Plasma Synthesis of Highly-Integrated Graphene Nanoribbons and its Advanced Applications

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We have developed a new, simple, scalable method based on novel plasma catalytic reaction for directly fabricating narrow graphene nanoribbons (GNRs) devices on an insulating substrate. Since the establishment of our novel GNRs fabrication method, direct conversion of a Ni nanobar to a suspended GNR is now possible. Indeed, GNRs can be grown at any desired position on an insulating substrate without any post-growth treatment, and the wafer-scale synthesis of suspended GNRs arrays with a very high yield (over 98%) is realized. The growth dynamics of suspended GNRs is also investigated through the systematic experimental study combined with molecular dynamics simulation and theoretical calculations for phase diagram analysis. Unique optoelectrical property, known as persistent photoconductivity (PPC), was observed in our suspended GNRs devices. GNRs-based non-volatile memory operation was demonstrated by using the PPC. High thermoelectric performance was also shown, which was explained by relatively clean edge and surface of our as-grown suspended GNRs.

Recently, we have also demonstrated the scalable fabrication of GNR-based quantum dot devices by adjusting GNR structures and growth conditions in our plasma CVD. Systematic investigation revealed that fine structures are formed at the middle of the GNRs (Fig. 1), which can be considered as the origin of the quantum-dot features in our GNRs. Detailed measurements at cryogenic temperatures revealed that clear orbital-level spacings (ΔV_{ds_ex}) between the ground state (GS) and excited states (ES) exist in our GNR-based quantum-dot device (Fig. 2). Furthermore, the orbital levels were found to be very stable even at high-temperature conditions (~20 K), which can be explained by the very fine structures formed in the middle of the GNR and relatively light effective mass of the GNR. More than 18% of devices fabricated within the same substrate showed orbital levels, indicating that integration of GNR-based quantum-dot devices is possible with our method. These findings further the fundamental study of GNR-based quantum devices toward practical applications.

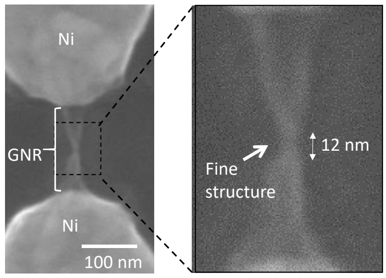

Fig. 1. Scanning electron microscope (SEM) images of suspended GNR with fine structures grown by our plasma CVD.

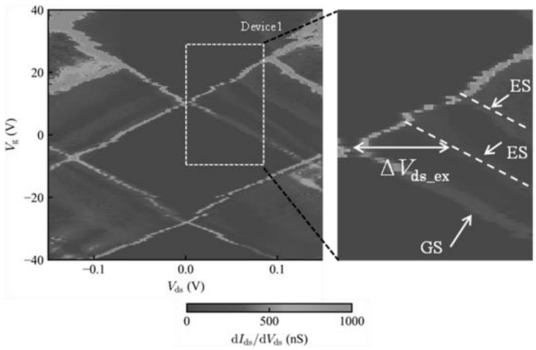

Fig. 2. Large Coulomb diamonds observed from our GNR-QD device. The dashed lines highlight ESs parallel to the edges of the diamonds (GS).

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