Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
National Metrology Institute

Near-field Imaging and Nano-FTIR Spectroscopy using Synchrotron Radiation from the Metrology Light Source (MLS)

Peter Hermann, Arne Hoehl, Bernd Kaestner, Matthias Kruskopf, Klaus Pierz, Burkhard Beckhoff and Gerhard Ulm

Introduction: Near-field optical microscopy (SNOM) is a versatile technique for imaging of nanoscale structures with a spatial resolution significantly below the diffraction limit. IR-SNOM measurements performed with laser sources provide spatially resolved information about the optical properties of the sample at discrete wavelengths. However, the spectra acquisition is time consuming since it requires repeated measurements at different wavelengths, the number (hence spectral resolution) of which is also limited. Thus near-field FTIR spectroscopy using broadband radiation such as from thermal sources or electron storage rings is desireable.

In this work we couple a scattering-type IR-SNOM to the IR-beamline at the MLS [1]. Compared to conventional thermal sources the use of synchrotron radiation provides several major advantages such as (i) a higher brilliance, (ii) pulsed radiation in the ps range, and (iii) polarized radiation. In the following we analyse graphitized 6H-SiC to demonstrate high-resolution imaging and nano-FTIR spectroscopy by using a broadband synchrotron radiation source, and compare to laser based near-field imaging at different wavelengths. We find significant differences in the contrast mechanisms and indications of strong plasmon reflections at SiC step-edges.

Samples:

* E3: 6H-SiC (0001) oriented (Si-face), vanadium doped, semi-insulating
* G033, G068: H-etching of substrates like E3 [2] resulting in step -bunching; subsequently graphitized [3] (thermal decomposition), resulting in 60% monolayer coverage (n-type with densities >10^{12}cm^{-2}), as well as some bi-layer formation
* D01: 6H-SiC, undoped

Nano FTIR Measurements, using 4th harmonic:

* Enhanced emission of graphene wrt. pure SiC surface due to plasmon -phonon coupling [4]. Note opposite effect in laser imaging, see Fig. 7
* Spectra vary for doped and undoped SiC samples, Fig. 8
* Weak influence of graphitization (pure SiC region on G033) wrt. starting material (E3), see Fig. 8
* Almost no difference between bilayer and monolayer graphene, Fig. 8

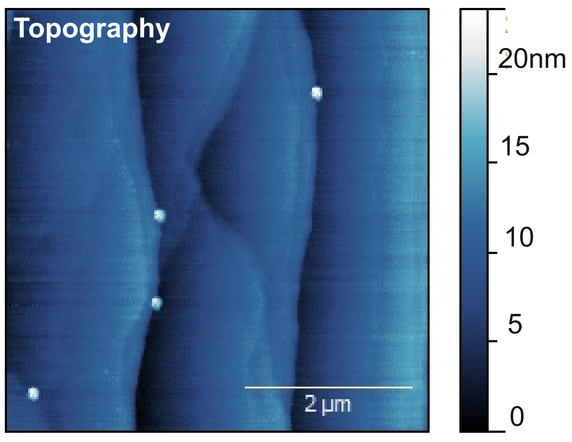

Fig 1: AFM image showing topography of G033 sample

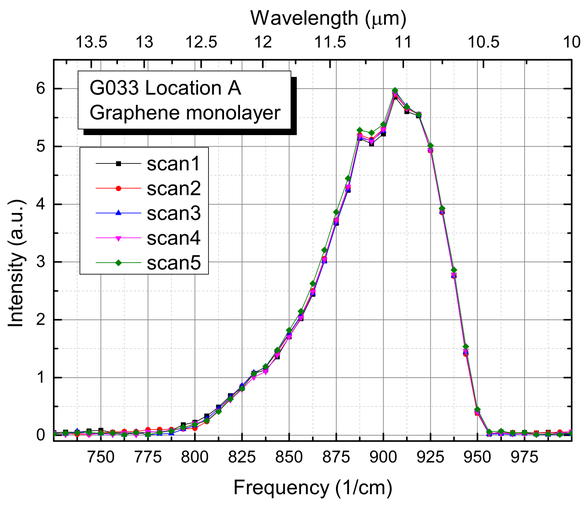

Fig 3: nano FTIR spectrum at location A on G033, storage ring current I_s = 117mA.

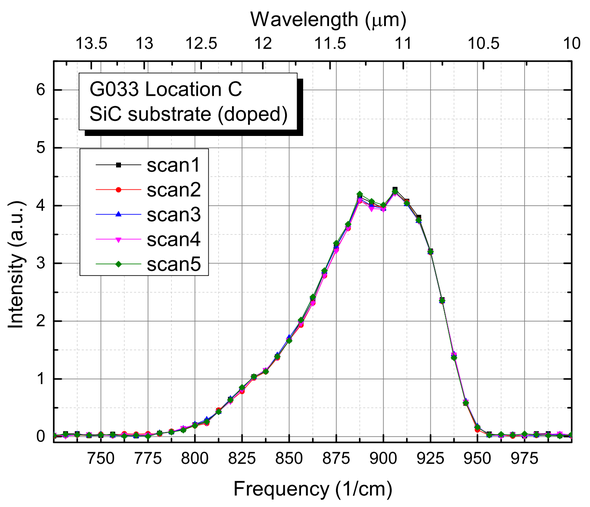

Fig 5: Spectrum at C on G033, storage ring current I_s=121mA;

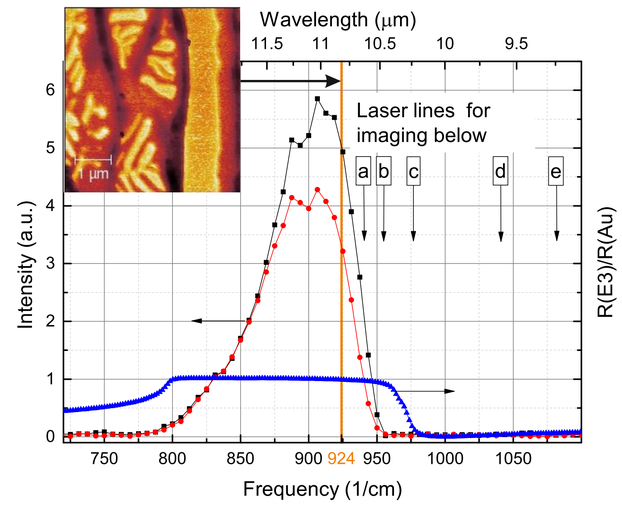

Fig 7: Spectra at A (black) and C (orange); far-field reflectivity spectrum shown by the blue triangles

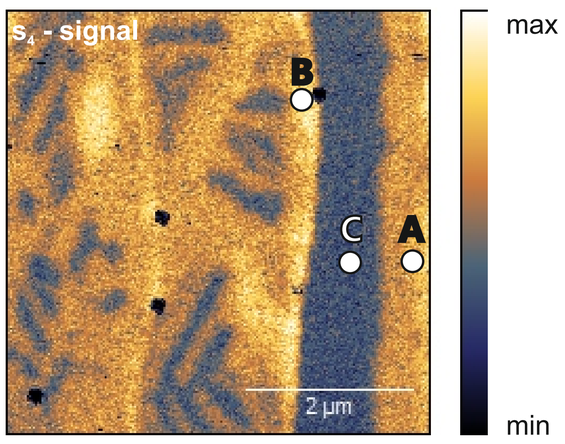

Fig 2: 4th harmonic signal intensity s_4 corresponding to Fig 1 using broadband IR excitation; Location A and B corresponds to SiC covered by mono- and bilayers, respectively. C shows the uncovered SiC surface.

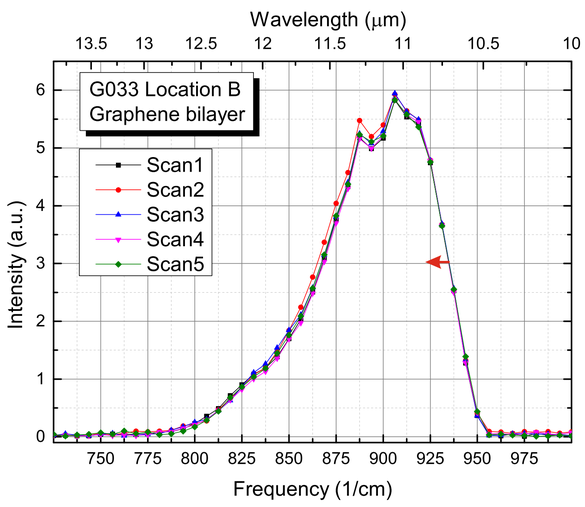

Fig 4: Spectrum at location B on G033, storage fing current I_s= 109mA; slightly narrower wrt. mono-layer, as indicated by arrow.

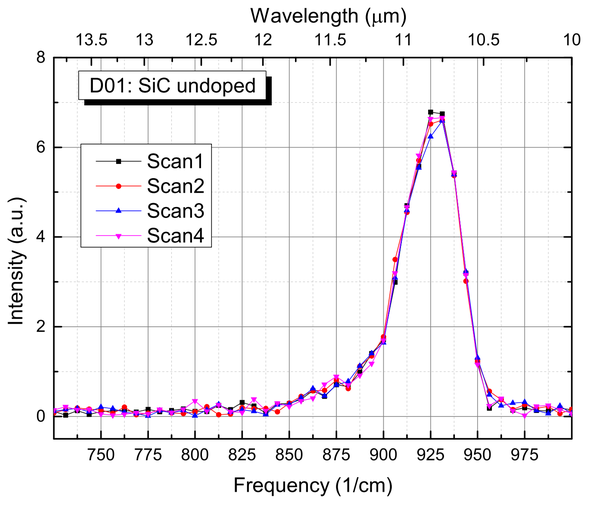

Fig 6: FTIR spectrum of undoped SiC sample D01; recorded in a different measurement run; single peak maximum at 927cm^{-1}.

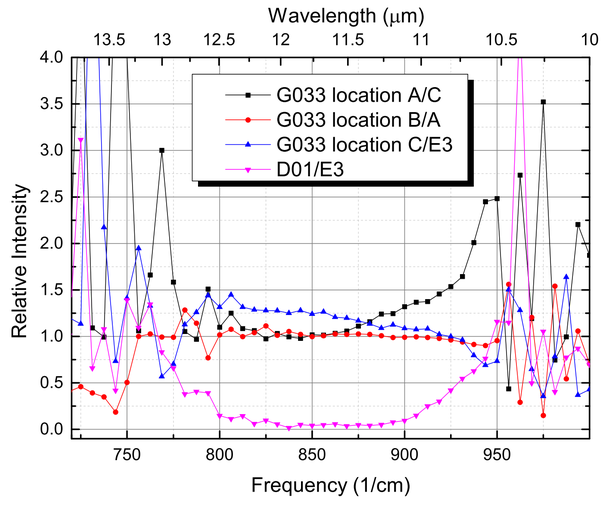

Fig 8: Intensity ratios between different spectra; black squares show plasmon enhanced SiC phonon peak towards higher frequencies; the variation D01/E3 (triangles) comes from the peak-shift of the doped SiC (E3) towards a smaller frequency of 927cm^{-1}

Laser based near-field imaging

Imaging of G068 sample as function of laser wavelength using 4th harmonic signal intensity s_4

* Depending on wavelength uncovered SiC (marked in Fig. 9), graphene or stepedges dominate
* Contrast inverses compared to broadband imaging (see also Fig. 7)
* Enhanced emission at SiC step edges, as well as signal fluctuations along the edges, as recently observed by Chen *et al.* [5] on quasi-free-standing monolayer graphene; in contrast, in G033/G068 the buffer layer was not decoupled;
* Note: over graphene regions SNOM signal remains constant for all excitation wavelengths;

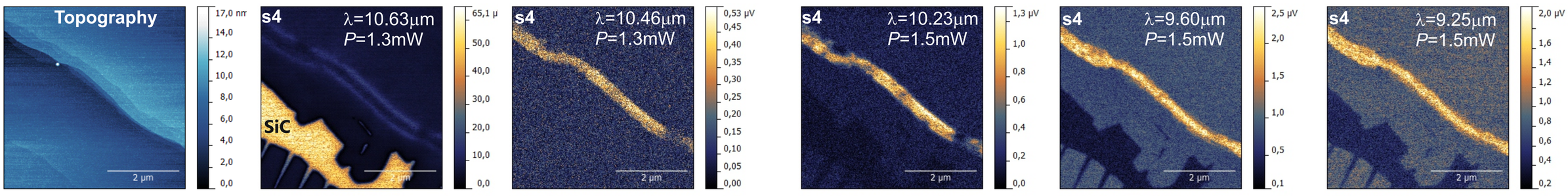

Fig 9 Corresponding AFM (a) and laser based SNOM images (b-f), recorded at different laser wavelengths; Laser power measured at interferometer entrance is indicated;

References:

[1] P. Hermann *et al.*, Optics Express **21**, 2913 (2013)
[2] J. Robinson *et al.*, ACS Nano **4**, 153 (2009)
[3] A. van Bommel *et al.*, Surface Science **48**, 463 (1975)
[4] Z. Fei *et al.*, Nano Letters **11**, 4701 (2011)
[5] J. Chen *et al.*, Nano Letters **13**, 6210 (2013)

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Bernd Kästner
Department 7.2
Cryophysics and Spectrometry

Abbestraße 2-12
10587 Berlin
Telefon: +49 30 3481 7104
Fax: +49 30 3481 69 7104
Email: Bernd.Kaestner@ptb.de
www.ptb.de

Nanolight
2014, March 02 - March 08