Strain engineering bandgap tunability confined in small areas of MoS_2 bilayer membranes

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2D crystals can retain its structural integrity at much larger strains than those achievable in bulk 3D materials, mainly due to the absence of imperfections at their surfaces. Moreover, highly anisotropic strain in 2D sheets is limited into a small area inside a single crystalline domain and far from clamping points and edges. Therefore, strain engineering, as a general strategy employed in semiconductor manufacturing to enhance device performance, can be adapted to van der Waals materials to alter their electronic properties. In this work, a simple technique for strain engineering of MoS_2 bilayer sheets supported onto a polymer substrate is presented. The strain distribution of the membrane is analyzed and defined by three independent measurements, namely AFM, Raman and photoluminescence spectroscopies.

MoS_2 bilayer sheets are mechanically cleaved from bulk crystals and deposited onto a thick PMMA bar covered with a partially cured SU8 film. The sample is then heated at 80 ^oC for 10 min. During curing and solidification of the SU8, air bubbles with diameters of ~2 μm are trapped between the polymer and the bilayer membrane. The mismatch in thermal expansion coefficients of polymer and the MoS_2 bilayer generates anisotropic compressive strain on the sheet, and the hemispherical bubbles buckle. A typical buckling of a MoS2 bilayer bubble is shown in fig. 1.

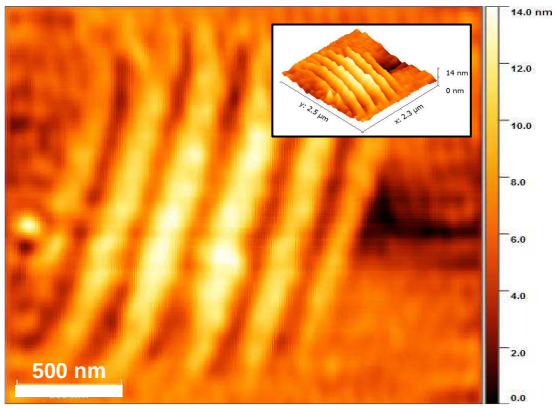

Figure 1: The topography of a buckled MoS_2 bilayer bubble.

An AFM image of a buckled bubble is shown in fig. 1. The wavelength and the amplitude of the buckles were found to be ~300 nm and ~ 6-12 nm respectively. It is interesting to note that the orientation of buckles denotes the development of an anisotropic strain field, being compressive in a direction normal to the buckles. A detailed Raman map of the shifts of the E_{1g} Raman band provides an estimate for the range of the developed residual strains during cleavage and deposition of the order of 0.2% (Fig.2). An AFM coupled with a Raman spectrograph was employed to record a detailed Photoluminescence (PL) map of the

bubble. It was found that the PL maximum of both I and A excitons were tunable by ~ 5 meV/μm. Therefore, the direct (A) and indirect (I) band gap of the bilayer are strain engineered within a small area of the bilayer of about 2.8 μm^2.

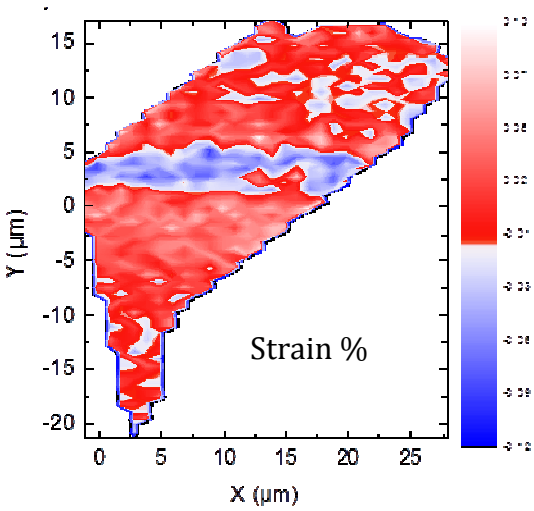

Figure 2: Residual strain (%) Raman map of the bilayer.

A simple technique for strain engineering a tunable bandgap into a small area of ~2.8 μm^2 of a MoS_2 bilayer supported onto polymeric substrates was presented. The tunability is 10 meV/μm for both direct and indirect gaps.

References

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