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Graphene on metals - structure and properties

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The “metal route” to graphene, i.e., the epitaxial growth of graphene on a metal surface by chemical vapor deposition (CVD) of hydrocarbon molecules and the following transfer of the graphene film to an insulating support, has recently made great progress [see, e.g., S. Bae et al., *Nature Nanotechnol.* 5, 574 (2010)]. However, structurally and from their charge carrier mobilities, metal-grown graphene samples have not yet reached the quality of exfoliated graphene, most likely resulting from uncontrolled processes during the CVD. In order to better understand how graphene interacts with metal surfaces we have performed a series of surface science studies. As experimental techniques we have applied STM, ARPES, LEED, and SXRD, mainly on Ru(0001)/graphene, and we have performed extensive DFT analyses. We find a short metal-graphene separation, a strong deformation of the graphene, a lifting of the Dirac point, and shifts of the electronic bands. The structural and electronic properties evidence surprisingly strong interactions of the graphene with the Ru surface which are probably prototypical for other metals such as Co, Ni, and Pd. A second group of metals, namely Ir, Pt, Cu, Ag, and Au, only show weak interactions. In situ STM experiments at high temperatures (between 380 and 780 C) show that the usual “carpet mode” by which graphene grows across steps of the metal surface [P. W. Sutter et al., *Nature Mater.* 7, 406 (2008)] can lead to defects. However, the growth mode changes at high temperatures and low pressures of the hydrocarbon precursor, partially a result of the relatively high Ru-graphene interactions. They lead to a faceting of the surface, and one can grow extremely large single-crystalline graphene films on single terraces in this way.