Anisotropic quantum Hall effect in graphene on stepped SiC surfaces

T. Schumann, K.-J. Friedland, M. H. Oliveira, Jr., A. Tahraoui, J. M. J. Lopes, H. Riechert

Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany schumann@pdi-berlin.de

With its two-dimensional nature and extraordinary electrical properties, graphene is one of the most promising materials for future electronic applications. The synthesis of graphene by the depletion of Si from the surface of SiC is thereby of particular technological interest, since it offers the possibility of preparing graphene on a large scale directly on an insulating substrate.

Epitaxial graphene prepared on the hexagonal SiC(0001) face exhibits a stepped surface with regular terraces and step edges with graphene growing carpet-like over the complete substrate and forming a closed layer. The influence of steps on the electrical transport at zero magnetic field has recently been studied by different groups [1,2]. It was shown that step edges and monolayer-bilayer junctions contribute to an intrinsic resistance. Other works [3] show that the electrical properties (i.e. carrier concentration and mobility) are not altered by the existence of steps on the SiC surface on the transport properties of graphene, especially in the presence of magnetic fields. Here, we report on an anisotropic behavior of the magnetotransport in graphene at high magnetic fields for Hall bars aligned parallel and perpendicular to surface terraces.

Monolayer graphene was prepared on semi-insulating 6H-SiC(0001) substrates with a miscut of ~1%. Subsequently, Hall bars with a width of 2 μ m and a length of 30 μ m, oriented perpendicular or parallel to the step edges on the surface, were defined by optical lithography and oxygen plasma etching. Their surface morphology was investigated by atomic force microscopy and their structural quality by Raman line scans. The Raman scans (not shown) reveal a strong variation in the position of the G- and 2D-line for Hall bars oriented perpendicular to the terraces (i.e. crossing several step edges).

Hall- (ρ_{xy}) and longitudinal (ρ_{xx}) resistivity were measured at a temperature of 320 mK and magnetic fields (B) perpendicular to the surface up to 14 T. The results are shown in figure 1. In both cases, the Hall resistances at high magnetic fields show for both directions a similar behavior with only one clearly recognizable Hall plateau. Carrier densities *n* and mobilities μ were derived from the Hall coefficients and the resistivities at zero magnetic field.

However, the longitudinal resistivities show a quite different behavior for the two alignments at high magnetic fields. While the Hall bar oriented parallel to the terraces shows a conventional quantum Hall effect, the resistivity shows an overall increase with increasing magnetic field in the case where the current crosses many surface steps. This behavior can not only be an effect of enhanced scattering, e. g. at defects or impurities, since the resistivity at zero magnetic field is comparable. The anisotropy at high fields strongly indicates an influence of the steps of the SiC substrate on the magnetotransport properties of epitaxial graphene.

To interpret this anisotropy, we adopt a simple model (figure 2). At high magnetic fields, the conductivity is governed by a low number of channels at both edges of the Hall bar. The number of conductive channels is given by the filling factor v and is proportional to n/B. In the region of the step edges, additional conductive channels (corresponding to higher filling factors) may appear. One reason may be the lower effective magnetic field (B_{eff} ~0.9 B₀) at the steps, caused by the tilt between the SiC surface (and hence the graphene) and the step facet. A second reason might be differences in carrier

concentration between step edges and terraces. These additional channels enable the possibility that electrons scatter between channels at opposite sides, since the spatial separation between the additional edge channels is reduced. This enhances the backscattering, as indicated in Fig. 3, and may increase the longitudinal resistance at high magnetic fields.

References

- [1] M. K. Yakes et al. Nano Letters 10, 5 (2010) 1559.
- [2] S.-H. Ji et al. Nature Materials 10, **11** (2011) 114.
- [3] J. Jobst et al. Solid State Communications 151, 16 (2011) 1061.

Figures



Figure caption

Figure 1 - Longitudinal- (ρ_{xx}) and Hall resistivity (ρ_{xy}) as a function of magnetic field (B) in Hall bar structures, aligned parallel (black) and perpendicular (red) to the SiC terraces, respectively.

Figure 2 - Model of the magnetotransport in graphene for narrow Hall bars on stepped SiC surfaces in side-view (a) and top view (b).