TUT 1: Careers in Science (joint session MA/TUT)

Time: Sunday 16:00–17:30 Location: H1

Tutorial TUT 1.1 Sun 16:00 H1

Careers in science: "To boldly go where no one has gone before" — •Manfred Fiebig — Department of Materials, ETH Zurich

What does it take to do a career in science and become a university professor? An obvious answer is: you have to do outstanding research. But just doing great science plays a surprisingly small part — and what defines scientific work as outstanding anyway? Then, you also need to communicate your findings well. The best result is worth little if you present it in an awful talk or manuscript. You also need to be "good with people", may these be your students or your colleagues. Even luck can play an important role in a successful scientific career, but is very important to distinguish luck from "luck". I will refer to all these points and analyze what "being lucky" has actually to do with luck. I will present a list of points that I consider essential for a prosperous start into a scientific career. Some of these points are surprisingly unnoticed, so following them may put you ahead of the crowd.

Questions and discussion

TUT 2: 2D Quantum Materials and Heterostructures: From Fabrication to Applications (joint session HL/TUT)

Due to the atomic thickness of 2D materials, stacking of different monolayers has opened the door for artificial van der Waals heterostructures. By exploiting the strongly different nature of the individual layers (semiconducting, metallic, magnetic, superconducting, etc.) and rotating them from layer to layer, heterostructures with unique physical properties and functionalities can be envisioned for novel electronic or optical devices. The tutorial will cover the fabrication of these heterostructures and their potential use in applications ranging from electronic to optical devices, operating at the quantum level.

Time: Sunday 16:00–18:20 Location: H2

Tutorial TUT 2.1 Sun 16:00 H2

Discovering, Creating, and Exploring Novel Atomically-Thin Materials and Heterostructures — •Joshua Robinson — The Pennsylvania State University, University Park, PA, USA

The last decade has seen an exponential growth in the science and technology of two-dimensional materials. Beyond graphene, there is a huge variety of layered materials that range in properties from insulating to superconducting. Furthermore, heterogeneous stacking of 2D materials also allows for additional dimensionality for band structure engineering. In this talk, I will discuss recent breakthroughs in two-dimensional atomic layer synthesis and properties, including novel 2D heterostructures and realization of unique 2D allotropes of 3D materials (e.g. 2D metals and oxides). Our recent works demonstrate that the properties and doping of 2D materials, especially synthetic 2D materials, are extremely sensitive to the substrate choice. I will discuss substrate impact on 2D layer growth and properties, doping of 2D materials, selective area synthesis of 2D materials, and creating 2D allotropes from traditionally 3D materials for photonic and quantum applications. Our work and the work of our collaborators has lead to a better understanding of how substrate not only impacts 2D crystal quality, but also doping efficiency in 2D materials, and stabilization of 3D materials at their quantum limit.

Tutorial TUT 2.2 Sun 16:35 H2

Non-identical moire twins in bilayer graphene — •Rebeca Ribeiro-Palau[1], Everton Arrighi[1], Viet-Hung Nguyen[2], Mario Di Luca[1], Gaia Maffione[1], Kenji Watanabe[3], Takashi Taniguchi[3], Dominique Mailly[1], and Jean-Christophe Charlier[2] — [1]Universite Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies (C2N), 91120 Palaiseau, France — [2]Institute of Condensed Matter and Nanosciences, Universite catholique de Louvain (UCLouvain), 1348 Louvain-la-Neuve, Belgium — [3]National Institute for Materials Science, 1-1 Namiki, Tsukuba, Japan

I will present recent results which demonstrate that the moire superlattice formed by a bilayer graphene aligned with BN, is present every 60 deg, but the symmetry is broken between the 0 deg and 60 deg alignments, creating non-identical "moire twins" with different electronic properties. In particular, electron transport measurements display a fully developed valley Hall effect at 0 deg while on the contrary, it is completely absent at 60 deg. We explain this effect by performing numerical simulations, which highlight the central role of the atomic-scale structural relaxation of the second graphene layer. This in-plane atomic relaxation, different for the two alignments, impacts on the electronic band structure of our system. Our results demonstrate that in situ control of the rotational order provides a unique insight on the interplay between mechanical and electronic properties, and increases the posibilities for band-structure engineering on van der Waals heterostructures.

Tutorial TUT 2.3 Sun 17:10 H2

Single-photon emitters in 2D materials — •Steffen Michaelis de Vasconcellos — University of Münster, Institute of Physics and Center for Nanotechnology, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

Single-photon sources are key components for quantum technologies, such as communications, cryptography, computation, and metrology. Recently, the family of solid-state quantum light emitters was joined by single-photon sources in atomically thin materials [1]. Compared to 3D bulk materials, the 2D host crystals with their high structural flexibility allow for a high photon extraction efficiency, new methods for the deterministic creation, and convenient integration with photonic circuits.

In this tutorial, I will introduce the basic properties of single-photon emitters in different 2D van der Waals material systems and discuss present experimental methods for their creation, control, and coupling to photonic nanostructures.

[1] S. Michaelis de Vasconcellos et al., "Single-Photon Emitters in Layered Van der Waals Materials," Phys. Status Solidi B **2022**, 259, 2100566

Tutorial TUT 2.4 Sun 17:45 H2

Introduction to 2D superconducting spintronics — •Elke Scheer — Department of Physics, University of Konstanz, Konstanz

The proximity effect between a conventional (s-wave) 3D superconductor (S) and a ferromagnet (F) can lead to the formation of Cooper pairs with parallel-spin (spin-triplet) alignment instead of the conventional antiparallel-spin (spin-singlet) state. The demonstration of spin-triplet generation in S/F systems [1,2] has inaugurated the field of superconducting spintronics aiming at developing energy-efficient spintronic devices [3]. Both superconductivity and ferromagnetism depend on the dimensionality of the system, but have been shown to exist in 2D or quasi-2D systems [4,5]. The possibility to exfoliate layered van der Waals (vdW) materials down to the few-layer limit [6] in combination with the existence of S and of F vdW materials makes this material basis in particular promising to explore triplet S in 2DS/2DF heterostructures. In this tutorial talk I will briefly recall the physics of SF spintronics in 3D, before I will describe the particular properties and challenges in the investigation of 2D-SF hybrid systems and give an overview over the so far best-studied material combinations and

target devices.
[1] R. Keizer et al., Nature 95, 825 (2006)
[2] A. Buzdin, Rev. Mod. Phys. 77, 935 (2005)
[3] J. Linder & J. Robinson, Nature Phys. 11, 307 (2015)
[4] B. Huang et al., Nature 546, 270 (2017)
[5] M. Smidman et al., Rep. Prog. Phys. 80, 036501 (2017)
[6] A. K. Geim & I. V. Grigorieva, Nature 499, 419 (2013).

TUT 3: Functional Ferroics (joint session KFM/TUT)

Chair: Dr. Jan Schultheiß (Augsburg University / NTNU Trondheim)

Time: Sunday 16:00–18:15 Location: H3

Tutorial TUT 3.1 Sun 16:00 H3
Domains and domain walls in functional ferroics — •Dennis Meier — Department of Materials Science and Engineering, Norwegian University of Science and Technology — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway

Ferroic materials with spontaneous magnetic or electric long-range order are a rich source for functional phenomena. Ferromagnets, for example, are used in hard discs and read heads, whereas ferroelectrics find application as capacitors, energy harvesters, and in tunnel junctions. The rich functionality of ferroic materials is closely linked to their domain structures and the responses of the domains to external stimuli.

In this tutorial, I will give an introduction to the fundamentals that underpin the domain formation in ferroics and discuss different microscopy techniques that allow for imaging electric and magnetic domains. Furthermore, we will talk about more exotic systems, such as improper ferroelectrics and multiferroics, where the interplay of coexisting order parameters gives rise to completely new domain and domain wall properties at the nanoscale. Open experimental challenges will be addressed, as well as future application and research opportunities.

Tutorial TUT 3.2 Sun 16:45 H3
Theory and simulations of ferroelectrics and related materials — •Jorge Iniguez — Luxembourg Institute of Science and Technology — University of Luxembourg

In this tutorial I will introduce the theoretical and simulation methods most frequently employed to investigate ferroelectrics and related materials (antiferroelectrics, multiferroics). I will start from the general electronic-structure methods that permit predictive calculations at the atomic scale, and introduce successive simplifications to eventually reach continuum field schemes that give us access to the mesoscale. I will illustrate the specificity and usefulness of the different approaches by presenting, for each of them, one or two classic examples of application. In passing, this will allow me to emphasize the key role that simulation has played in our field, and to touch upon interesting possibilities for application in energy-related problems.

Jorge Íñiguez's work on ferroelectrics and related materials is mainly funded by the Luxembourg National Research Fund, currently through projects FNR/C18/MS/12705883/REFOX/Gonzalez, INTER/NWO/20/15079143, and C21/MS/15799044.

Tutorial TUT 3.3 Sun 17:30 H3
Atomic scale analysis of ferroic domain walls — •Shelly Conroy — Department of Materials, London Centre of Nanotechnology, Imperial College London, United Kingdom

The dynamic interfaces of ferroic materials known as domain walls bypass the static limitations of traditional nano-device designs. In contrast to hetero-interfaces between different materials, domain walls can be created, moved and removed via an applied stimulus. By combining multiple ferroic properties such as electricity and magnetism, new multi-functional interactive device applications are possible. As these mobile walls can be atomically sharp, it is essential to have physical characterisation at this scale spatially and time-resolved. In this tutorial, I will give an introduction to electron microscopy techniques starting with how to identify domain patterns in the bulk samples, and the most appropriate electron microscopy techniques to use with increasing magnification, leading to pico-meter characterisation. We will discuss some of the most recent advances in electron microscopy characterisation methods for ferroelectrics such as visualising electric charge density at sub-angstrom resolution, and the benefits of coupling polarisation characterisation with electron energy loss spectroscopy band structure analysis. We will then talk about how one can probe multiferroic properties such as magnetic field, strain and phonon modes. As one of the most exciting aspects of ferroic domain walls is their mobility, the various in situ options to investigate their dynamics will be detailed.

TUT 4: Stochastic Processes from Financial Risk to Genetics (joint session SOE/TUT/BP/DY)

Macroscopic and microscopic models from Economy to Biology must account for stochasticity on various levels. While classical physics strives for deterministic descriptions through differential equations from fundamental level to thermodynamics, many physics-based models on higher level explicitely include stochasticity from various sources. Discrete and continuous stochastic processes then become the mathematical foundation of these models. This tutorial highlights classical as well as current methods and approaches of probabilistic models and stochastic processes in physics, biology as well as socio-economic systems, thereby bridging the risk to extinction in genetics with its economic counterpart. (Session organized by Jens Christian Claussen.)

Time: Sunday 16:00–18:30 Location: H4

Tutorial TUT 4.1 Sun 16:00 H4
Diffusion approximations for particles in turbulence — •Bernhard Mehlig — University of Gothenburg, Gothenburg, Sweden

The subject of this tutorial is the dynamics of particles in turbulence, such as micron-sized water droplets in the turbulent air of a cumulus cloud. The particles respond in intricate ways to the turbulent fluctuations. Non-interacting particles may cluster together to form spatial patterns – even though the turbulent fluid is incompressible [1]. In this tutorial I explain how to understand spatial clustering using diffusion approximations, highlighting an analogy with Kramers' escape problem [2]. I introduce/review the necessary elements of diffusion theory. My goal is to give a pedagogical introduction to diffusion approximations in non-equilibrium statistical physics, using particles in turbulence as an example.

[1] K. Gustavsson and B. Mehlig, Statistical models for spatial patterns of heavy particles in turbulence, Adv. Phys. 65 (2016) 57 (read Sections 1, 3.1, and 6.1).
[2] H. A. Kramers, Brownian motion in a field of force and the diffusion model of chemical reactions, Physica 7 (1940) 284 (read up to

eq. (17)).

Tutorial TUT 4.2 Sun 16:50 H4

Probabilities in physics, paradoxes and populations — •Tobias Galla — Instituto de Física Interdisciplinary Sistemas Complejos, IFISC (CSIC-UIB), Campus Universitat Illes Balears, E-07122 Palma de Mallorca, Spain

It is notoriously hard for humans to develop a good intuition for probabilities and stochastic processes. Our brains are not able to do this naturally, and there are numerous mistakes which are easy to make. These mistakes are in fact made regularly in the press (sometimes perhaps deliberately). More worrisome, decision makers such as judges, doctors or politicians are also prone to mishandling probabilities. In this tutorial I will outline a few of these traps, and how to avoid them. I will also discuss the nature of probabilistic models of physical processes – is there genuine randomness in the world around us? I will then present a number of instances in which physics approaches combined with stochastic modelling can make a difference. As one example, I will outline experimental and theoretical results which highlight the importance of stochastic processes in population dynamics. Other examples will include stochastic processes in genetics, the evolution of cancer and in game theory.

Tutorial TUT 4.3 Sun 17:40 H4

Risk Revealed: Cautionary Tales, Understanding and Communication — •Paul Embrechts — Department of Mathematics, ETH Zürich

The title of the tutorial refers to a forthcoming book, to be published by Cambridge University Press, co-authored with Valérie Chavez-Demoulin (Lausanne) and Marius Hofert (Waterloo). Extreme Value Theory (EVT) offers a mathematical tool for the modeling of so-called What-If events, or stress scenarios. I will present several examples of risk-based decision-making and show how EVT can be used as part of the solution. The current pandemic has clearly shown that the communication of scientific evidence has a difficult stand in the ubiquitous environment of social media. I will discuss some examples of this struggle.