Characterization and manipulation of graphene using AFM

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Monolayer graphene is one of the most interesting materials applicable to next-generation electronic devices due to its transport properties. However, realization of graphene devices requires suitable nanoscale lithography as well as a method to open a band gap in monolayer graphene. Nanoscale hydrogenation and oxidation are promising methods to open an energy band gap by modification of surface structures and to fabricate nanostructures such as graphene nanoribbons (GNRs). Until now it has been difficult to fabricate nanoscale devices consisting of both hydrogenated and oxidized graphene because the hydrogenation of graphene requires a complicated process composed of large-scale chemical modification, nanoscale patterning, and etching. I will report on nanoscale hydrogenation and oxidation of graphene under normal atmospheric conditions and at room temperature without etching, wet process, or even any gas treatment by controlling just an external bias through atomic force microscope lithography.[1]

On the other hand, graphene produced by mechanical exfoliation has not been able to provide and ideal graphene with performance comparable to that predicted by theory, and structural and/or electronic defects have been proposed as one cause of reduced performance. I will report the observation of domains on exfoliated monolayer graphene that differ by their friction characteristics, as measured by friction force microscopy.[2] Angle-dependent scanning reveals friction anisotropy with a periodicity of 180° on each friction domain, as shown in Fig. 1. The frictioni anisotropy decreases as the applied load increases. It is proposed that the domains arise from ripple distortions that give rise to anisotropic friction in each domain as a result of the anisotropic puckering of the graphene.
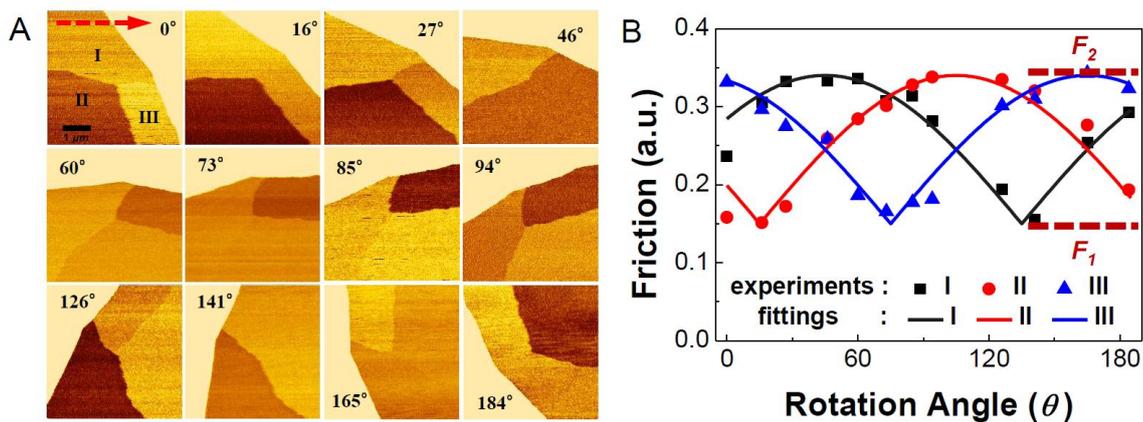
Figure 1. (A) Friction force images showing the changing friction contrast as the sample is rotated counterclockwise from 0° to 184° relative to the horizontal scan direction (red dashed arrow). Roman numerals indicate the three friction domains. (B) Normalized friction force versus rotation angle for each domain, showing 180° periodicity. The lines show that the variations in friction can be fitted by a simple sine

modulus function.

[1] Ik-Su Byun, Duhee Yoon, Jin Sik Choi, Inrok Hwang, Duk Hyun Lee, Mi Jung Lee, Tomoji Kawai, Young-Woo Son, Quanxi Jia, Hyeonsik Cheong, and Bae Ho Park, ACS Nano 5, 6417 (2011).
[2] Jin Sik Choi, Jin-Soo Kim, Ik-Su Byun, Duk Hyun Lee, Mi Jung Lee, Bae Ho Park, Changgu Lee, Duhee Yoon, Hyeonsik Cheong, Ki Ho Lee, Young-Woo Son, Jeong Young Park, and Miquel Salmeron, Science 333, 607 (2011).