Shear stress between bilayer graphene measured by atomistic thick bubble technique

Subject Code：A02

With the support by the National Natural Science Foundation of China，Prof. Zhang Zhong (张忠) and Prof. Liu Luqi (刘璐琪) from the National Center for Nanoscience and Technology，China，and Prof. Xu Zhiping (徐志平) from Tsinghua University developed a bubble loading technique to induce the shear deformation between bilayer graphene sheets and found that the graphene adheres weakly with each other with shear resistance of 40 kPa. This work has been published in *Physical Review Letters* (2017，119：036101).

Graphene is a one-atom-thick material that possesses extraordinary mechanical and electronic properties，while the most exciting applications might come from stacking them into multilayer structures. A critical issue is hence raised that the performance and reliability of these applications greatly depend on the interlayer interactions，especially in the case of the weak van der Waals forces dominated interface. Up to now，corresponding mechanical parameters are far from well characterized due to the challenges in manipulating the individual graphene sheets experimentally.

To measure the shear interactions，they adopted a blister test on bilayer graphene sheets. In detail，the graphene sheet was firstly exfoliated onto the silicon-dioxide substrate patterned with micron-sized holes. The air pressure inside the hole could then be tuned precisely to push the graphene membrane upwards and form a circular bubble in the region above the hole，with the size identified by atomic force microscopy. Meanwhile，such a bubble tended to pull the substrate-supported graphene (outside the hole) towards the center of the hole，thus creating a shear zone dominated by the resistance to counter the relative sliding. Raman spectroscopy was used to monitor the local strains in terms of shift of specific Raman peak and record the growth of the shear zone with increasing gas pressures. These results showed that the interlayer shear resistance between neighboring graphene sheets is around 40 times lower than that of the interfacial shear resistance between graphene and the silicon-dioxide substrate. Molecular dynamics simulation was provided to support the mapping of the shear zone development. This is the first measurement of the interlayer shear resistance for 2D crystals as one of the thinnest structures possible.

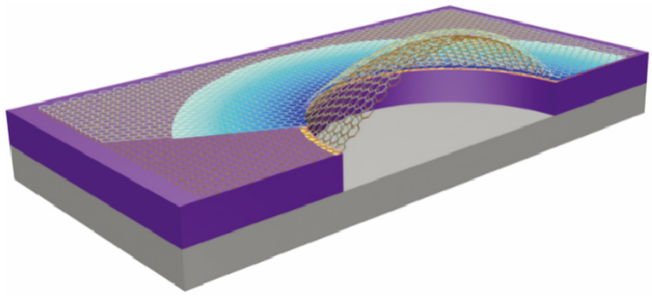

Figure This cutaway demonstrates that a bilayer graphene was blown up by the precisely controlled air pressure. The size of the shear zone of the upper-layer graphene (blue) around the hole is much larger than that of the bottom-layer one (yellow) based on both experimental and simulating results.

This finding provides an essential factor in many graphene-based devices where the interlayer shear stress plays a significant role，and opens up ample opportunities for fundamental studies and applications on interfacial and interlayer performance in 2D hetero-structures.