Fabrication of MoS_2 nanoribbon by direct transfer for in-situ TEM observation

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Recently, significant attention has been devoted to the edge structures of MoS_2. An important reason is that MoS_2 edge structures are highly correlated with its bandgap. Pan et al. indicated that the zigzag nanoribbons showed ferromagnetic and metallic behavior, whereas the armchair nanoribbons were nonmagnetic and semiconducting by theoretical calculation.[1] The influence of the edge structure is further reflected in the changes in the conductivity of MoS_2. Wu et al. observed the strong conductance inhomogeneity of MoS_2 field-effect transistors (FET) by microwave impedance microscopy (MIM) and confirmed the significant contribution of edge states to the channel conductance at threshold voltage. [2] However, the exact relationship between the edge structure and electrical properties of MoS_2 has not been addressed to date, which requires an in-situ observation at the atomic scale.

The in-situ transmission electron microscopy (TEM) method is a powerful tool for understanding nanomaterials' structure-dependent electronic properties. By the in-situ TEM method, Liu et al. reported that the electrical conductivity of suspended graphene nanoribbons (GNRs) with mixed edges changes from metallic to semiconducting behavior during the thinning process. [2] In this study, the MoS_2 nanoribbon devices will be fabricated and mounted on a custom in-situ TEM holder for measurement. The result will be analyzed to determine the relationship between the conductivity and the edge structure of MoS_2 nanoribbons.

Nevertheless, the transfer method during the fabrication of MoS_2 nanoribbon devices remains a challenge. The edge structures of MoS_2 are sensitive to capillary forces involved in the conventional wet transfer method, and the contamination left is hard to be removed. In this research, an all-dry deterministic transfer method that uses poly(propylene) carbonate (PPC) is employed to move the MoS_2 monolayer flake from the substrate to the special TEM chip. Using a SiO_2 substrate with a specific thickness, the number of layers of MoS_2 can be screened through the optical contrast and later confirmed through Raman spectroscopy. The PPC stamp with strong viscosity is applied and the viscosity of the transfer stamp will be adjusted by change of temperature to precisely control the pick-up and peel-off process of desired flakes.

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[1] Pan, H., et al. (2012). Journal of Materials Chemistry, 22(15), 7280-7290.

[2] Wu, D., et al. (2016). Proceedings of the National Academy of Sciences, 113(31), 8583-8588.

[3] Liu, C., et al. (2020). Carbon 165: 476-483.