Bubbles in 2D heterostructures: universal shape and van der Waals pressure

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Trapped substances between a two-dimensional (2D) crystal and an atomically flat substrate lead to the formation of bubbles [1]. Their size, shape and internal pressure are determined by the competition between van der Waals attraction of the crystal to the substrate and the elastic energy needed to deform it, allowing to use bubbles to study elastic properties of 2D crystals and conditions of confinement. Using atomic force microscopy, we analysed a variety of bubbles formed by monolayers of graphene, boron nitride and MoS_2 [2]. Their shapes are found to exhibit universal scaling, in agreement with our analysis based on the theory of elasticity of membranes (fig.1a). We also measured the hydrostatic pressure induced by the confinement, which was found to reach tens of MPa inside submicron bubbles (fig. 2b). This agrees with our theory estimates and suggests that for even smaller, sub-10 nm bubbles the pressure can be close to 1 GPa and may modify properties of a trapped material [3, 4].

References

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[3] Lim, C. H. Y. X. et al., Nat. Commun. 4, 2013, 1556
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Figures

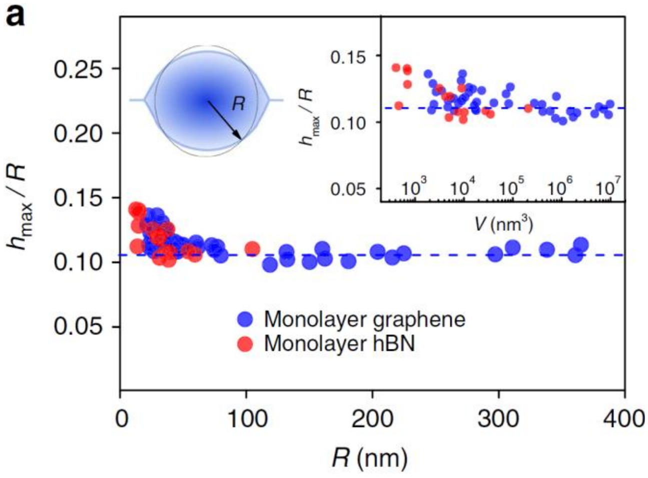

Figure 1: Universal aspect ratio of graphene and hBN, (a) dependence of aspect ratio on the radius and volume (top right inset) of the bubbles, top left inset shows a sketch of typical bubble and definition of radius.

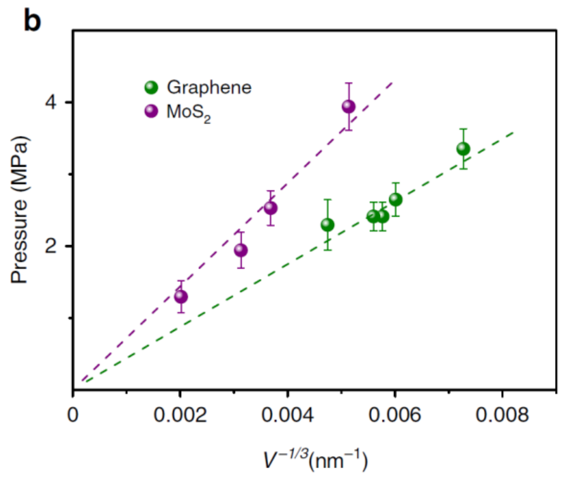

Figure 2: Dependence of pressure on the size of the bubbles for graphene on hBN and MoS_2 on MoS_2.