Direct transfer of graphene without the removal of a metal substrate using a liquid polymer

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We report a facile and effective method for the direct and controlled transfer of multilayer graphene from a Co substrate to polydimethylsiloxane (PDMS). Liquid PDMS was used for conformal contact with graphene, and the amount of curing agent was varied to control the surface energy of the PDMS. When the Co substrate was detached from the solid PDMS, graphene was transferred to the PDMS. The number of graphene layers transferred depended on the mixing ratio of the curing agent. Moreover, the morphology of the Co substrate was also transferred to the PDMS surface. This method enables the transfer of graphene on a wavy and uneven surface.

Figure 1 illustrates the process of graphene transfer using liquid PDMS. First, we placed multilayer graphene on a Co substrate in the rectangular frame, leaving space around the perimeter. Next, liquid PDMS and the curing agent were poured into the frame. To remove bubbles from the liquid PDMS, the sample was evacuated in a vacuum chamber for 10 min. After hardening for 60 min at 60°C in air, the solid PDMS was carefully separated from the frame. Finally, the Co substrate was manually detached from the PDMS. An advantage of using this process is that the Co substrate can be reused. We considered that graphene transfer may have occurred via three types of adhesion: PDMS–graphene, graphene–graphene, and graphene–Co substrate. If PDMS–graphene had a greater adhesion force than graphene–graphene, graphene would be transferred to PDMS. Under this assumption, the amount of curing agent should control the adhesion force between PDMS and graphene. Moreover, solution-phase PDMS exhibited a strong adhesion force due to fully conformal contact with the graphene surface. When the mixing ratio of the curing agent was varied, the adhesion force between PDMS and graphene changed, allowing control of the number of graphene layers transferred.

To characterize graphene before and after transfer, Raman spectra (Fig. 3) were collected for the Co substrate before and after transfer, and for the PDMS surface after transfer. The D peak at 1360 cm–1 provides information on graphene defects during synthesis and transfer. The graphene samples on the Co substrate showed few defects before transfer. The D peaks for graphene on PDMS were similar before and after transfer. Thus, the intrinsic structure of graphene was preserved during transfer to PDMS. Additionally, the position, shape, and intensity of G and 2D peaks were used to determine the number of graphene layers. In our experiments, the four samples of graphene synthesized on the Co substrate were multilayer graphene. After graphene transfer, the intensity and shape of the Raman peaks were distinct compared to the peaks of pristine graphene. The positions of the 2D and G mode peaks did not change, indicating that graphene was transferred from the Co substrate without structural changes.

References

[1] Changhyun Kim, Ju Yeon Woo, Kyungnam Kim, Jinwoong Choi, Junghee Park and Chang-Soo Han, Scripta Merialia, **66** (2012) 535.

Figures

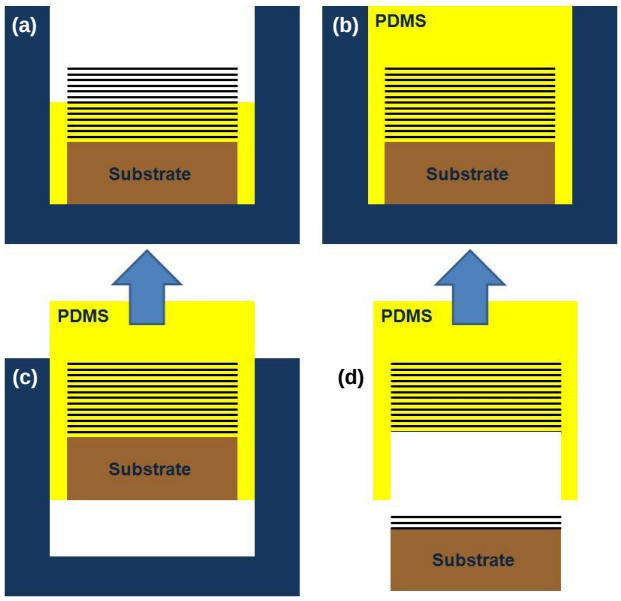

Figure 1. Transfer of graphene from a Co substrate using liquid PDMS. (a) The substrate was placed on a metal box frame. (b) After the curing agent and PDMS were mixed together, the liquid was poured into the box. (c) After curing, PDMS was separated from the box, and (d) the Co substrate was detached from PDMS.

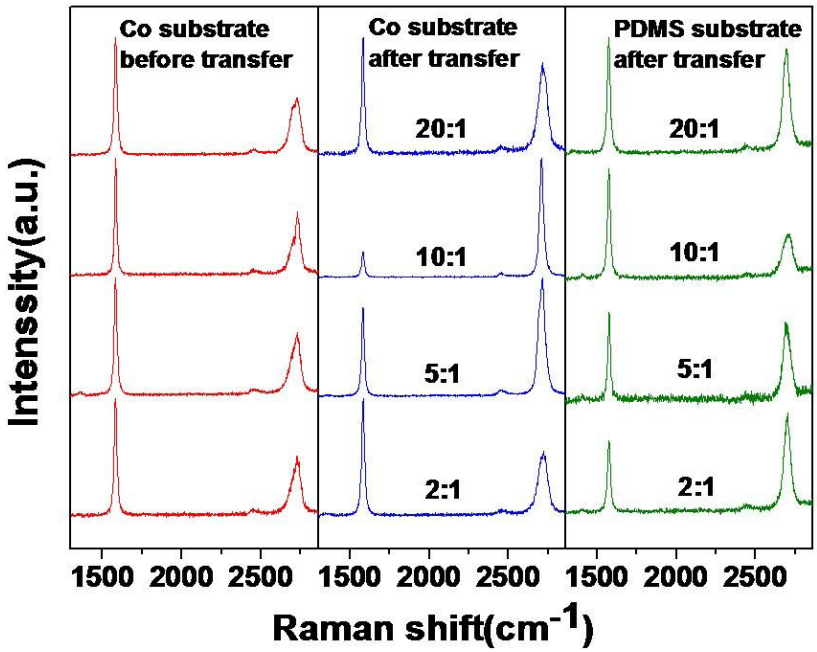

Figure 2. Raman spectra of graphene on the Co substrate before transfer (left), after transfer (middle), and on PDMS after the transfer for four samples (right).