Electronic structure of graphene mono and multilayers on SiC probed by STM.

J-Y Veuillen (1), I. Brihuega (2), P. Mallet (1), H. González-Herrero (2), G. Trambly de Laissardière (3), M. M. Ugeda (2), L. Magaud (1), J.M. Gómez-Rodríguez (2), F. Hiebel (1), F. Ynduráin (2)

(1) Institut Néel, CNRS-UJF, Boîte Postale 166, F-38042 Grenoble, France
(2) Dept. Física de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain
(3) LPTM, Université de Cergy-Pontoise-CNRS, F-95302 Cergy-Pontoise, France
jean-yves.veuillen@grenoble.cnrs.fr

Abstract
Scanning Tunneling Microscopy (STM) and Spectroscopy (STS) are efficient probes of the electronic structure of supported graphene layers. Besides revealing intrinsic properties of graphene, these techniques can be used to probe the interaction between the graphene surface layer and the supporting material. We shall present examples related to our recent works on the electronic structure of graphene mono and multi-layers grown on hexagonal SiC substrates. We shall first briefly discuss the role of the pseudo-spin in quasiparticle interference patterns detected by STM [1] and the analysis of the stacking dependence of the interaction between graphene and localized levels [2].
The presentation will then focus on an appealing route for modifying graphene's band structure by exploiting a rotation between stacked graphene layers [3]. Theory suggests that the interlayer interaction strongly impacts the band structure of the twisted layers for rotation angles θ smaller than 15°: the band velocity is reduced [3, 4] and low energy van Hove singularities (vHs) appear in the density of states (DOS) [5]. Their energy decrease with decreasing θ and they converge towards the Dirac point for low θ values (<1°) where weakly dispersive bands develop at low energy. The electronic structure of twisted bilayer graphene is thus expected to be tunable using the rotation angle θ as a control parameter.
We will present an STM/STS study complemented by ab-initio and tight binding calculations, of the local DOS (LDOS) of twisted layers grown on the 6H-SiC(000-1) face. Our experimental and theoretical data [6] show that vHs exist in a wide range of rotation angles ($1°<\theta<10°$), and that they are robust against perturbations (stacking sequence, layer corrugation) to the ideal model usually considered by theory. These results are consistent with previous measurements made in a smaller θ range on samples prepared on other substrates [5], which establishes the intrinsic character of the rotation-induced features. A simple data analysis gives directly the value of the interlayer coupling parameter [6].

References
[1] P. Mallet, I. Brihuega, S. Bose, M. M. Ugeda, J. M. Gomez-Rodriguez, K. Kern and J. Y. Veuillen, Phys. Rev. B **86** (2012) 045444
[2] F. Hiebel, P. Mallet, J.-Y. Veuillen, and L. Magaud, Phys. Rev. B **86** (2012) 205421
[3] J. M. B. Lopes dos Santos, N. M. R. Peres, and A. H. Castro Neto, Phys. Rev. Lett., **99** (2007) 256802
[4] G. Trambly de Laissardière, D. Mayou, and L. Magaud, Nano Lett., **10** (2010) 804
[5] G. Li, A. Luican, J. M. B. Lopez dos Santos, A. H. Castro Neto, A. Reina, J. Kong and E. Andrei, Nat. Phys., **6** (2010) 109
[6] I. Brihuega, P. Mallet, H. González-Herrero, G. Trambly de Laissardière, M. M. Ugeda, L. Magaud, J.M. Gómez-Rodríguez, F. Ynduráin, and J.-Y. Veuillen, Phys. Rev. Lett., **109** (2012) 196802

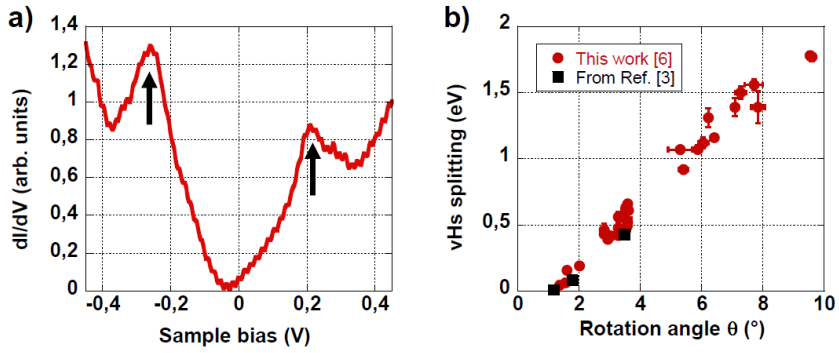

Figure 1 : a) vHs (arrows) in the LDOS of twisted layers (with θ=3.3°) measured by STS. b) Splitting of the vHs as a function of θ (dots from [6], squares from [5]).