Momoko Onodera[1]
Takashi Taniguchi[2], Kenji Watanabe[2], Satoru Masubuchi[1], Tomoki Machida[1,3]
[1] *Institute of Industrial Science, University of Tokyo, Tokyo, Japan*
[2] *National Institute for Materials Science, Tsukuba, Japan*
[3] *CREST, Japan Science and Technology Agency, Japan*

monodera@iis.u-tokyo.ac.jp

Transport properties of graphene on h-BN grown with an alloy solvent at atmospheric pressure

Hexagonal boron nitride (h-BN) has been used in research institutes all over the world as an insulating substrate for other 2D materials. The h-BN crystal of the highest quality is grown with Ba-BN solvent under high pressure and high temperature (HPHT) [1]. Although HPHT method yields high-purity h-BN, it requires large-scaled high-pressure apparatus, limiting the place of production of the crystals. In addition, it has recently been found that the HPHT h-BN crystal has a distinct domain in its center, which has high density of carbon impurities. This C-rich domain is not recognized under optical microscope or by AFM, unknowingly incorporated into van der Waals heterostructures.

On the other hand, the condition of the synthesis of h-BN crystals can be controlled by changing the solvent. By using a metal solvent instead of Ba-BN, one can obtain h-BN crystals at atmospheric pressure and high temperature (APHT) [2]. The FWHM of the Raman spectrum of the APHT h-BN crystals was roughly equivalent to that of HPHT ones, which suggested that the quality of the APHT crystals were comparable to that of HPHT ones. Furthurmore, the CL image of the APHT h-BN crystals showed that they don't have any domains. Thus, one can use APHT h-BN crystals without concerning the effect of the C-rich domains.However, there has been no investigation about the quality of the APHT h-BN as a substrate for other layered materials. It is very important for the 2D material community to confirm whether it can be used for practical device applications.

In this work, we reveal the transport properties of graphene on APHT h-BN. We fabricated h-BN/graphene/h-BN/graphite van der Waals heterostructures on p^+-doped Si/SiO_2 substrate by pick-up method [Fig. 2(a)]. The bottom graphite was used as a back gate. At T = 1.6 K, R_{xx} of the graphene showed a sharp peak at Dirac point [Fig. 2(a)]. The carrier mobility exceeded 1,000,000 cm^2/Vs [Fig. 2(c)]. The magnetic focusing of carriers was also studied in the device using the wiring scheme shown in Fig. 3(a). The first and second focusing peak was clearly observed at T = 1.6 K [Fig. 3(b)], and they remained at T = 160 K. The cyclotron radius r_C was estimated as $2r_C$ = 1.85 μm for the first focusing peak. In another device, we observed the Hofstadter butterfly diagram [Fig. 4], which is an indicator of moire potential introduced in the graphene/h-BN superlattice. In conclusion, one can obtain high enough carrier mobility in graphene on APHT h-BN, and it can be used for fabricating devices aimed at ballistic transport measurements or moire superlattice.

References

[1] K. Watanabe, T. Taniguchi, H. Kanda, Nat. Mater. **3**, 404 (2004)..
[2] Y. Kubota, K. Watanabe, O. Tsuda, and T. Taniguchi, Science **317**, 932 (2007).

Figures

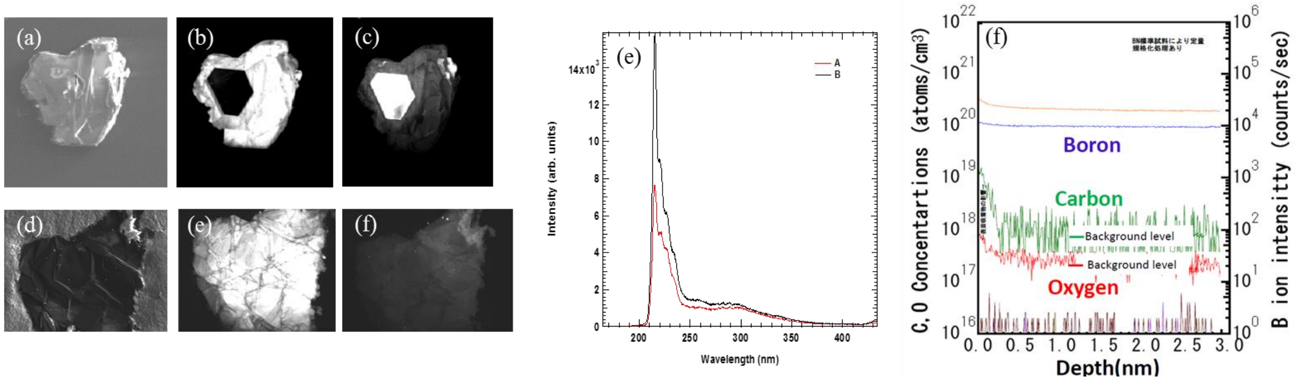

Figure 1: (a-c) SEM image, CL image of 230 nm and CL image of 320 nm, respectively, of a HPHT h-BN crystal. (d-f) SEM image, CL image of 230 nm and CL image of 320 nm, respectively, of an APHT h-BN crystal. (e) CL intensity of an APHT h-BN crystal. (f) C and O concentration and B and B+N intensity of the central region of a APHT h-BN crystal.

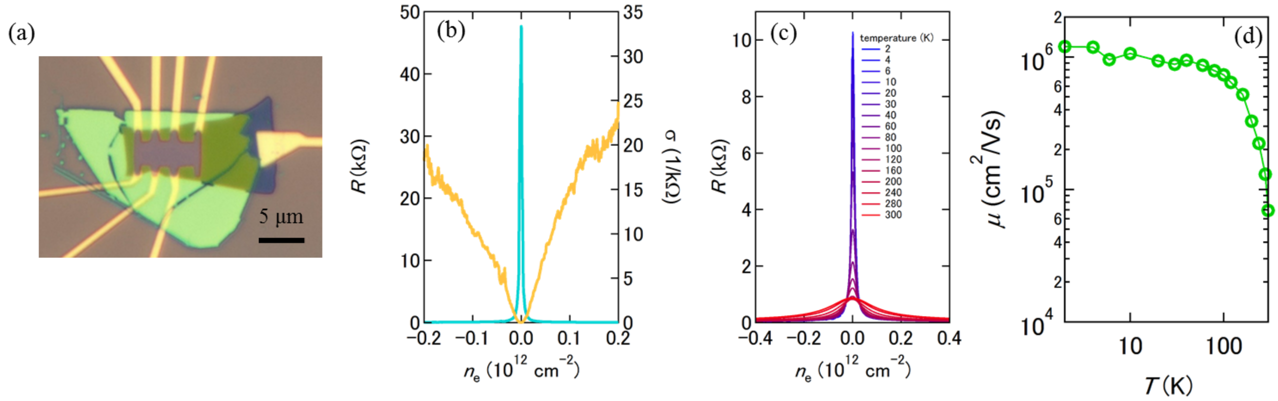

Figure 2: (a) Optical image of the device. (b) R_{xx} (blue) and conductivity σ (yellow) at T = 1.5 K as a function of carrier density n_e. (c) Temperature dependence of R_{xx}. (d) Carrier mobility μ as a function of T.

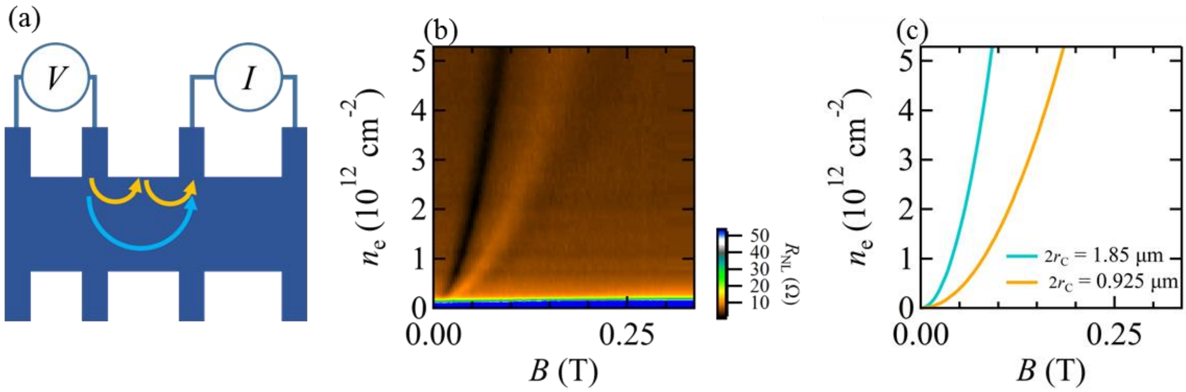

Figure 3: (a) Measurement geometry of the device for R_{NL}. (b) R_{NL} as a function of $B_\perp$ and n_e. (c) Numerical plot for $2r_C$ = 1.85 (blue) and 0.925 (orange) µm.

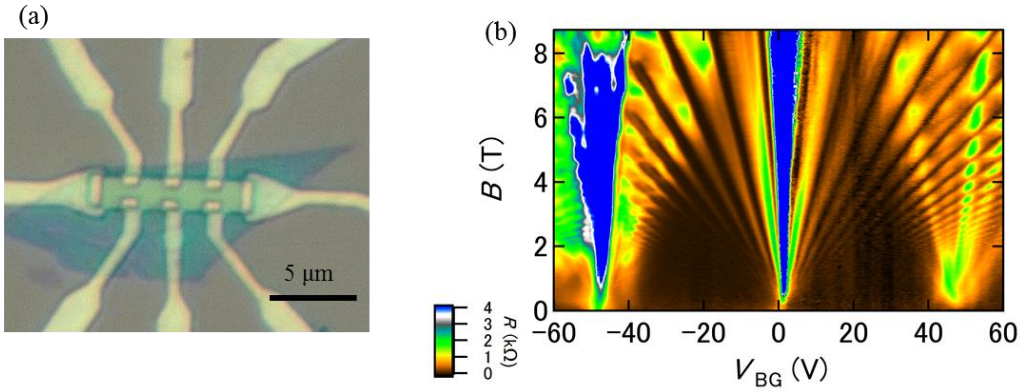

Figure 4: (a) Optical image of the device. (b) R_{XX} plot as a function of V_{BG} and $B_\perp$.