Friedrich-Alexander-Universität
Erlangen-Nürnberg

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New Energy Conversion Systems IGK 2495 Block Lecture Series (FAU SS 2022): Device development and advanced characterization techniques

Crystal Growth and Material Processing - Experimental and Numerical Approaches (30.05.2022 – 02.06.2022)

Introduction to the phase-field method for crystal growth, processing and multiferroics — Dr. Wendler

This lecture introduces the key ingredients to understand and implement the phase-field method (PFM), which has established as an important simulation tool to understand mesoscopic structure evolution in alloys, ceramics and soft matter. In the course the focus lies on applications in crystal growth, solidification and thin film growth of multi-component systems (alloys and minerals), but we will also touch domain or variant evolution in multiferroic systems, such as ferroelectrics, shape memory alloys (SMAs) and ferromagnetic SMAs.

The basic idea of introducing diffuse interfaces that simplify the numerical treatment of this kind of free boundary value problems is explained, and the mathematical and physical background including thermodynamics is developed. A lecture of its own will be dedicated to implementation of this method, including feasible and flexible software packages that can be used without long-standing experience in numerics.

From elementary description of interfacial phenomena to the kinetics of crystalline interfaces, increasingly complex models including single phase-field to multiple phase-field methods are exploited. Important transport processes containing diffusion, fluid flow and mechanical deformation are coupled. The goal is to convey a tool to study intricate pattern formation during solidification (dendrites), eutectic lamellae growth, precipitate growth and solutal crystal growth. Additional chapters on the relationship of PFM to atomistic simulation techniques (MD, DFT) will be presented, allowing for a length scales bridging in computational modeling.

Crystal growth of semiconductor and material processing using ultrashort laser pulses — Prof. Miyagawa

This course provides basic and latest knowledge on the crystal growth of semiconductor materials, especially about epitaxial growth. This course also provides the latest fine processing technique using ultrashort pulse lasers.

Advanced Structural Characterization Techniques (13.06.2022 – 17.06.2022)

Vibrational spectroscopy of amorphous to nucleated to fully crystallized materials — Dr. Cicconi

This lecture introduces theory and practice of Vibrational Spectroscopy techniques. You will learn the fundamentals, the instrumentation, and the challenges in data acquisition/interpretation. Therefore, if allowed Hands-on training sessions are planned.
1) Basic theory and fundamentals; 2) Raman and FTIR spectrometers; 3) Applications & Complementary techniques
4) PRACTICE: Sample preparation & measurements (if allowed); 5) PRACTICE: Data handling: from calibration to data presentation; 6) PRACTICE: Interpretation: quantitative vs qualitative

Synchrotron radiation techniques for materials science — Prof. Hayashi

This lecture introduces materials characterization techniques using synchrotron radiation, which produce strong and energy tunable X-rays. Unlike ordinary X-ray analyses, you will learn how powerful synchrotron-based X-ray techniques for element-selective structural analyses.
1) Basics of Synchrotron Radiation; 2) Introductions of Various Synchrotron-Based X-ray Techniques; 3) X-ray Absorption Fine Structure (XAFS); 4) X-ray Fluorescence Holography (XFH)

Advanced Modeling Techniques for Mechano-Electrical Systems (18.07.2022 – 22.07.2022)

Advanced computational simulation of mechano-electrical systems — Prof. Mergheim

The course provides an overview of modeling and simulation approaches for piezoelectric energy harvesters. In the first part of the course, there is a short introduction about the applications of piezoelectric energy harvesters. Then, the basic equations of electro-mechanical models are derived, both for linear and nonlinear material behavior. Building on these continuous equations, the simulation of piezoelectric structures using the finite element method is shown. This is followed by a discussion of the simulation of electric circuits and their coupling with electromechanical structures. Examples of linear energy harvesters and their dynamic simulation using harmonic response analysis follow. In the last part of the course, the coupled simulation of nonlinear energy harvesters with nonlinear circuits is discussed.

Advanced lecture on motor drives — Prof. Kosaka

In recent years, an electric and a fuel cell vehicle have been put to practical use in the market for a demand of CO2 emission reduction for protecting global warming. These kinds of vehicles employ electric motor drives for their propulsion. This lecture provides explanations about various types of the electric motors and their working principles, drive methods based on power electronics and aspects from a viewpoint of the vibration that is a dominant source of noise to be suppressed by piezo-actuated shape-adaptive structures as well as gives us an opportunity of developing piezo-actuated energy harvesting system.

Communications Systems Design (25.07.2022 – 29.07.2022)

Electronics design for energy harvesting system — Prof. Fischer

This lecture will focus on the circuit topologies used with energy harvesters and pay special attention to power and energy budgets. It will consist of several parts:

1) Imperfections of passive and active components used with harvester circuits, component modelling including parasitics
2) Simple rectifier/harvester circuits, loss mechanisms present in these circuits, realistic views on achievable power and efficiency figures
3) Advanced rectifier/harvester circuits, differences between harvesting schemes for stationary processes (e.g. vibration) versus instationary processes (e.g. stepping, shock actuation) optimization of circuitry and minimization of losses, Advanced harvester topologies making use of resonant phenomena, discussion on timings and I/U transient behavior
4) System architectures including battery management and voltage conversion, State of Charge SoC derivation, power and energy budget calculations

Application examples of power needs by circuitry in wearables and medical electronics with wireless interfaces, schemes for energy management, benefits from duty cycles in wireless communication.

Body area communications — Prof. Hirata, Prof. Wang

This lecture will introduce basic knowledge and application examples using body area communication. It mainly consists of five parts. (1) On-body transmission mechanism and characteristic, (2) In-body transmission mechanism and characteristics, (3) Transceiver design example, (4) Application to wireless robot control, and (5) Related electromagnetic compatibility (EMC) issues. Furthermore, this lecture explains computational techniques for human exposure to electromagnetic field, including resultant temperature rise. The relationship between exposure and product safety standards is discussed including the rationale from engineering viewpoint from extremely low frequencies to millimeter waves. Recent standardization related to emerging wireless communications system is also summarized.

As part of the collaboration between FAU and Nagoya Institute of Technology, Japan, the IRTG offers four new interdisciplinary graduate level lectures on device development and advanced characterization methods in the summer semester 2022. Those interdisciplinary graduate level week-long lectures (5 ECTS) will be given by a joint FAU-NITech PI team. The lectures will provide doctoral researchers and master students with an excellent overview on characterization and analysis techniques, state-of-the-art simulation methods, and device development. Each 5 ECTS module is compatible with elective modules especially in the master courses: EEI, ET, MWS, NT, MAP, WING, MB, ME, CE, AOT (TechFak) and Chemistry (NatFak).

More information about the IRTG “Energy Conversion Systems“ here.

For more infos and for registration write to Julia Berger (julia.b.berger@fau.de).