

Research in the Center

All projects in the Center involve multiple Co-PIs, with the majority of the projects involving Co-PIs from multiple institutions. The Center is configured along three synergistic thrusts.

I - Kinetics and Non-Local Transport

II - Multiphase Plasmas

III - Customizing Fluxes for Plasma Surface Interactions

Thrust I is developing the fundamental experimental and computational techniques for controlling $f(\epsilon)$ in mildly reacting systems. *Thrust II* is employing those techniques in multiphase systems exemplified by nano-dusty plasmas, thereby providing a higher level of complexity to test and refine those techniques. *Thrust III* is developing the knowledge base required to control $f(\epsilon)$ in systems with active boundaries (that is, when plasmas interact with surfaces and surfaces emit fluxes of particles), and also test and refine the techniques developed in *Thrusts I* and *II*.

Website

The Center website (<http://doeplasma.eecs.umich.edu>) contains up-to-date information about the Center and its activities, as well as links to publications and conference presentations by Co-PIs.

Web Seminars

The Center sponsors a web-seminar series in which Co-PIs of the Center and LTP researchers present their most recent research results. The seminars are now open to the general community and the presentations are on the Center website. See the website for seminar schedules.

Annual Meetings

The Annual Meeting of the Center is held in May during which progress and results are shared and to receive feedback from our advisory board, colleagues, and sponsors. Attendance of the Annual Meeting is open to the general plasma and interested community. Meeting information is available on the Center website.

The Center is Guided by an External Advisory Board

Industry

- Dr. Jeffrey Marks, Lam Research Inc.
- Dr. Tim Sommerer, General Electric
- Dr. Nick Fuller, IBM
- Dr. Mark Strobel, 3M, Inc.

International

- Prof. Uwe Czarnetski, Ruhr University, Bochum
- Dr. Pascal Chabert, CNRS, France
- Prof. William Graham, Queen's University, Belfast, N. Ireland

Universities

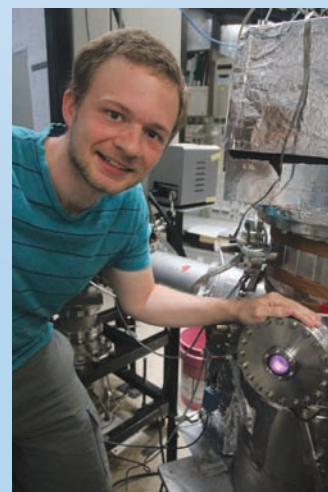
- Prof. Edward Thomas, Auburn University
- Prof. Cary Forest, University of Wisconsin
- Prof. Harold Weitzner, New York University

National and Defense Laboratories

- Dr. Adam Cohen, PPPL
- Dr. Pat Colestock, LANL
- Dr. Bish Ganguly, Wright Aero-Laboratories

Industrial Collaborations

The Center welcomes engagement with industry on fundamental and applied topics. The combined expertise of the Co-PIs of the Center are able to address a wide range of plasma technologies. Most of our researchers have a long productive record of industrial collaborations. Please contact the Center Director if there are projects that would benefit from a collaboration between the Center and your company.



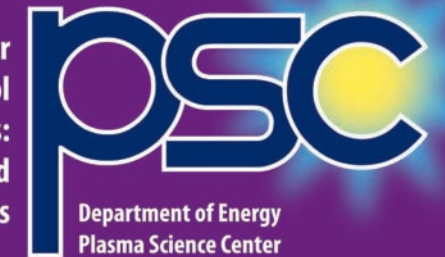
Graduate student Nick Fox-Lyon works on an ICP reactor running Ar plasma used in PSC plasma-surface interaction studies.



U.S. DEPARTMENT OF
ENERGY

Office of Science

Center for
Predictive Control
of Plasma Kinetics:
Multi-Phase and
Bounded Systems



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About the DOE Center for the Predictive Control of Plasma Kinetics: Multi-Phase and Bounded Systems

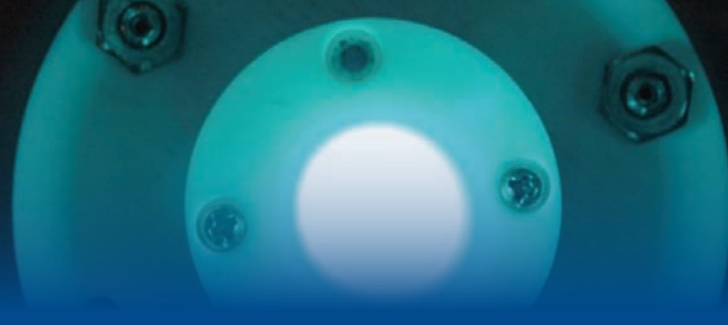
The Science and Technology of Low-Temperature Plasmas

Low-temperature plasmas (LTPs) are partially ionized gases that are used as the basis of technological devices ranging from microelectronics fabrication, lighting and lasers to biomedical applications. In LTPs, electrons and ions are accelerated by electric and magnetic fields. Gaining sufficient energy, electrons and ions collide with atoms, molecules, and surfaces to generate excited states, chemically reactive radicals, and activated surface sites. These products then radiate photons, deposit films, or modify surface properties, and so create the basis of untold numbers of everyday and advanced technologies – microelectronics to solar cells and highly efficient combustion.

The ability of LTPs to efficiently and selectively produce the photons, radicals, and chemically active species required for these technologies depends on shaping the distribution of electron and ion energies to match the energy dependent

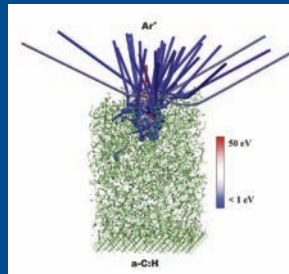
activation probabilities of the atoms, molecules, and surfaces that electrons and ions collide with. The distributions of electron and ion energies, $f(\epsilon)$, must be well matched to

these energy dependent probabilities of excitation in order to maximize the societal benefit that LTPs provide. To date, the means to selectively control $f(\epsilon)$ to provide this societal benefit is at best poorly understood. As described in the National Research Council Decadal Report, *Plasma Science: Advancing Knowledge in the National Interest*, achieving this control is the highest level of science challenge in the LTP field.

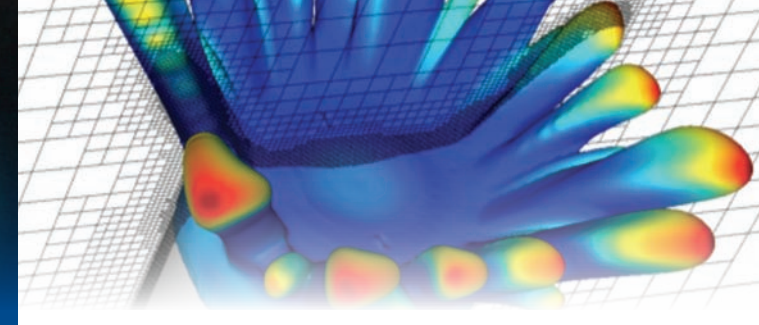


The Department of Energy Plasma Science Center for the *Predictive Control of Plasma Kinetics: Multi-Phase and Bounded Systems* has as its unifying theme the control of plasma kinetics and control of $f(\epsilon)$ of electrons, ions, photons, and neutrals. By advancing the science base for controlling $f(\epsilon)$, the Center will also enable advances in the society benefiting technologies that use LTPs. The Center stands out as the first major center level activity focusing on LTPs under the auspices of the DOE Office of Fusion Energy Science (OFES).

LTPs are perhaps unique among the fields of plasma science in that particle energy distributions – electrons, ions, neutrals, photons – are not in equilibrium. That is, not only do all of these particles have different temperatures, their distribution functions $f(\epsilon)$ are not Maxwellian. Although electrons can have temperatures of many to tens of eV, the heavy ions and neutral particles have temperatures near ambient. These non-equilibrium conditions enable LTPs to intimately and non-destructively interact with their environments (that is, their containers) up to the point of having solid or liquid materials within the plasma in the form of particles and aerosols. These non-equilibrium conditions afford a unique opportunity to craft and control distribution functions in order to maximize the interaction of electrons and ions with their collision partners. Achieving this control will revolutionize technologies using LTPs.



Controlling $f(\epsilon)$ of plasma species is to a large degree an *inverse problem*. If one specifies the local electric and magnetic fields (magnitudes, orientation, and frequency), gas pressure and gas compositions, the LTP community is good at predicting $f(\epsilon)$. However, if you ask “what are the electric and magnetic fields applied to the boundaries of the plasma that will produce a desired $f(\epsilon)$ at a specific location?”, we are far less capable of specifying those conditions. This capability is, however, critical to the development of new technologies. How does one uniquely craft $f(\epsilon)$ at a specific time and location in the plasma so that production and activation of reactive species are optimized? This is the highest level of scientific challenge in LTPs, and the unifying theme of the *Center*.



The Center for Predictive Control of Plasma Kinetics

The Center is a unique collaboration between 9 universities and 2 national laboratories, involving 21 Co-Principle Investigators.

Mark J. Kushner, Director
University of Michigan

Co-Principal Investigators:
**Assoc. Director and Thrust Leader

- **Igor Adamovich**, Ohio State University
- **Eray Aydil**, University of Minnesota
- **Ed Barnat**, Sandia National Laboratory
- **Iain Boyd**, University of Michigan
- **Vladimir Demidov**, West Virginia University
- **Vincent Donnelly**, University of Houston
- **Demetre Economou**, University of Houston
- **Alec Gallimore**, University of Michigan
- **Steven Girshick****, University of Minnesota
- **Valery Godyak**, University of Michigan
- **David B. Graves****, University of California, Berkeley
- **Gregory Hebner**, Sandia National Laboratory
- **Noah Hershkowitz**, University of Wisconsin
- **Igor Kaganovich****, Princeton Plasma Physics Laboratory
- **Mark Koepke**, West Virginia University
- **Vladimir Kolobov**, CFDR/University of Alabama, Huntsville
- **Uwe Kortshagen**, University of Minnesota
- **Walter Lempert**, Ohio State University
- **Michael Lieberman**, University of California, Berkeley
- **Gottlieb Oehrlein**, University of Maryland
- **Yevgeny Raitsev**, Princeton Plasma Physics Laboratory

