Engineering electronic properties of electrodeposited Bi films

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Bi is a semimetal which combines high electrical conductivity, reasonable thermoelectric parameters, resistance to strong ionizing radiation and lowest toxicity among pure heavy elements. Bi attracts attention of reserachers in applied sciences and in fundamental physics as well due to a wide spectrum of applications and unusual electronic structure [1].

Single crystals of Bi are expensive to synthesize so there is a demand for cheaper techniques of high-quality sample fabrications. Electrochemical deposition method provides dense polycrystalline samples and combines low costs with high deposition rate (up to 200 μm/h) [1].

We study the influence of cathode current on the electrical properties of resulting Bi deposits fabricated using the novel perchlorate electrolyte. We consider three DC cathode current regimes for current densities j = 20 mA/cm^2, 15 mA/cm^2, 10 mA/cm^2 and one pulse regime with density j = 10 mA/cm^2, pulse duration and pause equal to 1s.

It was found that resistivity of all samples (given in Figure 1) lies in a range (1 – 1,6)·10^{-6} Ohm·m which is of the same order of magnitude as the resistivity of single-crystals. Relative magnetoresistance at 2 K reaches about 10^2 under 8 T field which is about the two orders of magnitude lower than magnetoresistance of single-crystals which indicates suppression of electron mean free path due to scattering on the grain boundaries.

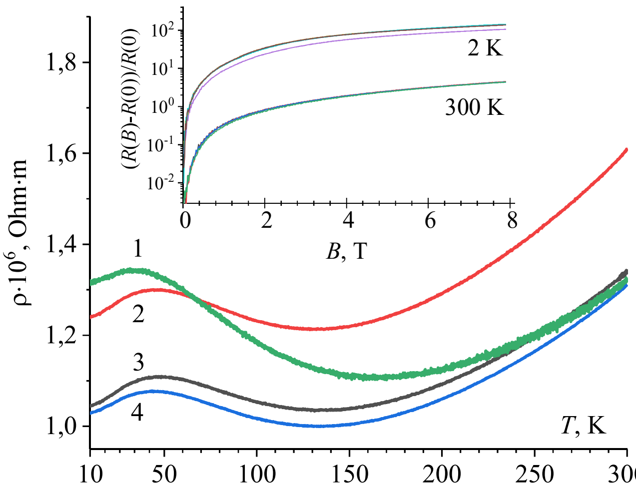

Figure 1. Resistivity temperature dependence for Bi samples: 1 – DC regime, j = 10 mA/cm^2, 2 – DC regime, j = 15 mA/cm^2, 3 – DC regime, j = 20 mA/cm^2, 4 – pulse regime, j = 10 mA/cm^2 Inset: relative magnetoresistance dependence on magnetic field at temperature T = 2 K and T = 300 K

The effect of pulse regime usage instead of DC (1 and 4 in Fig.) is in weakened temperature dependence of resistivity. During electrical measurements of pulse-deposited samples we observe higher noise of electric signal than for any of DC-deposited samples. Moreover, real thickness of pulse-deposited samples is about 30 μm while for DC-deposited samples thickness is about 25 μm. We suggest that pulse-deposited sample has more micropores which acts as capacities and define noisy behaviour of resistivity signal during measurements.

QMSA [1] method has shown that the non-monotonous temperature dependences of resistivity are result of competition between concentration and mobility temperature dependences of two charge carrier types. This opens wide possibilities for engeineering the temperature dependencies of Bi resistivity through change of deposition conditions and Bi grain size.

References

[1] Fedotov, A. [et al.] Electrodeposition conditions-dependent crystal structure, morphology and electronic properties of Bi films. J. Alloys Compd. 887 (2021), 161451.