Elementary processes and factors influencing the intercalation between graphene and iridium

Sergio Vlaic[1,2], Amina Kimouche[1,2], Johann Coraux[1,2], Benito Santos[3], Andrea Locatelli[3], Nicolas Rougemaille[1,2]

[1] Univ. Grenoble Alpes, Inst. NEEL, F38042 Grenoble, France
[2] CNRS, Inst NEEL, F-38042 Grenoble, France
[3] Elettra – Sincrotrone Trieste S.C.p.A., S.S. 14 km 163.5 in Area Science Park, I-34149 Basovizza, Trieste, Italy.
sergio.vlaic@neel.cnrs.fr

Abstract

Besides their potential for mass production of graphene, epitaxial graphene systems make it possible to manipulate graphene's properties and to induce new ones, in a finely controlled manner, by nanostructuring, defect engineering, strain engineering, and intercalation. The latter consists of inserting foreign species between graphene and its substrate and has attracted a great deal of attention since the last 5 years. It has allowed one, for instance, to fully decouple graphene from its substrate (H intercalation [1]), to spin-polarize graphene's electronic bands (Au intercalation [2]), and to manipulate the ferromagnetism of an intercalated Co layer [3].

Even though intercalation has been known since the 1980's, it has only been recent that pathways explaining how intercalation initiates have been pursued. To date only a few have been identified: graphene edges [4] and pre-existing point defects, on flat graphene regions [5] as well as at the intersection between graphene wrinkles (linear delamination of graphene from its substrate) [6].

Real time monitoring of the intercalation of cobalt between graphene and Ir(111) with the help of low-energy electron microscopy (LEEM), has provided us with greater insight. We discovered unanticipated intercalation pathways, unveiled the processes energetics and how both depend on the graphene-substrate interaction.

More specifically, we found that intercalation does not require the pre-existence of point defects inside the graphene lattice to proceed, but can occur at curved regions, such as those found at graphene wrinkles and on top of substrate step edges (Fig.1 a) and b)) [7]. Curved region intercalation is found to be in competition with edge intercalation (Fig. 1 c)). We show that these two processes and their relative occurrence can be controlled by temperature and the interaction of graphene with the substrate [7-8].

References

[1] C. Riedl, C. Coletti, T. Iwasaki, A. A. Zakharov, and U. Starke, Phys. Rev. Lett. **103**, (2009), 246804.

[2] A. Varykhalov, J. Sanchez-Barriga, A. M. Shikin, C. Biswas, E. Vescovo, A. Rybkin, D. Marchenko, and O. Rader, Phys. Rev. Lett. **101**, (2008), 157601.

[3] N. Rougemaille, A.T. N'Diaye, J.Coraux, C. Vo-Van, O. Fruchart, and A. K. Schmid, Appl. Phys. Lett. **101**, (2012), 142403.
J. Coraux, A. T. NDiaye, N. Rougemaille, C. Vo-Van, A. Ki- mouche, H.-X. Yang, M. Chshiev, N. Bendiab, O. Fruchart, and A. K. Schmid, J. Phys. Chem. Lett. **3**, (2012), 2059.

[4] P. Sutter, J. T. Sadowski, and E. A. Sutter, J. Am. Chem. Soc. **132**, (2010), 8175.

[5] M. Sicot, P. Leicht, A. Zusan, S. Bouvron, O. Zander, M. Weser, Y. S. Dedkov, K. Horn, and M. Fonin, ACS Nano **6**, (2012), 151.

[6| M. Petrović, I. Šrut Rakić, S. Runte, C. Busse, J. T. Sadowski, P. Lazić, I. Pletikosić, Z.-H. Pan, M. Milun, P. Pervan, N. Atodiresei, R. Brako, D. Šokčević, T. Valla, T. Michely and M. Kralj, Nat. Commun. **4**, (2013) 2772.

[7] S. Vlaic, A. Kimouche, J. Coraux, B. Santos, A. Locatelli, N. Rougemaille, *under review.*

[8] S. Vlaic, A. Kimouche, J. Coraux, B. Santos, A. Locatelli, N. Rougemaille, *submitted.*
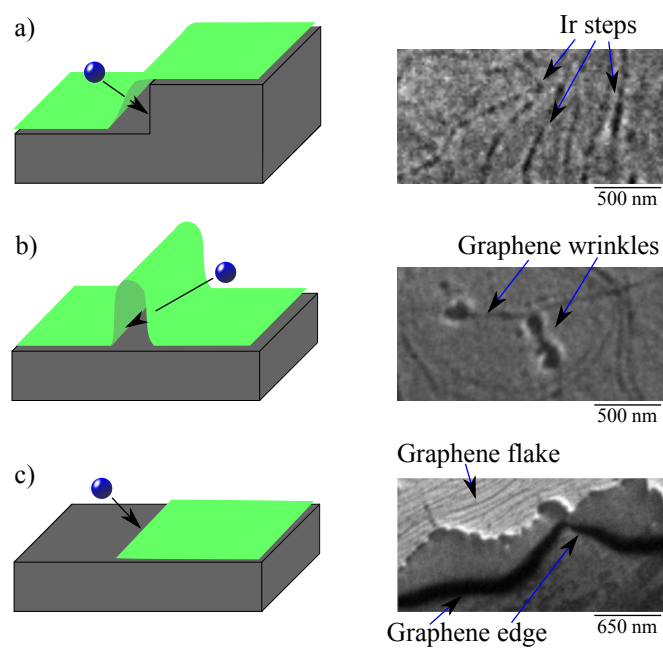
Figure

Figure 1: Schematic representation (left) and LEEM image (right) of Co intercalation between graphene and Ir(111) at the substrate step edges (a), at graphene wrinkles (b) and at the graphene free edges (c). Darker areas under the graphene sheet represent the intercalation regions.