Formation of regular degradation patterns in chemical vapor deposited tungsten disulfide crystals under ambient condition

Nagoya Institute of Tech., °(DC) Rakesh Mahyavanshi, Golap Kalita, Masaki Tanemura

E-mail: rmahyavanshi@gmail.com

Introduction: Monolayer transition metal dichalcogenides (TMDCs) are the emerging class of two-dimensional direct band gap semiconductors for future nanoelectronic and optoelectronic applications. The stability study of these 2D materials against environmental degradation, is critical for device fabrication [1]. The surface protection by inert coating without damaging the material can be explored for further use of these atmospheric sensitive materials. In this study, we found the occurrence of regular degradation patterns in chemical vapor deposited WS_2 crystals after long-term ambient exposure.

Experimental: WS_2 crystals were synthesized by chemical vapor deposition (CVD) method on cleaned 100 nm SiO_2 coated Si substrate. The synthesized samples were kept in atmospheric pressure, temperature and humidity without controlling any parameters. The samples were characterized; 1) immediately after synthesis and 2) exposing to ambient conditions for different durations.

Results and discussion: Scanning electron microscopy (SEM) analysis shows formation of triangular degraded area in triangular WS_2 crystals as shown in fig. 1a with long term exposure to ambient conditions (~15 months). Considerable change in the Raman peaks is observed at the regular degraded areas due to deformation of S-W-S layer structure as shown in fig. 1b. X-ray photoelectron spectroscopy (XPS) and auger electron spectroscopy (AES) measurements at various positions within a WS_2 grain clearly show that these degradation patterns appear due to oxidation and significant loss of sulfur (fig. 1c).

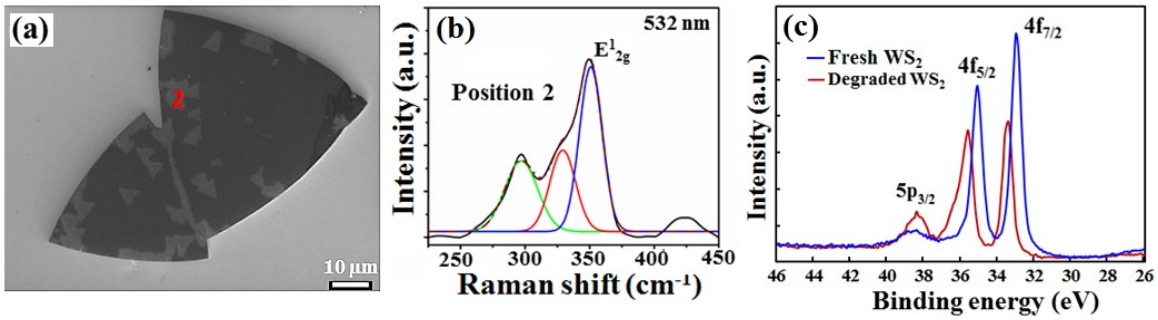

Figure 1. (a) SEM, (b) Raman and (c) XPS analysis of the WS_2 crystals with triangular degraded areas.

We demonstrate a dry encapsulation approach of the CVD synthesized WS_2 crystals by thermal evaporation of hydrophobic Teflon layer, a fluorocarbon polymer to prevent atmospheric oxidation and degradation. Our findings can be significant to understand the degradation process of dichalcogenide crystals with long-term exposure to the ambient condition and necessary measures to prevent degradation.

References

[1] J. Gao, et al., Aging of Transition Metal Dichalcogenide Monolayers. ACS Nano, 10, 2628-2635 (2016).