Mechanical properties of freely suspended semiconducting graphene-like layers based on MoS_2

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Two-dimensional crystals are promising materials for next-generation flexible electronic devices. Indeed graphene, which exhibits a very high mobility, has been recently applied as transparent and flexible electrode.[1] The lack of a bandgap in pristine graphene, however, hampers its possible application in semiconducting devices. Up to now, two different strategies have been employed to fabricate semiconducting two-dimensional crystals. While the first one relies on opening a bandgap in graphene through top-down engineering [2] or chemical modification,[3] the second one involves the use of another two-dimensional crystal with a large intrinsic bandgap.[4, 5] Atomically thin crystals of the semiconducting transition metal dichalcogenide molybdenum disulphide (MoS_2) have emerged as a very interesting substitute/complement to graphene in semiconducting applications due to its large intrinsic bandgap of 1.8 eV and high mobility $\mu > 200\ cm^2V^{-1}s^{-1}$. Nevertheless, the mechanical properties of this nanomaterial, which will dictate their applicability in flexible electronic applications, remain unexplored so far.

We study the elastic deformation of freely suspended MoS_2 nanosheets (Figure 1) by means of a nanoscopic version of a bending test experiment, carried out with the tip of an atomic force microscope (Figure 2a). The force *vs.* deformation traces show a unique thickness dependent non-linearity (Figure 2b) that can be accounted for by a continuum mechanics model in which the nanosheets are considered as elastic membranes under an initial pre-tension and with a non-negligible bending rigidity. Our measurements enable us to determine mechanical properties of MoS_2 nanosheets such as the Young's Modulus and the initial pre-tension. The Young's modulus is extremely high (0.30 TPa), comparable to the one found in exfoliated graphene, and the deflections are reversible up to tens of nanometers.

References

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Figures

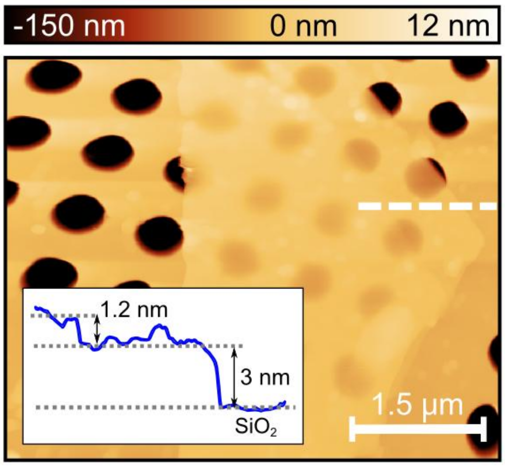

Figure 1. Contact mode AFM topography of a 3-4.2 nm thick MoS2 flake (5-7 layers thick). (inset) Topographic line profile acquired along the dashed line.

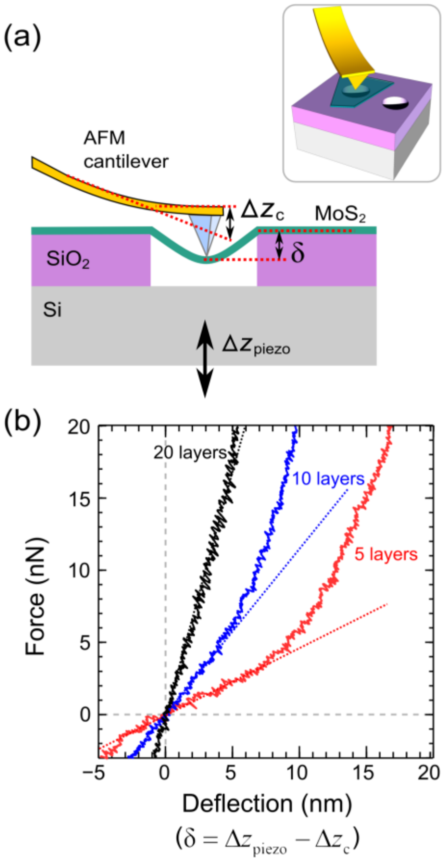

Figure 2. (a) Schematic diagram of the nanoscopic bending test experiment carried out on a freely suspended MoS$_2$ nanosheet. When a displacement of the sample is made by the AFM scanning piezotube, both the cantilever and the flake are deformed Using both the known piezo displacement and the measured laser deflection, both the force F and deflection δ can be extracted. (b) Force *vs.* deflection traces measured at the center of the suspended part of MoS$_2$ nanosheets with 5, 10 and 20 layers in thickness. The slope of the traces around zero deflection is marked by a dotted line.