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## GRAPHENE ON METAL SURFACES: GROWTH AND ELECTRONIC PROPERTIES BY CORE LEVEL PHOTOEMISSION

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The rising interest of the scientific community to graphene, a single layer of carbon atoms arranged in honeycomb structure, is motivated by its unique electronic and physical properties which make it one of the most promising materials for future nano-technologies. Many experimental and theoretical works have been performed, aimed to the synthesis and characterization of graphene, to the study of its properties and also to highlight fundamental aspects of physics. Graphene growth on transition metal (TM) surfaces exploiting the dissociation of small hydrocarbons represents an easy and challenging way for its synthesis. Peculiar mechanisms of graphene growth as well as the interaction with the underlying substrate have been already found to strongly depend on the metal substrate used. However, a detailed understanding of the growth process and of many other graphene properties calls for further investigations.

Different techniques have been employed to study graphene. Here we show how synchrotron radiation core level photoemission spectroscopy experiments, performed at the SuperESCA beamline of Elettra, were used to shed light on (i) the interaction and the growth mechanisms of graphene on top of the Ir(111) metal surface and (ii) the dispersive nature of graphene core electrons.

High-resolution photoemission spectroscopy experiments were performed on the Ir  $4f_{7/2}$  and C1s core levels during ethylene dose on the Ir(111) surface at different temperatures, for different carbon concentrations and after the formation of a long-range ordered graphene layer. The experimental results have been compared to density functional theory (DFT) calculations. The weak interaction of the graphene layer with the Ir surface is reflected in the near constancy of the Ir  $4f_{7/2}$  surface core level spectrum, with respect to the clean surface case. On the contrary, the presence of carbon clusters bound to the surface gives rise to different components in both C1s and Ir  $4f_{7/2}$  core levels. Their behavior at different

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conditions highlights the growth mechanisms of graphene: its growth on Ir(111) proceeds via the formation of peculiar dome-shaped carbon nano-islands that represent an intermediate phase between strongly coupled carbidic clusters and a quasi-free-standing graphene layer [1].

The high resolution C1s core level photoemission spectra measured on a fully developed graphene layer on Ir(111), at many azimuthal and polar emission angles and different photon energies, show the presence of a single, very narrow C1s component. Indeed, a good fit to all the C1s spectra of extensive data sets, is obtained with a single component with same lineshape parameters. Strong intensity modulations are observed due to photoelectron diffraction effects. The intensity modulation function perfectly agrees with multiple scattering simulations for a flat, free-standing graphene layer. The resulting binding energy modulation, when shown as a function of  $k_{\parallel}$ , is periodic in the reciprocal space of graphene. However, the periodic pattern does not coincide with the reciprocal lattice mesh. This behaviour is due to the formation of a bonding and anti-bonding band between the 1s states of the two atoms in the unit cell of graphene [2]. The apparently wrong periodicity of the binding energy modulation is due to a curious interference effect between the two carbon atoms in the unit cell of graphene, which modulates the intensity of the two bands such that for some  $\Gamma$  points only the bonding band is observed, for others only the anti-bonding band.

## References

- [1] P. Lacovig *et al.*, Phys. Rev. Lett, 103 (2009) 166101.
- [2] S. Lizzit *et al.*, Nature Physics, 6 (2010) 345.