

## O 62: Graphene: Applications, Luminescence and Spin Relaxation (HL with O/TT)

Time: Wednesday 16:45–18:45

Location: ER 270

O 62.1 Wed 16:45 ER 270

**Fabrication and Growth of Three-dimensional Graphene Electrodes with Controllable Pore Size** — ●SIMON DRIESCHNER, MICHAEL WEBER, EVANGELOS MAKRYGIANNIS, and JOSE A. GARRIDO — Walter-Schottky-Institut, Physik Department, TU München, Am Coulombwall 4, 85748 Garching

Three-dimensional graphene-based electrodes combine graphene's unique properties like high conductivity, chemical inertness, and mechanical stability with a high surface to volume ratio, which could be of great interest for energy applications. However, tuning the pore size of 3D graphene networks is a non-trivial challenge, since the growth of graphene depends on the shape and structure of the metal substrate. Here we demonstrate the fabrication of 3D electrodes by using metal powder providing an interconnected scaffold which serves as substrate for the growth of graphene by chemical vapor deposition. The pore size distribution is shown to be controlled by the used metal particles and the growth temperature. After wet chemical etching of the metal catalyst, a freestanding and stable graphene foam of low mass and high crystalline crystal quality as confirmed by Raman spectroscopy is obtained. Cyclic voltammetry and electrochemical impedance spectroscopy measurements are used to confirm its excellent electrochemical properties. Our work highlights the great potential of these 3D graphene electrodes for energy storage and sensing applications.

O 62.2 Wed 17:00 ER 270

**Graphene microelectrode arrays for the electrochemical detection of neurotransmitters** — ●MARTIN LOTTNER<sup>1</sup>, LUIS BATISTA-PIRES<sup>2</sup>, and JOSE A. GARRIDO<sup>1</sup> — <sup>1</sup>Walter Schottky Institut, TU München, München, Deutschland — <sup>2</sup>Catalan Institute of Nanoscience and Nanotechnology, ICN2, Barcelona, Spain

Graphene has great potential for use as stimulation and sensing material in neural and cardiac implants. Its flexibility and chemical stability anticipate a good biocompatibility, which cytotoxicity studies have underlined. It is transparent to visible light and non-magnetic, which allows for unperturbed optical stimulation and post-implantation MRT imaging. In this contribution, we present graphene microelectrode arrays for the electrochemical detection of neurotransmitters. Vacancy defects were introduced by ozone exposure and growth conditions were varied to increase double layer content of the electrodes. The modifications were validated using Raman spectroscopy. Cyclic voltammetry studies show an electrochemical window of about 1V. Ferricyanide redox studies have been performed upon increasing defect density and double layer content, to investigate the transition from macro- to microelectrode behaviour. Further, a sensitivity for the detection of norepinephrine and dopamine below 1nM is demonstrated. This study shows that modified CVD graphene microelectrodes can be used for highly sensitive detection of neurotransmitters. Taking advantage of the high interfacial capacitance and large electrochemical window of graphene electrodes, we will discuss their use for safe extracellular stimulation.

O 62.3 Wed 17:15 ER 270

**Structural study of mono- and bilayer graphene nanoribbons directly grown on SiC(0001)** — ●LAUREN A. GALVES, TIMO SCHUMANN, JOÃO MARCELO J. LOPES, and HENNING RIECHERT — Paul-Drude-Institut für Festkörperelektronik, 10117 Berlin, Germany

Graphene nanoribbons (GNR) are very promising for nanoelectronics, since they possess unique electronic properties which are dependent on their width, edges, as well as number of graphene layers [1-2]. Therefore, achieving the controlled and high-quality synthesis of GNRs is anticipated to be of great importance. One of the methods which show great potential is the growth of GNRs on surface facets of SiC(0001) by the graphitization method [3]. In this contribution we report on the controlled growth and characterization of epitaxial mono- and bilayer GNRs on SiC(0001) surfaces. They were synthesized by utilizing the surface graphitization method at high temperatures and a straightforward air annealing (for bilayer GNRs) [4]. The influence of the surface step heights (i.e. facet sizes) on the ribbon growth and properties was analyzed. A correlation between steps heights and ribbons width was established. The nanostructures were analyzed by AFM height and phase contrast images. This allowed the determination of the SiC surface morphology as well as ribbons width. Raman spectroscopy was

employed to gain information about the thickness of the GNRs (i.e. mono- or bilayer graphene) and their preferential edge type.

[1] V. Barone et al., Nano Lett. 6, 2748 (2006); [2] T.S. Li et al., Eur. Phys. J. 64, 73 (2008); [3] M. Sprinkle et al. Nat. Nanotechnol. 5, 727 (2010); [4] M.H. Oliveira Jr. et al., Carbon 52, 83 (2013).

O 62.4 Wed 17:30 ER 270

**Correlation of the crystallite sizes and D band frequency of non-graphitic carbons** — ●DOMINIQUE B. SCHUEPFER<sup>1</sup>, KRISTIN FABER<sup>2</sup>, BERND M. SMARSLY<sup>2</sup>, ROMAN V. YUSUPOV<sup>3</sup>, and PETER J. KLAR<sup>1</sup> — <sup>1</sup>Institute of Experimental Physics I, Justus-Liebig-University Giessen, Germany — <sup>2</sup>Institute of Physical Chemistry, Justus-Liebig-University Giessen, Germany — <sup>3</sup>Institute of Physics, Kazan Federal University, Russia

Raman spectroscopy is often used to determine the crystallite size  $L_a$  of non-graphitic carbons by taking into account the intensity ratio of the defect-induced D band and the G band. We present an analysis of soft pitches via Raman spectroscopy in comparison to wide-angle X-ray spectra revealing discrepancies for  $L_a$ . Significant errors can be caused by known issues, for example the superposition of certain bands while estimating the intensities. Therefore, we introduce an alternative approach: An analysis of the D band revealed a correlation between its position and the crystallite size in the range of crystallite sizes less than 2 nm. The Raman shift significantly increases for smaller  $L_a$  using an excitation wavelength in the visible range. UV light yields the opposite behavior of the D band position, probably because of resonant absorption processes. To further characterize the samples in different  $L_a$ -ranges ( $L_a < 2$  nm and  $L_a > 2$  nm) electron paramagnetic resonance spectroscopy (EPR) has been carried out. Isotropic shaped EPR spectra are observed up to a crystallite size of 2 nm and samples containing crystallite sizes larger 2 nm show anisotropic signals. This behavior correlates with the detected Raman shift.

O 62.5 Wed 17:45 ER 270

**Ultrafast photocurrents in back-gated graphene** — ●FELIX SCHADE, ANDREAS BRENNIS, JOSE A. GARRIDO, SIMON DRIESCHNER, and ALEXANDER W. HOLLEITNER — Walter Schottky Institut and Physik-Department, Technische Universität München, Am Coulombwall 4a, Garching, Germany

We present picosecond time-resolved photocurrent measurements of back-gated CVD grown graphene on sapphire substrates. We examine the optoelectronic dynamics with respect to (i) the thermal coupling of graphene to its environment [1], (ii) different doping levels by tuning the back-gate voltage with respect to the Dirac point, and (iii) thermoelectric, photovoltaic as well as bolometric contributions. To this end, the graphene sheets are contacted by a THz-stripline circuit, and the ultrafast response is read-out by an Auston-switch [2]. The back-gate is separated from the graphene by the help of ALD-grown sapphire.

The ERC grant NanoREAL is acknowledged.

[1] A. Brenneis, et al., Nature Nanotechnology, DOI: 10.1038/NNANO.2014.276 (2015). [2] L. Prechtel, et al. Nature Comm. 3, 646 (2012).

O 62.6 Wed 18:00 ER 270

**Coherent and Incoherent Photoluminescence from Photo-excited Graphene** — ●TORBEN WINZER<sup>1</sup>, RICHARD CIESIELSKI<sup>2</sup>, MATTHIAS HANDLOSER<sup>2</sup>, ALBERTO COMIN<sup>2</sup>, ACHIM HARTSCHUH<sup>2</sup>, and ERMIN MALIC<sup>1</sup> — <sup>1</sup>Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany — <sup>2</sup>Department Chemie, Ludwig Maximilians Universität München, Germany

Based on a microscopic theory and experimental measurements we investigate the ultrafast photoluminescence arising from photo-excited graphene. Our calculations, performed within the density matrix formalism, allow for energy- and time-resolved insights into the radiative processes where two distinct microscopic mechanisms are distinguished: Beside the incoherent photoluminescence, which is driven by recombination of excited carriers, we find a coherent contribution induced by the microscopic polarization [1]. The incoherent spectrum mainly depends on the excitation strength. In contrast, the coherent photoluminescence spectrally shifts with the excitation energy, which is demonstrated for the first time and confirmed by our measurements.

[1] T. Winzer, R. Ciesielski, M. Handloser et al., arXiv:1411.0531v1 (2014)

O 62.7 Wed 18:15 ER 270

**Polarised Hot Carrier Photoluminescence in Graphene** — •THOMAS DANZ, ANDREAS NEFF, REINER BORMANN, SASCHA SCHÄFER, and CLAUS ROPERS — 4th Physical Institute, University of Göttingen, Göttingen, Germany

The thermalisation of photogenerated hot charge carriers in graphene leads to photoluminescence at wavelengths far away from that of the exciting pump laser [1,2]. To date, no polarisation properties of the photoluminescence have been reported, although recent numerical simulations show a strong anisotropy of the underlying relaxation processes in graphene [3]. This is in agreement with the results of transient pump-probe measurements showing a dependence of the transmissivity on the angle between pump and probe polarisations [4]. Here, we present polarisation- and time-resolved two-pulse excitation photoluminescence measurements with sub-30fs ultrashort laser pulses. We demonstrate an anisotropic nature of the emitted photoluminescence and use these findings to discuss complementary insights into the ultrafast carrier response in graphene.

[1] C. H. Lui *et al.*, Phys. Rev. Lett. **105**, 127404 (2010)

[2] W. Liu *et al.*, Phys. Rev. B. **82**, 081408 (2010)

[3] E. Malic *et al.*, Appl. Phys. Lett. **101**, 213110 (2012)

[4] M. Mittendorff *et al.*, Nano Lett. **14**, 1504 (2014)

O 62.8 Wed 18:30 ER 270

**Spin Relaxation in Graphene** — •FRANK ORTMANN<sup>1</sup>, DINH. V. TUAN<sup>2</sup>, DAVID SORIANO<sup>2</sup>, SERGIO O. VALENZUELA<sup>2,3</sup>, and STEPHAN ROCHE<sup>2,3</sup> — <sup>1</sup>Institute for Materials Science and Dresden Center for Computational Materials Science, TU Dresden, Germany — <sup>2</sup>ICN2 Barcelona, Spain — <sup>3</sup>ICREA, Barcelona, Spain

Spin polarization of electrons in graphene has been under great attention in recent years due to intrinsically small spin-orbit coupling and hyperfine interaction and high carrier mobilities. However, experimental spin-relaxation times are 3-4 orders of magnitude too short compared to theoretical predictions. Such discrepancy, together with contradictory proposals for spin-relaxation mechanisms, triggered a debate about its behavior in clean and/or defective graphene.

We observe an intrinsic spin-dephasing mechanism in graphene that is most strongly impacting the Dirac point, which can be enhanced by the adsorption of heavy ad-atoms.[1] The extracted spin relaxation times ( $\tau_s$ ) from our simulations show good agreement with experimentally observed energy dependencies of  $\tau_s$ .

[1] D. V. Tuan, F. Ortmann et al. Nature Phys. 10, 857 (2014).