

急速加熱プラズマCVD成長架橋グラフェンナノリボンの合成機構解明と光電子デバイス応用

Growth Mechanism of Suspended Graphene Nanoribbon by Rapid-Heating Plasma CVD and its Optoelectronic Device Application

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Graphene nanoribbons (GNRs) combine the unique electronic and spin properties of graphene with a transport gap that arises from quantum confinement and edge effects. This makes them an attractive candidate material for the channels of next-generation transistors. Although GNRs can be made in a variety of ways, the reliable site and alignment control of GNRs with high electrical properties remains a challenge.

Up to now, we developed a novel method based on the advanced plasma CVD method [1] with nano scale Ni catalyst (Ni nanobar) for directly fabricating suspended GNRs devices [2]. However, the growth yield of suspended GNRs is low and understanding the growth mechanism is required to solve this problem.

Based on this background, we attempted to elucidate the growth dynamics of GNRs in our method. Through the comparison of molecular dynamics simulation and phase diagram calculation with the systematically obtained experimental results, it is found that the Ni nanobar becomes liquid state during the high temperature condition ($\sim 900^\circ\text{C}$) and only the Ni nanobar under plasma CVD can maintain its fine structure with liquid phase due to higher carbon composition. Then, phase separation between graphene and Ni happens during the cooling process, which accelerates the dewetting and the destabilization of liquid phase Ni nanobar under the GNR, resulting in the formation of suspended GNR (Fig. 1(a)). By following this growth model, the yield of suspended GNR growth can be drastically improved ($\sim 90\%$) and wafer scale synthesis of 1,000,000 suspended GNRs has been realized (Fig. 1(b)(c)) [3].

The optoelectronic properties of suspended GNR were also investigated. In case of GNRs array, photoresponse is clearly observed under the solar simulator illumination of which very weak light intensity ($200\text{mW}/\text{cm}^2$) and its responsivity is above $100\text{A}/\text{W}$ at room temperature, whereas

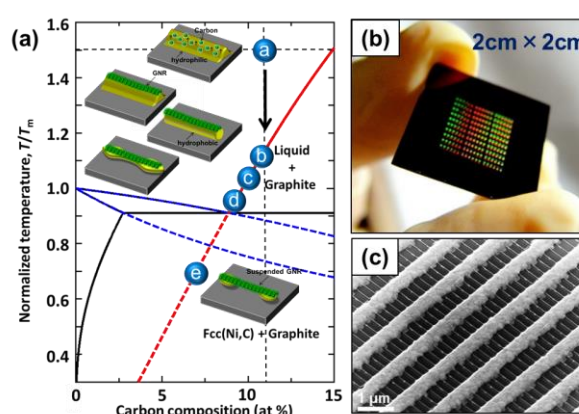


Fig. 1: (a) Growth model of suspended GNR, (b) optical microscope image, and (c) scanning electron microscope image of suspended GNRs array in wafer scale.

photoresponse is not observed under same conditions from conventional 2D graphene sheet. The temperature and time dependence of photoresponse are also systematically investigated to elucidate the photoresponse mechanism of GNR. It is found that the two mechanisms contribute to the photoresponse of GNR, one is bolometric and the other is carrier-trapping effect. The trapping effect is dominant near the room temperature condition and the photoresponse can persist more than 1 hour. These results imply that the GNR array can be used as the high performance nonvolatile optical memory.

[1] H. Suzuki, T. Kato and T. Kaneko, Plasma and Fusion Res. **9**, 1206079 (2014).

[2] T. Kato and R. Hatakeyama, Nature Nanotechnology **7**, 651 (2012).

[3] H. Suzuki, T. Kaneko, Y. Shibuta, M. Ohno, Y. Maekawa and T. Kato, Nature Communications **7**, 11797 (2016).