Thermoelectric properties of W-doped Bi_2Se_3 single crystals

Vladimír Kucek[1], Čestmír Drašar[2], and Ludvík Beneš[1]

[1]*Department of General and Inorganic Chemistry, Faculty of Chemical Technology, University of Pardubice, Studentska 573, 532 10 Pardubice, Czech Republic*
[2]*Institute of Applied Physics and Mathematics, Faculty of Chemical Technology, University of Pardubice, Studentska 573, 532 10 Pardubice, Czech Republic*

There is currently a boom in a search for alternative power resources. One of the alternatives is the usage of the thermoelectric effect. Research on thermoelectric (TE) materials is thus a very active field of research. Efficiency of a TE material is expressed in terms of a so-called dimensionless figure of merit, ZT, where $ZT = \alpha^2\sigma T/\kappa$. In this formula, σ, α, T and κ are the Seebeck coefficient, electrical conductivity, absolute temperature and thermal conductivity, respectively [1]. Next to the low thermal conductivity, the numerator $\alpha^2\sigma$ (so called power factor PF) needs to be high for a large TE performance.

Bi_2Se_3, which adopts the tetradymite structure, is one of the constituents of room-temperature thermoelectric (TE) materials. Recently we observed the extraordinary behavior of the Seebeck coefficient and carrier mobility leading to an enhanced power factor in the doped crystals in Cr-doped Bi_2Se_3 single crystals [2]. Considering to this fact we examine the influence of tungsten (as like chromium the transitive metal of 6^{th} group) doping on single crystals of bismuth selenide in terms of thermoelectric and transport properties.

The series of $Bi_{2-x}W_xSe_3$ single crystalline samples with varying values of x (for x = 0 - 0,035) was prepared by the self-flux method. The phase purity of the products was verified by X-ray diffraction. The samples were then characterized by the measurement of electrical conductivity, the Hall coefficient and the Seebeck coefficient over a temperature range of 100 - 475 K. We discuss the influence of W substitution on the free carrier concentration and the thermoelectric performance. All of the samples demonstrate n -type conductivity. The results further showed low solubility of tungsten in bismuth selenide (x $\leq$ 0,005) as well as decreased value of power factor suggesting that tungsten doping of bismuth selenide is contrary to chromium doping not promising in regard to thermoelectric applications.

[1] G. S. Nolas, J. Sharp, H. J. Goldsmid, Thermoelectrics / Basic Principles and New Material Developments, Springer-Verlag, Berlin, 2001, p. 128.

[2] P. Cermak, P. Ruleova, V. Holy, J. Prokleska, V. Kucek, K. Palka, L. Benes and C. Drasar, J. Solid State Chem. 258 (2018) 768-775.