# Application of graphene to electronic devices

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**Abstract**

Nanocarbon materials, such as graphene and carbon nanotubes, have excellent electrical, thermal, and mechanical properties and are thus expected to be used for future electronics devices. We have been working on synthesis of nanocarbon materials and their application to transistors and interconnects for years. In this talk, we first describe our efforts to grow nanocarbon materials, which include graphene growth over a 300-mm wafer by chemical vapor deposition (CVD), and synthesis of an interesting carbon structure consisting of multilayer graphene combined with the upper ends of vertically aligned multiwall carbon nanotubes on a substrate.[1] Bottom-up synthesis of graphene nanoribbons (GNRs) on Cu twin crystals (Fig. 1) and step edges is also explained.[2,3] CVD-synthesis of multilayer hexagonal boron nitride (hBN), which can be good substrate and passivation film for graphene devices, is also described。

As for transistor applications, we briefly review theoretical and experimental studies on transport properties of GNR-channel transistors first. We then explain one of our approaches to obtain a high current on-off ratio of graphene channel transistors. In fact, we used a graphene channel irradiated by helium ions, demonstrating a sizable transport gap and an on-off ratio of about two orders of magnitude at room temperature.[4] We then describe a double-gate graphene transistor and its applications, which includes a binary digital phase modulator making use of ambipolar properties of graphene.[5]

We also explain the application of graphene to interconnects. We actually fabricated GNR interconnects with widths as narrow as 8 nm using electron beam lithography (Fig. 2).[6] The GNR interconnects were heavily doped by intercalation of $FeCl_3$ molecules and demonstrated resistivity and reliability better than those of Cu with similar dimensions.

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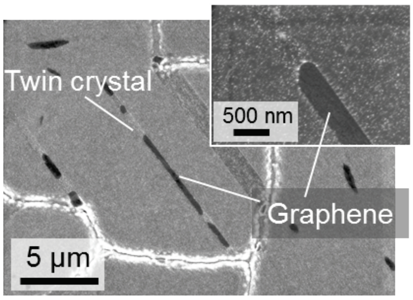


Fig. 1. Graphene ribbons formed on Cu twin crystal regions

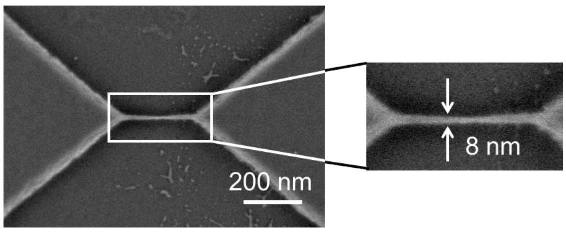


Fig. 2. Graphene naroribbon interconnect with a width of 8 nm