High-quality single crystalline SnSe grown by vapor phase methods for thermoelectric applications

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Great interest in 2D materials, initiated by research on transition metal dichalcogenides, has recently expanded to include chalcogenides from group IV-VI, such as SnSe. In particular, orthorhombic structure of SnSe leads to crystal anisotropy and anharmonicity of chemical bonds responsible for its extremely low thermal conductivity in the plane with zig-zag ordering of ions and for very high value of thermoelectric figure of merit parameter ZT reaching 2.6 [1]. Excellent thermoelectric properties of single crystalline SnSe have become a new motivation for research on SnX (X=Se, S) materials, already known for their high absorption coefficient and infrared photosensitivity. Consequently, SnX compounds are a very promising group of semiconductors that can be used in integrated systems for photo-thermoelectric energy conversion.

We discuss the growth of SnSe samples by self-selective vapour growth (SSVG) method known for obtaining highest quality single crystalline samples of (Pb,Sn)Se and (Pb,Sn)Te topological crystalline insulators [2]. Complementarily, we also use physical vapour deposition (PVD) method to obtain thin SnSe layers on GaAs substrate. Using the SSVG method we have obtained high quality single crystalline samples, often in the shape of macroscopic, thin disks with a diameter of about 1 cm and orthorhombic structure. Material resulting from PVD method is in the form of SnSe layer with thickness varying from 1 to 20 μm and covering the both side of GaAs substrate - this property is particularly attractive from the point of view of "flexible thermoelectricity". SEM analysis of both types of SnSe samples revealed their layered morphology with clearly visible terraces on their surface. However, in the case of SSVG monocrystals, the observed terraces have the form of atomically flat surfaces with sharp and straight edges. Thickness of these terraces, determined on the basis of AFM analysis, is exactly equal to half of the lattice parameter along the *a* direction obtained from XRD measurements (a_a = 11.5 Å). Therefore, our single crystalline samples grown by SSVG method seem to be the best material suitable for studying the thermoelectric properties of the record-breaking semiconductor SnSe in the form of a bulk crystal, as well as low-dimensional (single- or multilayer) material obtained, for example, by exfoliation technique from monocrystals. Thermoelectric parameters of the obtained samples will also be discussed

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