Thermoelectric properties of Bi$_2$Te$_3$, Sb$_2$Te$_3$ and Bi$_2$Se$_3$ single crystals with magnetic impurities

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Abstract:
Semiconductors containing transition or rareearth ions in an amount excluding direct exchange interaction between their magnetic moments are referred to as diluted magnetic semiconductors (DMS) [1]. Ferromagnetism was observed at low temperatures in AlIIBV and later in Bi$_2$Te$_3$, Sb$_2$Te$_3$ DMS [2]. In Bi$_{2-x}$Fe$_x$Te$_3$ the Curie temperature, $T_c$, increases as a function of $x$ up to $T_c = 12$ K for $x = 0.08$. In $n$-Bi$_{2-x}$Fe$_x$Se$_3$ samples ferromagnetism was not detected. In Sb$_{2-x}$Cr$_x$Te$_3$ the value of $T_c$ is about 5.8 K at $x=0.43$at%. It is not only of a scientific interest but is also practically important because it offers strong possibilities of using a magnetic field for the control of properties of various devices. From this point of view, of special interest are thermoelectric compounds, especially those based on Bi$_2$Te$_3$, Sb$_2$Te$_3$, and related mixed crystals, because they are the most efficient currently available thermoelectric materials. In the present study temperature dependence of Seebeck coefficient $S$, electrical conductivity, heat conductivity and figure of merit of single crystals of $p$-Bi$_2$Te$_3$, $n$-Bi$_2$Se$_3$ doped by Fe and Sb$_2$Te$_3$ doped with Cr were carried out in the temperature interval $7<T<300$ K. At $T=4.2$ K Shubnikov-de Haas and Hall effect measurements have been measured in high-magnetic field up to 40 T. By increasing the Fe content, the hole concentration decreases in $p$-Bi$_{2-x}$Fe$_x$Te$_3$, while the electron concentration increases in $n$-Bi$_{2-x}$Fe$_x$Se$_3$. The hole concentration in Sb$_{2-x}$Cr$_x$Te$_3$ decreases with Cr-doping. This demonstrates that Fe or Cr act as donors. The Seebeck coefficient increases in $p$-Bi$_{2-x}$Fe$_x$Te$_3$ and Sb$_{2-x}$Cr$_x$Te$_3$ with increasing Fe or Cr content, while it decreases in $n$-Bi$_{2-x}$Fe$_x$Se$_3$. We found that magnetic impurity significantly increases Seebeck coefficient in $p$-Bi$_2$Te$_3$ and Sb$_2$Te$_3$ and decreases thermal conductivity. For Bi$_{2-x}$Fe$_x$Te$_3$ and Bi$_{2-x}$Fe$_x$Se the value of ZT increase at $T<100$ K. In the case of Sb$_{2-x}$Cr$_x$Te$_3$ dimensionless figure of merit ZT increase at $T>150$ K.

References: