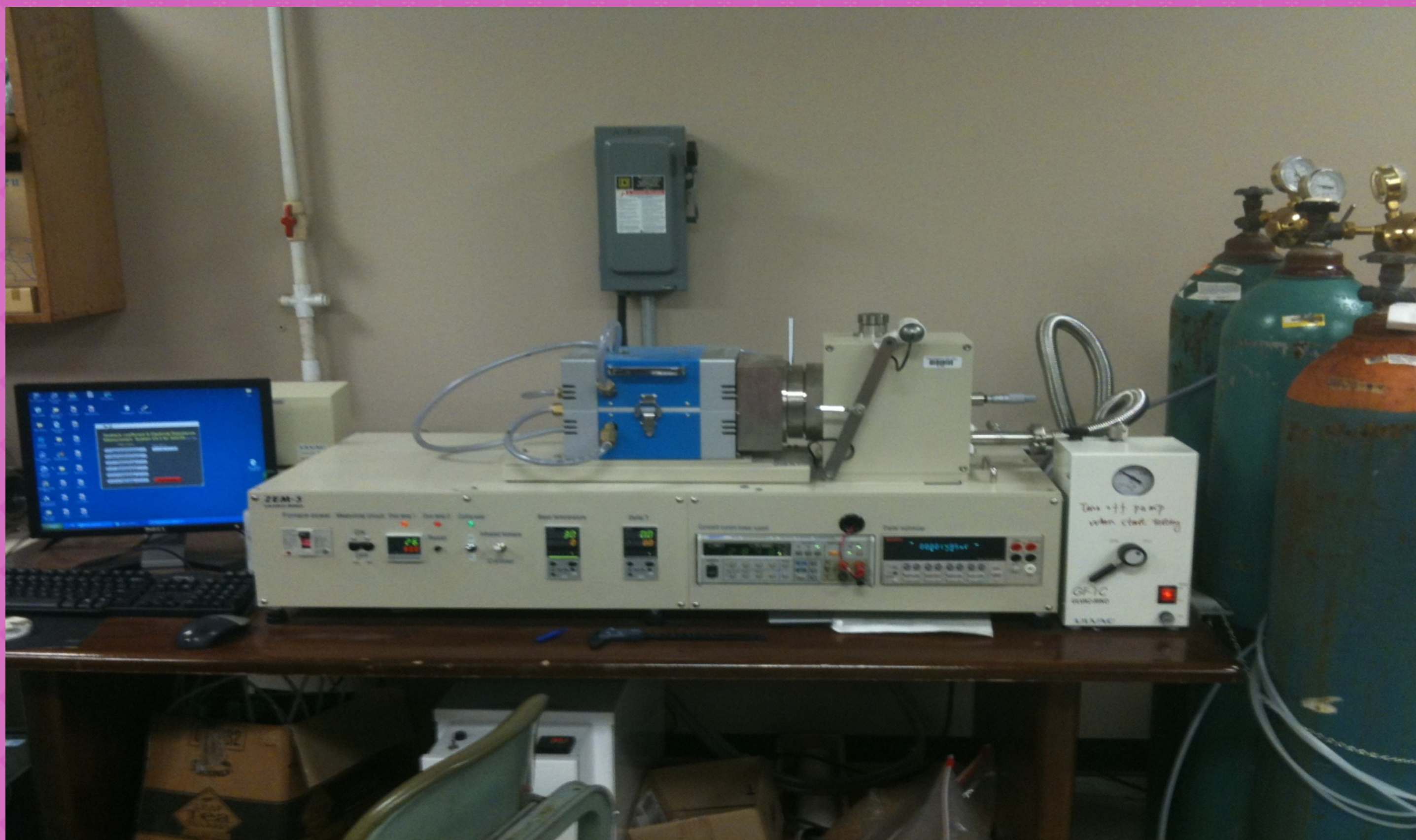
The powder was then put through a hydrogen reduction process to prevent further oxidation for 20 hours with a hydrogen flow rate of 30-40 sccm.

• **0°C**	• **140 min**
• **280°C**	• 120 min
• **280°C**	• 30 min
• **330°C**	• 120min
• **330°C**	• 30 min
• **380°C**	• 300 min
• **380°C**	• 150 min
• **-120°C**	• 7000 min

EXPERIMENTAL SET UP AND PROCEDURES CONT'D

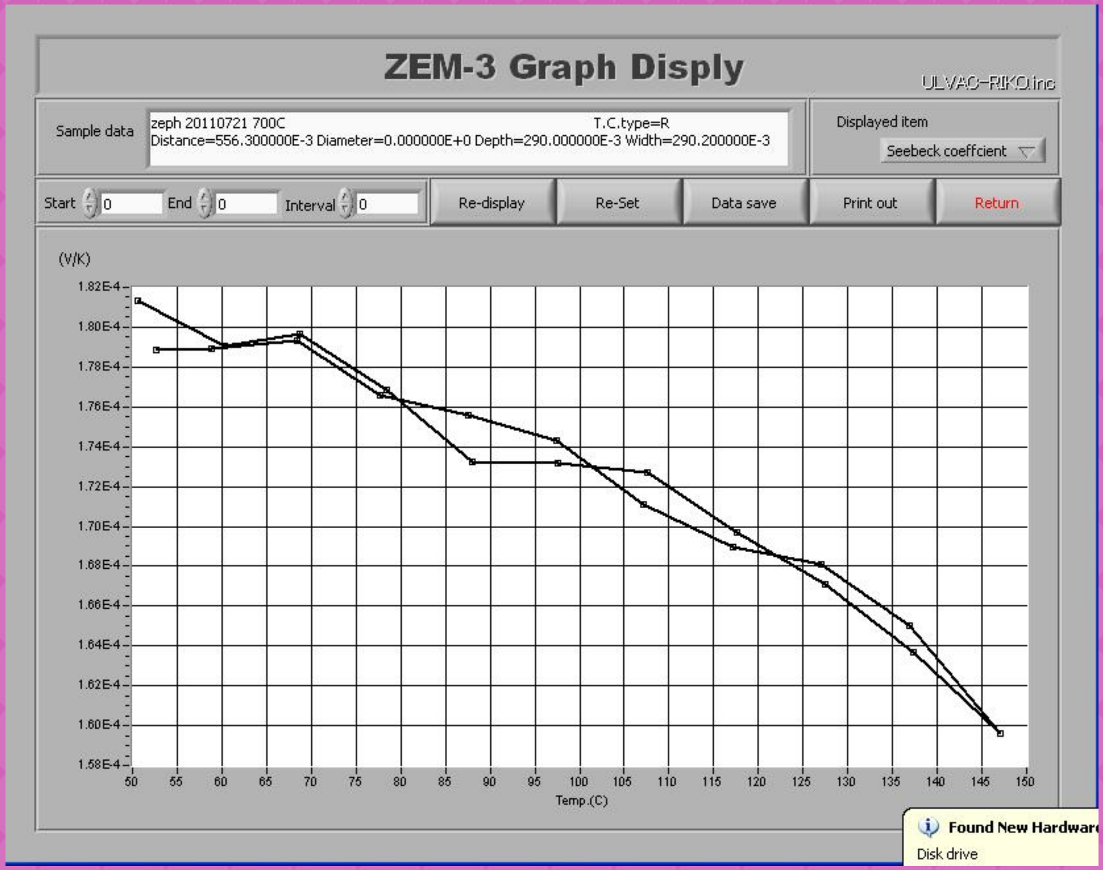
- Once the hydrogen reduction was completed, the nanopowders were loaded into a cold press at 12MPa for one hour to create a disk of 2.25mm.
- The disk was then annealed using the same process as the hydrogen reduction. This was done for 24 hours with the same hydrogen flow rate.
- Once the disk was created, the sample was then cut into bars of 1.6mm by 1.3mm
- The bars were then sandpapered for the Seebeck coefficient, electrical conductivity, and thermal conductivity.

ZEM 3 MACHINE AT LSU



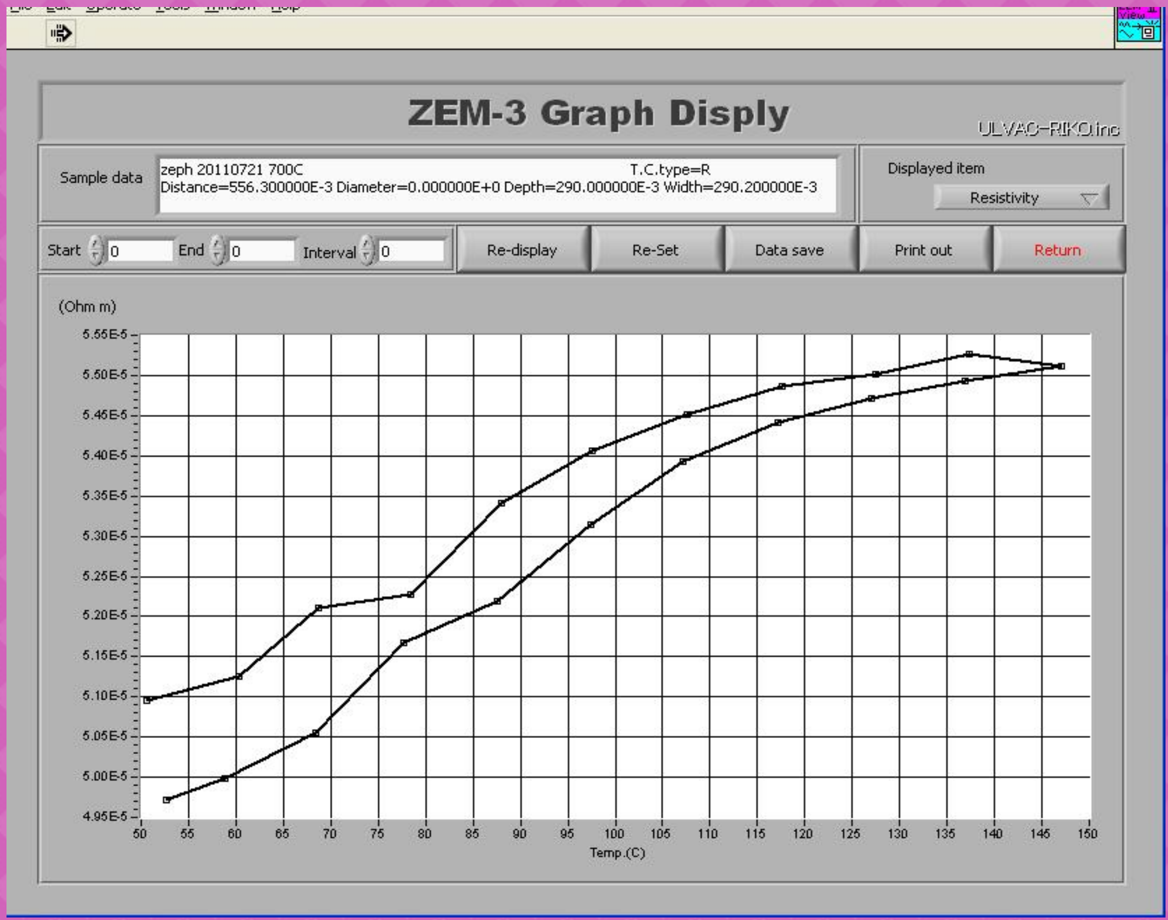
RESULTS

Figure 1. Thermoelectric Seebeck coefficient of nano structured $Bi_{0.5}Sb_{1.5}Te_3$



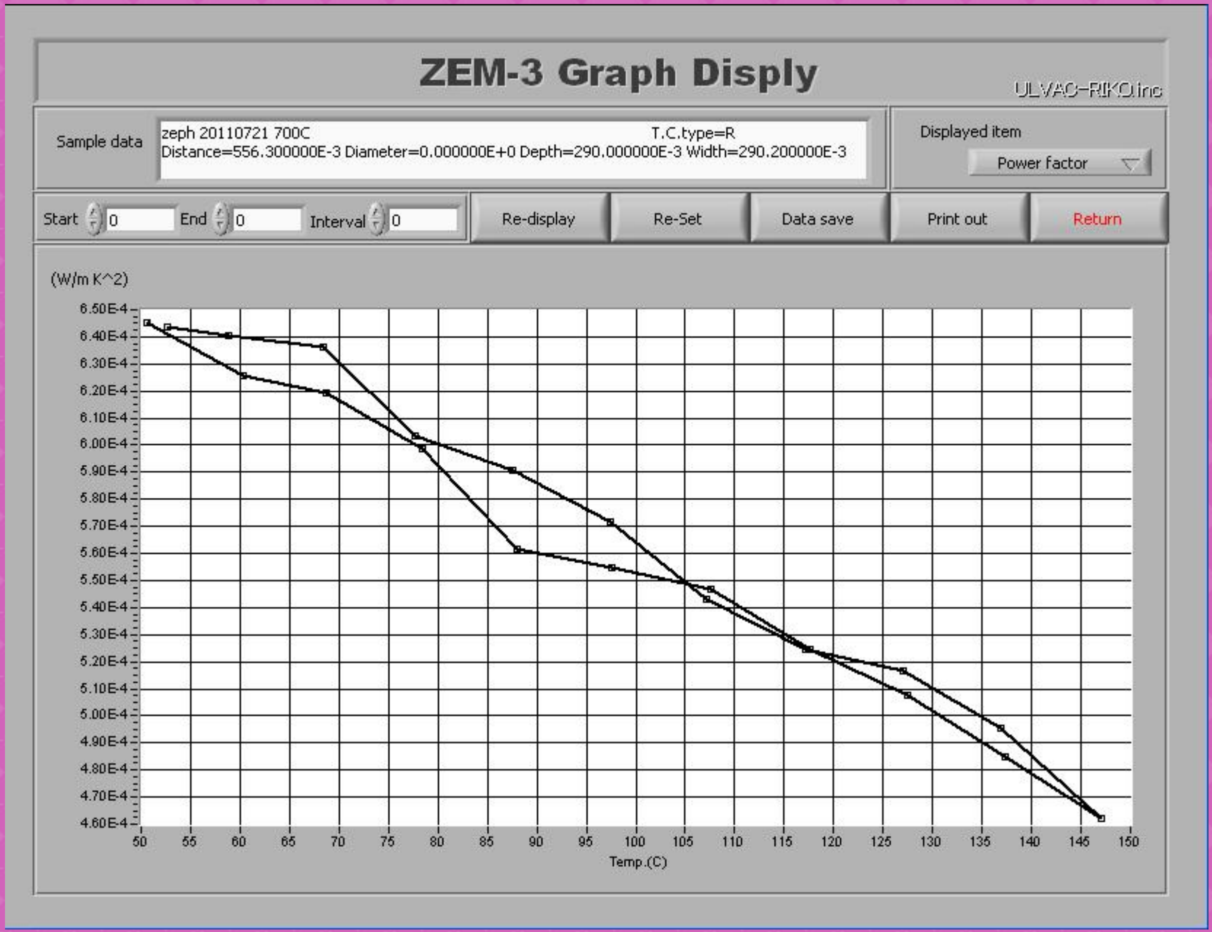
RESULTS

Figure 2. Thermoelectric resistivity of nano-structured $Bi_{0.5}Sb_{1.5}Te_3$



RESULTS

Figure 3. Thermoelectric power factor of nano- structured $Bi_{0.5}Sb_{1.5}Te_3$



DISCUSSION

In order to investigate the thermoelectric properties, the Seeback coefficient, electrical resistivity and power factor dependence of temperature were obtained with the accuracy instrument ZEM-3 system. After doing the average of the data belong to delta temperature 50°C to 75° C respectively, the Seeback coefficient *S* (Fig.8) of the nanostructured alloyed sample is drawn. The function between *S* and temperature *T* shows that the value of Seeback coefficient will decrease along with the increasing temperature. The maximum value which is about 178μV/K to 180 μV/K appears in the range being above 50℃ and below 100℃. The characterization result of the electrical resistivity ρ of the sample is also shown in Fig.9. Being versus temperature, the changing discipline is similar to the one about the Seeback coefficient. However, the value reaches to the highest one of about 4.97×10^{-5} Ωm to 5.13×10^{-5} Ωm from 50 ℃ to 75 ℃. It has been seen clearly that the temperature dependence of the power factor[5] of which value is defined by S^2/ρ (Fig.10). Around 55℃, the power factor is about 6.45×10^{-4} W/mK^2 , which is the extramum of the curve.

CONCLUSION

- From the above results discussions, we have applied the ball milling, cold press and heat treatment techniques to make progress on the way to synthesize high figure of merit (*ZT*) nanostructured materials because it closely dependents on the value of power factor. The future work includes testing for the thermal conductivity of the sample as well as XRD and DSC testing. Obtaining high thermoelectric properties materials is foreseeable. The process, by using elemental shots, is significantly simplified in comparison to using Bridgman method[2]. The mechanical way to get the alloy is also economy and environmentally.

REFERENCES

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- “Structure Study of Bulk Nanograined Thermoelectric Bismuth Antimony Telluride”, Nano Letters, Volume 9 No 4 1419-1422 (2009)
- “High Thermoelectric Performance of Nanostructured Bismuth Antimony Telluride Bulk Alloys”, Bed Poude, Science 320, 634 (2008)

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