Functionalization of epitaxial graphene by proximity to heavy metals and TMDs

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The proximity effect allows for the functionalization of graphene by introducing properties into it that are not inherent to it. In this study, heavy metals and transition-metal dichalcogenides (TMDs) are brought into contact with monolayer graphene (MLG)/SiC(0001) with the aim of increasing graphene's negligible spin-orbit interaction, and investigated by magneto transport, electron diffraction and scanning tunneling microscopy.

Bi deposited at 300 K on MLG/SiC forms of a majority of needle-like Bi(110) islands elongated in the Bi(110) zig-zag direction, which are aligned with the MLG armchair direction except for a small misalignment angle of about 1.75°. Additionally, we observed a minority of needle-like Bi(110) islands orientated roughly orthogonal to the majority structure, whose concentration significantly increased after an annealing step at 410 K. This minority structure has four sub-domains, which we attribute to the formation of mirror twin boundaries, resulting in two potential alignments of Bi(110) majority and minority domains with respect to each other, in addition to two possible alignments of the majority domain with respect to graphene (see figure). The carrier concentration determined from the SdH oscillations remains at $1 \times 10^{13}\ \mathrm{cm}^{-1}$independent of the Bi coverage. In contrast, photoemission spectroscopy shows a strong doping of the graphene by Bi [1], indicating that the carrier concentration is highly anisotropic. This is confirmed by a positive, temperature independent contribution to the magneto resistivity, which indicates that the Bi covered regions are electrically dead zones causing the electrons to scatter at the boundaries. This reduces the mobility from around $2250\ \mathrm{cm}^2/(\mathrm{Vs})$ for MLG to $1920\ \mathrm{cm}^2/(\mathrm{Vs})$ at 2.4 BL Bi, a decrease of approximately 14%. [2,3]

Additionally, single layer MoS_2 flakes and epitaxial WS_2, which are expected to introduce strong spin-orbit coupling in graphene due to their inherent spin structure [3], were brought into contact with MLG/SiC. The influence of the SiC substrate results in TMD states intersecting the Fermi level and therefore contributing to the transport. Sondheimer oscillations were observed in the magneto resistance, indicating a hybridization of the TMD layer with the graphene.

References:
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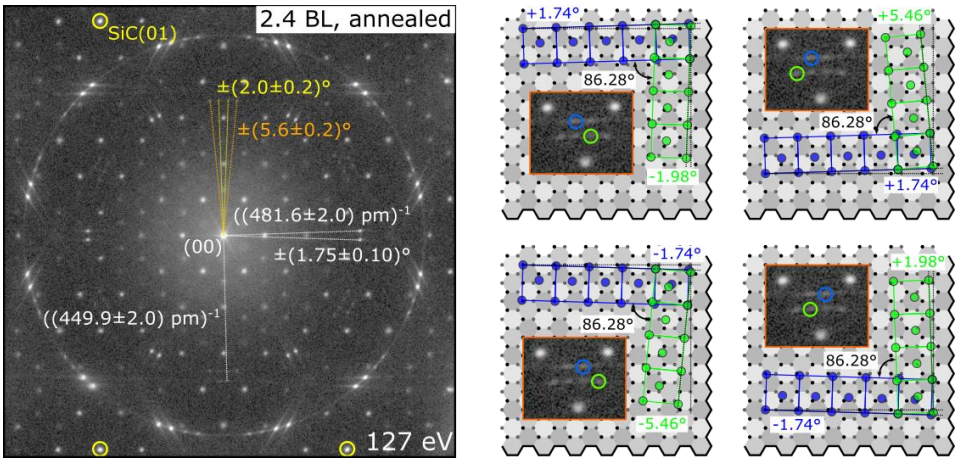

Fig. 1: LEED image of MLG with a Bi coverage of 2.4 BL after annealing at 410 K for 30 min recorded at 127 eV (left). Alignment of the Bi(110) majority (blue) and minority (green) islands with respect to graphene (right). [1]