### Pre-conference Tutorial XV ICEBI / XIV EIT 2013
**21 April 2013 in Heilbad Hellenstein, Lecture Hall at Institut für Bioprozeß- und Analysenmeßtechnik**

| Time          | Session                        | Speaker          |
|---------------|--------------------------------|------------------|
| 10:00 – 10:45 | Impedance basics               | Orjan Martinsen  |
| 10:45 - 11:30 | Modeling                       | Sverre Grimnes   |
| 11:45 – 12:30 | Electrode Polarization         | Friedrich Kremer |
| 12:30 - 13:15 | EIT basics                     | Richard Bayford  |
| Lunch         |                                |                  |
| 14:00 – 14:45 | AC-electrokinetic phenomena    | Jan Gimsa        |
| 14:45 - 15:30 | Lab-on-Chip-application        | Andrea Robitzki  |
| Lunch         |                                |                  |
| 15:45 – 16:30 | Time Domain Spectroscopy       | Uwe Pliquett     |
| 16:30 – 17:15 | Signal processing              | Mart Min         |

**Orjan Martinsen, Impedance basics**

It is important in our field to have a common basic understanding of the fundamental concepts. We will talk about things like impedance and admittance and material properties like resistivity, conductivity and permittivity. More exotic things like memristor and memcapacitors will also be mentioned. Lastly we will go through different electrode systems and their respective sensitivity field features.

**Sverre Grimnes, Modeling**

Why do we need models, what are they for? Is it to have a simplified picture of the behavior of the modeled thing or process? E.g. a simple electronic circuit having the same impedance spectrum as the tissue. Is it to understand better or being able to give prognoses? I will discuss the most common models: Coulomb, Maxwell, Debye, Cole, Cole-Cole, the transducing and the Universal model.

**Friedrich Kremer, Charge transport and electrode polarization**

Charge transport at the interfaces between electronic and ionic conductors is a topic of special technological and fundamental importance in contemporary science. The quest for quantitative understanding of the extent and nature these interfaces is necessitated by the need for more efficient and optimal power sources among others. For practical purposes, the dynamics of the charge carriers around these boundaries needs to be understood over the broadest range of frequencies and temperatures possible. Due to its ability to measure the complex dielectric function (and hence the complex conductivity) over many orders of magnitude in frequency and in a wide temperature interval, Broadband Dielectric Spectroscopy (BDS) turns out to be an ideal experimental tool in this field.

**Richard Bayford, EIT basics**

Electrical impedance tomography (EIT) is a often referred to as a relatively new imaging method that has evolved over the past 30 years. It has the potential to be of great value in clinical diagnosis; however, EIT is a technically difficult problem to solve in terms of developing hardware for data capture and the algorithms to reconstruct the images. This lecture looks at the development of EIT and how it has evolved. It focuses on its clinical applications, examining hardware for the collection of data and reconstruction algorithms to generate images.
Jan Gimsa, AC-electrokinetic phenomena
The lecture considers DC- and AC-electrokinetic effects which can be used for the characterization or manipulation of suspended objects, media or interfaces. The classical DC-electrokinetic effects refer to particle and medium movements which are either induced by an external DC field (electrophoresis and electroosmosis) or by external forces. External forces may induce either sedimentation or streaming potentials. Because DC-electrokinetic effects are based on fixed surface charges they yield information on these charges and the Zeta potential. Also in AC-electrokinetics, particle and medium movements are observed, though at frequencies from the low Hz up to the GHz ranges. The effects can be exploited in spectroscopy methods, measuring various frequency-dependent force effects. AC fields induce charges at the structural interfaces of particles and biological cells. The interaction of these charges with the inducing field generates forces which are the basis for AC-electrokinetic effects such as electrorotation, dielectrophoresis (DP), electroorientation, electrodeformation, field-trapping and travelling-wave DP. In media, local heating may alter the dielectric properties, leading to "smeared interfaces" which may be polarized by AC fields similar to structural interfaces. This may result in medium convections which can be exploited for pumping or mixing.

Andrea Robitzki, Lab-on-Chip: Bioimpedance Based High Content-Screening of Organotypic Tissues
The tutorial will address the development and use of interdigital microarrays, high dense electrode and microcavity arrays for the characterization of organotypic tissues via impedance spectroscopy. The focus of the report will be (i) the coupling of e.g. viable brain slice cultures on microelectrode arrays consisting of semiconductive electrode materials for impedance spectroscopy, (ii) field potential recording and (iii) high resolution microscopy on one and the same sensor. For a high sensitive recording the biomimetic interface on the microelectrode is the relevant key point for an intensive cell-electrode contact. Switching between different biophysical measurement methods on the same device demands on a feasible microcontroller directing the sharing of same frequency ranges without any disturbance of the impedance or filed potential signals. Therefore, the presented technique is of great benefit for the pharmaceutical industry, especially in respect of functional lead identification or efficacy of active pharmaceutical ingredients. The cellular dielectric spectroscopy (CDS) or electric impedance spectroscopy (EIS) can be used to measure frequency dependent alterations of passive electrical properties of complex tissues. For this purpose, an alternate voltage current is applied to a biological sample e.g. a tissue slice whereby the current flows from an active working electrode through and beneath the organotypic tissue to a counter electrode. Under these non-invasive conditions the tissue itself reacts as a resistor and capacitor affecting the recorded impedance. Depending on the frequency and the dielectric properties of tissue structure and architecture, it is possible to monitor different biological or physiological processes described by an electric circuit model.

Uwe Pliquett, Time Domain Spectroscopy
A frequency sweep for assessment of an impedance spectrum is time consuming and therefore not appropriate for monitoring material with fast changing passive electrical properties. A way out is the use of a broad bandwidth excitation signal and tracing its response as a function of time. Depending on the explicit application, especially on the frequency range of interest, transmission or reflection measurements arranged in single or differential configuration are possible. Measurements within the β-dispersion region with sub-millisecond resolution are possible but better precision is achieved by averaging over several periods of a periodic excitation signal. The lecture will start with the basics of time domain spectroscopy followed by the most popular excitation signals and conclude with selected applications.

Mart Min, Signal Processing
Experimental characterization of bioimpedance needs measurements in a wide frequency range (impedance spectroscopy). For the performing of measurements, synthesis and generation of an excitation or stimulus signal (current of voltage) and extracting of information from the response signal (voltage of current) is required. One classical way is to have a sine wave excitation with controllable frequency and use a phase-sensitive detection of the sine wave response signal. However, the other waveforms are more effective in many cases where the fast spectral analysis of the impedance is of interest. In this case the waveforms like multi-sine and chirp/chirplet signals and their binary and ternary modification can be much more effective. Also the methods and algorithms for the processing of response signal as short time and fast Fourier Transforms (STFFT) and other are in use as the most suitable ones. Such and similar questions will be discussed in the signal processing tutorial.