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# Microwave Sintering of $Bi_2Te_3$- and PbTe-Based Alloys: Structure and Thermoelectric Properties

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Microwave sintering is well known as an expeditious process in applications involving ceramics and biomaterials. For powders in the nanometer range, rapid microwave heating could reduce material exposure to elevated temperatures, thus preserving nanostructures in the resulting materials. To investigate the potential of this technique for thermoelectric (TE) materials, we have prepared samples of bismuth-telluride- and lead-telluride-based alloys from powders, for both materials, having sizes of partially agglomerated particles distributed from 0.15 $\mu$m to 7 $\mu$m. Sintering of the cold-pressed powders was carried out in a microwave furnace for 900 s at temperatures in the range of 583 K to 623 K for bismuth telluride and 793 K to 813 K for lead telluride specimens. For optimized sintering times and temperatures, the samples obtained showed relative densities of almost 95%. Scanning electron microscopy shows some residual porosity and a reduction of grain size, up to a factor of 5 for PbTe, compared with optimized hot-extruded specimens. For bismuth telluride samples, the TE performance in the range of 300 K to 460 K is poor, which is attributed to the arbitrary texture obtained from cold pressing of a highly anisotropic alloy prior to its sintering. In contrast, PbTe exhibits isotropic properties, hence deficiency of texturing is not expected to have a negative impact on its TE properties. Harman measurements show a value of $ZT = 0.42$ at 617 K for PbTe $p$-type sintered samples, which is comparable to hot-extruded alloys from similar powders. The present work demonstrates that microwave sintering is a promising alternative to other powder consolidation techniques for polycrystalline materials exhibiting isotropic TE properties.

**Key words:** Microwave sintering, thermoelectric, nanostructure, lead telluride, bismuth telluride

## INTRODUCTION

The performance of thermoelectric (TE) materials is usually expressed by the dimensionless figure of merit $ZT$, where $T$ is the absolute temperature and $Z = \sigma S^2/\kappa$, where $S$ is the Seebeck coefficient, $\sigma$ is the electrical conductivity, and $\kappa$ is the thermal conductivity.[1] The three properties $\sigma$, $S$, and $\kappa$ are interrelated and difficult to control independently. However, to increase TE performance, it is important to provide strategies to reduce the thermal conductivity without decreasing the power factor $\sigma S^2$, and one of the strategies proposed is nanostructuration of bulk TE materials.

$Bi_2Te_3$- and PbTe-based alloys have been widely studied; besides conventional directional growth from the melt, these materials are currently prepared by powder metallurgy and spark plasma sintering or hot extrusion.[2–8] We have conducted extensive bibliographical research and found no evidence that these materials have ever been

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