3D Nanostructures in 2D crystals for optoelectronic applications

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Strain engineering refers to a general strategy employed in semiconductor manufacturing to enhance device performance. A similar strategy has been proposed for a new class of materials, namely two dimensional (2D) atomic crystals derived from layered materials that possess strong in-plane bonding and weak van der Waals bonding between crystal planes. Isolated monolayers and few-layer crystals of graphene, hexagonal boron nitride, molybdenum disulphide (MoS_2) and other dichalcogenides are exceptional members of this family and have unique electronic, optical and mechanical properties[1,2]. 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.

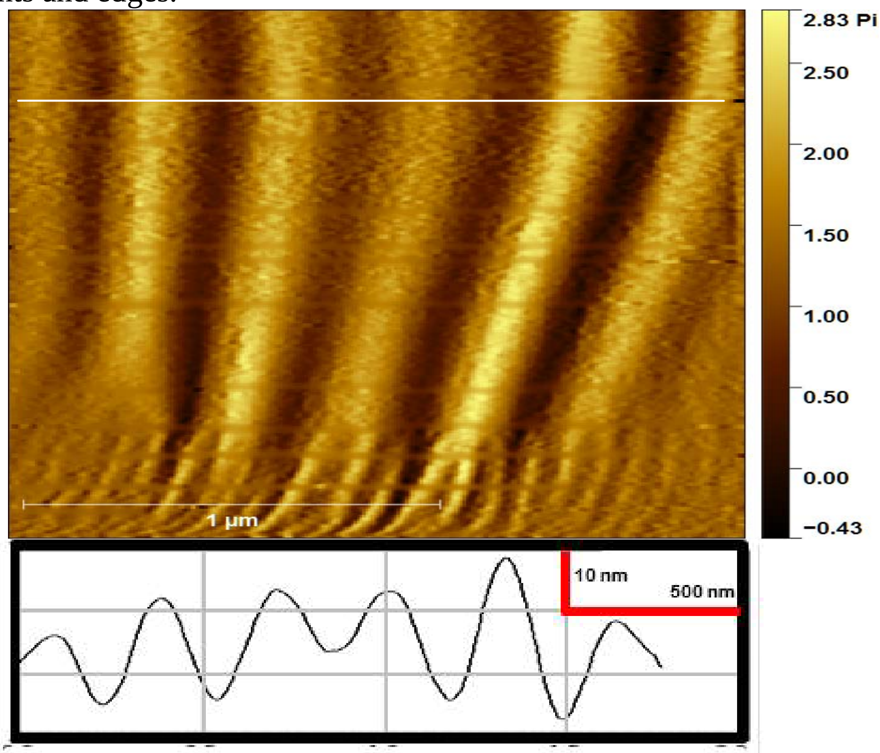

Figure 1: AFM image (phase) of a part of a bubble formed in a bilayer graphene. At the edge of the bubble wrinklons[3] are clearly formed. The diagram represents the height profile in nm of the white line.

In this presentation, simple techniques for strain engineering of single layer graphene and MoS_2 sheets supported onto polymeric substrates are presented. MoS_2 bi and trilayer sheets are mechanically exfoliated onto a thick PMMA polymer bar covered with partially cured SU8 film. During curing and solidification air bubbles with diameters of ~3 μm are trapped between the polymer and the atomic sheet. During bubble inflation anisotropic strain is applied on the sheet which fails into buckles with a wavelength of ~200-300 nm and amplitude of ~10-12 nm (Fig. 1). It is found that both direct and indirect band gap of the bilayer can be tunable within the small area of the bubble of about 2.8 μm^2.

A single graphene sheet is produced onto a thin copper sheet under CVD conditions and is wet transferred onto an epoxy resin substrate. Strain engineering is achieved during the transferring procedure and has the form of a well-defined sinusoidal corrugation with 0.3-1 μm in wavelength and 20 nm in amplitude (Fig.2). It has been proven that sinusoidal corrugated single layer graphene can be used for the generation of THz light based on a cyclotron-like radiation process[4]. Raman and photoluminescence spectroscopies coupled with the AFM topography are used for strain measurements within an area of a few μm^2 on the surface of the atomic sheets.

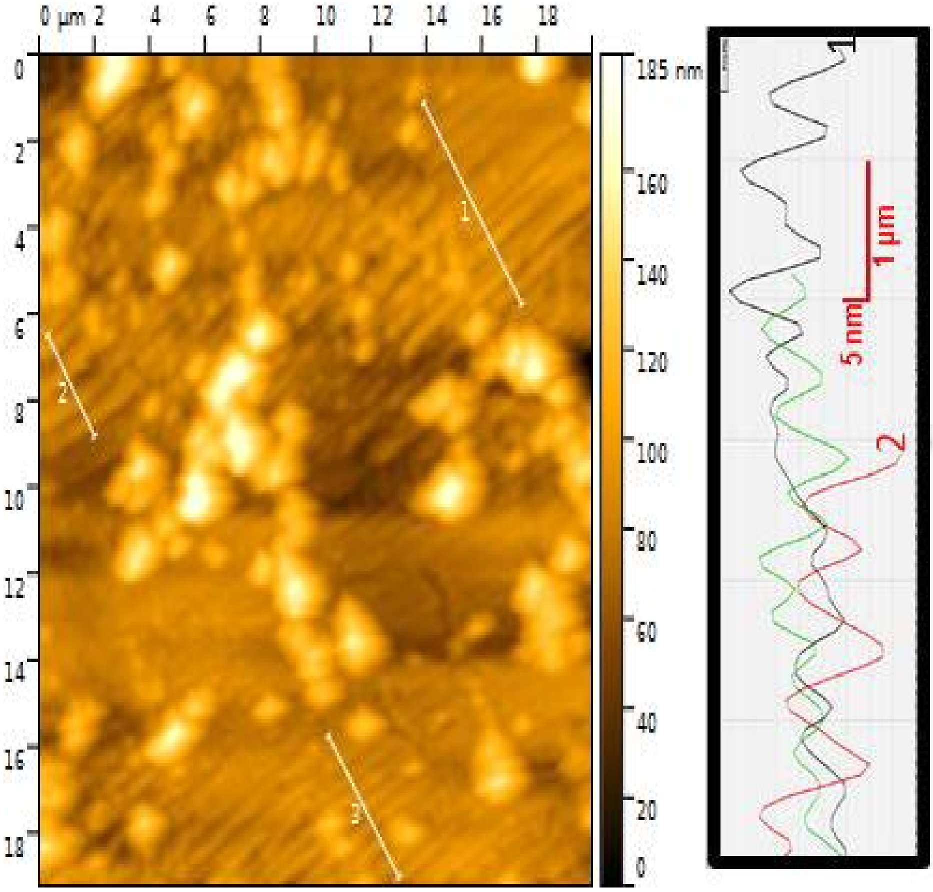

Figure 2: AFM image (height) of the sinusoidal corrugation formed by depositing CVD grown graphene ono an epoxy resin substrate. The diagram on the left side presents the height profiles of each of the white line shown in the AFM image where 1 is black, 2 is red and 3 is green.

References

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