Nanopatterning by helium ion beam: Only as good as the sample

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Since the commercial introduction of the gas field ion source (GFIS) that is at the heart of focused gas (light) ion beam systems, unprecedented milling resolution and versatility has been achieved. Thanks to the atomically small yet incredibly bright source (only ions generated from a single tip atom are directed on the sample) and the shorter wavelength of light ions compared to electrons, very narrow beam diameters down to 0.25 nm have been achieved. Such beams have been used to pattern various materials, including gold to form plasmonic antennae [1], graphene nanoribbons [2], graphene nanomesh [3] or investigate inner forces in graphene nanoscrolls [4].

Based on the published results, one might assume that any material can be readily patterned into such dimensions. However, equally often poor results are obtained that don't make it into published literature. For example, Figure 1a shows thin gold on a 50 nm thin SiN membrane that is cut. In this sample, the gold was deposited by using a shadow mask that makes the edges undefined. Furthermore, a poor sample mounting was responsible for considerable drift. As drift is uncontrolled, dose condition development is futile, and the increased low dose exposure increases surface sputtering without removal. Thus, the gold could not be cut. Drift was eliminated by careful sample mounting and slots as well as pores could finally be reproducibly patterned (Fig. 1b).

Nanopatterning of free-standing graphene (formation of graphene nanoribbons or nanomesh [3], cutting of nanoscrolls [4]) is another example of the importance of sample preparation. Figure 1c and d show examples of unsuccessful and successful patterning, respectively. The former is caused by drift and contamination. Drift spreads the helium ions over a larger area, reducing the dose. This dose is not enough to fully cut the graphene but causes swelling and deformation, or completely destroying the graphene.

In this presentation, we will share our experience in sample preparation for HIM milling and discuss strategies for successful experiments.

Acknowledgment: The help of M. Uno with the usage of the GFIS-FIB is acknowledged. T. Iijima is acknowledged for the usage of the HIM at AIST SCR Station**.** This research was supported through the Grant-in-Aid for Scientific Research (A) No. 18H03861from Japan Society for the Promotion of Science.

References:

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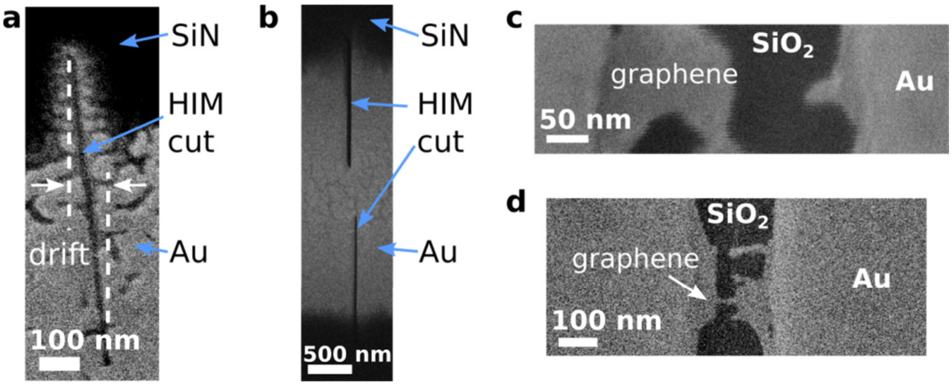

Figure 1: (a) HIM SE image of unsuccessful cutting attempt of gold on SiN membrane. Strong drift occurred. (b) Eliminating drift significantly improved milling result. (c+d) Sub-10-nm wide graphene nanoribbon formation by HIM in suspended single layer graphene.