Ballistic and phase coherent transport in high-mobility graphene antidot lattices made on h-BN

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Antidot lattice is a two-dimensional conductor with a regular array of holes. This is one of typical systems that show wave-particle duality. To date, antidot lattice of Dirac electron system is less explored as compared with conventional two-dimensional electron gas. Here we show particle and wave nature of Dirac electrons in antidot lattices. Particle nature was observed as commensurability magnetoresistance arising from ballistic electron transport in a triangular antidot lattice of high-mobility graphene that was made on h-BN (Fig. 1). For the mono- and bilayer graphene antidot lattice devices with carrier mobility of about 3×10^4 cm^2/Vs and mean free path of about 400-600 nm, we observed bipolar magnetoresistance peaks that originate from commensurability of cyclotron orbits with the antidot lattice. Detailed study of the magnetoresistance peak as a function of carrier density revealed that the commensurability occurred when cyclotron diameter matches the lattice constant, *i.e,* $2R_c=a$, where R_c is a cyclotron radius and a is a lattice constant [1]. Shapes of the magnetoresistance traces were approximately reproduced by numerical calculation of conductivity components using a semiclassical Kubo-type formula for chaotic orbits. The peaks appeared when the carrier mean free path was approximately larger than the lattice constant, which quantitatively agreed with our experiment. On the other hand, wave nature was observed as small period magnetoresistance oscillations that are reproducible from sweep to sweep.[2] In particular, near $B=0$ we found magnetoresistance oscillation with a period of $\Phi = h/2e$, which is the Altshuler-Aronov-Spivak (AAS) oscillations arising from interference of coherently back-scattered paths with time reversal symmetry. AAS oscillations share a common origin with the weak localization or anti-localization in two-dimensional electron system. The phase of the AAS oscillations was the same as that originating from weak localization rather than weak anti-localization, in that R_{xx} exhibited a local maximum rather than a local minimum at the vicinity of zero magnetic fields. This is different from a simple prediction that AAS oscillations with the phase same as anti-localization should occur in monolayer graphene because of π-Berry phase. Our experiment indicated that system was influenced by frequent inter-valley scattering possibly due to boundary scattering. We also observed that AAS oscillations switched to the Aharonov-Bohm (AB) type oscillations with a (h/e)-period in higher magnetic fields.

References

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