EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** **Graphene intercalation compounds**	**Experiment number**: SI-2386
Beamline: ID32	**Date of experiment**: from: 26.9.2011 to: 5.10.2011	**Date of report**: 31.8.2012
Shifts: 18	**Local contact(s)**: Julien Duvernay Jörg Zegenhagen	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Carsten Busse*, II. Phsikalisches Institut, Universität zu Köln, Germany
Johann Coraux*, Institut Néel, CNRS-UJF, Grenoble, France
Thomas Michely, II. Phsikalisches Institut, Universität zu Köln, Germany

Report:

Graphene (gr) on metal surfaces is a widely used system to explore the fascinating electronic and mechanical properties of this new material. Especially gr/Ir(111) can be used for model studies as the carbon layer can be grown with a high degree of structural quality [Coraux2008, NDiaye2008], while its electronic structure is largely identical to the one of free graphene [Pletikosic2009]. In a previous beamtime at ESRF, we were able to precisely measure the distance between the graphene sheet and the metal substrate [Busse2011] using x-ray standing waves (XSW). Together with extensive DFT calculations we could thereby show that graphene on Ir(111) is only weakly bound to the substrate through Van-der-Waals-forces.

This beamtime was devoted to the study of graphene intercalation compounds: When an additional species is inserted between the graphene sheet and its substrate, the properties of the system can be significantly changed: Charge transfer between the intercalate and the carbon atoms leads to pronounced doping, where both n- and p-doping are possible. Theoretical studies even suggest that superconductivity in graphene can be a consequence of this charge transfer [Profeta2012]. Also the binding to the substrate is altered, in favorable cases the intercalation can then allow the exfoliation of epitaxial graphene [Herbig2012].

The experiment run without problems, the issues regarding the electron beam heating in previous sessions have been solved, remaining smaller problems wer solved during the beamtime. Graphene on Ir(111) could be prepared routinely. We intercalated Eu, Cs (using our own sources) as well as O. The sample morphology was veryfied using LEED. In XPS the signal of the intercalated species was well visible for all preparations. We were able to reproduce and extend existing experiments on the shift of the C1s core level, which depends on the degree and direction of charge transfer between the intercalated species and graphene. XSW measurements were performed using the (111)-reflection, a few runs using the (222) reflection have also been performed. The height of the graphene layer and of the intercalate could be analysed and interpreted by using graphite intercalation compunds as a reference. Significant changes in graphene's geometry depending on the species and ammount of intercalated material could be determined, showing qualitative differences between the n-doping metals (Eu, Cs) and the p-doping oxygen. The results have been presented at several conferences and a publication is in preparation.

In summary, the beamtime can be considered as a success, yielding important results on the geometry of graphene intercalation compounds. Full evaluation of the data is almost completed, a publication is in preparation.

[Busse2011] C. Busse, P. Lazić, R. Djemour, J. Coraux, T. Gerber, N. Atodiresei, V. Caciuc. R.Brako, A. T. N'Diaye, S. Blügel, J. Zegenhagen, T. Michely, Phys. Rev. Lett. 107, 036101 (2011) (see also ESRF Highlights 2011, 33)

[Coraux2008] J. Coraux, A. T. N'Diaye, C. Busse, T. Michely, Nano Lett. 8, 565 (2008)

[Herbig2012] C. Herbig, M. Kaiser, N. Bendiab, J. Coraux, S. Schumacher, D. F. Förster, K. Meerholz, T. Michely, C. Busse, J. Phys. Condens. Mat. 24, 314208 (2012)

[NDiaye2008] A. T. N'Diaye, J. Coraux, T. N. Plasa, C. Busse, T. Michely, New J. Phys. 10, 043033 (2008)

[Pletikosic2009] I. Pletikosić, M. Kralj, P. Pervan, R. Brako, J. Coraux, A. T. N'Diaye, C Busse, T. Michely, Phys. Rev. Lett. 102, 056808 (2009)

[Profeta2012] G. Profeta, M. Calandra, F. Mauri, Nat. Phys. 8, 131 (2012)