OPTIMUM SINTERING METHOD AND TEMPERATURE FOR COLD COMPACT BISMUTH TELLURIDE PELLETS FOR THERMOELECTRIC APPLICATIONS

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ABSTRACT

We propose to prepare low-cost, scalable, quick and highly efficient p-type and bismuth telluride thermoelectric material through cold compaction combined with a sintering process. We perform different characterization techniques such as structural, microscopic, electric, and thermal to determine the efficiency of the final product. Also, Broadband Dielectric Spectroscopy study of the compounds were done to draw a detailed picture of the dielectric properties essential to study the electron transport behavior in the samples.

INTRODUCTION

- Thermoelectricity is conversion of heat into electricity or vice versa.
- **Advantages :** Solid-state, ecofriendly, noise-free and highly efficient operations.
- **Applications**: Power generation, heating, refrigeration, cooling, waste-heat recovery in automobiles and industries, etc.
- Cold compaction is a simple, fast, scalable and low-cost method for making pellets from material powder.
- Bismuth Telluride is a famous low-temperature (300 K-500 K) TE material used for refrigeration and cooling purpose.
- An ideal TE material should have high electrical and low thermal characterization (Phonon Glass Electron Crystal- PGEC effect).

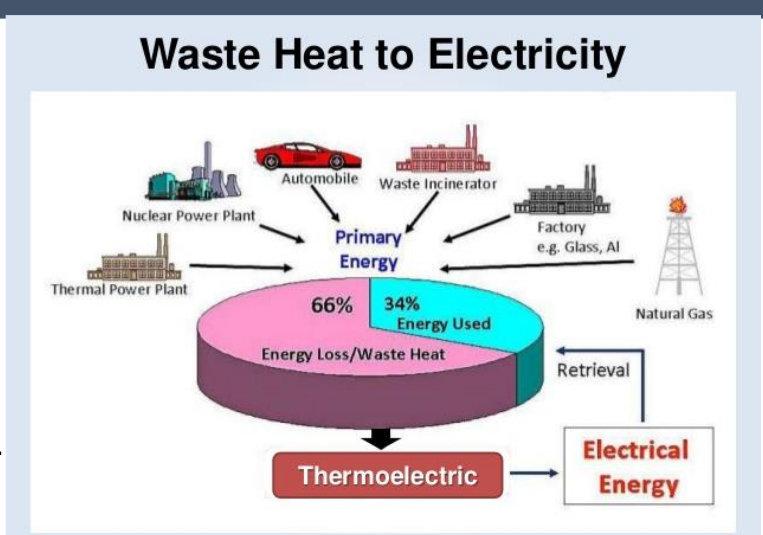

Fig 1. Waste Heat retrieval.

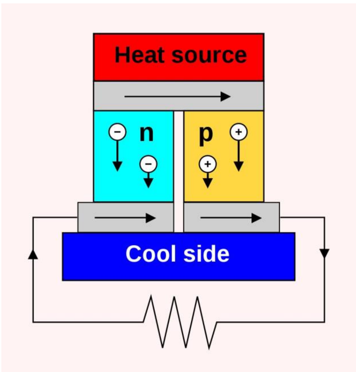

Fig 2. TE principle.

OBJECTIVE

- To investigate the optimum sintering method and temperature that can improve the efficiency of bismuth telluride cold compact pellets, for the thermoelectric applications.

METHODOLOGY

- Prepare p-type and n-type bismuth telluride pellets by Cold Compaction.
- Sinter the samples through three types of sintering: Conventional (Box), Microwave and Tube at 250°C, 300°C, 350°C, and 400°C.

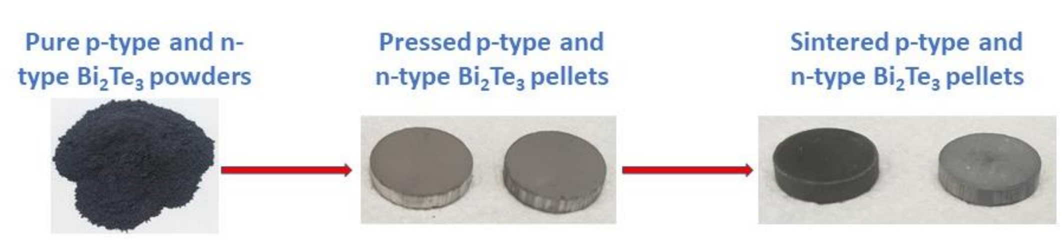

Fig 3. Bismuth telluride sample preparation.

CHARACTERIZATION

1. **Structural (XRD):**

- Sharp peaks can be observed indication high crystallinity.
- Phase shifts and oxides can be observed in samples sintered at 350°C and 400°C.

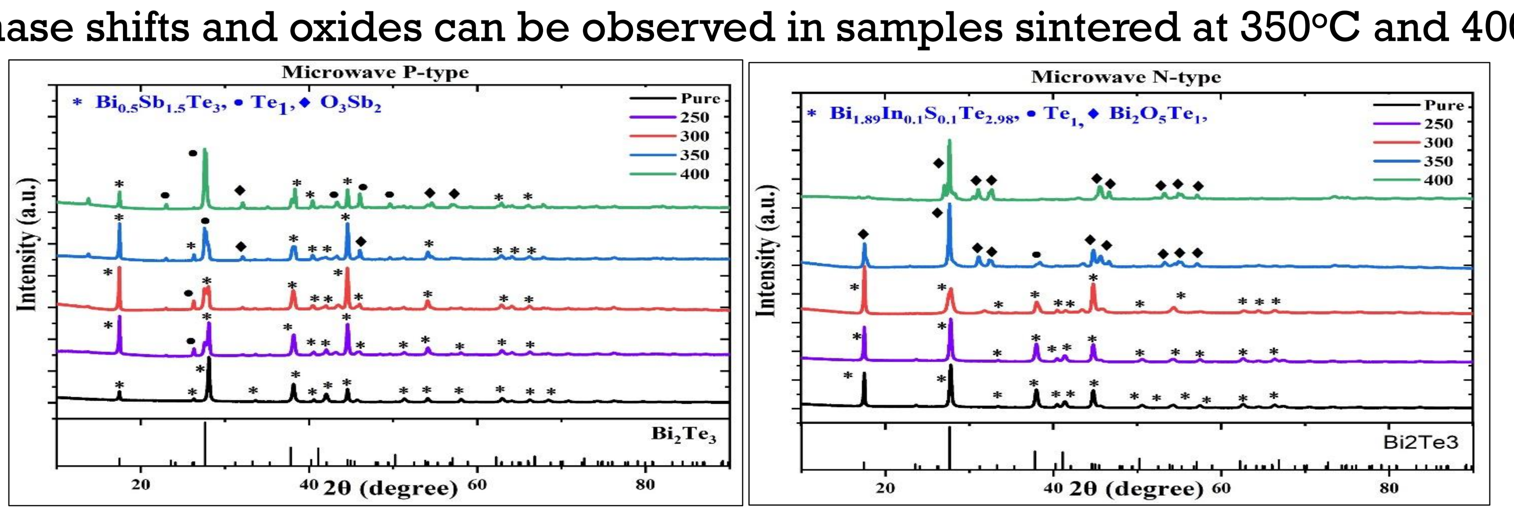

Fig 4. XRD profile of p-type and n-type microwave sintered bismuth telluride samples.

2. **Scanning Electron Microscopy (SEM):**

- Sub-microns of size 500 nm-900 nm and 400 nm-700 nm for p-type and n-type respectively can be observed in the sintered samples.

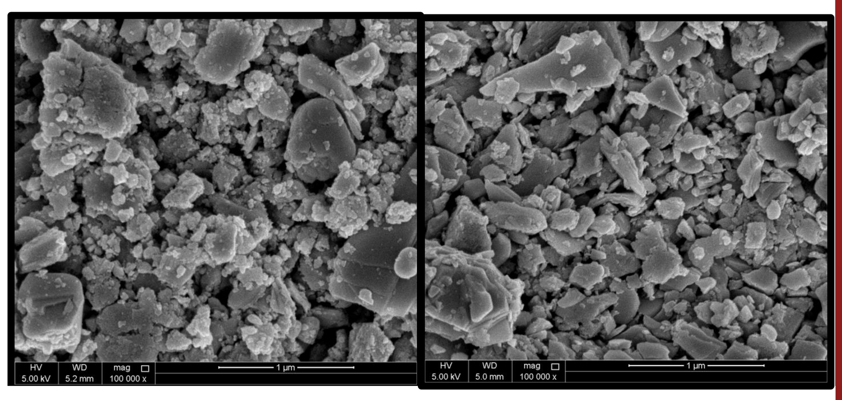

Fig 5. SEM image of p-type and n-type microwave sintered bismuth telluride samples at 300°C.

3. **DC Electrical Conductivity:**

- The DC electrical conductivity improved after sintering and decreased from 130 $S.m^{-1}$ to 15 $S.m^{-1}$ with increase in sintering temperatures.

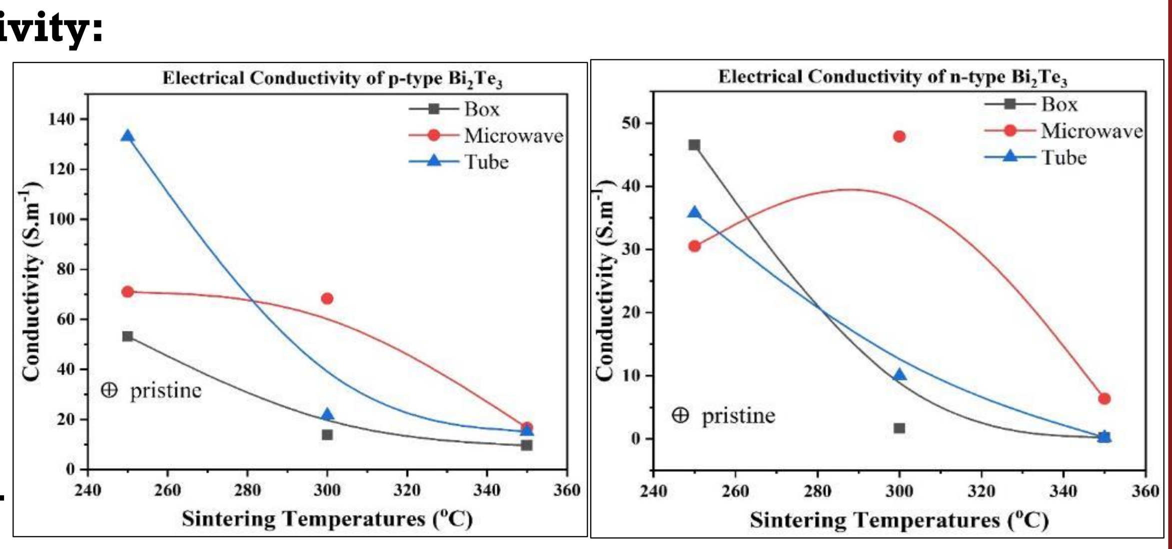

Fig 6. Electrical conductivity variation of p-type and n-type bismuth telluride samples.

CHARACTERIZATION

4. **Thermal Conductivity:**

- The thermal conductivity increased with increase in sintering temperature from 0.4 W/m/K to 1.1 W/m/K.

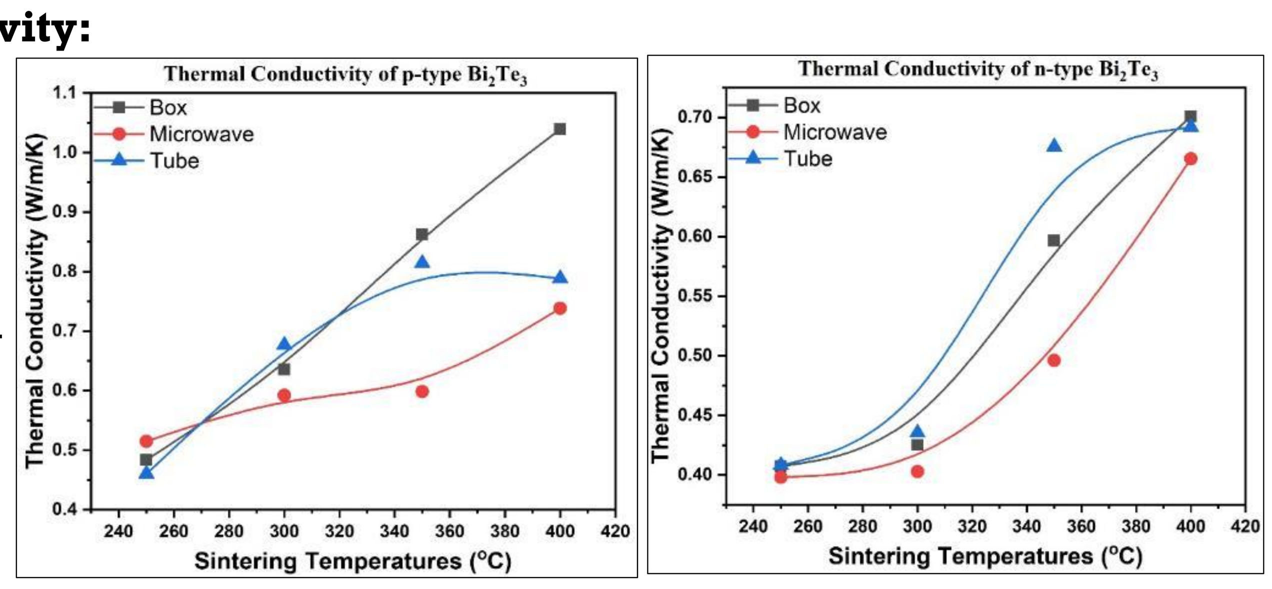

Fig 7. Thermal conductivity variation of p-type and n-type bismuth telluride samples.

BROADBAND DIELECTRIC SPECTROSCOPY STUDY

Broadband Dielectric spectroscopy is a powerful means to investigate dielectric material characterization:

1. **AC Conductivity vs Temperature:** The p-type samples had high electrical conductivity of 1.1 S/cm and beyond 250°C, there has been a sudden spike in the conductivities, probably due to the introduction of defects .
2. **AC Conductivity vs Frequency:** A sudden increase of the conductivity around 1MHz indicates decreased polarization at higher oscillations in the high-frequency dispersive region.

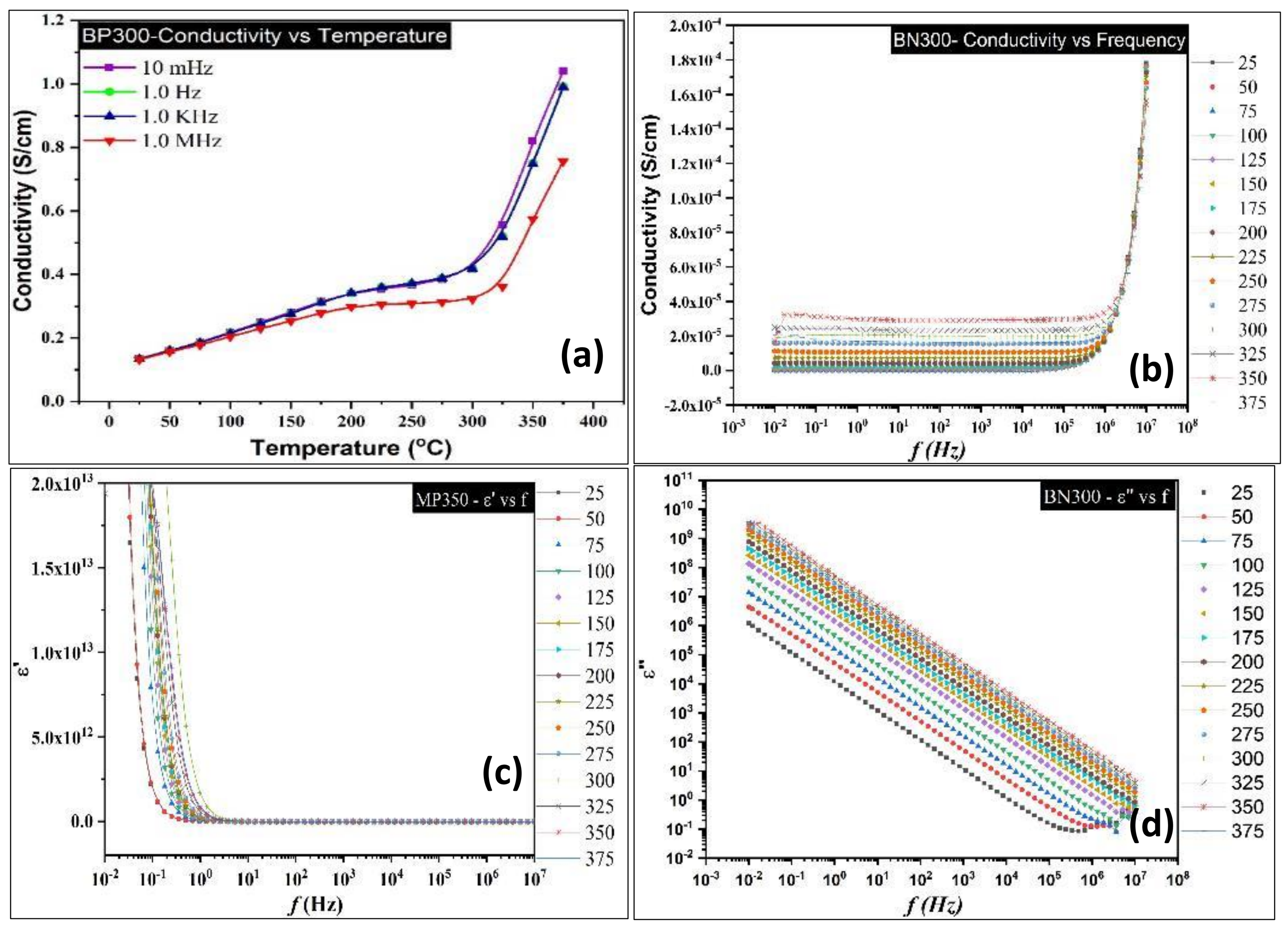

Fig 8. (a) AC conductivity vs temperature, (b) AC conductivity vs frequency, (c) Dielectric permittivity storage vs frequency, (d) Dielectric permittivity loss vs frequency.

3. **Dielectric permittivity storage vs Frequency: T**he dielectric storage decreases with increasing frequency. This may be related to the tendency of dipoles in the sample pellets to orient themselves in line with the applied electric field direction
4. **Dielectric permittivity loss vs Frequency**: The dielectric loss increases with a temperature rise and decreases with an increase in frequency.

CONCLUSION

- We have prepared low cost, quick, scalable and efficient p-type and n-type bismuth telluride thermoelectrics with ultra-low thermal conductivity of 0.4 W/m/K and high electrical conductivity of 130 $S.m^{-1}$
- Microwave furnace had the best electrical and thermal properties at annealing temperatures of 250°C and 300°C.
- Broadband dielectric spectroscopy confirmed the samples had more glass-like behavior.

Sintering Method	Advantages	Disadvantages
Box	• Parallel processing	• High impurity • Long sintering times
Microwave	• Least impurity • Better electrical and thermal characteristics	• Difficulty in batch processing
Tube	• Moderate impurity due to presence of argon gas	• Higher production cost

Acknowledgements

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