Nanoimprint and Nanoprint – Based Routes for Producing Organized Few-Layer-Graphene Nano/Microstructures

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Scientific Thrust Area

Nanoimprint and nanoprint technology (NNT) appeared as a newly efficient and economical nanoscale pattern formation technology.[1] It also provided new routes for engineering and integrating nanomaterials into complex functional structures. One of the nanomaterials we have been working on is graphene. Graphene is of great interest as a material for next-generation electronics and energy storage media because of its superior electronic properties.[2] Two of important challenges for scale-up applications are incorporating graphene over large areas and patterning nanostructures to achieve desirable electronic characteristics. Obviously, a nanofabrication-based approach to simultaneously achieve graphene micro- and nanostructures over large areas would be a benefit to the practical applications of graphene.

Research Achievements

We explore novel nanoimprint/nanoprint technologies (NNTs) for producing organized graphene nanostructures. In general, such approaches consist of two steps: (1) prepatterning of nanostructures onto a high-quality graphite substrate, which serves as a template; (2) exfoliation and printing of prepatterned graphene nanofeatures onto device substrates.

To prepattern graphite templates, we not only exploited standard nano/microlithographic techniques such as photolithography (Fig. 1a), electron-beam induced deposition (EBID) (Fig. 1b), and focused ion beam (FIB), but also developed a new chemical approach, named as catalytic-assisted nanoimprint lithography (CANIL) (Fig. 1c).[3] In CANIL, an imprinting template bearing catalytic metal nanofeatures is brought into contact with a graphite substrate. At elevated temperature, the metal nanofeatures (e.g. Ag) can catalytically induce gasification of carbon material and therefore produce nanostructures in graphite. CANIL enables the direct parallel patterning of densely arranged ultrasmooth nanofeatures over large areas (Fig. 1c).

In order to exfoliate/print prepatterned graphene features, we developed a new nanoprinting approach, which uses a combination of electrostatic exfoliation with lithographically patterned highly oriented pyrolytic graphite (HOPG) to produce organized pristine graphene features.[4] With this method, we have successfully demonstrated the exfoliation/printing of few-layer-graphene (FLG) features ranging from 18 nm to 10s μm (Fig. 2). Furthermore, we have fabricated field-effect transistors (FETs) using patterned graphene nanolines, which exhibit excellent transport properties (Fig. 3).

Future Works

Our future works will be focused on (1) understanding the physical and chemical mechanisms underlying the catalytic nanoimprinting and building model for describing the dynamic process of the pattern formation; (2) fabricating well-defined graphene-based devices for studying the electrical and optical properties of graphene nanostructures, such as the effect of the edge states and quantum confinement on the electronic structures of graphene nanolines as well as evolution of Raman and two-photon-photoluminescence (TPPL) peaks as a function of graphene feature size.

References

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Publications

1. Liang, X. G.; Chang, A. S. P.; Zhang, Y. G.; Harteneck, B. D.; Choo, H.; Olynick, D. L.; and Cabrini. S, Nano Lett. 9(1), 467-472 (**2009**).
2. Liang, X. G.; Chang, A. S. P.; Zhang, Y. G.; Harteneck, B. D.; Choo, H.; Olynick, D. L.; and Cabrini. S, The 53rd International Conference on Electron, Ion, Photon Beams and Nanolithography (EIPBN 2008) May 26 – 29, **2009**, Marco Island, Florida.

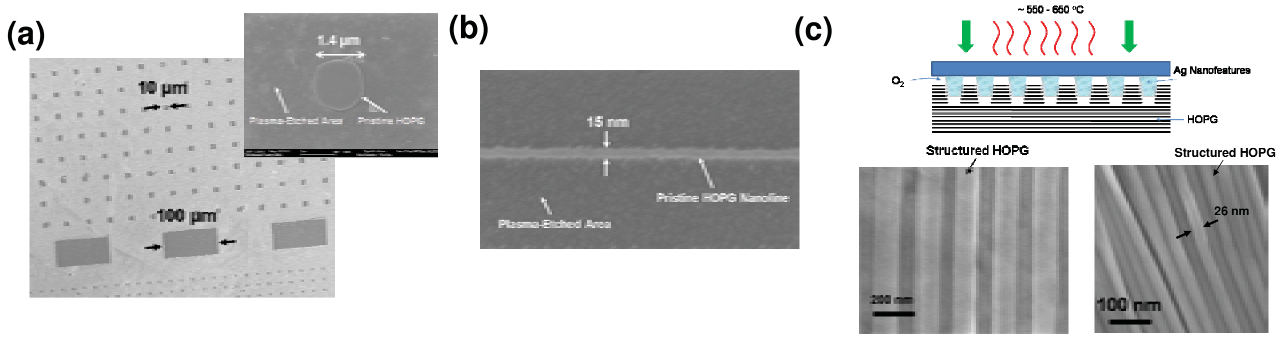

Fig. 1 SEM images of features prepatterned on graphite templates, which includes (a) 5 x 5 µm, 10 x 10 µm, and 100 x 50 µm rectangles and 1.4 µm size pillars, fabricated by photolithography, (b) 15 nm nanolines fabricated by electron beam induced deposition, and (c) 200 nm and 26 nm pitch smooth nanolines fabricated via catalytic-assisted nanoimprint lithography (CANIL) (the inset schematically illustrates the CANIL process).

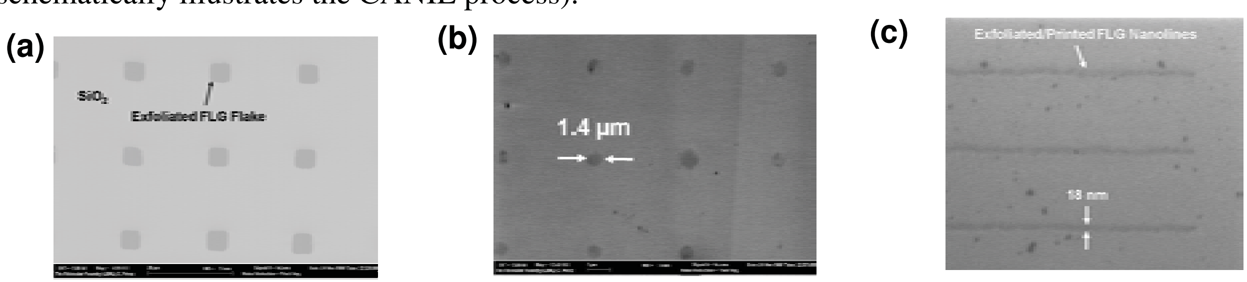

Fig. 2 Representative SEMs of electrically exfoliated/printed few-layer-graphene (FLG) features, which includes (a) 5 x 5 µm squares, (b) 1.4 µm size periodic pillars, and (c) 18 nm wide nanolines.

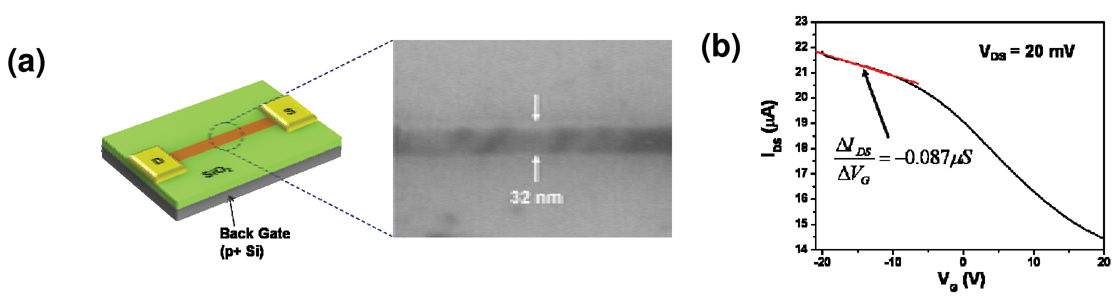

Fig. 3 (a) A back-gated graphene field-effect transistor (GFET) with a 32 nm wide, 0.53 µm long as-exfoliated FLG line as the channel. (b) I_{DS} - V_G of the GFET, from which the hole mobility is extracted to be μ_h = 1,050 cm^2/Vs.

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