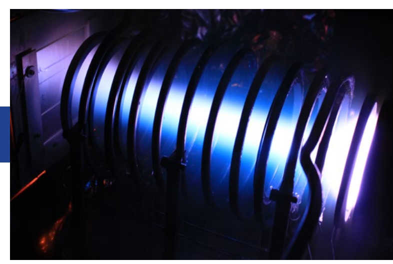
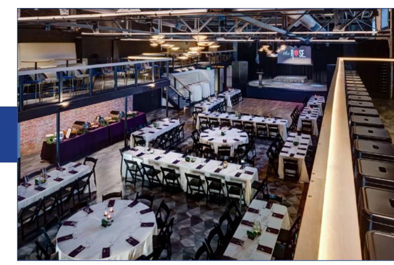
110th IUVSTA Workshop on Advanced Plasma Diagnostics for Surface Engineering and Film Deposition

October 5 – 8, 2026

The Rose Event Center – 1119 Washington Ave., Golden, CO, USA 80401

The workshop includes Plenary Lectures, Poster Sessions, Tutorials, Networking Meals & Local Tours





Bringing together plasma diagnostics and thin film deposition enables us to tune processing plasma for precisely engineered films in terms of materials composition and microstructure. This can lead to otherwise unattainable novel materials and thin film systems for diverse areas of high impact.

Example topics of interest include:

- Correlation of fundamental process characteristics (ion or electron energy, ion flux densities, plasma chemistry, etc.) for plasma-based vapor deposition (PVD, ALD, etc.) to obtain films for optical, electronic, machining, and other applications.
- Novel approaches to plasma characterization or analysis yielding data influencing directly thin film deposition and surface engineering processes including etching, cleaning and functionalization.
- Thin film and surface engineering innovations enabled by plasma characterization data.
- Since both plasma diagnostics and thin film deposition are increasingly relying on large data acquisition, image and data processing, and machine learning, the topic also includes modern and timely approaches connecting the fields of plasma diagnostics and thin film synthesis.

To preserve and nurture an informal and intimate workshop setting, total attendance at the workshop will be limited to 50 attendees

Workshop organizers:

***André Anders** (Plasma Engineering LLC, Berkeley, CA USA)

Christopher Muratore (University of Dayton, Dayton, OH USA) *IUVSTA SED Chair*

Frank Zimone (Society of Vacuum Coaters, Albuquerque, NM USA) *SVC Executive Director*

Contact: andre.anders@plasmaengineering.com for workshop information and additional details

SVC Workshop Partner

CLICK HERE to submit an abstract to *2026 110th IUVSTA Workshop on Advanced Plasma Diagnostics for Surface Engineering and Film Deposition*

MESSAGE FROM THE **ORGANIZERS**

We are pleased to host a series of keynote talks by experts performing research at the boundary between the two disciplines of plasma diagnostics and surface engineering. Their collective work on non-equilibrium materials processing and characterization of low temperature plasmas provides insights into the realization of novel materials, devices, and technologies in areas of high economic, societal, and environmental impact. The speakers work in plasma-based materials processing methods ranging from ALD/ALE to HiPIMS and plasma diagnostics techniques from optical to electrostatic. Convergence of global leaders in these fields at the workshop will facilitate insightful discussion and new ideas to accelerate progress in these fields. In addition to the keynote speaker program outlined here, we encourage attendees to submit abstracts for poster presentations. We will have an oral poster flash session for all poster presenters to introduce their works prior to the poster session.

The city of Golden, Colorado was selected for the workshop venue for its status as an iconic city of the American West nestled in the foothills of the Rocky Mountains and within easy reach of the USA's top winter resorts during peak mountain snow season. The Rose Event center in downtown Golden is one of the oldest buildings in the city. This venue provides a sophisticated atmosphere promoting exchange of information and networking essential to the success of the event. Additionally, excursions to the famed Coors Brewery and the Colorado School of Mines are all within a short walking distance of the workshop meeting venue. The National Laboratory of the Rockies (NLR) houses a number of leaders in plasma-based surface engineering techniques and applications of interest to prospective workshop attendees, is also located in Golden, and attendees will have an opportunity to tour this advanced facility. Please join us for what promises to be a productive and impactful event.

Plasma diagnostics for surface engineering topics addressed by speakers include:

- Selective discrimination between incident fluxes of neutral and ionized species, even in processes with high fractions of ionized species, such as HiPIMS.
- Analysis and quantification of reactive species (e.g., atomic ions and neutral species borne from molecules, etc.) and impact on materials structure and properties.
- Measurement of plasma sheath dynamics and resulting particle energy distributions enabling knowledge-based processes for surface engineering applications.
- Application of AI and ML methods to process real-time, in situ plasma characterization data collected in processing systems common in both industry and R&D.

Organizing Committee:

André Anders
Plasma Engineering LLC, Berkeley, CA USA

Christopher Muratore
University of Dayton, Dayton, OH USA
IUVSTA SED Chair

Frank Zimone
Society of Vacuum Coaters, Albuquerque, NM USA
SVC Executive Director

Workshop Schedule

	Monday | October 5, 2026	Tuesday | October 6, 2026	Wednesday | October 7, 2026	Thursday | October 8, 2026
8:00 A.M.		**Sponsored Breakfast** The Rose Event Center	**Sponsored Breakfast** The Rose Event Center	**Sponsored Breakfast** The Rose Event Center
9:00 A.M.		*15 Minute Pass Break*	*15 Minute Pass Break*	*15 Minute Pass Break*
9:15 A.M.		Welcome - Introduction	Welcome - Introduction	Welcome - Introduction
9:30 A.M.		**Plasma Diagnostics as a Tool for Improved Film Properties and Processes** *(Peter Kelly | Manchester Metropolitan University)*	**In situ Plasma and Surface Diagnostics to Understand Surface Reactions During Atomic Layer Deposition** *(Sumit Agarwal | Colorado School of Mines)*	**Quantitative Time-resolved Diagnostics of Precursors in HiPIMS Deposition** *(Tiberiu Minea | University of Paris Saclay/CNRS)*
10:00 P.M.		**Non-invasive Diagnostics for Characterizing Conditions at Plasma Electrodes During Thin Film Growth** *(Daniel Lundin | Linköping University)*	**Lab Tour** **Colorado School of Mines** *Hosted by Sumit Agarwal*	**Multi-Pulse HiPIMS Discharge Dynamics Toward Enhanced Reactive Process Controllability** *(Tetsuhide Shimizu | Tokyo Metropolitan University)*
11:00 A.M.		***Discussion***		***Wrap Up and Future Directions***
11:30 A.M.		**Probing Ion Drag and Electric Field Forces in CCRF Plasmas with Optical Tweezers** *(Jessica Schleitzer | Christian-Albrechts-Universität zu Kiel)*		
12:15 P.M.		***Discussion***	***Discussion***	
12:30 P.M.		**Sponsored Lunch** The Rose Event Center	**Sponsored Lunch** The Rose Event Center	**Sponsored Lunch** The Rose Event Center
1:00 P.M.	**Short Course #1** Plasma Optical Emission Spectroscopy (OES): Opportunities and Limitations *(André Anders)*			
1:15 P.M.			***Poster Session***	**Coors Brewery Tour**
1:30 P.M.		**Latest Advances of Complementary Plasma Monitoring Technologies for Process Development, Production Control and Machine Learning (ML)** *(Thomas Schütte | PLASUS GmbH)*		
2:15 P.M.		**The Role of Plasma in Plasma Enhanced Atomic Layer Deposition** *(Scott Walton | U.S. Naval Research Laboratory)*	**Plasma-Assisted Atomic Layer Etching of Diamond** *(David B. Graves | Princeton University)*	
3:00 P.M.		***Discussion***	**Plasma-driven Transport Far From Thermodynamic Equilibrium** *(Steffen Schüttler | Ruhr University Bochum)*	
3:30 P.M.		***Poster Flash Session***		
3:45 P.M.			***Discussion***	
4:00 P.M.		*30 Minute Passing Break*		
4:15 P.M.			**Diagnostics of Magnetron Sputtering: Particle Fluxes and Concentrations** *(Jaroslav Hnilica | Masaryk University)*	
4:30 P.M.		**National Renewable Energy Laboratory Tour**		
5:00 P.M.				
5:30 P.M.	**Welcome Reception and Workshop Overview** (Sponsored Event)			
7:00 P.M.				

For more information, contact André Anders: andre.anders@plasmaengineering.com

SVC Workshop Partner

Invited Speakers

Tuesday, October 6, 2026 | 9:30 A.M.

Plasma Diagnostics as a Tool for Improved Film Properties and Processes

Peter Kelly, *Surface Engineering Group, Manchester Metropolitan University, Manchester, UK*
peter.kelly@mmu.ac.uk

Functional films are ubiquitous in modern life and underpin the performance of components and devices from virtually every sector including automotive, aerospace, consumer electronic, medical, construction, energy, and transport. In applications such as wear resistance or corrosion resistance, the film may be a single metallic or ceramic layer, but in other applications, such as sensors, smart glazing, optical filters, photovoltaics, touch screens, semiconductors, etc., the device may rely on a multi-layer stack consisting of individual films with specific optical, physico-chemical and/or electronic properties (refractive index, transmission, resistivity, etc.). The properties of functional films are, though, notoriously sensitive to process parameters and, for a given film composition, depend on control of properties, such as structure, crystallinity, grain size, and defect density. For a commercially viable product the films must deliver optimized performance, whilst being deposited at maximized rates. Consequently, the performance of the coating is inextricably linked to the capabilities of the deposition process.

Many technologies are available; however, magnetron sputtering is a well-established, industrialized low temperature technological plasma-based process, which has become the process of choice for the deposition of functional films for many applications. Typical plasma densities are in the range 1016 m-3, with electron temperatures of 2 - 3 eV, although much higher densities and energy populations can also be created when operated in a pulsed mode. Ions are extracted from a glow discharge plasma in front of the cathode plate and strike the cathode with sufficient energy to remove target atoms (mainly) that can then condense on the substrate as a growing film. Ions currents are also drawn at the substrate and concurrently bombard the growing film, modifying its structure. The strength and design of the magnetic trap at the target and the driving voltage waveform (DC, RF, pulsed DC, AC, HiPIMS) used to power the plasma are key parameters in determining the resultant structure and properties of the deposited film. In particular, pulsing the discharge in the mid-frequency range (20-350 kHz) may cause stochastic heating of the plasma through sheath expansion at the target on re-ignition. The resulting higher bulk electron temperatures, compared to continuous processing, give rise to increased floating potentials and contribute to increased ion energy fluxes to isolated substrates. HiPIMS, another pulsed plasma variant, involves the application of high peak power density (~10's kW/cm2) pulses at the cathode target and can generate a highly ionized metal flux (e.g., up to 70% for titanium), which provides the possibility of significantly enhanced deposition conditions.

In the Surface Engineering Group at Manchester Metropolitan University, we have utilized these sputtering techniques to produce functional films for many applications including oxidation protection of components in hostile environments; enhanced tribological and antimicrobial surfaces; and the coating of particulates with visible light photocatalysts for remediation of organic pollutants in water. These examples will be briefly discussed, along with diagnostic studies (undertaken in collaboration with Prof James Bradley, University of Liverpool) that highlight how specific operating parameters and design features control the discharge parameters and plasma stability, which in turn control the deposition process.

Peter Kelly is Head of the Surface Engineering Group at Manchester Metropolitan University in the UK. The group specializes in the development and applications of the magnetron sputtering technique, concentrating, in particular on the pulsed magnetron sputtering process, including HIPIMS (high power impulse magnetron sputtering). Kelly's core activities are the production of functional thin films with application specific properties; the characterization of the physical, structural, optical, catalytic, chemical, tribological, etc., properties of the thin films; and the characterization and development of advanced deposition processes. His work is highly applied in nature, working closely with industry and generally focused on the end use of the particular coating/substrate system. Recent examples include the Development of oxidation resistant coatings on nuclear fuel rods; Novel Optical Absorbers for Energy Efficient Solar Control Glazing; Developing sustainable food packaging; Development of high efficiency photocatalytic materials for water treatment and chemical synthesis; and Development of Coatings for Hostile Environments. Kelly runs a thriving and diverse research group with over 30 doctorate conferrals to date. He served as Program Chair to ICMCTF in 2025 and will be General Chair in 2026 and was Conference Chair for the Reactive Sputter Deposition conference in 2025.

Tuesday, October 6, 2026 | 10:15 A.M.

Non-invasive Diagnostics for Characterizing Conditions at Plasma Electrodes During Thin Film Growth

Daniel Lundin[1], Xiao Li[2], Ivana Venkrbcová[2], Ulf Helmersson[1], Martin Čada[2], and Zdeněk Hubička[2]; *[1] Department of Physics, Chemistry and Biology (IFM), Linköping University, Linköping, Sweden; [2] Institute of Physics V. V. I., Academy of Science of the Czech Republic, Prague, Czech Republic*
daniel.lundin@liu.se

Experimental plasma characterization in the vicinity of a plasma electrode is a long-standing major challenge in plasma physics. The reason is that most diagnostic tools here perturb the plasma or cannot withstand the harsh conditions in the vicinity of the plasma source. This is particularly challenging in thin-film synthesis by magnetron sputtering, which relies on the use of an actively driven plasma electrode onto which the source material (target) is mounted, and where plasma conditions change continuously due to effects including target erosion, compound formation, and change of magnetic field strength. In this work we will introduce novel non-invasive diagnostics that will allow unprecedented real-time plasma characterization directly at plasma electrodes during thin-film growth. Our solution is based on the application of a non-perturbing radio frequency (RF) voltage signal directly onto the plasma/sputtering source coupled with precise RF voltage and RF current waveform measurements. The method allows us to monitor plasma properties including ion flux, plasma sheath impedance, electron density, and electron temperature at the plasma electrode during film growth. These types of measurements have so far required the insertion of a probe , and thus facing the same challenges as other invasive diagnostics. To illustrate the capabilities of these diagnostics we have characterized high-power impulse magnetrons sputtering (HiPIMS) discharges in non-reactive as well as reactive mode.

[1] *Sobolewski, J. Vac. Sci. Technol. A 10, 3550 (1992).*
[2] *Sezemsky et al., Plasma Sources Sci. Technol. 28, 115009 (2019).*

Daniel Lundin is a Senior Associate Professor at Linköping University, Sweden. He received his Ph.D. in Physics from Linköping University in 2010, with a thesis focused on High Power Impulse Magnetron Sputtering (HiPIMS). Since 2006, he has been at the forefront of international research efforts on developing and characterizing new plasma-based methods for synthesizing thin films. Following postdoctoral and researcher positions funded by the Swedish Research Council at Université Paris-Sud and KTH Royal Institute of Technology, as well as a guest professorship at Kiel University, he was appointed a permanent senior researcher at the French National Center for Scientific Research (CNRS) in 2015. In 2019, he returned to Linköping University, where he leads the Plasma and Coatings Physics research group. He is a frequent invited speaker and instructor at international HiPIMS tutorials and is among the most cited researchers in the HiPIMS field. Dr. Lundin is also a co-founder and Chief Technology Officer of Ionautics AB and serves on its Board of Directors.

Tuesday, October 6, 2026 | 11:30 A.M.

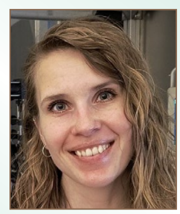
Probing Ion Drag and Electric Field Forces in CCRF Plasmas with Optical Tweezers

Jessica Schleitzer, Viktor Schneider, and Holger Kersten; *Institute of Experimental and Applied Physics; Christian-Albrechts-Universität zu Kiel, Kiel, Germany*
schleitzer@physik.uni-kiel.de

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Information about local electric fields, energy fluxes, and momentum transfer by ions to the particles can be obtained based on their behaviour in the plasma. Especially, the manipulation of microparticles by an optical tweezer is of interest, as it enables the microprobe to be positioned in areas of the plasma typically inaccessible to conventional diagnostic methods, such as the plasma sheath.

In this study, optically trapped microparticles in a highly focused laser beam are used to investigate both the electrostatic field force in the sheath and the ion drag force in the presheath of a capacitively coupled radio-frequency discharge. These forces differ by roughly one order of magnitude, requiring adjustments of the trapping laser power to control the sensitivity of the optical trap accordingly.

By observing the displacement of the trapped particle under varying gas pressure and phase angle in dual-frequency discharges, the spatial structure and parameter dependence of both forces are resolved. These measurements allow the experimental reconstruction of the fundamental plasma structure comprising bulk, presheath, and sheath.



Jessica Schleitzer is a postdoctoral researcher in plasma physics at Kiel University (Christian-Albrechts-Universität zu Kiel), Germany. She received her PhD (Dr. rer. nat.) in 2025, focusing on the structure and dynamics of dual-frequency plasmas investigated by a multi-diagnostic approach spanning bulk plasma, presheath, and sheath regions.

Her research combines advanced plasma diagnostics with optically trapped microparticles to directly measure force profiles, ion drag forces, and sheath properties in capacitively coupled RF discharges. In addition to optical diagnostics, her work includes Langmuir probe measurements. She has extensive experience in experimental plasma physics, data analysis, and the development of diagnostic techniques.

She earned her bachelor's degree in physics with a focus on astrophysics in 2017, followed by a master's degree in physics specializing in plasma physics in 2021, both at Kiel University. Throughout her academic training, she has been actively involved in experimental research, student supervision, and international scientific exchange, and she actively participates in conferences and collaborations within the plasma physics community.

Tuesday, October 6, 2026 | 1:30 P.M.

Latest Advances of Complementary Plasma Monitoring Technologies for Process Development, Production Control and Machine Learning (ML)

Thomas Schütte, Jan-Peter Urbach, Peter Neiß, Marius Radloff, and Hokuto Kikuchi; *PLASUS GmbH, Mering, Germany*
schuette@plasus.de

As specifications in the thin film industry become more and more demanding, high production yields and cost-effective production becomes a major factor in this competitive market. Increasing demand for better specifications and lower scrap rates drive the demand for efficient process control systems.

In addition, data analysis using artificial intelligence (AI) and machine learning (ML) technologies has made tremendous progress in recent years, sparking interest in using these methods for the diagnostics and control of plasma applications.

This presentation will highlight the opportunities and advantages of utilizing the latest developments in real-time in-situ data acquisition of different diagnostic techniques in a single system: Spectroscopic plasma process monitoring acquires data from the actual process plasma whereas in-situ broadband photometric measurements gather properties of the growing coating such as film thickness or color values. In addition, time-resolved electrical measurements of generator power, voltage and current provide valuable electrical process information especially in pulsed plasma applications.

Selected plasma applications are used to illustrate how process variations influence the results of the different measurement techniques. Consequently, by combining different methods and analyzing the complementary data in real-time, interdependencies between process and product properties become visible and can be used to achieve more accurate and reliable process control. At the same time, the collected data can be fed into the analysis using AI and ML techniques to improve product quality and long-term production stability.

Real-time process control examples combining different diagnostic methods will be presented and first approaches to the application of ML methods will be illustrated using various coating applications from industry and R&D, such as metallic and reactive sputtering, HIPIMS and PECVD processes for tribological, optical and glass coating processes.

Thomas Schütte is founder and president of PLASUS GmbH, dedicated to the development of spectroscopic plasmas process control systems for R&D and industry.. After graduating in Electrical Engineering at the Technical University Munich, Germany and the University of Southern California, Los Angeles, CA, USA, he found his passion for plasma, spectroscopy, and software during his Ph.D. thesis at the former Institute of Plasma Research in Stuttgart, Germany. He founded the company PLASUS in 1996 and introduced one of the first pure spectroscopic plasma monitor and control system suitable for operation in production lines in 2003 Since than Thomas Schütte and the team at PLASUS pushed the development of plasma process control systems to new frontiers always trying to adapt to new coating and production technologies, like HIPIMS, atmospheric plasma or machine learning. Thomas Schütte participates in German, European, Asian, and American societies for plasma and surface technologies and he shares his experience and latest developments in this field in numerous contributions on conferences around the globe.

Tuesday, October 6, 2026 | 2:15 P.M.

The Role of Plasma in Plasma Enhanced Atomic Layer Deposition

S.G. (Scott) Walton[1], D. R. Boris[1], M.J. Johnson[1], M.E. Meyer[2], V.D. Wheeler[3], M.G. Sales[2] ,P.M. Litwin[2], D.J. Pennachio[3], and J.M. Woodward[3]; *[1]Plasma Physics Division, U.S. Naval Research Laboratory, Washington, DC 20375, USA; [2]NRC Postdoctoral Fellow residing at the Naval Research Laboratory, Washington, DC 20375, USA; [3]Electronics Science & Technology Division, U.S. Naval Research Laboratory;*
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Plasma-enhanced atomic layer deposition (PE-ALD) is a low temperature, conformal, layer-by-layer deposition technique that is based on a pair of self-terminating and self-limiting gas-surface half-reactions, in which at least one half-reaction involves species from a plasma. This approach generally offers the benefit of substantially reduced growth temperatures and greater flexibility in tailoring the gas-phase chemistry to produce amorphous, crystalline, and epitaxial films of varying types and characteristics. The plasma-based advantages come at the cost of a complex array of process variables that can significantly impact the growth modes and resulting film properties. Accordingly, understanding the process parameter-to-material property relationship is both critical and challenging. We approach this problem by combining plasma diagnostics and simulations with material growth and characterization techniques. Plasma diagnostics including VUV-NIR spectroscopy, Langmuir probes, and ion energy analyzers are used to understand the production and subsequent delivery of reactive and energetic species to the growing films in PE-ALD systems. In particular, we assess the spatial variation of plasma parameters, flux and energy of ions reaching the substrate surface, and the relative fractions of chemically active species generated in the plasma over a variety of operating powers, gas pressures, and gas input flow fractions typically used during growth. Changes in plasma parameters are then linked with changes in growth modes and film properties using both ex-situ and in-situ characterization techniques. We will discuss the results of this approach to investigate the growth of InN, Ga2O3, and V2O5 as examples. This work is supported by the Naval Research Laboratory base program.

Scott Walton is the Head of the Plasma Applications Section in the Plasma Physics Division at the Naval Research Laboratory (NRL) in Washington DC. After receiving his Ph.D. in physics from the College of William and Mary, he came to NRL as a National Research Council Postdoctoral Research Associate in 1998. He has been a staff member in the Plasma Physics Division since 2002. As Section Head, he manages the Plasma Applications Laboratory and research programs related to the production, characterization, and use of low temperature plasmas in applications for both low- and high-pressure environments. The programs cover topics ranging from fundamental to applied and have provided the opportunity to collaborate with researchers from academia, national laboratories, and industry to address challenging but exciting problems. His primary interest is understanding the interaction of plasmas and surfaces. On this and related topics, he has more than 110 peer-reviewed journal articles, 13 patents, and has given more than 60 invited talks. He is a fellow of the AVS and a Fellow-Mentor of the Society of Vacuum Coaters (SVC).

Wednesday, October 7, 2026 | 9:30 A.M.

In situ Plasma and Surface Diagnostics to Understand Surface Reactions During Atomic Layer Deposition

Sumit Agarwal; Colorado School of Mines, Golden, Colorado USA
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Atomic layer deposition (ALD) is extensively used in semiconductor device fabrication due to its ability to deposit conformal films with atomic scale control over the thickness with abrupt interfaces with the underlying material. More recently, to enable certain device structures, it is desirable to selectively deposit with ALD only on a target material (growth surface) with nanoscale precision with almost no deposition on other non-growth surfaces that are also exposed to ALD precursors. Area-selective atomic layer deposition (AS-ALD) can be achieved through either inherent growth selectivity or by blocking reactive sites on the nongrowth surface with inhibitor molecules. However, inherent growth selectivity is generally not observed on chemically similar surfaces since their surface functional groups may have similar reactivity with ALD precursors. Therefore, development of AS-ALD processes for chemically similar growth and nongrowth surfaces is challenging. In this presentation, I will demonstrate that in situ optical diagnostics such as attenuated total reflection Fourier transform infrared spectroscopy and spectroscopic ellipsometry can be used to study the reaction of inhibitor molecules with different growth and nongrowth surfaces, and to understand how and when nucleation of ALD occurs on the nongrowth surface. I will demonstrate that information from in situ optical diagnostics can be used to develop AS-ALD processes relevant to semiconductor device manufacturing.

Sumit Agarwal is a Professor of Chemical and Biological Engineering at the Colorado School of Mines (CSM) since 2005. He joined CSM after his post-doctoral research at the University of Massachusetts – Amherst. Prior to this, he received his Ph.D. in Chemical Engineering from the University of California – Santa Barbara, and his M.S. and B. Tech. degrees from the University of New Mexico and the Indian Institute of Technology, Varanasi, respectively. His current research is focused on studying surface processes during atomic layer processing of materials for semiconductor applications, plasma processing of materials, and development of industrially relevant fabrication techniques for ultra-high efficiency crystalline silicon solar cells. He has received the Paul Holloway Young Investigator Award from the AVS and the NSF CARRER Award. He is a Fellow of the AVS.

Wednesday, October 7, 2026 | 2:15 P.M.

Plasma-Assisted Atomic Layer Etching of Diamond

David B. Graves*, Princeton University, Department of Chemical and Biological Engineering, Princeton, New Jersey USA*
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Nitrogen-vacancy (NV) centers in diamond are promising for multiple applications in quantum information processing and sensing, including in the fields of high power/high frequency electronics, quantum computing and quantum sensing. However, these diamond quantum devices are often limited by near surface (<10 nm) defects that compromise charge stability and spin coherence. One strategy to improve diamond surface engineering is to employ an advanced plasma processing technique developed in the semiconductor industry, namely plasma-assisted atomic layer etching (ALE). The proposed ALE approach for diamond reverses the conventional ALE sequence in which the surface modification step is usually chemical modification (e.g., oxygen-containing species would be a likely choice for the chemical modification step in the case of carbon films), followed by a removal step using Ar+ impacts. In the proposed version of diamond ALE, the initial surface modification step consists of Ar+ ion bombardment. This creates an amorphous carbon layer at the surface of the diamond film, the thickness of which is controlled by the ion energy. A second ALE step impacts the amorphous carbon layer with O+ between about 1 and 5 eV. Although we assume the energetic O is in the form of a positive ion accelerated across a plasma sheath, the key factor is the kinetic energy. Hyperthermal neutral O could also be used in the proposed scheme. Classical molecular dynamics simulations show that in this energy range O+ will selectively remove the amorphous carbon but will not etch the underlying diamond, assumed here to be a (100) surface. This approach exploits the fact that amorphous carbon and diamond carbon are significantly different in their chemical reactivity to oxygen at energies lower than about 10 eV. In addition to selectively etching a-C over diamond C, the O+ impacts are predicted to smooth the

surface by selectively attacking the edges of any isolated diamond (100) terraces. Post O+ exposure, the diamond surface is predicted to consist of mainly ether (C-O-C) bonding between the surface diamond carbon and the terminating O. The remaining O is predicted to be ketone (C=O) bonds. Preliminary experimental validation is shown of the proposed scheme.

David B. Graves joined the University of California at Berkeley Department of Chemical Engineering in 1986 after receiving the PhD from the University of Minnesota. He retired from UCB in May 2020 and served as Associate Lab Director at the Princeton Plasma Physics Lab from 2020-2022. He is currently Professor in the Department of Chemical and Biological Engineering at Princeton University. His research interests are in plasma materials processing and other applications of non-equilibrium, low temperature plasma phenomena.

Wednesday, October 7, 2026 | 3:00 P.M.

Plasma-driven Transport Far from Thermodynamic Equilibrium

Steffen Schüttler[1,2], Philipp Maaß[1], Hanna-Friederike Poggemann[3], Anna Lena Schöne[4], Julian Held[1], Judith Golda[2], and Achim von Keudell[1]; *[1]Experimental Physics II, Ruhr University Bochum, Bochum, Germany; [2]Plasma Interface Physics, Ruhr University Bochum, Bochum, Germany; 3Institute of Electrochemistry, Ulm University, Ulm, Germany; [4]Chair of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, Bochum, Germany*
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The directed and controlled flux of particles to samples is an important requirement for most plasma processes, such as deposition or etching processes. Non-equilibrium plasmas are used in which temperature, pressure, and density gradients prevail, and transport is far from thermodynamic equilibrium. Therefore, knowledge of transport phenomena in non-equilibrium plasmas is crucial for generating directed, structured particle fluxes and controlling the energy, momentum, and reactivity introduced into a sample medium.

Within our group, transport phenomena of particles from various non-equilibrium plasmas to different samples have been investigated in recent years. Our research focused on transport processes in HiPIMS discharges, more specifically on radial transport losses from the target to the substrate [1]. In addition, the deposition rate and profile of zirconium layers in a plasma-enhanced chemical vapor deposition process using a microwave plasma were investigated to understand the transport and formation processes of the layers [2]. Finally, a plasma jet was used to introduce H2O2 into a liquid sample, and the transport of the plasma-generated H2O2 from the plasma to the liquid via the effluent was tracked [3].

In this presentation, I will introduce these three examples and discuss the transport phenomena of each system. Although these processes are quite different, transport phenomena are crucial for controlling particle fluxes in every system. The insights gained from these systems can then be transferred to other non-equilibrium plasma systems.

1. Steffen Schüttler et al., Plasma Sources Sci. Technol. 32 105008 (2023)
2. P. A. Maaß et al., Plasma Process Polym. 20:e2300050 (2023)
3. Hanna-Friederike Poggemann et al., J. Phys. D: Appl. Phys. 58 135208 (2025

Steffen Schüttler began studying physics in 2015 at Ruhr University Bochum. Beginning with his bachelor's thesis, he started his work in the fascinating field of non-equilibrium plasma physics. Starting with the investigation of CO2 conversion in a plasma-catalysis system at atmospheric pressure, he moved to low-pressure plasmas and studied the radial transport of sputtered atoms in HiPIMS discharges. For his PhD, which he successfully defended in beginning of 2025, he switched back to atmospheric pressure plasmas where he investigated the reactive species supply from a plasma jet into a liquid sample. He published his work in various publications of renowned journals about low-temperature plasma physics and presented the results at international conferences worldwide, including an invited talk at the plasma division of the German Physical Society (DPG). He now works as a Researcher at the Chair for Experimental Physics II – Reactive Plasmas (Prof. Achim von Keudell), including the research group Plasma Interface Physics (Prof. Judith Golda), both located at Ruhr University Bochum.

Wednesday, October 7, 2026 | 4:15 P.M.

Diagnostics of Magnetron Sputtering: Particle Fluxes and Concentrations

Jaroslav Hnilica[1], Peter Klein[1], Martin Ondryáš[1], Gergely Lelovics[1], Martin Učík[2], Vjačeslav Sochora[3], Matej Fekete[1], Pavel Souček[1], Petr Vašina[1]; *[1]Masaryk University, Czech Republic; [2]SHM s.r.o., Czech Republic; [3]PLATIT a.s., Czech Republic*
106259@mail.muni.cz

Advanced physical vapor deposition (PVD) processes increasingly rely on ionized plasmas to achieve precise control over thin film growth. In contrast to conventional sputtering, ionized PVD techniques such as arc-based deposition and High Power Impulse Magnetron Sputtering (HiPIMS) generate high ion fluxes and elevated ionization degrees of the sputtered material, fundamentally altering plasma–surface interactions. The resulting ion energy and flux distributions strongly influence adatom mobility, film densification, stress development, and microstructural evolution.

A key parameter governing these effects is the ionized metal flux fraction (IMFF), which quantifies the relative contribution of metal ions to the total deposition flux. Accurate determination of the IMFF is therefore essential for correlating plasma conditions with thin film growth mechanisms. Gridded and magnetic quartz crystal microbalances (QCMs) provide a powerful diagnostic capability by selectively discriminating between neutral and ionized species in the deposition flux. In non-reactive sputtering of metallic targets, this approach enables direct quantification of the IMFF under well-defined plasma conditions.

Recent work has further extended the applicability of biasable QCM diagnostics, allowing the measurement of argon ion fluxes impinging on the growing film. Although argon ions do not directly contribute to film formation, their bombardment plays a crucial role in determining the coating's structure and properties by transferring kinetic energy into the growing film.

This contribution presents several case studies illustrating deposition rate measurements and IMFF determination for different sputtering configurations, target materials, and experimental conditions. The results highlight QCM-based diagnostics as a powerful and versatile tool for advanced plasma diagnostics in surface engineering and thin film deposition.

Jaroslav Hnilica is an Associate Professor in the Department of Plasma Physics and Technology at Masaryk University, Czech Republic. He earned his Ph.D. in Plasma Physics in 2013 and completed his habilitation in 2023. His research focuses on plasma diagnostics, instabilities in magnetron discharges, pulsed-power excited discharges, and the development of advanced thin-films. He actively collaborates with industry on the development and diagnostics of sputtering processes and engages in international research partnerships to advance plasma-based technologies. Jaroslav has published over fifty peer-reviewed papers in leading plasma and surface science journals, with more than eight hundred citations and an h-index of 17 (according to the Web of Science). His scientific mission is to deepen the understanding of plasma processes in magnetron discharges and their impact on thin-film deposition. Beyond research, he serves as a reviewer for scientific journals and funding agencies and has led several fundamental and industry-oriented projects. At Masaryk University, he teaches physics and plasma diagnostics courses and has supervised numerous students in plasma physics.

Thursday, October 8, 2026 | 9:30 A.M.

Quantitative Time-resolved Diagnostics of Precursors in HiPIMS Deposition

Tiberiu MINEA, Anna Kapran, and Charles Ballage; *University of Paris Saclay/CNRS, Laboratoire de Physique des Gaz et des Plasmas - LPGP, 91405 Orsay, France*
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High-power impulse magnetron sputtering (HiPIMS) has already proven its benefits relative to conventional magnetron deposition techniques. Nowadays, research focuses on optimizing the deposition process by managing plasma excitation power. Among the most common, there are bipolar HiPIMS, revisited chopped HiPIMS, enhanced electron HiPIMS, etc. As in the past, the magnetic trap balance is also investigated for all these pulsed plasma variants.

A crucial piece of information for further optimization should distinguish between the energy and flux effects of the film precursors during deposition. However, most conventional diagnostic techniques provide average plasma parameters, whereas ionized species are mainly created during the pulse and persist for a while in the immediate afterglow. Hence, time-dependent diagnostics are crucial for understanding and optimizing all time-dependent plasmas, as HiPIMS. Moreover, highly ionized sputtered material and the precise moment at which it intercepts the substrate are crucial for discriminating the specificities of each particular HiPIMS excitation.

Using a magnetized quartz crystal microbalance (M-QCM) probe, we developed a microsecond time-resolved diagnostic that quantifies the flux and energy of film precursors, both ionized and neutral [1]. By mapping the space in front of the cathode, the optimal position of the substrate for several balancing of the magnetron cathode [2,3] can also be determined.

1. *Ch. Ballage, A. Kapran, O. Vasilovici, A. Bennacef, and T. Minea, Surf. & Coat. Technol. 520 (2026) 133047 – https://doi.org/10.1016/j.surfcoat.2025.133047*
2. *A. Kapran, C. Ballage, Z. Hubička, T. Minea, Vacuum 238 (2025) 114324; https://doi.org/10.1016/j.vacuum.2025.114324*
3. *A. Kapran, C. Ballage, Z. Hubička, T. Minea, J. Appl. Phys. 135(17) (2024); https://doi.org/10.1063/5.0198423*

Tiberiu MINEA has been a full Professor at the University of Paris-Saclay since 2008. He directed one of the leaders' plasma physics laboratories in France, the Laboratory of Physics of Gases and Plasma (LPGP), from 2015 to 2025, founded in 1960 under the CNRS and the University. He has led the group Theory and Modeling of Plasmas-Discharge and Surfaces at LPGP since 2006. He was the president of the Plasma division of the French Physical Society (2010-2013), the President of the French Federation of the Scientific Societies (F2S) clustering the Physical, Optical, Electrical, and Vacuum Societies (2014-2017), and deputy president of F2S (2018-2022). He has been the President of the Scientific and Technical Committee of the French Vacuum Society (SFV) since 2013 and has served on the board since 2008.

Thursday, October 8, 2026 | 10:15 A.M.

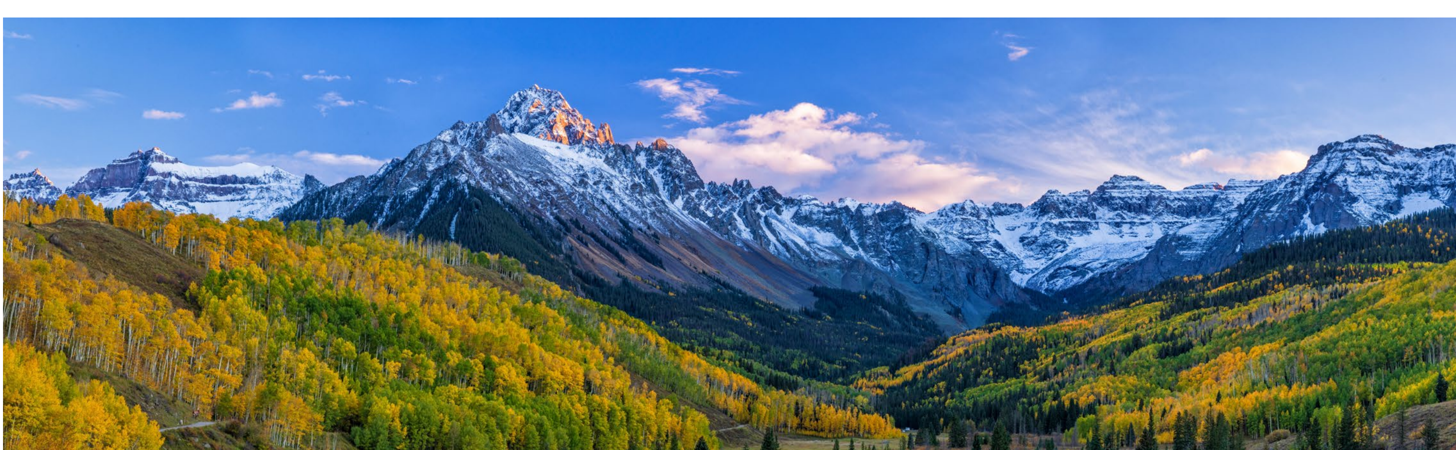
Multi-Pulse HiPIMS Discharge Dynamics: Toward Enhanced Reactive Process Controllability

Tetsuhide Shimizu[1,4], Joshua Chen[1], Caroline Hain[2], Stephanos Konstantinidis[3], and Daniel Lundin[4]; *[1]Thin-film Process Engineering Laboratory, Tokyo Metropolitan University, Tokyo, Japan; [2]CERN, European Organization for Nuclear Research, Geneva, Switzerland; [3]Plasma-Surface interaction Chemistry, University of Mons, Mons, Belgium; [4]Plasma & Coatings Physics Division, Linköping University, Linköping, Sweden*
simizu-tetuhide@ed.tmu.ac.jp

High Power Impulse Magnetron Sputtering (HiPIMS) has emerged as a powerful thin-film deposition technique due to its ability to generate highly ionized sputtered fluxes and to broaden the process window through enhanced bombardment by metal ions, i.e., film forming species, during film growth to thin-film growth. Conventionally, HiPIMS operation has been discussed primarily in terms of single-pulse discharge regime. Therefore, tailoring the pulse pattern is relatively limited. In this work, we demonstrate that multi-pulse HiPIMS, allowing the generation of micro-pulse trains, with modification of the number of pulses and duration of the whole pulse wave pattern and macro-pulse (pulse package) repetition frequency, offers a substantially expanded parameter space, enabling enhanced process flexibility and stability. The central concept is that temporal modulation of plasma excitation within a millisecond-scale pulse package allows dynamic control of ionization, gas rarefaction, and reactive species balance, which cannot be achieved using conventional single-pulse operation alone. As a representative case study, we present recent results on the reactive sputtering of vanadium dioxide (VO_2), where multi-pulse HiPIMS was systematically applied to control the reactive mode transition. Time- and energy-resolved plasma diagnostics using an ion mass spectrometer reveal pronounced differences in ion flux composition and temporal evolution between single-pulse and multi-pulse discharges across the reactive mode transition. We further discuss how key multi-pulse parameters, including micro-pulse on-time, pulse number per macro-pulse, and macro-pulse frequency, govern the stability and position of the transition region through their influence on plasma chemistry and the target surface chemical state. By exploiting these additional degrees of freedom, stable operation within the transition regime was achieved, enabling reproducible growth of VO_2 thin films with superior thermochromic performance. These findings highlight multi-pulse HiPIMS as a versatile platform for diagnostics-guided process design in reactive sputtering and advanced functional thin-film deposition.

Tetsuhide Shimizu is an Associate Professor in the Faculty of Systems Design at Tokyo Metropolitan University, where he leads the Thin-film Process Engineering Laboratory. Since 2015, he has been a visiting scientist at Linköping University in Sweden, collaborating internationally on plasma-based thin film technologies. His research focuses on the surface engineering of functional thin film coatings, particularly the low-temperature synthesis of functional thin films, including transition metals (TM) and TM nitrides, oxides and carbon-based materials using high power impulse magnetron sputtering (HiPIMS). He has also contributed significantly to nanoparticle synthesis via high power impulse hollow cathode sputtering and to the advancement of plasma diagnostics for sputtering process design. He has published over 100 peer-reviewed papers and review articles and holds multiple Japanese patents. His achievements have been recognized with a number of awards, including the JSME Young Engineers Award and several best paper and presentation awards in the fields of thin film engineering.

Shimizu has served in leadership roles within several international academic societies, including as Conference Chair of the International Symposium on Sputtering and Plasma Processes (ISSP). He is also a board member of multiple international organizing committees related to vacuum science, thin films, and surface coatings. He has led and participated in competitive research grants funded by JSPS, focusing on advanced surface processing and international collaborative research. His work continues to bridge applied surface science, materials engineering, and thin-film process innovation.



Short Course

All conference registrants are invited to attend, at no charge, the following tutorial

Monday, October 5, 2026 | 1:00 P.M.

***Short Course:* Plasma Optical Emission Spectroscopy (OES): Opportunities and Limitations**

André Anders, *Plasma Engineering LLC, El Cerrito, CA USA*
andre.anders@plasmaengineering.com

Syllabus

1. Defining plasmas and sheaths
2. Excitation and deexcitation of atoms, molecules, and ions
   a. Types of collisions
   b. Radiational deexcitation
3. Optical emission spectra
   a. Spectrometers
   b. Line radiation, Grotian diagrams
   c. Molecular bands
   d. Continuum radiation
4. High resolution OES
   a. Line shapes
   b. Line broadening mechanism
5. OES with spatial resolution: Spectral imaging
6. OES with time resolution
7. Plasma parameters from OES
   a. Species analysis, process end-point detection
   b. Deriving electron temperature and density
   c. Controlling plasma deposition and etch processes
8. OES in the context of other optical plasma diagnostics

André Anders is the Founder/CEO of Plasma Engineering LLC with Guest Affiliations in Berkeley, California, Leipzig, Germany, and Ben Guerir, Morocco. Until Spring 2025, he was appointed Professor of Applied Physics at Leipzig University and Director and CEO of the Leibniz Institute of Surface Engineering, Leipzig, Germany. He assumed these positions in 2017 after working for 25 years at Lawrence Berkeley National Laboratory in Berkeley, CA, USA. He studied physics in Wroclaw, Poland, Berlin, (East) Germany, and Moscow (Russia, then Soviet Union), to obtain his PhD degree from Humboldt University in Berlin in 1987. André has worked in plasma physics and materials sciences, especially on thin film deposition and surface engineering. He has authored 3 books and about 400 peer-reviewed journal papers (h 81, > 26,000 citations, Google Scholar). For ten years, 2014-2024, he served as the Editor-in-Chief of Journal of Applied Physics published by AIP Publishing, Melville, NY. André is one of the AVS Directors for the 2026/27 term.

For more information, contact André Anders: andre.anders@plasmaengineering.com

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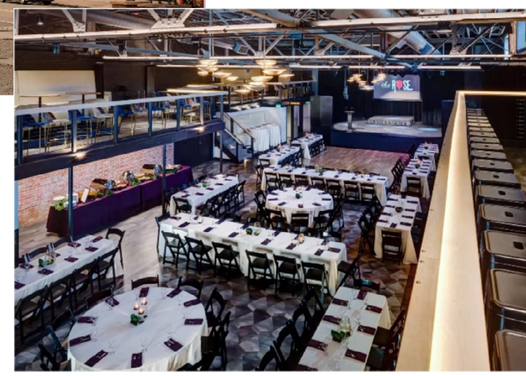

The 110th IUVSTA Workshop on Advanced Plasma Diagnostics for Surface Engineering and Film Deposition will be held at the Rose Event Center. In addition to all presentations, a welcome reception, breakfast, and lunch will be held onsite at the Rose. The Rose has a concert-quality sound system, a theater-quality video projection system, and an elevated stage enabling a state-of-the-art workshop experience.

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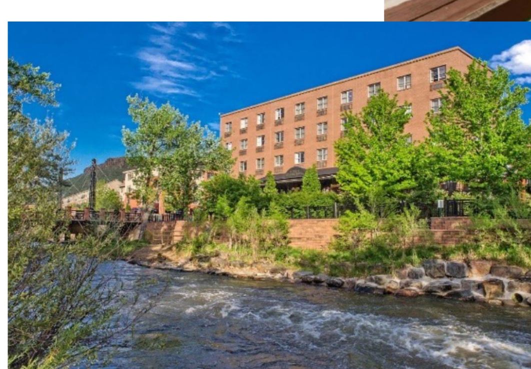
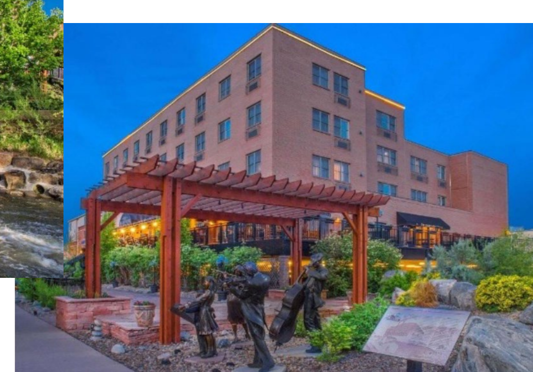
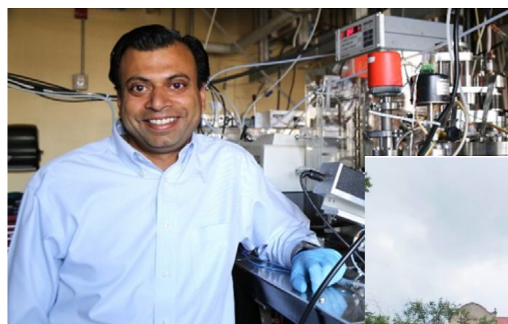


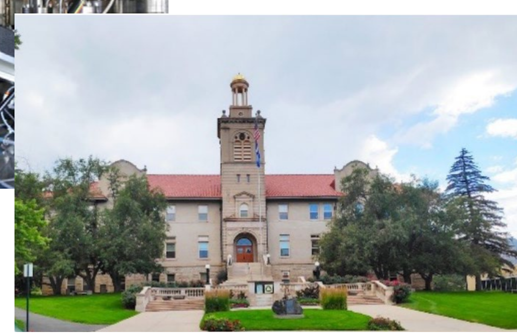


The Golden Hotel

Offsite Tours

Coors Brewery, also known as the Molson Coors Brewery, is a major American brewery located in Golden, Colorado. It was founded in 1873 by Adolph Coors and is one of the largest craft breweries in the United States. The brewery is situated at the foothills of the Rocky Mountains and is known for its iconic beer brands such as Coors Banquet, Coors Light, and Blue Moon. Visitors can take a tour of the brewery, which includes a tasting room, a beer garden, and a gift shop. The brewery is also a popular destination for beer enthusiasts and history buffs.





Sumit Agarwal is a Professor in Chemical and Biological Engineering at the ***Colorado School of Mines***. His lab specialized in in situ characterization of deposition and etching processes for thin films for semiconductor device applications. The lab has several plasma reactors equipped with surface diagnostics including in-situ infrared spectroscopy and ellipsometry. In addition, his lab also performs gas-phase diagnostics of neutrals and ions in low-temperature plasmas using quadrupole mass spectrometry, optical emission spectroscopy, I-V probes, and retarding field energy analyzers. He also holds a joint appointment with the National Lab of the Rockies where his group does research on monocrystalline silicon-based photovoltaics.

The National Laboratory of the Rockies (NLR) in Golden, Colorado specializes in the research and development of renewable energy, energy efficiency, energy systems integration, and sustainable transportation. NREL researchers are recognized for development of advanced, high-throughput laser fabrication and materials synthesis processes.

For more information, contact André Anders: andre.anders@plasmaengineering.com

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