Scanning Tunneling Microscopy Studies of CVD Graphene on Mica

Kevin T. He, Joshua D. Wood, Eric Pop, and Joseph W. Lyding

University of Illinois at Urbana-Champaign, Beckman Institute, 405 N. Mathews Ave., Urbana, IL, USA
lyding@illinois.edu

Research in graphene has skyrocketed in recent years due to its unique electronic and mechanical properties [1]. Graphene has become not only a sandbox for scientists to study rare physical phenomena [2], but also a potential material for use in future semiconductor devices [3]. However, many issues still need to be resolved before graphene can be commercially viable. For instance, depending on the substrate on which graphene is deposited, there is a major shift in measured carrier mobility [4]. It was recently shown that the ultraflat, insulating boron nitride substrate helps to preserve many of the electronic properties normally seen only in suspended graphene [5]. However, sheets of single-crystal boron nitride can be difficult to obtain, leading to the investigation of other flat, insulating substrates on which graphene can be incorporated.

One widely available mineral which satisfies these conditions is mica. Muscovite ($KAl_2(Si_3Al)O_{10}(OH,F)_2$) is the most common form of mica, with a perfect cleavage plane along the [100] direction, resulting in easily obtainable, atomically flat surfaces. Mica is already used as an insulator in the electronics industry due to its high electronic band gap (~7.8 eV), making it a good candidate for a substrate in graphene-based devices.

Recent atomic force microscopy (AFM) studies of graphene deposited onto mica surfaces have yielded some very interesting results in terms of surface topology [6] and the effect of water adlayers [7]. We present the next logical progression of that work, which is using scanning tunneling microscopy (STM) to characterize the surface with atomic resolution. We transfer graphene grown via chemical vapor deposition (CVD) of methane on copper onto a cleaved mica surface. From the wet transfer process, one or more adlayers of water are adsorbed to the mica surface and become trapped between the mica and graphene after deposition. The graphene acts as a protective covering over the water, preventing evaporation during insertion into ultra-high vacuum (UHV) and subsequent high-temperature degas. Raman spectroscopic analysis confirms the presence of monolayer graphene. The D and G bands on the graphene have large intensities, suggesting locally defective graphene regions or the presence of ice [7].

An STM image of the graphene-water-mica surface can be seen in figure 1. A very interesting spider-web structure appears on the surface, most likely caused by a layer of adsorbed water. We believe that this spider-web structure appears from the high wettability of water on mica [8]. The height of the layer is ~4 Å, closely matching the height of the water layer reported by Xu *et al* [9]. The entire surface is covered in a layer of graphene, and the honeycomb graphene lattice is easily resolved, as seen in the inset. The top water layer appears fairly rough, with a non-periodic structure permeating over the entire surface. As of yet, it is still unclear whether the depression is graphene over bare mica, or graphene over a bottom water layer. The measured roughness of the areas in the depression is much lower than that of the top water layer; whatever it may be has a non-amorphous crystal structure.

Figure 2 shows a 3D image rendered from an STM topograph containing a graphene grain boundary. A hexagonal Moiré pattern with period ~2.8 Å can be seen over the left grain. The cause of this Moiré pattern is unknown. The structure suggests that it could be due to two misaligned graphene lattices, but we observe areas where the Moiré pattern is imperfect, which would not occur with stacked graphene.

References

[1] A.K. Geim and K.S. Novoselov, Nature Materials, **6** (2007) 183.
[2] Y. Zhang, Y.T. Tan, H.L. Stormer, and P. Kim, Nature, **438** (2005) 201.
[3] P. Avouris, Z. Chen, and V. Perebeinos, Nature Nanotechnology **2**, (2007) 605.
[4] X, Du, I. Skachko, A. Barker, and E.Y. Andrei, Nature Nanotechnology **3**, (2008) 491.
[5] C.R. Dean, A.F. Young, I. Meric, C. Lee, L. Wang, S. Sorgenfrei, K Watanabe, T. Taniguchi, P. Kim, K.L Shepard, and J. Hone, Nature Nanotechnology, **5**, (2010) 722.
[6] C.H. Lui, L. Liu, K.F. Mak, G.W. Flynn, and T.F. Heinz, Nature, **462** (2009) 339.
[7] J.R. Scherer and R.G. Snyder, J. Chem. Phys. **67**, (1977) 4794.
[8] L. Xu, A. Lio, J. Hu, D.F. Ogletree, and M. Salmeron, J. Phys. Chem. B, **102** (1998) 540.
[9] K. Xu, P. Cao, and J.R. Heath, Science, **329** (2010) 1188.

Figures

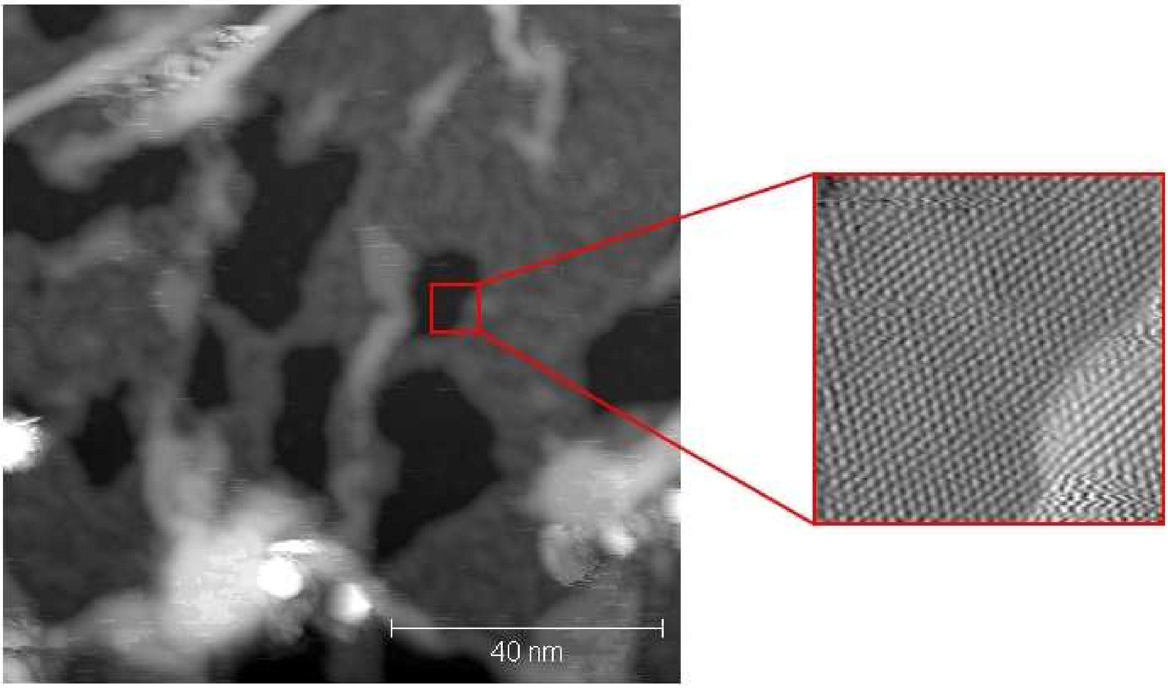

Figure 1:*Scanning tunneling microscope topograph of graphene deposited onto the mica surface.*

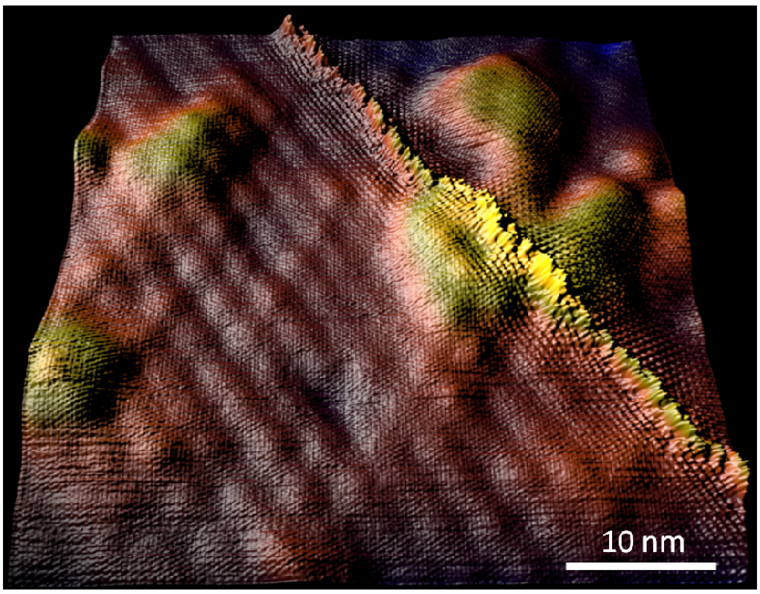

Figure 2: *3D rendering of an STM topograph showing a graphene grain boundary and Moiré pattern.*