From Nanoscale Chemical Identification to Real-Space Mapping of Graphene Plasmons

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The performance of the next-generation electronic devices based on Graphene is strongly influenced by the structure-function relationship. A novel technique which combines the best of two worlds, the high spatial resolution of Atomic Force Microscopy (AFM) and the analytical power of infrared spectroscopy makes now possible the nanoscale mapping of such nano-devices. The spatial resolution of about 10nm of our unique NeaSNOM microscope opens a new era for modern nano-analytical applications such as chemical identification, free-carrier profiling and plasmonic vector near-field mapping. Recent research highlights including contact-free direct access to local conductivity, electron mobility and intrinsic doping via plasmon interferometry imaging demonstrated the power of the NeaSNOM microscope [1-4]. The Experiment involves launching plasmons from the NeaSNOM's tip, having them propagate, reflect from the graphene edge, and influence the backscattering amplitude. Two unique properties of the NeaSNOM microscope were instrumental for this success: (i) the high spatial resolution of <20nm allowed to easily resolve the plasmon standing waves which have periods as small as 100 nm, and (ii) more subtle, the highly confined light at the tip helps to efficiently launch the plasmons, giving them the momentum "kick" needed, 50-times that of plasmons. Using plasmon interferometry, NeaSNOM microscope can investigate losses in graphene by exploring real-space profiles of plasmon standing waves formed between the tip of our nano-probe and the edges of the samples (Fig1.). Plasmon dissipation quantified through this analysis is linked to the exotic electrodynamics of graphene.
New technical developments of the NeaSNOM microscope enables now real-space graphene mapping of big area scans at high-resolution and industrial speeds (Fig2). An outlook of further several application potential of nanoscale chemical mapping by local infrared spectroscopy will be presented elsewhere:

- Quantitative measurement of local infrared absorption and dielectric function;
- Semiconductor free carrier distribution [6];
- Graphene used as H2 storage
- Nanoscale phase transition [5];
- Free carrier dynamics (ultrafast plasmonics);
- Bio-medical nano-imaging [7,8];

References

[1] Z. Fei, A. S. Rodin, W. Gannett, S. Dai, W. Regan, M. Wagner, M. K. Liu, A. S. McLeod, G. Dominguez, M. Thiemens, Antonio H. Castro Neto, F. Keilmann, A. Zettl, R. Hillenbrand, M. M. Fogler and D. N. Basov, Nature Nanotechnology **8** (2013) 821.
[2] J. Chen, M. L. Nesterov, A. Y. Nikitin,S. Thongrattanasiri, P. Alonso-González,T. M. Slipchenko, F. Speck, M. Ostler, T. Seyller, I. Crassee, F. H. L. Koppens, L. Martin-Moreno, F. J. García de Abaj, A. B. Kuzmenko and R. Hillenbrand Nano Letters **13** (2013) 6210.
[3] Z. Fei, A. S. Rodin, G. O. Andreev, W. Bao, A. S. McLeod et al. Nature **487** (2012)
[4] J. Chen, M. Badioli, P. Alonso-González, S. Thongrattanasiri, F. Huth, R. Hillenbrand & F. H. L. Koppens Nature **487** (2012) 82.
[5] M. M. Qazilbash, M. Brehm, Byung-Gyu Chae, P.-C. Ho, G. O. Andreev, Bong-Jun Kim, Sun Jin Yun, A. V. Balatsky, M. B. Maple, F. Keilmann, Hyun-Tak Kim and D. N. Basov Science **318** (2007) 1750.
[6] M. K. Liu, M. Wagner, E. Abreu, S. Kittiwatanakul, A. McLeod, Z. Fei, M. Goldflam, S. Dai, M. M. Fogler, J. Lu, S. A. Wolf, R. D. Averitt, and D. N. Basov Physical Review Letters **111** (2013) 096602.
[7] I. Amenabar, S. Poly, W. Nuansing, E.H. Hubrich, A.A. Govyadinov, F. Huth, R. Krutokhvostov, L. Zhang, M. Knez, J. Heberle, A.M. Bittner and R. Hillenbrand, Nature Communications, **4** (2013) 2890.
[8] S Amarie, P Zaslansky, Y Kajihara, E Griesshaber, WW Schmahl and F Keilmann, Beilstein Journal of Nanotechnology **3** (2012) 312.

Figures

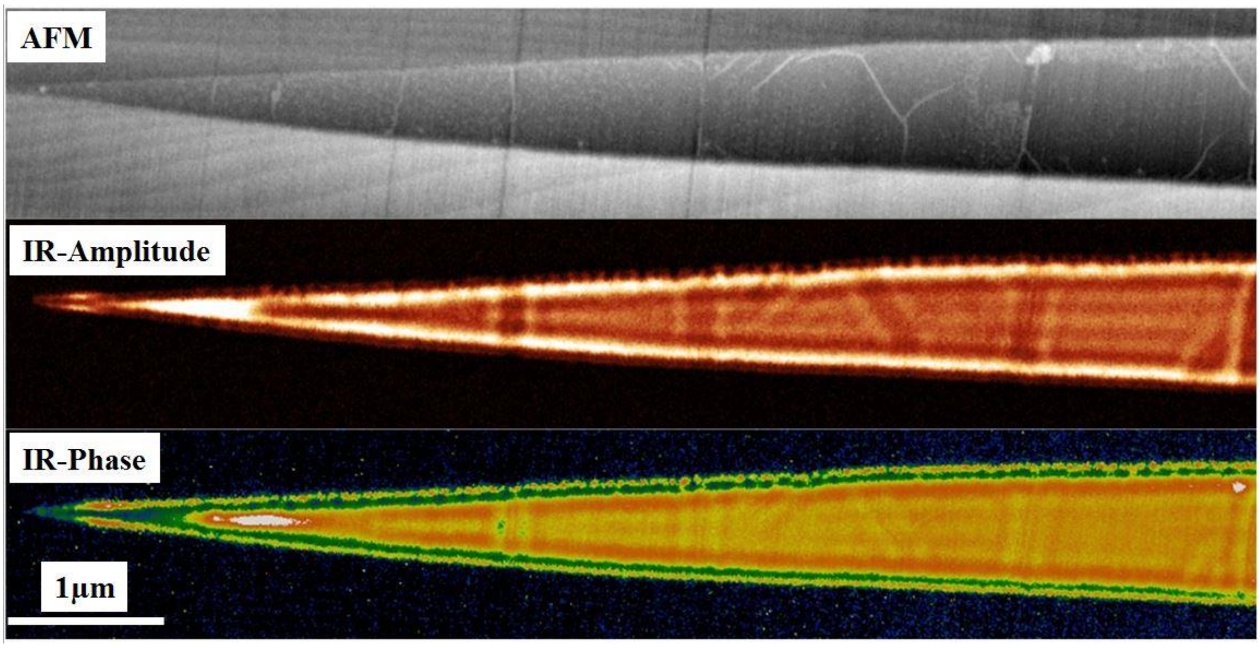

Fig1. NeaSNOM correlative AFM-IR microscopy. Contact-free direct access to local conductivity, electron mobility and intrinsic doping via plasmon interferometry imaging.

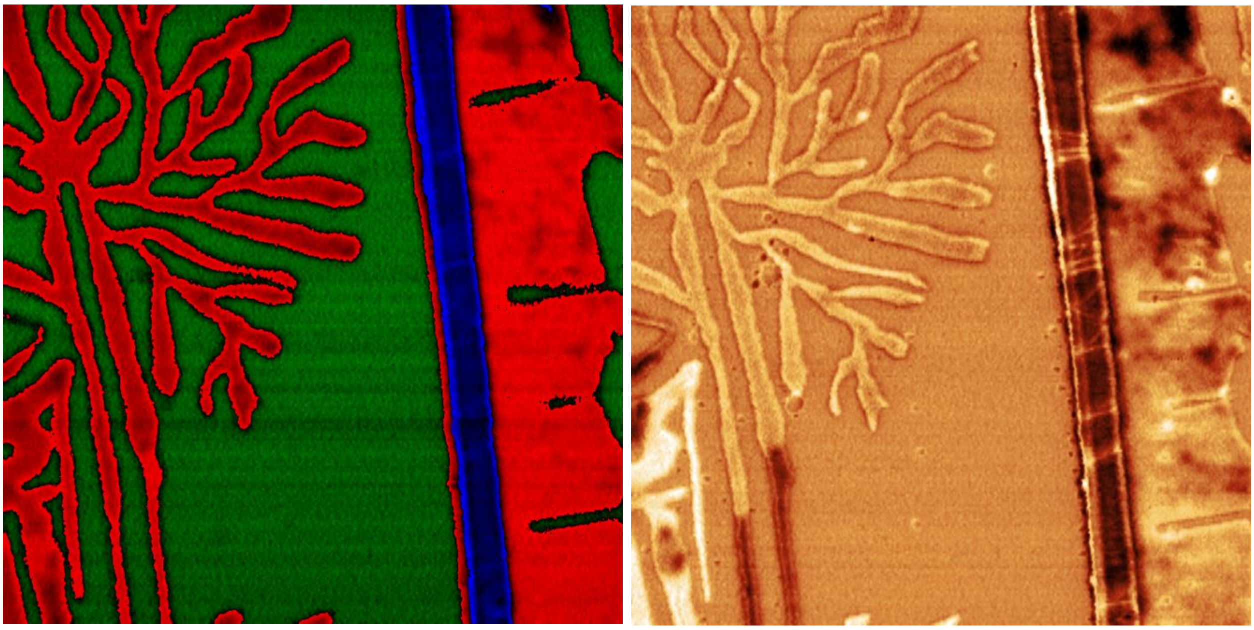

Fig2. Epitaxial grown grapheme. NeaSNOM measurements with 10nm resolution of near-field phase (left) and near-field amplitude components (right).

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