High-resolution Nanopatterning of Graphene Using Direct Helium Ion Beam Milling

Ahmad N. Abbas, He Liu, Gang Liu, Yuhan Yao, Gang Liu, Chongwu Zhou, and Wei Wu*
Department of Electrical Engineering, University of Southern California, Los Angeles, CA 90089
* wu.w@usc.edu

Douglas A. A. Ohlberg and R. Stanley Williams
Cognitive Systems Lab, HP Labs, HP Co.
Palo Alto, CA 94304

Graphene is a promising material for future electronic and photonic devices and circuits due to its unique properties, such as high mobility. Great progresses have been made. However, in order to utilize its full potential as the material for the future ultra-fast and energy-efficient electrical and electro optical devices, Graphene has to be patterned into nanostructures, such as nanoribbons, in order to create proper bandgaps. Moreover, the band structure of Graphene is very sensitive to the arrangement of atoms at pattern edges; therefore, a manufacture process that can pattern Graphene nanostructures at atomic precision with clean edges is needed.

Helium ion microscope and Helium ion beam lithography (HIBL) were developed recently[1,2]. Great progresses have been made on high-resolution HIBL and direct He ion beam milling[3-5]. Besides resolution, we also want to emphasize that He is inert. Therefore, He ion beam doesn't contaminate Graphene edges. That makes direct He ion beam milling an ideal tool to pattern Graphene nanostructures.

Here, we report our progress of patterning Graphene nanoribbons (GNRs) with half-pitch down to 5 nm using direct He ion beam milling. Figure 1a, b & c show scanning He ion microscope images of GNRs at half-pitches of 5 nm, 7.5 nm and 10 nm respectively. We also characterized the quality of the edges using Raman spectroscopy. The peak ratio between the D band (defect mode) and G band (breathing mode) can be used as an indicator of the roughness of the edges. The rougher the edges are, the higher D band peak is. Figure 1d shows the Raman spectrum of a 10 nm half-pitch GNRs. The D-to-G peak ratio shown in Figure 1d is much better than that of previously reported lithographically defined GNRs at similar sizes. This shows the quality of the He ion beam patterned GNRs. More optical and electrical characterizations will be presented in the conference.

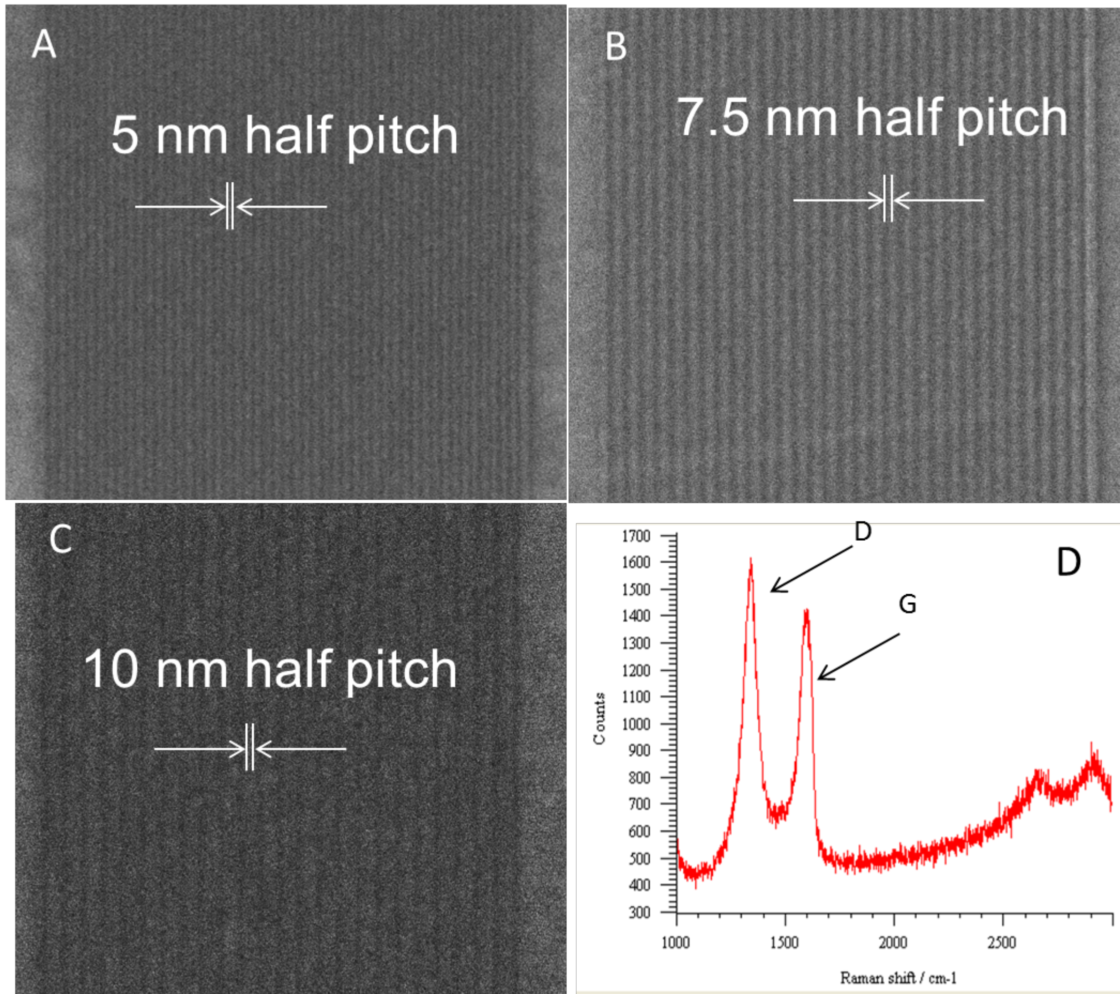

Figure 1:(A-C) Scanning Helium Ion beam microscope images of GNRs patterned by direct He ion beam milling at 5 nm, 7.5 nm and 10 nm half-pitches respectively. (D) Raman spectrum of GNRs at 10 nm half-pitch.

Referenes

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