Europium on graphene: phase coexistence of clusters and islands

Thomas Michely[1], Daniel F. Förster[1], Tim O. Wehling[2,3], Stefan Schumacher[1], Achim Rosch[4]

[1] II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany
[2] Institut für Theoretische Physik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany
[3] Bremen Center for Computational Materials Science, Am Fallturm 1a, 28359 Bremen, Germany
[4] Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937Köln, Germany
michely@ph2.uni-koeln.de

In recent years, it has become apparent that the properties of graphene, even if present in high structural quality, depend critically on its environment, e.g. on the type and distribution of chemical species adsorbed to graphene. This critical dependence of the graphene properties on the environment may also be turned into an advantage if new compound materials are constructed that bestow graphene with novel properties while keeping the desirable features of its electronic structure intact (e.g. its conical bands and the Dirac cone). As an example, it was proposed to bring the ferromagnetic insulator EuO into contact with graphene in order to induce a spin split Dirac cone with the resulting option for spin filtering in graphene [1]. Due to the large magnetic moment of $7\mu_B$ of the Eu 4f-shell, also metallic Eu is a material with the potential to bestow graphene with magnetic properties.

As a prerequisite for future work in this direction, it is necessary to understand in detail the adsorption and growth of Eu on graphene. Moreover, we believe that a systematic study of Eu adsorption and growth as a function of coverage and temperature under controlled ultra high vacuum conditions offers insight into fundamental aspects of the interaction of graphene with an entire class of materials.

In this work [2], we investigate the adsorption and equilibrium surface phases of Eu on graphene on Ir(111) in the temperature range from 35 to 400K and for coverages ranging from a small fraction of a saturated monolayer to the second layer. We combine temperature-dependent Eu growth and annealing experiments, scanning tunnelling microscopy, work function measurements by I(*z*) scanning tunneling spectroscopy, low-energy electron diffraction, density functional theory calculations including 4f-shell Coulomb interactions and qualitative modelling of electronic interactions in order to gain an understanding of the Eu/graphene adsorbate system.

Most remarkably, at 300K in an intermediate coverage range a phase of uniformly distributed Eu clusters (size 10–20 atoms) coexists in two-dimensional equilibrium with large Eu-islands in a $(\sqrt{3}\,x\,\sqrt{3})R30°$ structure. We argue that the formation of the cluster phase is driven by the interplay of three effects: Firstly, the metallic Eu–Eu binding leads to the local stability of $(\sqrt{3}\,x\,\sqrt{3})R30°$ structures. Secondly, electrons *lower* their kinetic energy by leaving the Eu clusters, thereby doping graphene. Thirdly, the Coulomb energy penalty associated with the charge transfer from Eu to graphene is strongly reduced for smaller clusters.

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References

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Figures

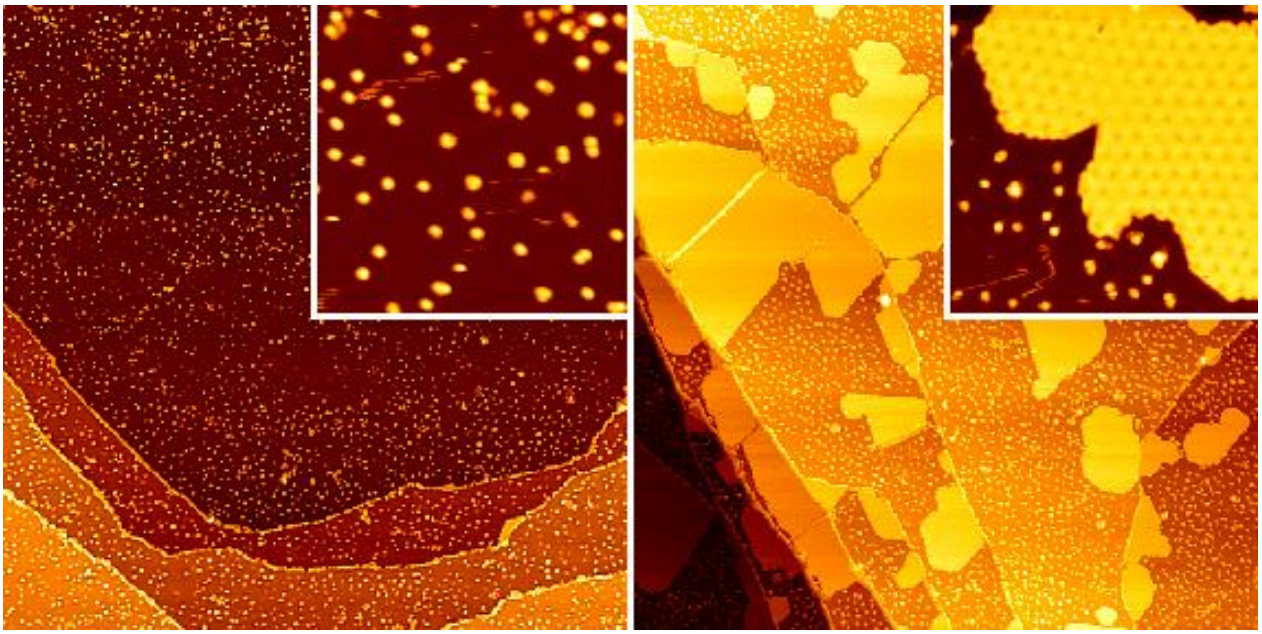

Figure caption: Scanning tunneling microscopy topographs taken at 35 K after Eu deposition at 300K on a perfect graphene layer on Ir(111). Left: 3.3% ML Eu coverage. Right: 12% ML Eu coverage. 100% ML corresponds to one adsorbed atom per graphene unit cell. Image size 320 nm x 320 nm. Inset size 40 nm x 40 nm.