Ballistic transport in step edge aligned cross junctions on epitaxial graphene

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We studied ballistic transport in nanoscale orthogonal cross junctions fabricated from epitaxial monolayer graphene grown on the Si-face of SiC. Measurements were performed on conventionally grown [1] and hydrogen intercalated graphene films [2, 3]. The devices were aligned parallel to the step edges of the SiC substrate. Using ac and dc measuring techniques, we obtained a negative bend resistance for low temperatures, which indicates electronic transport in the ballistic regime. As temperature is increased, a transition to the diffusive regime is observed.

Sample A is prepared by thermal decomposition of SiC(0001) under Ar atmosphere [1]. Sample B was additionally hydrogen intercalated after film growth, resulting in a quasi-freestanding monolayer graphene film [2, 3]. Hall bar structures (600 nm wide and 3 µm long) for film characterization and cross junctions with four identical leads of 50 nm width and 400 nm length are prepared using a mix-and-match process [4].

First of all samples A and B are characterized by Hall measurements in a temperature range of 1.5 K ≤ T ≤ 300 K. At T = 4.2 K for sample A a mobility of µA = 4180 cm2V−1s−1 and an electron density of n2D,A = 2.6 . 1012 cm-2 are determined, which is equivalent to a mean free path of le = 78 nm. As temperature is increased to T = 300 K the mobility decreases nearly linearly to µA = 1470 cm2V−1s−1. For sample B we obtain a mobility and hole density of about µB = 1920 cm2V-1s-1 and p2D,B = 5.1 . 1012 cm-2, respectively. These values are constant in the whole temperature range and correspond to a mean free path of le = 50 nm.

For sample A the cross junctions are studied in bend resistance geometry by dc transfer measurements [Fig. 1, (b)]. A bend resistance of R12,43 = –175 indicates ballistic transport [Fig. 1 (a)]. The negative slope is nearly the same for all four measurement configurations due to the geometrical symmetry of an orthogonal cross junction. Corresponding measurements for unaligned devices on another sample demonstrated a strong dependence of the bend resistance on the measurement configuration [5], which indicates that scattering at step edges destroys ballistic transport. Since the mean free path of sample B is close to the device dimensions, the bend resistance of the device is close to zero in the absence of magnetic field. Therefore we used lock-in technique to study the differential bend resistance r12,43 as a function of a perpendicular magnetic field B [Fig. 2 (b)]. Figure 2 (a) shows r12,43 for sample B as a function of B at T = 4.2 K. The magnetic field dependent negative peaks indicate ballistic transport. The maximum value r12,43 = −147 at B = 200 mT is comparable to the results of sample A and former ballistic transport measurements [5]. As temperature is increased to T = 50 K the signatures of ballistic transport disappear which indicates a transition from the ballistic into the diffusive transport regime. These results point out that in contrast to 2D measurements, which yield a mean free path le independent of T, and surface spectroscopy measurements [3], which promise epitaxial graphene-based ballistic devices even at room temperature, additional scattering in 1D systems plays an important role and must be studied in detail.