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Effect of thickness on electrical conductivity of Bi_2Se_3 thin films at low temperatures

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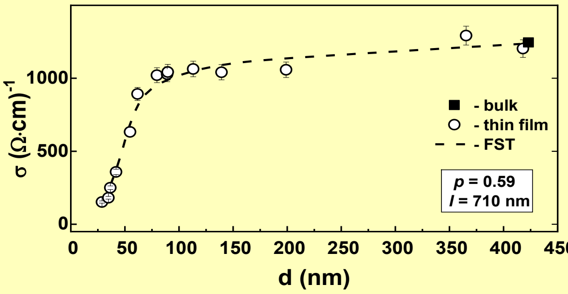
Introduction

Bi_2Se_3 is a narrow-gap **thermoelectric (TE) material** [1], which also exhibits the topological insulator properties. The **possibility of increasing the TE figure of merit in low-dimensional** structures based on **V_2VI_3** compounds stimulates the investigations of properties of Bi_2Se_3 thin films. **In thin films**, when the film thickness *d* is of the order of the mean free path of charge carriers, the **classical size effect (CSE)** can be observed. It is important to take CSE into account for film applications.

An **increase** in electrical conductivity ***σ*** with **increasing** film thickness ***d*** **at room temperature** for thin films **Bi_2Se_3** was observed and attributed to the manifestation of CSE and described in terms of the Fuchs-Sondheimer theory (FST) [2]. At lower temperatures, the *d*-dependences of the TE properties of Bi_2Se_3 thin films have not been studied.



The goal of the work

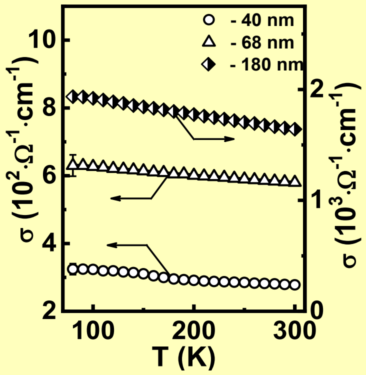
Investigation of the effect of the film thickness *d* on electrical conductivity in Bi_2Se_3 thin films in the temperature range (77-300) K.

Methods

The Bi_2Se_3 films (*d* = 15-365 nm) were prepared by thermal evaporation of an undoped stoichiometric *n*-Bi_2Se_3 polycrystal in vacuum (10^{-5}–10^{-6} Pa) onto freshly cleaved glass. The film thicknesses were controlled with the help of a pre-calibrated quartz resonator located near the substrate. The electrical conductivity *σ* was measured using a conventional *dc* method with the error ± 5%. The high structural quality of the investigated films was confirmed in [3].

Results

Bi_2Se_3 thin films exhibit ***n*-type** conductivity similar to the crystal. ***σ* changes slowly with temperature** (explained by the degeneracy of electron gas)



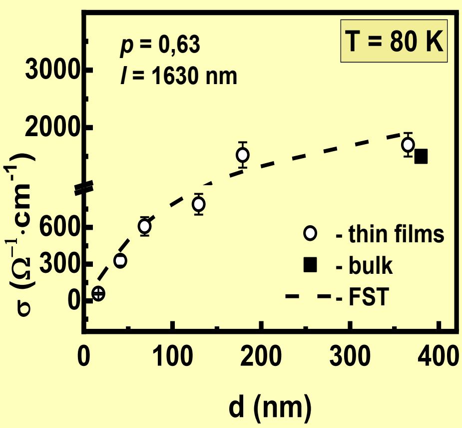
σ* increases with increasing *d (explained by the manifestation of CSE associated with an increase in the contribution of diffuse scattering of electrons at the thin film interfaces as *d* decreases)

Fuchs-Sondheimer theory (FST):

$$\sigma_d = \sigma_\infty \cdot \frac{3}{4} \cdot \frac{1+p}{1-p} \cdot \frac{d}{l} \cdot \ln\frac{l}{d}, \quad d < l$$

p is the specularity parameter;
l is the mean free path of electrons;
σ is conductivity of an infinitely thick film

The difference between the values of *p* and *l*, calculated in [2] and in the present work, is explained by the weaker phonon scattering at lower temperatures.



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3. *Rogacheva E.I., Fedorov A.G., Krivonogov S.I., Mateychenko P.V., Dobrotvorskaya M.V., Garbuz A.S., Nashchekina O.N., Sipatov A.Yu.* Structure of thermally evaporated bismuth selenide thin films // Func. Mat.-2018.-**25**.-P.516-524