

## Course Topics

### EEE598: Advanced Biosensor Concepts

**Prerequisites:** Graduate Engineering Student

**Catalog Course Description:** The recent development in the field of biosensors is driven by creating robust and reliable devices for a vast variety of analytes while constantly improving the detection speed and the specificity. Biosensors use a bio-(chemical) process as a signal transduction mechanism to produce an electrical signal that can be used to perform electronic data analysis. By being able to use the current data processing technology, these devices are extremely easy to use and do not require special training to operate them, which makes them ideally suited for small labs and point-of care diagnostics. However, there are still a lot of challenges to meet with a lot of the current biosensor devices. In particular, the complexity of the tools has to be taken into account, which gets reflected in the price per measurement. Thus there is a strong drive in research towards using the least complex solution towards a biosensing problem, without sacrificing selectivity and specificity.

This course will provide an introduction into the most common biosensing principles, giving background information on the underlying theory as well as the current limitations of these technologies. The most prominent example here is the amperometric glucose sensor, which proves to be a huge success. Besides covering the sensing principle itself, the course will go into detail on fabrication aspects, stressing how microfabrication can be used to miniaturize these sensors. From here, the course will address field-effect-based biosensing techniques, such as the measurement of nerve cell action potentials using MOSFETs.

Moreover, the course will cover emerging biosensor technologies based on whole-cell patch clamping for pharmaceutical drug screening. An emphasis will be put on the instrumentation required to accomplish reliable noise-free measurements of electrical currents in the picoampere range. Various high-throughput screening concepts (planar patch-clamp) will be introduced and discussed. Taking the patch-clamp approach one step further, the course will cover the technology of ion channel reconstitution and show how engineered ion channels can be used as specific detectors or as nanopores to detect DNA translocation events. Finally, various DNA sensing concepts will be introduced, ranging from translocation through natural and artificial nanopores or nanowires to cantilever-based hybridization sensors to the widely used optical detection arrays.

**Course Topics:**

- Introduction: What makes up a biosensor, classification of biosensors, the glucose sensor as an example, Biosensor Performance Metrics: What do we have to look for?
- Biochemical recognition elements, Immobilization strategies
- Cyclic Voltammetry, Diffusion-controlled current
- Electrical biosensors: Amperometric sensors
- Electrical biosensors: Potentiometric sensors
- Electrical biosensors: The reference electrode
- Electrochemical impedance spectroscopy
- The ISFET - an integrated potentiometric sensor
- Conducting polymer-based FETs
- Cells and ISFETs – The Neurochip (I)
- The Neurochip (II)
- Nanowire devices (I) - Fabrication
- Nanowire devices (II) - Applications
- DNA hybridization: detection using impedance spectroscopy
- Conductimetric sensors – Coulter Counting
- Introduction to patch clamp measurements
- Noise in conductimetric circuits and systems
- Planar patch-clamp concepts, Ion channel reconstitution
- Artificial nanochannels and nanopores
- Biomineralized nanopore membranes, DNA hybridization: detection using nanopores
- Optical biosensors: Introduction
- Optical biosensors: Surface Plasmon Resonance
- Optical biosensors: Fluorescence-based sensors (FRET)
- Optical biosensors: Chemiluminescence