Silver Nanoparticle/Boron-doped Graphene Nanoribbon Nanocomposite for Effective Surface Enhanced Raman Scattering

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Surface-enhanced Raman scattering (SERS) provides high sensitivity and selectivity on molecule detection, making it attractive for biomedical and chemical detections. Generally there are two mechanisms to influence the SERS enhancement: electromagnetic mechanism (EM) created by the metals with surface plasmon resonance (SPR) property and chemical mechanism (CM) due to the charge transfer between the molecule and the substrate. The development of synthetic method to produce nanostructures with controllable EM and CM properties will lead to important advances on both fundamental study and innovative applications for SERS-based biomedical detections. Graphene nanoribbons (GNRs) represent a unique structure of carbon nanomaterials with controlled electronic properties by tuning their widths, making them can be potentially useful as the SERS-active substrate and used in other applications including energy, composites, biomedical and electronics.

Here we report a rational design to develop a SERS-active nanocomposite with improved EM and CM properties. Toward this goal, we prepared silver (Ag)/Boron-doped GNR (B-GNR) composites using a sequential reaction route. First we synthesized GNRs with averaged width around 4 to 5 nm by the chemical unzipping of singled-walled carbon nanotubes (SWCNTs). Additionally, the prepared GNRs were doped with B atoms by a controlled carbonthemic reaction under argon (Ar) flow at atmospheric pressure and the B dopant concentration was about 1.4 atomic percentage (atom%) according to the X-ray photoelectron spectroscopy (XPS) analysis. Ag NPs with 10 nm averaged size were decorated onto the B-GNRs surface through an atmospheric-pressure microplasma-assisted redox reaction. Detailed materials characterizations including transmission electron microscopy and UV-Vis spectroscopy show that Ag/B-GNR composites were successfully synthesized in our experiment. We further systematically studied the Raman response of the Ag/B-GNR composite using Rhodamine 6G (R6G) as the Raman probe molecules. The result indicates that the Ag/GNR composite shows superior SERS performance with low detection concentration of 10^{-12} M of R6G and high enhance factor (EF) of 1.9×10^{12}. We furthermore systematically studied the CM enhancement via different probing molecules and substrates. Results show that SERS performance is strongly influenced by the charge transfer mechanism induced by the energy gap between the substrate Fermi level and the LUMO energy of probing molecules. Our study provide the conception to design the applicable SERS substrates.

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