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Capillary Condensation in Nano-capillaries With Angstrom Precision

Abstract
Capillary condensation occurs almost in all systems of liquid-solid interfaces at pressures below saturation pressure of the bulk liquid. Capillarity is the tendency of wetting liquids to be drawn into a confined space. Nanoscale pores and capillaries have been studied intensively because of their importance in many natural phenomena and use in numerous applications. Significant progress has been achieved in fabricating artificial capillaries with nanometer dimensions, which led to the emergence of new research areas including nanofluidics. Our previous work has shown that ultimately narrow and smooth capillaries can be fabricated by van der Waals assembly of atomically flat materials using two-dimensional crystals as spacers in between [1]. By using this well-controlled atomically smooth nanoconfinement, it enables us to examine the mechanism of capillary condensation with angstrom precision and to elucidate the dynamics of the water transport process inside.
Relative humidity plays an important role in the process of capillary condensation according to Kelvin equation [2]. Due to van der Waals interaction and its own gravity, the top graphite in the nanoconfinement structure is partially collapsed. By increasing the relative humidity in a sealed chamber, we can see the snap-off of the collapsed graphite; similarly, decreasing in RH leads to partially collapse of the graphite again.

References

[1] B. Radha, A. Esfandiar, F. C. Wang, A. P. Rooney, K. Gopinadhan, A. Keerthi, A. Mishchenko, A. Janardanan, P. Blake, L. Fumagalli, M. Lozada-Hidalgo, S. Garaj, S. J. Haigh, I. V. Grigorieva, H. A. Wu, A. K. Geim, Nature 538 (2016), 222-225.
[2] van Honschoten, Joost W., Nataliya Brunets, and Niels R. Tas. "Capillarity at the nanoscale." Chemical Society Reviews 39 (2010): 1096-1114.

Figures

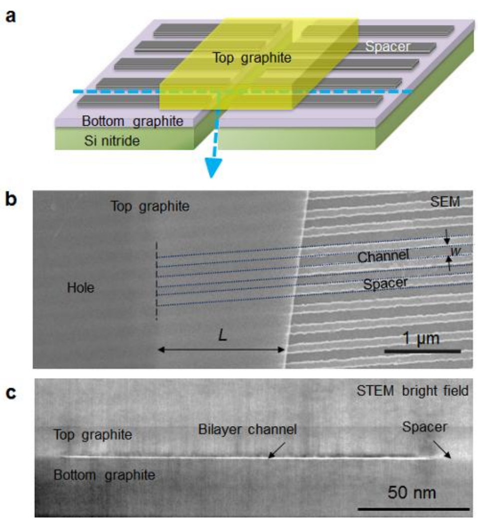

Fig. 1: Graphene capillary device. a, General schematic of devices. b, Scanning electron microscopy (SEM) image of a trilayer device (h ≈ 1.0 nm; top view). c, Cross-sectional bright field image of a bilayer capillary (h ≈ 7 Å) in a STEM.

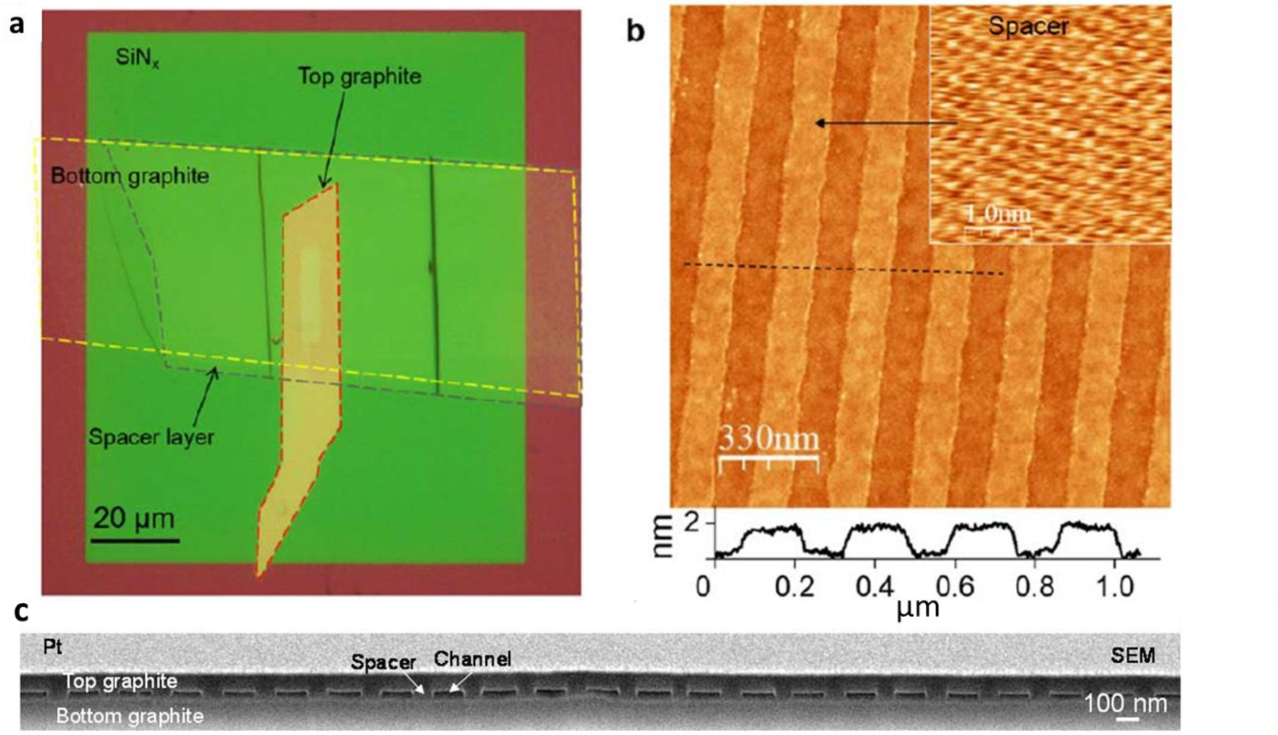

Fig. 2: Optical image of a final device and AFM image with a height profile shows that its atomically smooth Surface. Inset shows a high resolution AFM of the graphite lattice from the spacer. **c** visualize the nanochannels made of graphene.

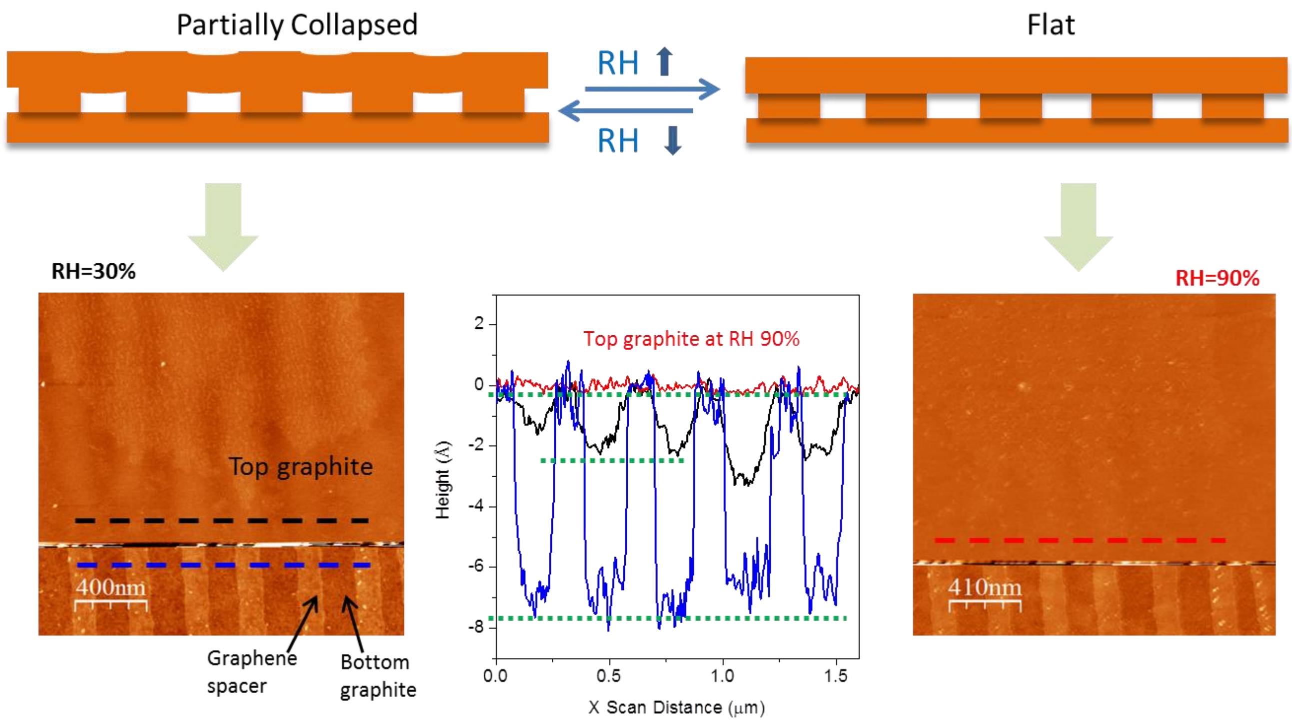

Fig. 3: Schematic and AFM images of the nanochannels before and after humidity change. The AFM profile shows the snap-off of the collapsed top graphite.