Oxidation of 2-Dimensional Semiconductors and Its Implication towards Applications

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Transition metal dichalcogenides, semiconducting 2-dimensional crystals, stand out among various emerging nano materials due to their unique electronic and optical properties. Their high surface atom fraction renders their material properties susceptible to physical and chemical perturbations at their surfaces. Surface oxidation, for example, may occur spontaneously in the ambient condition degrading the inherent properties, but can also be induced thermally or non-thermally allowing designed manipulation of the structure and properties. In this talk, I will present our recent studies on surface oxidation of 2-dimensional semiconductors, MoS$_2$ and WS$_2$. Thermal oxidation of single and few-layer MoS$_2$ was investigated using Raman and photoluminescence spectroscopy. Oxidative etching initiated at pre-existing point defects competes with formation of 2-dimensional oxides and their branching depends on the thickness and reaction temperature. By forming nanoscopic mechanical indents, we were able to induce pre-patterned conversion of WS$_2$ to WO$_3$. We also demonstrate that plasma-induced oxidation can be useful in generating ultraflat 2-dimensional oxides from sulfides. This non-thermal oxidation performed at room temperature proceeds from top to bottom and can be precisely controlled in a layer-by-layer manner. This work will exemplify chemical reactions of 2-dimensional crystals and promote further studies towards better understanding and manipulation of these novel materials.