Double-Side Masking and Stress-Released Etching for Fabrication of High Aspect Ratio Graphene Micro-Cantilever

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The remarkable mechanical properties of graphene make it as a promising candidate in application of high performance micro/nano-electromechanical (MEMS/NEMS) devices. In those applications, well-defined suspended micro/nano-structured graphene is highly expected. Already, two popular strategies have been developed for the purpose, i.e., resist-assisted methods [1] and direct-sculpting techniques [2]. As compared to the "resist-assisted methods", the sculpting strategy is effective and possesses the merits of high-resolution and well-process-flexibility for diverse geometrical layouts. Both the resist-assisted and direct-sculpting techniques have been well developed for the fabrication of bridged-structures. However, until now, only rarely non-distorted free-end cantilever has been obtained. [3] The asymmetric stress induced distortion would cause the micro/nano-structured graphene to adjust itself both in-plane and out-of-plane to a new balance, leading to curling or scrolling. It is the major obstacle that hinders the reliable fabrication of suspended micro/nano-structured graphene, especially for high-aspect-ratio cantilevers.

Here, we report a featured double-side masking and stress-released etching method to fabricate well-shaped micro-structured suspended graphene. We demonstrated that the one-step low energy (10 keV) electron beam induced deposition (EBID) of amorphous carbon on both sides of the graphene membrane, allowing its use as reliable masks for the following oxygen plasma etch. A rational ion-bombardment-assisted oxygen plasma etch was employed to realize the "self-crumpling" assisted stress release, forming the non-distorted suspended graphene micro-ribbon (Fig. 1a). Moreover, the stress-released etch enables the fabrication of graphene micro-cantilever with a high aspect ratio of 3.4 (Fig. 1b). The mechanisms accounting for the double-side EBID and the stress-released plasma etching (Fig. 2) were discussed. This work provides a promising method for making suspended structures of two-dimensional materials with in-plane flatness for potential MEMS/NEMS applications.

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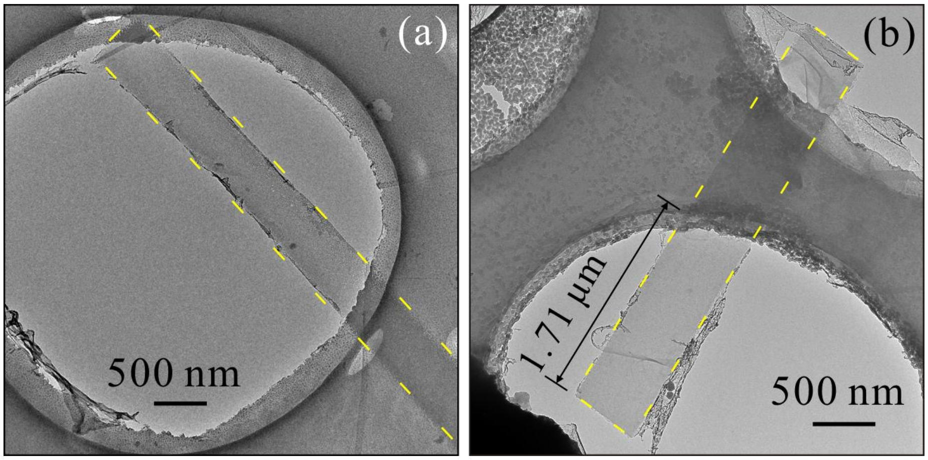

Figure 1. (a) and (b) are the representative TEM images of the micro-structured graphene bridge and cantilever that fabricated using the double-side masking and stress-released etching method, respectively.

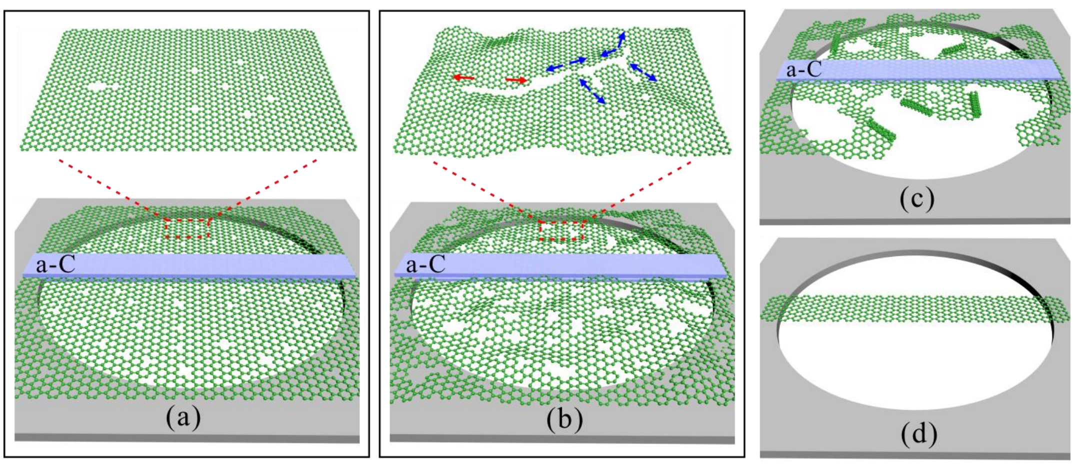

Figure 2. The schematic illustrations of the stress released process in the ion-bombardment-assisted oxygen plasma etch for making well-shaped graphene micro-ribbon, following the proposed "self-crumpling" model. (a) The high density vacancies induced by the ion bombardment. (b) The restrained crack propagation by the randomly distributed vacancies and the resulted crumpling. (c) and (d) illustrate the further etch to obtain the well-shaped micro-ribbon.

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