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Synthesis and application of carbon nanotubes, graphene, and graphene nanoribbons

We work on growth of carbon nanotubes (CNTs), graphene, and graphene nanoribbons (GNRs), and their application to electronic devices, such as transistors, interconnects, and sensors. We explain some of our recent results. As for CNTs, we have been working on application of CNTs to interconnects [1, 2], and thermal interface materials (TIMs) [3]. In particular, we fabricated TIMs consisting of bundles of vertically aligned CNTs, where the density of CNTs was increased by a newly-developed compressing method [3]. The thermal resistance of the CNT-TIM was found to be as low as that of indium film [3]. We also work on applications using graphene and graphene nanoribbons (GNRs). In fact, graphene can be used for high-frequency wave detection [4]. We actually proposed a diode consisting of a GNR heterojunction (Fig. 1) for such a purpose [4] The heterojunction consists of a hydrogen-terminated armchair-edge GNR (H-AGNR) and fluorine-terminated armchair-edge GNR (F-AGNR). Since there is a difference in electron affinity between them, we can construct a staggered-type lateral-heterojunction p-n diode. Simulations show that, due to band-to-band tunneling, the diode has a nonlinear reverse current of the order of kA/m. The junction capacitance is extremely small due to the small junction area. It has been found that the diode can have a much better sensitivity for terahertz wave than a GaAsSb/InAlAs/InGaAs heterojunction diode [5]. Furthermore, we recently developed a graphene-gate transistor, where the gate of a Si transistor was replaced with single-layer graphene (Fig.2) [6]. This graphene-gate transistor can be used as a gas sensor. In fact, when gas molecules adsorb on the graphene-gate surface, the Fermi level or work function of graphene can change, thus shifting the threshold of the Si transistor. This causes changes in the drain current if the gate voltage is kept constant. This graphene-gate sensor is very sensitive to NO_2 and NH_3. In fact, we found that the sensor can detect NO_2 with concentrations less than 1 ppb.
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References

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Figures

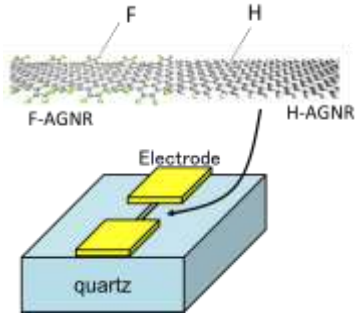

Figure 1: Illustration of a diode using a heterojunction of F-AGNR and H-AGNR.

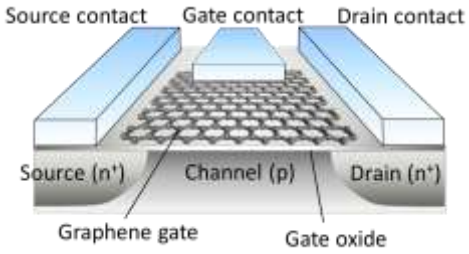

Figure 2: Schematic illustration of a graphene-gate transistor (sensor)