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Prospects for Dilute Bismuthides for Thermoelectric Applications

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Abstract: Thermoelectric power generation is an increasingly important technology for waste heat recovery and other energy-related applications. Efficiency of thermoelectric materials – whether for power generation using the Seebeck effect or solid state cooling using the Peltier effect – is determined by the dimensionless figure of merit ZT = S2?T/?, where S is the Seebeck coefficient, ? is electrical conductivity, and ? is thermal conductivity. Generally, these properties are interdependent, and so it is difficult to improve the efficiency of thermoelectric materials. Recent work has shown that nanocomposites based on metallic nanoparticles within III-V semiconductors can result in drastically improved efficiency of thermoelectric materials through two effects: (1) scattering of phonons by nanoscale inclusions, and (2) hot electron filtering to improve the thermoelectric power factor S2?. Despite these promising results, the performance of these nanocomposites is limited by non-ideal semiconductor matrices.

Dilute bismuthides offer the potential for improved performance by several mechanisms. First, the incorporation of bismuth is expected to reduce the lattice thermal conductivity of the matrix alloy. Second, the anomalous bandgap narrowing which has been observed in dilute bismuthides offers the potential to tune the matrix material for thermoelectric applications at any given temperature. It is expected that these materials will be quite compatible with several types of MBE-grown nanomaterials consisting of III-V matrices with metallic/semi-metallic inclusions. Finally, the unique energy level landscape within the dilute bismuthides offers significant potential for increased Seebeck coefficient due to large deviations from conventional bulk materials in the density of states.

We present details of the growth (by molecular beam epitaxy) of thermoelectric materials and the specific ways in which dilute bismuthides can result in improved performance relative to conventional III-V-based materials. This work is supported by the US Office of Naval Research as part of the Young Investigator Program and through an additional seedling grant.