In Situ SEM Experimental Studies on the Mechanical Properties of Two-Dimensional Materials

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Abstract

Two-dimensional (2D) materials represented by graphene and Ti3C2Tx have broad applications in flexible electronics, electromechanical devices, and structural membranes due to their unique physical and chemical properties. Here, by optimizing the sample preparation, cutting, and transfer protocols, we perform the direct in-situ tensile tests on monolayer Ti3C2Tx nanosheets using nanomechanical push-to-pull equipment under a scanning electron micro- scope. The effective Young's modulus is 0.484 ± 0.013 TPa, which is much closer to the theoretical value of 0.502 TPa than the previously reported 0.33 TPa by the disputed nanoindentation method. Moreover, during the process of tensile loading, the monolayer Ti3C2Tx shows an average elastic strain of _˜3.2% and a tensile strength as large as _˜15.4 GPa. In addition, we conducted in situ mechanical experiments on double-layered graphene using a scanning electron microscope and obtained its force-displacement response curve. The measured Young's modulus was approximately 0.829 TPa, which is highly consistent with the theoretical value. We also observed that the cracks fractured brittlely along the direction perpendicular to the tensile direction. This study proposed a reliable, direct and quantitative method that solves the problem of measuring the mechanical properties of two-dimensional materials and provides a solution for general atomic-scale nanomechanical testing.

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