Program for Advancing Strategic International Networks to Accelerate the Circulation of Talented Researchers

Japan-ASEAN Collaboration Research Program on Innovative Humanosphere in Southeast Asia:

In Search of Wisdom toward Compatibility Growth and Community in the World

Dispatch Report

Period: 01/12/2015~29/02/2016

Place of fieldwork: National University of Singapore (Singapore)

Name: Lim Hong En

1. Research background

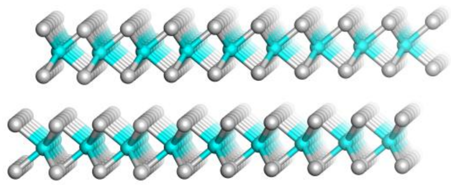
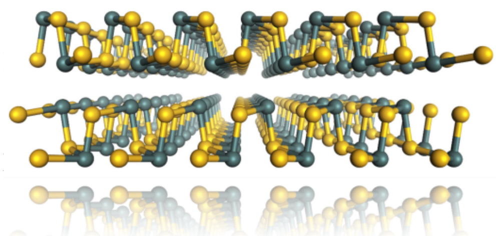


Figure 1. Structure of TMDCs. Mo, W: blue; S, Se: white.

Growing interest has been concentrated in the study of layered materials ever since the discovery of graphene, a single-atom thick carbon sheet. Due to the quantum confinement effect and their structural morphology, these materials portray unique physical properties dissimilar to bulk crystals when they are reduced to a thickness of less than one nanometer. For instance, reducing the dimensionality of transition metal dichalcogenides (TMDCs) such as molybdenum disulfide and tungsten diselenide has resulted in the transformation from indirect to direct bandgap. The lack of inversion symmetry in TMDCs allows selective formation of carriers with different magnetic moments by circularly polarized light, thus qualifying them as excellent candidates for valleytronic applications. Furthermore, a diverse range of two dimensional (2D) materials can be easily integrated to give van der Waals heterostructures with enhanced optical and electronic properties that are useful for optoelectronic and photovoltaic devices.

2. Research purpose and aims



ed materials, group
or Ge, X=Se or S) have
r peculiar features. In
as been predicted to be

a superior semiconducting 2D material for spintronics and valleytronics. Unlike conventional TMDCs, SnS possesses multiple valleys that can be optically pumped using linearly polarized light. At the same time, separation of these valleys can possibly be achieved via transverse non-linear conductivity. Motivated by the exciting theoretical findings, the present research has been initiated to develop an established approach for the fabrication of SnS monolayers and to explore their optical properties. Based on previous experience gained from other 2D structures, the chemical vapor deposition (CVD) method is adopted to attempt growth of this intriguing

Figure 2. Structure of tin (II) sulfide, SnS.
Sn: grey; S: yellow.

3. Results and achievements by fieldwork

Thus far, efforts have been attributed to the growth of SnS on insulating (e.g. oxide coated silicon wafer, SiO_2/Si and hexagonal boron nitride, hBN) and conducting surfaces (graphene). Keeping the reacting tin (II) oxide, SnO, to sulfur, S, ratio at 1:10, orthorhombic crystals of SnS were successfully grown at 750^{o}C under the Ar or Ar/H_2 ambient of 1 atm. A typical crystal size of approximately 16 x 16 μm was obtained when the reaction was performed on graphene and hBN, whereas smaller crystal flakes were generated on bare SiO_2/Si substrate. Upon excitation with a laser of 532 nm wavelength, characteristic Raman A_g and B_{3g} vibration modes of the orthorhombic crystal were registered at 94, 190, 217 and 162 cm^{-1}, respectively, consistent with those reported in the literature.

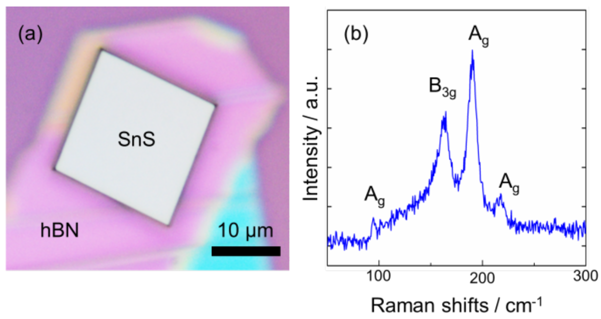


Figure 3. (a) SnS crystal grown on hBN and (b) its corresponding Raman spectrum registered at 532 nm excitation.

4. Implications and impacts on future research

The current results imply the significance of the surfaces used to generate the SnS crystals. The common perception up to now has been that layered materials are capable of providing clean, flat sites, thus encouraging the formation of larger SnS flakes. On the other hand, the presence of dangling bonds and other adsorbates on SiO_2/Si substrates is often detrimental to growth, thereby limiting the crystal size. Additionally, the ambient gas is another key factor that affects the formation of the SnS crystals. However, further study is required to understand the role the ambient gas plays during the formation process. The preliminary stage of synthesizing orthorhombic SnS crystals has been accomplished. The future challenge lies in finding an efficient approach to control the thickness of the crystal generated down to a single layer.