Precision synthesis of graphene nanoribbons by ambient-pressure chemical vapour deposition

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Abstract

Graphene nanoribbons (GNRs), quasi-one-dimensional narrow strips of graphene, have shown great promise for use as advanced semiconductors in electronics. Compared with the lack of structural control in GNRs fabricated by "top-down" approaches, atomically precise GNRs can be "bottom-up" synthesized by surface-assisted assembly of molecular building blocks under ultrahigh vacuum (UHV) conditions. However, a large-scale synthesis of uniformly narrow GNRs at low cost and their transfer to insulating substrates remain significant challenges[1-3]. Moreover, structural characterizations of GNRs have been limited to microscopic and spectroscopic methods, hindering the direct elucidation of the exact chemical composition, especially for heteroatom-doped GNRs[4]. To further exploring the structural information of GNRs and make them applicable for real device applications, we demonstrate an efficient CVD process for inexpensive and high-throughput growth of structurally defined GNRs over large areas under ambient-pressure conditions. The CVD-grown GNRs exhibit similar structures and properties with those synthesized under UHV conditions, as supported by Raman spectroscopy, high-resolution electron energy loss spectroscopy, and STM characterizations. Homogenous GNR films over areas of centimetres have been successfully transferred to non-conducting wafers and exhibited a large current on/off ratio of up to 6,000 in field-effect transistor devices, which is significantly larger than values reported so far for other GNR thin film transistors. Moreover, by using graphene electrodes, the contact resistance can be drastically reduced while preserving the high current on/off ratio. This "bottom-up" CVD method further allows the growth of N-doped GNRs as well as their heterojunctions, demonstrating the versatility and scalability of this process, which provides access to a broad class of GNRs with engineered structures and properties based on molecular-scale design. These results pave the way toward the scalable and controllable growth of GNRs for future nanoelectronic device applications.

References

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Figures

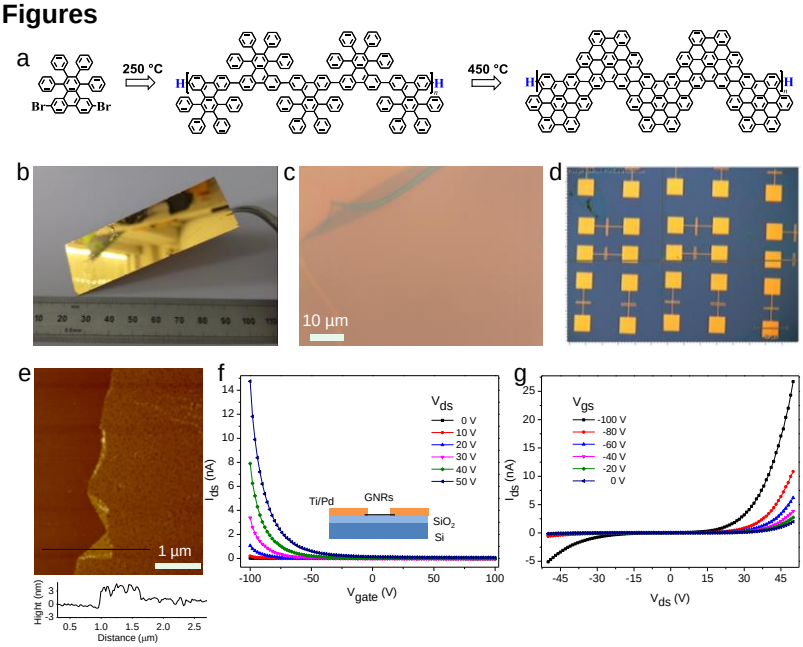

Figure 1. a, CVD reaction scheme to chevron-type GNRs. b, Photograph of a 25×75 mm^2 GNRs/Au/mica plate. c, Optical microscope image of the GNR film transferred on SiO_2/Si substrate. d, Photo image of the devices built on GNR film. e, AFM image of GNR film transferred on silicon wafer. f, Transfer curves of a typical GNR thin film field effect transistor measured at different V_{ds}. g, I_{ds}-V_{ds} curves of the GNR transistors.