2D Materials - Exciting Flatlands
WS 2020/2021, Ursula Wurstbauer (https://www.uni-muenster.de/Physik.PI/Wurstbauer/teaching/teaching.html)

Dear All,

Depending on the current pandemic situation we plan to pursue the master course *2D materials* in the winter term 2020/21 in a hybrid-mode giving all the opportunity to join and actively participate either onsite in the lecture Hall or online in the Zoom-room. For onsite participation we need to follow the current Corona regulations of university, department and government. You will find detailed information on content and organizational issues below.

Looking forward to see many of you either onsite and or online to discuss the exciting physics of 2D materials.

Best regards,
Ursula Wurstbauer

Basic facts:

- Thursdays: 14:00-15:30, first lecture on 5. November
- 2 SWS
- Language: English
- Hybrid-type of lecture planned with parallel on-site and online option via Zoom (access information in learnweb)
- Lecture Hall HS3 (might be subject to change; distance and current Corona regulations of the university and physics department apply) and Zoom room provided in learnweb;
- Materials: lecture slides will be provided before the lecture on learnweb pages of the course
- Literature: Research related literature provided in the lecture and advanced solid-state text-books, e.g.
  - Rudolf Gross und Achim Marx, Festkörperphysik De Gruyter Oldenbourg, 2014 doi:10.1524/9783110358704 (sorry, only in german)
  - Peter YU, Manuel Cardona, Fundamentals of Semiconductors, Springer Berlin, 2016, ISBN 978-3-642-00710-1 (excellent book, but I recommend to us it together with a standard solid-state textbook)
    - *Both books are available as e-book at the WWU library*
- Active participation via discussion and quiz

Content:

This module provides a detailed overview on a fascinating new class of solid-state materials and a fast growing research area: two-dimensional (2D) materials that are truly two-dimensional solids with a thickness of about 1 nm. Within a layer there is strong covalent bonding between atoms and weak van-der Waals coupling between adjacent layers. Nevertheless, the properties of 2D solids strongly depends on the number of layers and interaction with environment/substrate. Depending on the chemical compositions, those materials exhibit fascinating properties making them very promising for electronic, opto-electronic, spin- and valleytronics applications, but also for solar and (photo-)electrochemical energy conversion and for the realization of quantum technologies. In this lecture, the following aspects will be covered:

- Historical overview and introduction to the different classes of 2D materials
- Nanofabrication and preparation methods of 2D Materials
- Nanoanalytical methods to study 2D Materials
- Discussion of joint and contrasting properties of graphene and semiconducting transition metal dichalcogenides (relativistic charge carriers, spin- and valley properties, multivalley behavior)
- Studying the light matter interaction in 2D materials including
  - visibility contrast and microscopy methods,
  - dielectric functions by spectroscopic ellipsometry
  - excitonic properties
  - Raman spectroscopy to unravel the phonon fingerprint

- Applications of 2D Materials in advanced functional devices such as transistors, photo-detectors, solar cells, (photo-)catalyst and quantum light sources
- Focus topics to introduce peculiar properties of selected materials in more detail:
    - Relativistic charge carriers and the Quantum Hall effect in graphene and its role for the new systems of units;
    - Topological insulators;
    - Hetero-stacks, moiré effects, Mott-Hubbard simulator and 'magic' angles;

Learning Outcome:

After a successful participation of the module, the student is able to:

- Understand different classes of 2D solid state materials and to apply the classification scheme of further 2D solid state materials.
- Understand the preparation and nanofabrication methods for 2D materials and to evaluate suitable methodologies for novel materials.
- Understand optical and structural characterization methods for 2D materials, to analyze related results in recent literature and to apply suitable methodologies for given problems related to 2D material.
- Evaluate the Raman spectra from selected 2D materials.
- Evaluate absorption, excitonic and spin properties of transition metal dichalcogenides;
- Understand and discuss applications of 2D materials and their heterostructures for electronic, optoelectronic, spintronics devices and solar energy conversion.
- Remember magnetotransport phenomena such as the quantum Hall effect in graphene and transport in topological protected surface states, special role of moiré superlattices and the meaning of "magic angle" in the context of moiré superlattices;