Plasma Science and Technology Division
Room B130 - Session PS-WeA

Commemorating the Career of John Coburn (ALL INVITED SESSION)

Moderators: David Graves, University of California at Berkeley, R. Mohan Sankaran, Case Western Reserve University

2:20pm **PS-WeA1 INVITED TALK: A Tribute to John W. Coburn**, ***David Graves,*** University of California at Berkeley

Dr. John W. Coburn was one of the most influential low temperature plasma and surface scientists of the 20th century. He passed away in San Jose, California on November 28, 2018. In this talk, I will summarize some of John's many contributions and his enormous impact on both fundamental understanding and applications associated with plasma-surface interactions, thin film deposition and etching. John was born in Vancouver, British Columbia and received his BS degree in Engineering Physics and his PhD in Electrical Engineering from the University of Minnesota. After his postdoctoral work at Simon Fraser University, John joined IBM Research (Almaden, California) in 1978. He worked at IBM for 25 years, and retired in 1993. John joined the AVS while still in graduate school and he served as the National AVS Treasurer for many years and in addition served as President in 1988. In 1994, John began to collaborate with me at UC Berkeley as a Senior Research Associate in the department of Chemical Engineering. He had a tremendous impact on me and my group over a period of over 20 years. This impact was both scientific and personal. In this talk, I describe some of John's most important work in non-equilibrium plasma science and plasma-surface interactions, with a special emphasis on the work he did at UC Berkeley with me and my co-workers.

2:40pm **PS-WeA2 INVITED TALK: Interfacial Chemistry in Highly Reactive Systems**, ***Frances Houle,*** Lawrence Berkeley National Laboratory

I joined IBM shortly after John Coburn and his close collaborator, Harold Winters, began publishing their seminal papers on use of XeF_2 to understand fundamental processes involved in plasma etching of silicon. They introduced me to the world of disordered surface reaction environments, and to the techniques they used to carry out careful experiments that shed light on how manufacturing processes work. I saw that it was possible to use well-chosen model systems to make sense of what controls interfacial chemistry in highly reactive, complex systems, and have been working on this type of problem ever since. In this talk I will describe how I have used model systems and multiscale computation to investigate the chemistry of oxidation of nanoscale organic aerosol by OH, relevant to atmospheric processes, and the photochemical generation of charge in porous photoanodes, relevant to solar energy conversion. In both cases, the interplay between transport and reactions is very sensitive to the composition of the chemical system, revealing opportunities for learning how to think more generally about rules governing interfacial reactivity.

3:00pm **PS-WeA3 INVITED TALK: Rare Gas Actinometry Turns Thirty Nine and is Still Finding Applications**, ***Vincent M. Donnelly,*** University of Houston

Ever since the first paper on rare gas actinometry (as it would later be called), published by Coburn and Chen, this method has been widely used to measure relative and sometimes absolute number densities of atoms and small molecules. The problem originally chosen by Coburn and Chen of measuring F atom densities with Ar as the rare gas turns out to be one of the most reliable applications of this diagnostic method, for an important etchant species that is difficult to detect by other techniques. The precision of F-atom actinometry can be attributed, first, to the (apparent) match between the relative energy dependence for the electron-impact excitation cross section of F 703.7 nm emission, compared with that for Ar $2p_1$ emission at 750.4 nm. Second, the large degree of dissociation for even moderate density plasmas with typical feed gases (CF_4/O_2, SF_6, NF_3, etc.), produces high F concentrations, so dissociative excitation of F emission from other F-containing species is usually negligible. This talk will briefly review actinometry as a plasma diagnostic with an emphasis on the issues related to its quantitative application, including cases where it can be used reliably, and others that should be interpreted with caution. Recent experiments that highlight the power of this technique will be discussed, including several studies relying on other work by John Coburn.

3:20pm **PS-WeA4 INVITED TALK: A Leader In Etching (ALE): How John Coburn Paved the way for Atomic Layer Etching**, ***Jane P. Chang,*** University of California, Los Angeles

This talk pays tributes to John Coburn's seminal contributions in the field of anisotropic etching by plasmas. John Coburn's early publication on "a system for determining the mass and energy of particles incident on a substrate in a planar diode sputtering system " set the tone for his many decades of research effort – deciphering the complex reaction mechanisms during plasma-surface interactions. Inspired by John Coburn's dedicated and outstanding contributions to the field of plasma processing, this talk highlights how the most recent development in anisotropic atomic layer etching can trace its root to John Coburn's work on delineating the reaction synergism between energetic ions and reactive neutrals. In John Coburn's words, "Today each wafer is exposed to a plasma etching environment between 10 and 20 times during its manufacture and without the highly anisotropic etching provided by this critical process, high density integrated circuit manufacturing would not be possible." This talk does not attempt to review all of John Coburn's work but focuses on the insight he provided to the research communitythat enabled the continued advances in the field where desirable etch specificity, selectivity, and anisotropy can be simultaneously achieved at the atomic scale.

4:20pm **PS-WeA7 INVITED TALK: Materials Processing Using Low Temperature Plasma Surface Interactions: Examples of the Influence of John Coburn**, ***Gottlieb S. Oehrlein,*** University of Maryland, College Park

John Coburn's pioneering work on plasma-assisted etching reactions of materials has had a profound and lasting influence on our scientific understanding and approaches of studying mechanisms of low temperature plasma-assisted processing of materials. As a colleague at IBM Research I had the opportunity to learn from and interact with John, and his colleagues Harold Winters and Eric Kay, with whom he worked very closely for many years. In this talk I will discuss several topics that were important to John, and how they reflected in my own research and recent work performed by members of my group, including ion bombardment, ion-neutral synergies and etching directionality in pattern transfer, the fluorine/carbon ratio of fluorocarbon etching chemistries introduced by John and colleagues, and several related topics.

4:40pm **PS-WeA8 INVITED TALK: A Brief Overview on Molecular Dynamics Simulations of Plasma-surface Interaction in Reactive Ion Etching**, ***Emilie Despiau-Pujo,*** LTM, Univ. Grenoble Alpes, CNRS, France

In the mid-70s, John Coburn and his colleague Harold Winter started to study plasma etching and reactive ion etching (RIE) processes which, at that time, were starting to be considered for pattern transfer and stripping processes in the semiconductor industry. Their research work focused on the physico-chemical mechanisms involved in this process, emphasizing surface science aspects, and continued for almost 20 years until they both retired from IBM in 1993. By designing insightful experiments, they highlighted in particular the role of energetic ion bombardment in RIE or the mechanisms responsible for a good Si/SiO_2 selectivity. 25 years later, reactive ion etching is a key process which has played a crucial role in the progress made in micro- and nano-electronics, a field which has affected every aspect of our modern lives.

Nowadays, advanced transistors feature ultrathin layered materials and must be etched with a nanometric precision and a nearly infinite selectivity to preserve the electronic properties of active layers. This challenge can no longer be addressed by conventional CW plasma processes, in which the ion-neutral synergy tends to create thick reactive layers which can compromise the etch precision. Alternative plasma technologies are thus needed and various approaches are investigated, to reduce the ion energy by decreasing the electron temperature (e.g. pulsed or low-Te plasmas), to avoid thick reactive layers using sequential and limited reaction steps (e.g. plasma-enhanced ALE), or to decouple the action of ions and radicals using sequential ion modification and chemical removal steps.

As shown by John Coburn during his entire career, the development of advanced etch processes requires a fundamental understanding of the surface reaction mechanisms involved in plasma-material interaction. Coupled with plasma diagnostics and surface characterization tools, Molecular Dynamics (MD) simulations can provide information about the reactions processes involved at the atomic scale and help to understand the phenomena governing the etch process. Since the pioneering work of Harrison et al. in the late 60s [1], atomistic simulations have been routinely used to study RIE and were shown to be a powerful tool to understand how the flux and energy of plasma species affect the structural and chemical modification of substrates. This talk will provide a brief overview of the

basics of molecular dynamics for RIE simulations (principles, accessible time and length scales, suitable force fields, etc.) as well as a review of various works performed on this topic from the 70s until very recently.

[1] D. E. Harrison et al, J. Appl. Phys. 39, 3742 (1968)

5:00pm **PS-WeA9 INVITED TALK: Plasma ALD – A Discussion of Mechanisms**, *K. Arts, V. Vandalon,* Eindhoven University of Technology, The Netherlands, Netherlands; *H.C.M. Knoops,* Eindhoven University of Technology, The Netherlands; ***Erwin Kessels,*** Eindhoven University of Technology, The Netherlands, Netherlands

The profound contributions of John Coburn and Harold Winters to the field of plasma etching have inspired us at the Eindhoven University of Technology to study the mechanisms of plasma deposition [1]. In the last two decades our interest has mainly focused on the surface reactions during atomic layer deposition (ALD), especially on those during plasma-enhanced ALD (also referred to as plasma ALD or radical-enhanced ALD). In his late work, John Coburn has also worked on radical-enhanced ALD, more particularly on radical-enhanced ALD of TiN as investigated by fundamental beam studies [2]. As in his work on plasma etching, a lot of attention was given to the determination of sticking and reaction probabilities as quantitative knowledge of these parameters is key to gain a detailed understanding of the ruling reaction mechanisms. Moreover, quantitative information is needed for modelling purposes. In this contribution, some of our recent work on the determination of sticking and recombination probabilities during (plasma) ALD will be presented. Data obtained from broadband sum-frequency generation [3] and thin film conformality studies [4] will be reported and mechanisms underlying the ALD processes will be discussed.

[1] https://www.atomiclimits.com/2017/11/25/surface-science-aspects-of-plasma-ald-reactions-extending-the-legacy-of-harold-winters/

[2] F. Greer, D. Fraser, J.W. Coburn, and D.B. Graves, J. Vac. Sci. Technol. A 21, 96 (2003)

[3] V. Vandalon and W. M. M. Kessels, J. Vac. Sci. Technol. A 35, 05C313 (2017).

[4] K. Arts, V. Vandalon, R.L. Puurunen, M. Utriainen, F. Gao, W.M.M. Kessels, and H.C.M. Knoops, J. Vac. Sci. Technol. A 37, 030908 (2019)

5:20pm **PS-WeA10 INVITED TALK: RF Plasmas for Material Etching, Deposition, and Surface Modification**, ***Dennis Hess,*** Georgia Institute of Technology

For the past 40 years, rf plasmas have been used extensively for thin film etching and deposition in electronic and photonic device fabrication. However, unique surface properties on materials such as paper and other porous substrates can be generated using these low temperature reactive atmospheres. Examples of surface modification for applications in paper-based medical tests strips and microfluidic device structures through the use of fluorinated and non-fluorinated plasma treatments will be presented.

Author Index

Bold page numbers indicate presenter