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Doubly Anisotropic Thermal Oxidation of 2-Dimensional MoS_2 Supported on Silica Substrates

Atomically thin planar crystals may reveal novel knowledge on chemical reactions occurring in a low-dimensional space. Despite the importance of surface chemical reactions, interfacial mass transport between 2-dimensional (2D) materials and supporting substrates is not well understood. In this work, we studied substrate-mediated thermal oxidation of 2D MoS_2 supported on SiO_2/Si wafers. Single and few-layer MoS_2 samples were prepared by mechanically exfoliating bulk MoS_2 crystals onto SiO_2/Si substrates. Oxidation reactions were carried out in a quartz tube furnace for a range of temperatures and partial pressures of oxygen. To characterize the changes in morphology, vibrational and electronic structures, Raman and photoluminescence spectroscopies were employed with atomic force microscopy. We observed anisotropic thermal oxidation reactions which formed triangular oxides (TOs) in the bottommost layer and several times smaller triangular etch pits (TEs) in the topmost layer. The former indicates that oxygen molecules diffuse efficiently through the MoS_2-SiO_2 interface at elevated temperatures. Optical second-harmonic generation spectroscopy verified that the TOs and TEs structures are terminated with zigzag edges. MoS_2 crystals on hexagonal boron nitride and thick graphene did not form TOs, which indicates that the oxidation is greatly enhanced in direct contact with the SiO_2 substrates. We will discuss the possible roles of SiO_2 substrates and other various aspects of the oxidation reaction and oxidized MoS_2 crystals.