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: 01/04/2016~01/11/2017
Place of fieldwork: National University of Singapore (Singapore)
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1. Research title

Development of new atomically thin, two-dimensional crystals for efficient energy utilization

2. Research background

A profound interest has been concentrating recently on the study of two-dimensional, layered materials such as graphene, hexagonal boron nitride (hBN) and transition metal dichalcogenides (TMDCs) as they are considered useful for next generation nanodevices. Apart from the structural flexibility, they exhibit unique optical and electronical properties dissimilar to the bulk state when thinned to few layers thick. TMDCs, MX_2 (M= Mo, W and X= S, Se, Te), especially, are favored as they show striking optical features that interacts strongly with light at different spectrum, and therefore highly desired for the application in optoelectronics and light emiting devices.

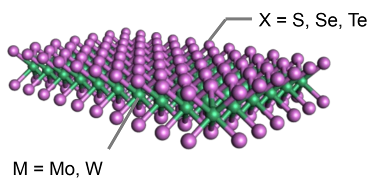

Figure 1. Structure of TMDCs.

3. Research purpose and aim

For the exceptional properties displayed in the chalcogenides of transition metals, this project is therefore, attributed to explore the chalcogenides of group 14 elements. We focus our attention on the preparation of monosulfide/selenide of tin, i.e. SnS and SnSe, as they are predicted to illustrate unusual optical feature that benefits the research on valleytronics. By using chemical vapor deposition, we attempt to synthesize ultrathin layers of SnS and SnSe.

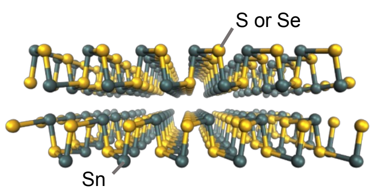

Figure 2. Structure of SnS or SnSe.

4. Results and achievements

During the previous stay, crystals of SnS and SnSe have been successfully fabricated either by the reaction of tin (II) oxide with sulfur or via the deposition of SnSe powder, respectively. The crystals prepared are somehow thick in general, way beyond the desired thickness of few nanometers, where they are anticipated to illustrate unusual optical features. Since then, efforts have been devoted to fine tune the reaction conditions in order to achieve

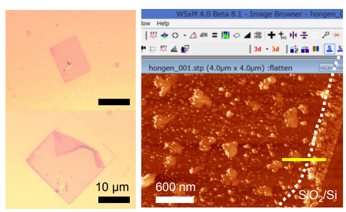

Figure 3. Optical and AFM images of the thin sheets obtained.

thin layer growth and to simultaneously seek a feasible method that may help in thinning the crystals grown. Later, we came to realize that annealing the crystals grown at high temperature in argon would significantly reduce their thickness to sub-nanometer-thick, as shown in Figure 3. The resulting semi-transparent films, however, were compensated with reduced crystal crystallinity. They are highly damaged, as can be seen from the undulating surface of the film in the atomic force microscopy (AFM) image.

5. Implications and impacts

The next challenge lies in preserving the quality of the products formed. Although thermal annealing is effective in preparing the desired ultrathin films, this method, however, has also caused damages to the crystals as can be seen from the AFM image. The present reaction conditions imposed might be too harsh for the films to survive and thus require further tuning of the annealing temperature, time and pressure. Milder treatment approach has to be explored/developed. In this context, wet chemical thinning with acids could be a good alternative as it allows etching at much lower temperature with more controllability. Revisiting the CVD growth conditions might be necessary to directly grow the thin films at one shot in future without tedious etching treatment.