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Novel Approach to Achieve High ZT Thermoelectric Materials

HELMUT BAUMGART, Dept., of Electrical & Computer Engineering, Old Dominion University

High efficiency thermoelectric materials have attracted considerable attention because of their application potential in power generation and refrigeration systems. The efficiency of thermoelectric materials is expressed by the figure of merit (ZT), ZT = S2T/ (L + e), where S is Seebeck coefficient, is electrical conductivity, T is the absolute temperature, and L + e are the thermal conductivity due to the lattice and electron contribution. It is observed that higher thermoelectric efficiency can be obtained by increasing the electron conductivity and reducing the thermal conductivity. A decrease of thermal conductivity could be achieved by a low dimensional superlattice structure, due to the quantum confinement or phonon scattering. Metal telluride based compounds such as bismuth telluride (Bi2Te3) and antimony telluride (Sb2Te3) alloys have a high figure of merit and work best for thermoelectric devices used for the temperature range of 200 to 400 K, while lead chalcogenides such as PbTe, PbS, and PbSe are ideal for the temperature range of 350 to 600 K. Here we review advances in the ALD synthesis of composite thermoelectric nanolaminates of alternating Bi2Te3 and Sb2Te3 thin films, and PbSe and PbTe films. Extensive physical and electrical characterizations were performed in order to elucidate the ALD nanolaminate growth mechanism. Nanolaminate structure of alternating ALD Bi2Te3 and Sb2Te3 layers exhibiting localized epitaxial growth within individual islands as revealed by high resolution TEM cross-section analysis, because of the similar lattice constants between the Bi2Te3 and Sb2Te3 ALD layers. The alternating telluride films grow localized in graphene like fashion in hexagonal layers. We discuss various approaches to enhance the figure of merit ZT and the Seebeck coefficient for ALD PbTe PbSe films employing quantum wells, quantum dots, and nanolaminates, which introduce a large density of interfaces to enhance phonon scattering resulting in an effective reduction of the thermal conductivity, and a concurrent significant improvement of ZT.