University of California, Irvine

THE DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MSE 298 SEMINAR

FALL 2025: MSE IN THE SPOTLIGHT

Chancellor's Professor
Plamen Atanassov
Chemical and Biomolecular Engineering

RESEARCH TALK:
ELECTROCATALYSIS AS ENABLING TECHNOLOGY FOR DECARBONIZATION

SHORT CAREER TALK:
1985-2025 - FORTY YEARS OF TECHNICAL ELECTROCHEMISTRY

Abstract: Renewable power generation by solar and wind have begun to transform and decarbonize electricity sectors around the world, but reliable and resilient systems based on such intermittent sources will require a combination of firm electricity generation, flexible demand, and energy storage. Aviation, long-distance freight transport, and high-temperature industrial processes, such as steel, cement and ammonia production are historically difficult to electrify and decarbonize. Electrochemical technologies offer unique solutions to these challenges by enabling low temperatures and pressures processes and using electricity to drive the reactions and store or convert energy. These include not only direct energy storage in batteries, but also options for converting electricity into chemical form via chemicals and fuels that could supplant fossil hydrocarbons in net-zero emissions energy systems. Electrochemical technologies support carbon dioxide capture, conversion and valorization, water desalination, wastewater treatment and reuse, contributing to climate change mitigation, improving air quality, urban sustainability, food production and addressing complex water availability quality for industrial, agricultural and urban use. (Abstract continued on page 2)

Bio: Plamen Atanassov graduated University of Sofia (1987) specializing in Chemical Physics & Theoretical Chemistry and received PhD in Physical Chemistry/Electrochemistry from the Bulgarian Academy of Sciences where he was a scientist at the Central Laboratory of Electrochemical Power Sources (now Budevski Institute for Electrochemistry & Power Systems). His dissertation was on bio-electrocatalysis and enzyme biosensors. Dr. Atanassov moved to the United States in 1992 and joined University of New Mexico (UNM) as researcher and later as faculty member with the Chemical & Nuclear Engineering department. During the 90s he contributed to the development of long-term implantable sensors for in vivo glucose monitoring, needle-type biosensors for glucose and lactate, flow-through immunosensors for rapid detection of bacteria and viruses. Dr. Atanassov joined a startup Superior MicroPowders (later sold to Cabot Corp.) where he developed and deployed catalysts for fuel cells based on spray pyrolysis. Returning to UNM as tenured-track faculty in 2000, Atanassov built research programs in electrocatalysis and bio-electrocatalysis. He founded UNM Center for Emerging Energy Technologies (CEET), was Associate Dean for Research of UNM School of Engineering and later served as director of UNM Center for Micro-Engineered Materials (CMEM). (Bio continued on page 2)

DATE: Thursday, November 6, 2025

TIME: 2:00 - 3:20 PM

LOCATION: McDonnell Douglas Engineering Auditorium

Abstract: We will present here a conceptual path is to enable net-zero emissions energy systems and improve human health and prosperity by transforming the chemical, manufacturing and energy sectors through electro-chemical engineering of the Hydrogen, Carbon and Nitrogen Cycles. Central convergent theme is the urgent need to address the decarbonization of manufacturing and chemical sectors, using the means of basic science and engineering integration with technoeconomic and socio-economic analysis, practiced dynamically over the network of multiple economic nodes, to inform and direct the scientific and engineering effort to the maximum impact.
As an energy storage medium, “green” H_2 is generated in electrolyzers and then is utilized (converted to electricity) in fuel cells – both processes being electrocatalytic ones. Moreover, the rate-limiting (and efficiency lowering) processes in those devices are oxygen evolution and oxygen reduction reaction (OER/ORR). These two processes surmount to a great proportion of electrocatalysis effort. The range of catalyst materials to be employed in such effort includes metals, oxides, and carbonaceous materials. We will present here an overview of our work on different catalysts synthesis protocols to engineer highly functional materials at nano/micro/meso scale with well-defined morphology, size, shape, surface and bulk composition and structure. An example of one such model material set based on N-doped carbon nanostructures decorated with atomically dispersed nonprecious metals, demonstrating control over carbon particle size and shape, distribution of nitrogen and metal sites. These materials are being coupled with various aqueous electrolytes with a wide pH range to demonstrate functionality in fuel cells, metal air batteries and microbial electrochemical systems.
Another major area of electrocatalysts technology is in capture and conversion of CO_2 to fuels and value-added chemicals. We will show here examples of nanostructured and atomically dispersed catalyst materials for the electrochemical carbon capture and conversion into syngas. The next target for the electrocatalyst development is to introduce new materials, electrolytes and optimum conditions for the conversion of CO_2 beyond CO and formate to multi-carbon species such as ethylene or alcohols. We will exemplify the issue with the use of metallic Cu-based electrocatalysts and the active role of 2D and 3D nanomaterials engaged as both supports and co-catalysts.
Current frontier in the development of electrocatalytic materials is in selective conversion of N_2 from air into fertilizers and ammonia by low-temperature and low-pressure electrochemical methods. Direct electrocatalytic reduction of ammonia would address major societal challenges related and is an area of fierce competition marred with sometimes mysterious achievements and overinterpretations. In all, we will present our take on the challenge and a strategy towards and electrochemical Haber-Bosch process.

Bio: Starting October 2018 Plamen Atanassov joined University of California Irvine (UCI) where he is a Chancellor’s Professor with the Department of Chemical & Biomolecular Engineering, holding secondary appointments with Materials Science & Engineering and Chemistry. His educational efforts are directing to creating a PhD program in Electrochemistry & Electrochemical Engineering. Plamen Atanassov materials for energy programs are focused on development of novel electrocatalysts: non-platinum electrocatalyst for fuel cells, nano-structured catalysts for oxidation of complex fuels, and new materials and technologies for energy conversion and storage. Atanassov bio-electrocatalysis research includes enzyme electrochemistry, enzymatic and microbial fuel cells, and systems for biological and bio-inspired energy harvesting. At present his research includes electrocatalysis for CO_2 reduction and valorization, ammonia synthesis and cascade multi-step electrocatalytic reactions.

At present his research is focused on new electrocatalysts for fuel cells, electrolyzers, CO_2 electroreduction and valorization, as well as ammonia and urea electrosynthesis. He has published more than 490 peer-reviewed papers (with 45K+ citations and forming an h-index of 108). He supervised 50 doctoral dissertations and 30 postdoctoral fellows. He holds 67 issued US patents, substantial number of which have been licensed and are at the core of several catalyst products. Atanassov is a fellow of National Academy of Inventors (NAI), The Electrochemical Society (ECS) and the International Society of Electrochemistry (ISE) of which he is currently the President.

Atanassov is on the leadership team of Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) – the California DOE Hydrogen Hub. As a commission of trust, Prof. Atanassov serves on the advisory boards for several large-scale EU and national programs for electrochemical energy conversion and storage and for decarbonization technologies in Bulgaria, Czech Republic, Hungary and Germany.