TUT 1: Tutorial: Modern Photovoltaics - Techniques beyond Silicon

Chair: Wichard J. D. Beenken, Institut für Physik, Technische Universität Ilmenau

Time: Sunday 16:00–18:30 Location: H2

Tutorial TUT 1.1 Sun 16:00 H2

CdTe thin-film solar cells — •Heinrich Metzner — Institut für Festkörperphysik, FSU Jena, Max-Wien-Platz 1, 07743 Jena

The global industrial production of CdTe solar modules exceeds one Gigawatt per year and so CdTe is probably the most successful thin-film technology of recent years.

In the tutorial, the specific features of the technology are elucidated which make it so competitive. Moreover, the open questions in the materials science of the CdTe-CdS-hetero-structure are discussed and key-issues are identified which are believed to potentially bring the CdTe solar cells to efficiencies well above 20 %.

Tutorial TUT 1.2 Sun 16:30 H2

CIGS thin-film solar cells — •Stefan Paetel — Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden Württemberg (ZSW), Industriestraße 6, 70565 Stuttgart, Germany

This talk covers the current status and understanding of high-efficiency $Cu(In,Ga)Se_2$ solar cells. Starting with the principal setup of these cells the various parts of the multilayer system will be introduced: substrate, back-contact, absorber, buffer and front contact. This includes the structural, optical and electronic properties of the materials. Furthermore relevant deposition methods are presented along with module manufacturing issues.

Tutorial TUT 1.3 Sun 17:00 H2

Dye-sensitized solar cells — •Sven Rühle — Institute for Nanotechnology and Advanced Materials, Dept. of Chemsitry, Bar Ilan University, Ramat Gan 52900, Israel

Dye-sensitized solar cells (DSSCs) are a low cost alternative to crystalline silicon p-n junction photovoltaic cells. DSSCs consist of a mesoporous nanocrystalline wide bandgap semiconductor (usually TiO_2) that is sintered onto a transparent conducting substrate (TCO). The nanocrystals are covered with a dye-monolayer and the pores are filled with a redox electrolyte which is in contact with a Pt counter electrode. Upon illumination light is absorbed by the dye molecules and electrons are injected from the excited dye state into the TiO_2 conduction band while the dye is regenerated by the electrolyte. Electrons diffuse through the mesoporous film to the TCO front contact while positive charges are transported by the redox species to the counter electrode. In DSSCs efficient charge separation occurs at the TiO_2/dye/electrolyte interface and build-in electrostatic fields play a minor role for cell operation in contrast to p-n junction solar cells. The basic principles of DSSC operation will be reviewed and theoretical efficiency limitations will be discussed.

Tutorial TUT 1.4 Sun 17:30 H2

Organic solar cells based on small molecules — •Moritz Riede — IAPP, Technische Universität Dresden, Germany

In recent years organic solar cells based on polymers or small molecules have received increasing attention from both science and industry, making it a very dynamic field of research. On the one hand, there are a number of open questions on the fundamental physics, e.g. the process of free charge carrier generation. On the other hand, there is the perspective of low cost solar power due to easy solar cell preparation, low-cost materials and processing technologies, and the possibility of producing large-area flexible devices on plastic substrates. Currently there are two main preparation technologies: solution processing and vacuum thermal deposition. This tutorial will focus on the main principles and concepts of the latter one. Despite its limitations to small molecules due to the thermal evaporation process, vacuum deposition has several distinct advantages: small molecules can be purified to a high degree, molecular doping of the organic layers is possible via co-evaporation, the layer thickness can be controlled well and stacked structures, e.g. for tandem solar cells, are easily accessible. Currently, metal-phthalocyanines and C_{60} are used as standard absorbers, but also new and promising materials have been introduced in recent years. Continuous material and device optimisation has lead to certified efficiencies of more than 6% on an device area exceeding $1cm^2$. Finally, an outlook on possible production routes is given.

Tutorial TUT 1.5 Sun 18:00 H2

Polymer Solar Cells — •Harald Hoppe — Institut für Physik, Technische Universität Ilmenau, Germany

Milestones in the development of conjugated polymer-based solar cells are reviewed. The presentation will cover an introduction to elementary photo-physical processes and fundamental working principles of polymer solar cells. Furthermore, processes limiting the individual photovoltaic parameters are discussed. Interesting examples of structure-property-relationships on the super-, inter- and intramolecular scale are given and demonstrate the necessity for multi-scale approaches in the optimization of polymer solar cells. Finally, several so far utilized donor-acceptor material systems are briefly reviewed.

TUT 2: Tutorial: Physics of NMR - Physics with NMR

Time: Sunday 16:00–18:30 Location: H3

Tutorial TUT 2.1 Sun 16:00 H3

Spins as Qubits — •Dieter Suter — Fakultät Physik, TU Dortmund

Processing of digital information has progressed at an enormous speed over the last decades and thus become an indispensable resource. Still, for some computational problems, no efficient algorithms are known for today's computers. For some of these problems, an exponential speedup is possible if the computers operate according to Schrödinger's equation, processing the information by unitary transformations. Nuclear spins were the first physical systems used to implement quantum algorithms; in the meantime, several other systems have become available for quantum information processing, all drawing directly from the techniques that NMR has developed for accurately controlling the dynamics of quantum mechanical systems. We will discuss some demonstration experiments that use magnetic resonance techniques to process quantum information stored in nuclear and electronic spins. Since today's quantum computers are based on a small number of qubits, their computational power is quite limited. To make them more powerful, it will be necessary to increase the number of qubits. Many concepts have been proposed that may eventually unlock this potential, some of them based on electronic and nuclear spins.

Literature: J. Stolze and D. Suter, *Quantum Computing: A Short Course from Theory to Experiment*, Wiley-VCH, Berlin, 2nd edition (2008).

short session break

Tutorial TUT 2.2 Sun 17:00 H3

Kernspin-Gitter-Relaxation: Grundlagen, Beispiele, Instrumentierung — •Franz Fujara — Institut für Festkörperphysik, TU Darmstadt, Hochschulstraße 6, 64289 Darmstadt

Im ersten Teil des Vortrags werde ich einige grundlegende Begriffe (Ratengleichungen, Wechselwirkungs-Hamiltonian, Übergangswahrscheinlichkeiten) der elementaren semiklassischen Relaxationstheorie einführen, womit dann Phänomene wie die Relaxationsrate, die Spindiffusion, die Spintemperatur und Fragen der (Nicht)ergodizität diskutiert werden können. Sodann möchte ich instruktive Resultate der traditionellen (Festfrequenz-)Relaxometrie vorstellen, die das Potenzial und die Limitierungen des Verfahrens verdeutlichen. Der letzte Teil des Vortrages behandelt moderne Field-Cycling (FC) Relaxometrieverfahren, sowohl elektronische als auch mechanische. Anhand aktueller experimenteller Beispiele soll ausgeführt werden, dass die FC-Relaxometrie als breitbandiges dynamisches Suszeptibilitätsverfahren betrachtet werden kann, welches mit erheblichem Gewinn gemeinsam mit der Messung anderer dynamischer Suszeptibilitäten, z. B. der di-

elektrischen Relaxation oder der dynamischen Lichtstreuung, eingesetzt werden kann.

Tutorial TUT 2.3 Sun 17:45 H3

NMR at High Pressures and High Fields — •Hans Robert Kalbitzer — Institute of Biophysics and Physical Biochemistry, University of Regensburg, D-93040 Regensburg, Germany

The two main methods for biomolecular structure determination are X-ray crystallography and NMR spectroscopy. The major advantage of the former is that virtually no size limit exists for the investigated macromolecules. Yet, only well crystallizeable systems can be analyzed preventing the investigation of for example transient complexes. NMR has the benefit that analysis can be performed in solution under nearly physiological conditions and dynamics can be studied in detail. High pressure NMR has developed in the last decade to a valuable tool for studying biophysical properties of proteins. Static pressure up to 400 MPa is applied to the sample located inside the high-field NMR spectrometer. The pressure is transferred to the sample cell via a pressurizing fluid and can be changed during the experiments. Besides an anisotropic compression of the protein, the most important feature of high pressure NMR spectroscopy is that conformational equilibria can be shifted reversibly, allowing the detection and structural characterization of excited states that are only weakly populated at ambient pressure. Time-dependent non-equilibrium states can be detected by pressure-jump NMR spectroscopy where the pressure is changed repeatedly by approximately 100 MPa in a time scale of 30 ms inside the NMR spectrometer. The pressure response is correlated to NMR parameters by introducing the pressure jumps in a complex pulse sequence (pressure correlation spectroscopy).

TUT 3: Tutorial: Functional (oxide) single crystals and epitaxial films - from growth to function

Time: Sunday 16:00–18:15 Location: H4

Tutorial TUT 3.1 Sun 16:00 H4

Influence of ferroelectric phase transitions on the melt growth of bulk oxide crystals — •Manfred Mühlberg and Manfred Burianek — Universität zu Köln, Institut für Kristallographie, Zülpicher Str. 49 b, 50674 Köln

Various applications in electronics, linear and nonlinear optics and other fields are connected with components taken from bulk single crystals. Also the determination of several fundamental physical properties like dielectric constants, piezo- or pyroelectric tensor components requires single crystalline samples. To meet these requirements one is primarily concerned with obtaining crystals of predetermined size with a high degree of structural perfection and a well-determined chemical composition.

In this introductory lecture, the most important growth methods from the melt and from high temperature solutions will be presented focusing on examples of selected ferroelectric perovskites and tetragonal tungsten bronzes. The chemical and thermophysical properties of the multi-component materials also represented by phase diagrams determine the synthesis steps and the details of the growth process.

A short overview of the defect types depending on the material properties and growth parameters will be given. Some options for reducing the defect content and improving the crystalline quality are reported for potassium lithium niobate and calcium barium niobate. Finally, a special attention is focused on the types and the influence of ferroelectric phase transitions being occuring between the growth temperature and the crystalline state at room temperature.

Tutorial TUT 3.2 Sun 16:45 H4

Electromechanical properties of crystals — •Eiken Haussühl — Institut für Geowissenschaften / Abt. Kristallographie, Goethe Universität Frankfurt

The knowledge of physical properties of crystals as bulk materials is rather limited in comparison to the huge number of known crystal structures. In this introductory tutorial fundamental aspects of crystal physics will be presented. The lecture is intended to provide the basics for the understanding of the distinctiveness of crystalline compounds and to bring closer the phenomenological aspects under the influence of symmetry. It is also intended to highlight practical considerations for the measurement of selected tensorial properties. The main part will be focused on the mechanical properties of the bulk material like thermal expansion, elasticity and on electrical properties like piezoelectricity. Different effects arising from phase transition of selected organic and inorganic materials like oxides will be discussed.

Tutorial TUT 3.3 Sun 17:30 H4

Epitaxial ferroelectric oxide thin films, nanostructures, and superlattices — •Dietrich Hesse, Ionela Vrejoiu, and Marin Alexe — Max Planck Institute of Microstructure Physics, Halle, Germany

Epitaxial ferroelectric thin films, nanostructures and superlattices represent a particularly interesting part of functional materials. In this tutorial, fundamental terms of epitaxial growth will be presented, along with a detailed characterization of growth-structure-property relations of a number of examples of perovskite-type ferroelectric structures. E.g., it will be shown how remanent polarization and switchability of pulsed-laser deposited $Pb(Zr,Ti)O_3$ (PZT) epitaxial thin films depend on the defect content (threading dislocations, stacking faults), and how the properties of antiferroelectric/ferroelectric $PbZrO_3$/PZT superlattices depend on the thickness of the individual layers via strain. The properties of epitaxial, ferroelectric $(Bi,La)_4Ti_3O_{12}$ nanostructures and Pt/PZT/Pt nanocapacitors of sub-100 nm size are shown to be determined by crystallographic orientation, crystal perfection, and size. The role of 2D defects will be highlighted, viz. ferroelectric 90 degree domain boundaries in epitaxial PZT films serving as nucleation centers for 180 degree switching, and the atomic structure of 180 degree boundaries influencing the switching process. Overall the interesting physical properties of epitaxial functional perovskite structures are discussed in terms of growth, crystal orientation, defect type, defect content, and strain.

TUT 4: Tutorial: Time Series Analysis in Sociophysics and Econophysics

Time: Sunday 16:00–18:00 Location: H10

Tutorial TUT 4.1 Sun 16:00 H10

Time Series Analysis in Sociophysics and Econophysics — •Johannes J. Schneider and •Tobias Preis — Center for Computational Research Methods in Natural Sciences, Johannes Gutenberg University of Mainz

In the last decades, an increasing number of physicists have applied models and methods from statistical physics to complex systems in various research fields, such as sociology, politology, finance, and economy, thus founding the new interdisciplinary research fields of sociophysics and econophysics. Due to the IT revolution, including the creation of large databases stored in data warehouses and the acceleration of business processes by replacing traditional ways of communication and transactions by modern electronic counterparts, nowadays a truly gargantuan amount of data is accessible for both elaborate applications and academic research. Based on these developments, the creation of models for the considered problems can be well founded and verified by the analysis of the available datasets. Thus, the first step is mostly to perform a statistical analysis of the available time series in order to detect the properties of the underlying system.

This tutorial will present both basic and advanced methods of time series analysis covering examples both from sociophysics and from econophysics. The focus will lie on two different scenarios: from socio-

physics, election results and their impacts on the member numbers of large parties shall be studied. In econophysics, a plethora of information exists—this tutorial will concentrate on financial market datasets. These data can be investigated by basic methods, such as correlation measures and scaling exponents. Furthermore, advanced procedures based on pattern comparisons and renormalization methods shall be described.