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High Pressures, Low Temperatures, and Magnetic Field Effects on $AgFeAsSe_3$ and $AgFeSbSe_3$ Properties

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Abstract—A procedure for synthesizing $AgFeAsSe_3$ and $AgFeSbSe_3$ is presented, and their electric and magnetic properties are investigated over a wide range of temperatures, pressures, and magnetic field variation. At 100–400K, the samples are characterized by semiconductor properties. Under pressures of ~25 and ~24 GPa, the electric properties of $AgFeAsSe_3$ and $AgFeSbSe_3$ change greatly.

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INTRODUCTION

It is of interest to synthesize multicomponent semiconductors based on silver and copper chalcogenides, and to investigate their electrical, magnetic and mechanical properties under extreme conditions (low temperatures, high pressures and magnetic fields presence) [1–5]. The synthesis and electric and magnetic properties of $AgFeAsSe_3$ and $AgFeSbSe_3$ over a wide range of temperatures, pressures, and magnetic field variation are examined in this work.

EXPERIMENTAL

Our samples were synthesized using the ampoule technique. According to X-ray structural analysis, the synthesized materials were a mixture of two phases: FeSe and $AgBSe_2$ (B = As, Sb). The relationship between impedance and temperature was investigated by impedance spectroscopy using an RCL-2010 impedance analyzer for frequencies ranging from 1 kHz to 1 MHz and temperatures from 78 K to 400 K. A high-pressure chamber with an polycrystalline diamond (carbonado) anvil of the rounded cone–plane type was used to generate high pressures [6]. $AgFeAsSe_3$ magnetization was measured on a MPMS XL7 SQUID magnetometer at temperatures ranging from 100 to 400K and under magnetic fields of up to 7 T.

Figure 1 shows the impedance hodographs for the investigated compounds at a temperature of 300K. In the high-frequency part, the hodographs can be approximated by a circular arc. To investigate the compounds' electric conductivity and dielectric permeability, we selected frequencies of 93 kHz and 200 kHz, which are higher than the boundary frequency that separates the area of electrode processes and the area where we can ignore boundary effects.

Figure 1b shows the temperature dependences for electric conductivity and dielectric permeability measured at 200 Hz. The temperature dependence of $AgFeAsSe_3$ is of the activation type and the energy of activation changes between 240–280K. In the temperature range of 220–250K, we can see an anomaly in the relationship between temperature and resistance. The same anomaly is observed for direct current at temperatures of 260–270 K [7]; i.e., if the frequency is raised, the anomaly drifts toward lower temperatures. The dielectric permeability rises if the temperature is raised, and upon heating at a frequency of 200 Hz we observe a small maximum at a temperature of ~240 K. When measuring at a frequency of 93 Hz, however, this maximum is virtually stable. The relationship between electric conductivity and temperature for $AgFeSbSe_3$ is of the activation type and the energy of activation changes at 220K.

Figure 2a shows the relationships between magnetization and temperature for $AgFeAsSe_3$ in fields of 4 T and 7 T. It can be seen that magnetization diminishes at temperatures of up to ~310K, and if the temperature is lowered more, it is virtually stable. This could be because the sample transitions from the paramagnetic state to a state with magnetic ordering at temperatures lower than 310 K. These results agree with the results obtained for lower fields and temperatures. We investigated how magnetization depends on the magnetic field and we found that if the field grows, magnetization also rises but saturation is not achieved in fields lower than 7 T. The curves corresponding to the field diminishing and field growing coincide at fields higher than 0.5 T (Fig. 2b).

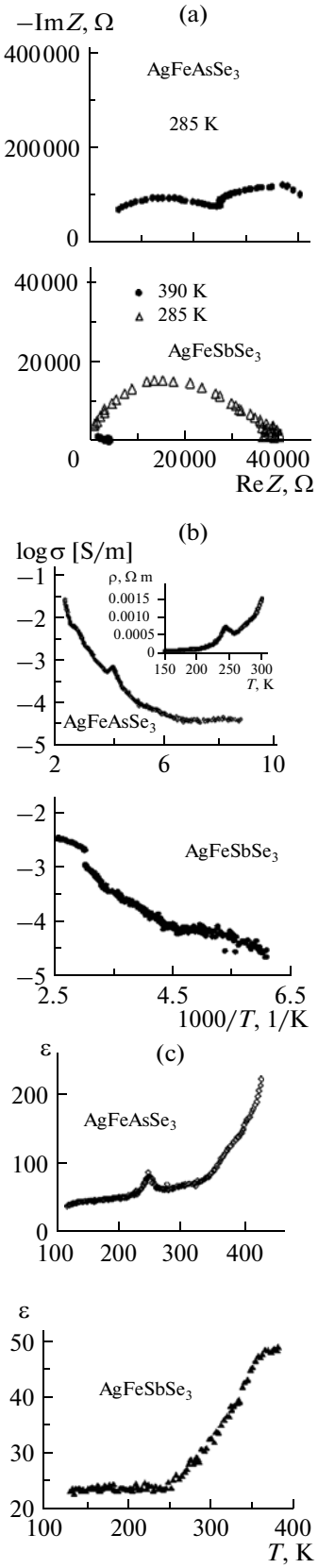

Fig. 1. (a) Hodograph for impedance and temperature curves for (b) electric conductivity and (c) dielectric permeability for $AgFeAsSe_3$ and $AgFeSbSe_3$.

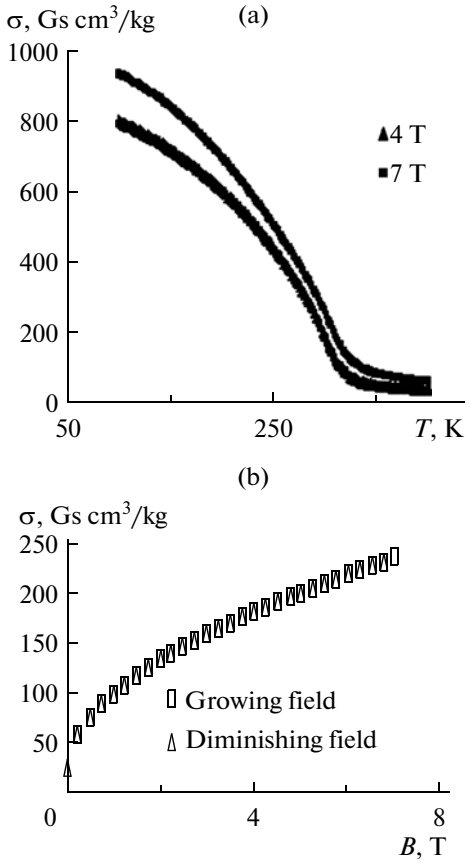

Fig. 2. Relationship (a) between temperature and magnetization and (b) between magnetization and field for $AgFeAsSe_3$.

Figure 3a shows the relationship between pressure and the resistance of $AgFeAsSe_3$ and $AgFeSbSe_3$ at 300K. If the pressure increase, $AgFeAsSe_3$ resistance falls to 25 GPa and is virtually constant after that. Perhaps a phase transition takes place in this pressure region. For $AgFeSbSe_3$, resistance drops sharply in the area of 24 GPa. To determine its regions of existence we investigated the relationship between pressure and resistance for magnetic fields lower than 1 T. It was found that the magnetic field influences sample resistance in the area of the assumed phase transition and not beyond it (Fig. 3b).

CONCLUSIONS

Our $AgFeAsSe_3$ and $AgFeSbSe_3$ samples were characterized by semiconductor properties at temperatures of 100–400K, and there was an anomaly on the $R(T)$ curve for $AgFeAsSe_3$ at temperatures of 220–250K. The relationship between magnetization and temperature for $AgFeAsSe_3$ changes the shape of the curve below ~310K, due to the material transition from the paramagnetic state to a state with magnetic ordering.

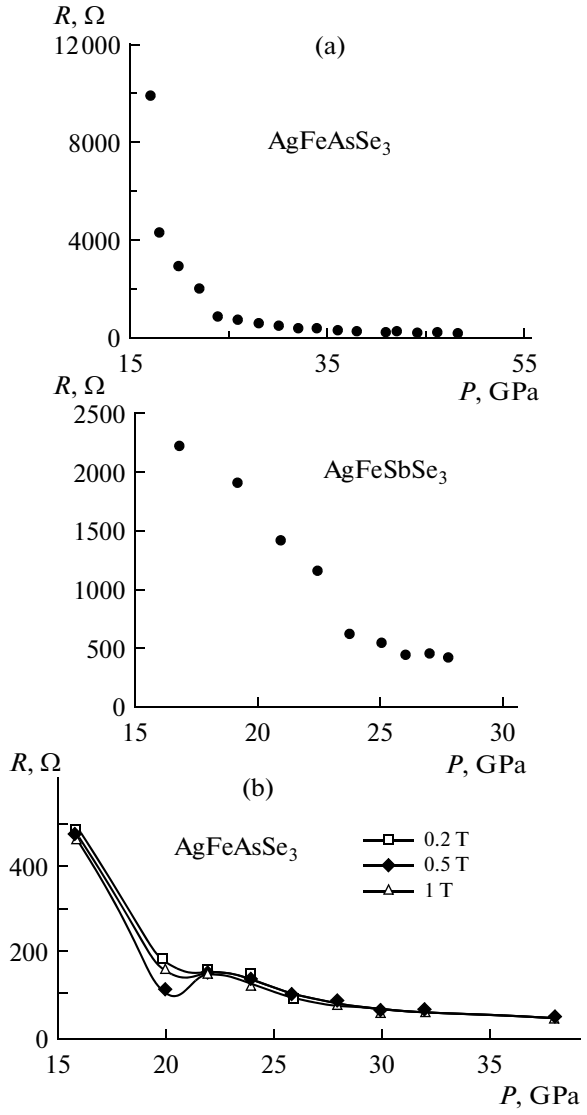

Fig. 3. Relationship between pressure and resistance for $AgFeAsSe_3$ and $AgFeSbSe_3$ if (a) there is no magnetic field and (b) if there is for $AgFeAsSe_3$.

Under pressures of ~25 and ~24 GPa, the electric properties of $AgFeAsSe_3$ and $AgFeSbSe_3$ change greatly. With allowance for experimental error, the field where the phase transition appears under high pressure does not change if arsenic is replaced with stibium.

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