University of Rochester
Department of Electrical and Computer Engineering
Colloquia Series

Bioelectronics: From Novel Concepts to Practical Applications

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Wednesday, September 26th
11:00 AM – 12:00 PM
Computer Studies Building (CSB) 209

Abstract: The talk will outline the conceptual foundations of the novel approach to biosensing and bioactuating based on multi-step processing of biochemical signals through biocatalytic/biorecognition processes, adapting ideas recently developed in the field of bioelectronics and biocomputing (biomolecular logic). Biomolecular computing is an emerging field of unconventional computing that attempts to process information with biomolecules and biological objects using digital logic. Enzymatic systems which involve biocatalytic reactions utilized for information processing will be exemplified. Extensive ongoing research in biocomputing, mimicking Boolean logic gates has been motivated by potential applications in biotechnology and medicine. Furthermore, novel sensor concepts have been contemplated with multiple inputs processed biochemically before the final output is coupled to transducing "smart-material" electrodes and other systems. These applications have warranted recent emphasis on networking of biocomputing gates. First few-gate networks have been experimentally realized, including coupling, for instance, to signal-responsive electrodes for signal readout. In order to achieve scalable, stable network design and functioning, considerations of noise propagation and control have been initiated as a new research direction. Optimization of single enzyme-based gates for avoiding analog noise amplification has been explored, as were certain network-optimization concepts. We review and exemplify these developments, as well as offer an outlook for possible future research foci. The latter include design and uses of non-Boolean network elements, e.g., filters, as well as other developments motivated by potential novel sensor and biotechnology applications. Recent advances in biomedical applications of enzyme-based logic systems, particularly for the analysis of pathophysiological conditions associated with various injuries will be briefly reviewed. Novel biosensors digitally processing multiple biomarker signals produce a final output in the form of YES/NO response through Boolean logic networks composed of biomolecular systems. The biocomputing approach applied to biosensors leads to a high-fidelity biosensing compared to traditional single-analyte sensing devices. By processing complex patterns of multiple physiological biomarkers, such multi-signal digital biosensors should have a profound impact on the rapid diagnosis and treatment of diseases, and particularly can provide timely detection and alert of medical emergencies (along with immediate therapeutic intervention). The novel biosensing concept has been exemplified with the systems for logic analysis of various injuries, including soft tissue injury, traumatic brain injury, liver injury, abdominal trauma, hemorrhagic shock and oxidative stress. Other developments in the general area of bioelectronics include novel biofuel cells operating in vivo. The first fully implanted biofuel cell continuously operating in a snail and producing electrical power over long period of time using physiologically produced glucose as a fuel will be discussed. The "electrified" snail, being a biotechnological living "device" was able to regenerate glucose consumed by biocatalytic electrodes, upon appropriate feeding and relaxing, and then produce a new "portion" of electrical energy. The snail with the implanted biofuel cell will be able to operate in a natural environment producing sustainable electrical micro-power for activating various implantable bioelectronic devices. Overall, integration of bioelectronics, biocomputing, materials science, and bionanotechnology resulted in the novel "smart" bioelectronic systems for medical, environmental and homeland security applications. The recent advances in this rapidly developing research area will be discussed.

Bio: Evgeny Katz received Ph.D. in Chemistry from Frumkin Institute of Electrochemistry (Moscow) in 1983. He was a senior researcher in the Institute of Photosynthesis, Russian Academy of Sciences (1983-1991), a Humboldt fellow at München Technische Universität (Germany) (1992-1993), and a research associate professor at the Hebrew University of Jerusalem (1993-2006). From 2006 he is Milton Kerker Chaired Professor at the Department of Chemistry and Biomolecular Science, Clarkson University, NY (USA). He has (co)authored over 340 papers in the areas of biocomputing, bioelectronics, biosensors and biofuel cells (Hirsch-index 70). Evgeny Katz was included by Royal Society of Chemistry in the list of top cited chemists with the worldwide rank 378 based on his H-index. Thomson Reuters released data identifying the world's top 100 chemists over the past 10 years as ranked by the impact of their published research - Evgeny Katz was included in the list as # 63 from approximately a million chemists indexed by Thomson Reuters.

Light refreshments will be provided.