O 8: Focused Session: Epitaxial Graphene I

Time: Monday 11:15–12:45 Location: SCH 251

Topical Talk O 8.1 Mon 11:15 SCH 251

Atmospheric pressure graphitization of SiC: a route towards wafer-size graphene films — K.V. Emtsev[1], A. Bostwick[2], K. Horn[3], J. Jobst[1], G.L. Kellog[4], L. Ley[1], J.L. McChesney[2], T. Ohta[4], S.A. Reshanov[1], J. Röhrl[1], E. Rotenberg[2], A.K. Schmid[5], D. Waldmann[1], H.B. Weber[1], and •Th. Seyller[1] — [1]FAU Erlangen-Nürnberg — [2]Advanced Light Source, USA — [3]FHI Berlin — [4]Sandia National Laboratories, UAS — [5]National Center for Electron Microscopy, USA

Graphene, a single monolayer of sp^2-bonded carbon, is a very unique 2-dimensional electron gas system with electronic properties fundamentally different to other 2DEG systems [1]. A manifold of applications has already been suggested, which requires a uniform, ordered growth of graphene on an insulating substrate. The growth of graphene on insulating silicon carbide (SiC) surfaces by high-temperature annealing in vacuum [2] was proposed for the development of graphene-based electronics [3]. However, vacuum decomposition of SiC yields graphene layers with small grains. We have investigated the growth of graphene on SiC(0001) in an argon atmosphere [4] which produces monolayer graphene films with significantly improved morphology and carrier mobility. The new growth process establishes a method for the synthesis of graphene films on a technologically viable basis. [1] A.H. Castro Neto, et al., arXiv:0709.1163v2. [2] A. Charrier, et al., J. Appl. Phys. 92 (2002) 2479. [3] C. Berger et al., J. Phys. Chem. B 108 (2004) 19912; C. Berger, et al., Science 312 (2006) 1191. [4] K.V. Emtsev, et al., arXiv:0808.1222v1.

O 8.2 Mon 11:45 SCH 251

Atomic Hole Doping of Graphene — •Isabella Gierz[1], Christian Riedl[1], Ulrich Starke[1], Christian Ast[1], and Klaus Kern[1,2] — [1]Max-Planck-Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]Institut de Physique des Nanostructures, Ecole Polytechnique Federale de Lausanne, CH-1015 Lausanne, Switzerland

Graphene is an excellent candidate for the next generation of electronic materials due to the strict two-dimensionality of its electronic structure as well as the extremely high carrier mobility. A prerequisite for the development of graphene based electronics is the reliable control of the type and density of the charge carriers. While gating has been successfully demonstrated, the development of reliable chemical doping methods turns out to be a real challenge. In particular hole doping is an unsolved issue. Here we show by angle-resolved photoemission spectroscopy (ARPES) that atomic doping of an epitaxial graphene layer on a silicon carbide substrate with bismuth, antimony or gold presents effective means of p-type doping. Bismuth and antimony are only able to reduce the substrate induced n-type doping of epitaxial graphene. Gold adatoms, however, shift the Dirac point into the unoccupied states. In combination with the intrinsic n-type character of epitaxial graphene on SiC, the charge carriers can be tuned from electrons to holes, without affecting the conical band structure.

O 8.3 Mon 12:00 SCH 251

Molecular Hole Doping and Band Structure Engineering of Epitaxial Graphene on SiC — •Camilla Coletti, Christian Riedl, Dong Su Lee, Klaus von Klitzing, Jurgen H. Smet, and Ulrich Starke — Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart

In view of its intriguing two-dimensional electron gas properties, graphene is a promising host material for next-generation electronics. In particular, graphene epitaxially grown on silicon carbide (SiC), offers realistic prospects for electronic device implementation. However, the intrinsic n-type doping and the consequent metallic nature of these epitaxial layers badly accommodate in conventional electronics. We show, via angle resolved ultraviolet photoelectron spectroscopy (ARUPS) and Raman analysis, how monolayer and few layer epitaxial graphene can be rendered truly semiconducting by functionalizing the graphene surface with the strong electron acceptor tetrafluorotetracyanoquinodimethane (F4-TCNQ). We also report how, in the case of bilayer graphene, the molecular layer influences the details of the band structure thus suggesting the possibility for band gap engineering. We provide via X-ray photoelectron spectroscopy (XPS) and valence band investigations a complete characterization of this charge transfer complex. Furthermore, by demonstrating air stability and the feasibility of implementation via wet chemistry we show that the F4-TCNQ/graphene heterostructure is extremely appealing for future, carbon based electronic applications.

O 8.4 Mon 12:15 SCH 251

Electronic excitations in epitaxial graphene layers grown on SiC(0001) — •Thomas Langer[1,2], Herbert Pfnür[1], Christoph Tegenkamp[1], Hans Werner Schumacher[2], and Uwe Siegner[2] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

Transport measurements on epitaxial graphene require flat and large-scale graphene layers to apply electrical contacts. For this purpose growth of graphene on SiC(0001) has been studied with spot profile analysis low energy electron diffraction (SPA-LEED) and has been controlled and correlated in addition with X-ray photoelectron spectroscopy (XPS). The lateral (H(S)-analysis) and vertical (G(S)-analysis) roughness of different prepared SiC samples has been investigated as a function of graphene layers. Only the buffer and the first graphene layer show almost no additional roughening within the transfer width (200 nm) after graphitization process. The influence of interfaces on the loss function of epitaxial graphene layers has been studied further by means of electron energy loss spectroscopy (EELS). Electronic transitions and plasmon losses are sensitive to the interface. The collective in-plane excitations show a characteristic blueshift after graphitization, while single electron transitions with dipole moments along the surface normal are suppressed for the buffer layer. These characteristics can be used to distinguish between the buffer layer and intact graphene layers on top.

O 8.5 Mon 12:30 SCH 251

Raman Spectra of Epitaxial Graphene on SiC and of Epitaxial Graphene Transferred to SiO_2 — Dong Su Lee, •Christian Riedl, Benjamin Krauss, Klaus von Klitzing, Ulrich Starke, and Jurgen H. Smet — Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart

Raman spectra were measured for epitaxial graphene grown on SiC and compared to those obtained for epitaxial graphene successfully transferred from SiC to SiO_2 [1]. The number of layers for graphene on SiC(0001) was preassigned by angle-resolved ultraviolet photoemission spectroscopy (ARUPS) [2]. The Raman spectra of epitaxial graphene show significant differences as compared to micromechanically cleaved graphene obtained from highly oriented pyrolytic graphite crystals. The G peak is found to be blue-shifted, presumably due to charge doping from the substrate. The 2D peak does not exhibit any obvious shoulder structures, but it is much broader and almost resembles a single-peak even for multilayers. However, the linewidth of the 2D peak is found to be an unambiguous fingerprint to identify the number of layers for graphene on SiC(0001). A comparison of the Raman data obtained for graphene on SiC(0001) with data for epitaxial graphene transferred to SiO_2 reveals that both the G peak blue-shift and the 2D peak lineshape of a single-peak are clearly due to the SiC substrate. The increased linewidth of the 2D peak however stems from the graphene structure itself and not from the substrate.

[1] D. S. Lee et al., Nano Letters, DOI: 10.1021/nl802156w.
[2] C. Riedl et al., Appl. Phys. Lett. **93**, 033106 (2008).