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14. ABSTRACT

This AASERT grant achieved its primary objective of helping to support US citizen graduate students who conducted research in the area of surface chemistry with particular emphasis on metallic oxidation, corrosion, and surface metallurgy. It emphasized expanded, augmentative, efforts in two directions: (i) atomic level imaging of metallic oxidation/corrosion reactions and polymer coatings using scanning tunneling and atomic force microscopy, and (ii) metallic oxidation/corrosion reactions using energetic oxidants such as atomic oxygen and high kinetic energy molecular oxygen. This augmentation award helped accelerate and expand an AFOSR program which has made significant contributions in several areas of DoD interest, and which has a demonstrated

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AASERT-96 Augmentation Award for STM Studies of Corrosion Reactions

AFOSR-F49620-96-1-0268

Final Technical Report: June 1, 1996 – May 31, 1999

Submitted by: Steven J. Sibener
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Contents

2. Objectives

This AASERT grant provided augmentation funds that helped support US citizen graduate students who conducted research in the area of surface chemistry with particular emphasis on metallic oxidation, corrosion, and surface metallurgy. It emphasized expanded efforts in two directions: (i) atomic level imaging of metallic oxidation/corrosion reactions and polymer coatings using scanning tunneling and atomic force microscopy, and (ii) metallic oxidation/corrosion reactions using energetic oxidants such as atomic oxygen. This augmentation award helped accelerate and expand an AFOSR program which has made significant contributions in several areas of DoD interest, and which has a demonstrated record of achievement in attracting and training US citizens in critical areas of technological need. The graduate and undergraduate students that have been able to join our research group are being trained on state-of-the-art scattering and microscopy instruments that were constructed with substantial DoD support, and have gone on to major research positions in US laboratories. The new scanning probe microscopy component of our program encompasses spatially-resolved surface chemistry experiments in air, electrochemical, and UHV environments. Metallurgical issues focussing on metallic corrosion, atomic level microstructure, passivation, and stress effects in surface chemistry provide the motivation for this project. *In situ* scanning probe microscopy including scanning electrochemical microscopy is being employed to examine oxidation/corrosion processes, including morphological evolution of the reacting interface, in a variety of environments. These studies are yielding new fundamental insights into oxidative surface chemical reactions, leading in turn to improved passivation, mechanistic control, and diagnostic methods for interfacial corrosion. We are also examining how externally applied stress fields influence surface reactivity, as well as how the crucial nucleation stage for surface oxidation proceeds for pure and intermetallic interfaces.

The AASERT supported students participated in research projects that were primarily funded by our "core" AFOSR sponsored programs, AFOSR-F49620-96-1-0084, "Surface Chemistry, Vibrational Dynamics, and Structural Stability" and, formally, AFOSR-F49620-93-1-0423, "Scanning Tunneling Microscopy Studies of the Morphology and Kinetic Pathways for Corrosion Reactions of Stressed Materials". The presence of AASERT supported students has certainly led to the acceleration and augmentation of these research programs.

3. Status of Effort

The primary goal of this AASERT grant was to augment research activities in our new STM/AFM/Electrochemistry facilities, and to enhance other ongoing projects in our neutral particle and electron scattering laboratories. These goals have been achieved: during the past 3 years this AASERT grant helped partially support several US citizen graduate students in the areas of surface chemistry, electrochemistry, metallic oxidation, and materials science. The presence of some of these students in the PI's research group would not have been possible without this grant. This statement refers in particular to Tom Pearl who launched our new effort in ultra-high vaccum scanning tunneling microscopy, and Julie Slezak, who examined metallic oxidation with energetic oxidants such as atomic oxygen. AFOSR funded research programs were significantly accelerated and enhanced by the presence of these individuals, with their efforts focussing on such important topics as metallic oxidation and corrosion kinetics, interfacial electrochemistry, and the surface structure and stability of metallic interfaces during the initial stages of metallic oxidation.

4. Accomplishments/New Findings

4.1 Summaries of Research Accomplishments

4.1a Ultra-High-Vacuum STM Imaging of Metals in Oxidizing Environments

Accomplishments have come both in instrumentation development/completion as well as in scientific discovery. **Tom Pearl** succesfully built (strarting from an empty laboratory) a world-class ultra-high vacuum STM. This has allowed us to do atomic-level imaging at elevated temperatures in real-time during chemical reactions. He has obtained, for example, atomically resolved images of Ni(111), as well as of oxygen islands on these surfaces which reveal the crucial role that step defects play in nucleating such structures. He has also recently achieved his main objective, namely the imaging stepped metals in real-time *during* oxidation, as well as atomically-resolved studies of electron stimulated oxidation. Our ability to conduct these experiments is largely due to the high degree of vibration isolation he has achieved, and the implementation of exceptionally quiet electronics for this microscope. In this arena Tom has continued to work quite closely with Topometrix Corporation (now ThermoElectron), giving them valuable feedback on needed improvements in their software package for STM control. Please note that the AASERT student has taken this project from its inception to operational status: he designed the layout for our new STM laboratory, designed the custom-built and vibrationally isolated ultra-high vacuum STM chamber, and successfully integrated all required sub-systems to produce a working UHV-STM with atomic resolution.

During the last year we have made "movies" of stepped Ni interfaces during oxidation. These real-space imaging measurements have helped us to further refine our current understanding of the sequence of structural changes which occur on a stepped, i.e., imperfect, metallic interface upon exposure to gas phase O_2. These include step doubling, step singling, the formation of two different ordered oxygen overlayers, and, finally, the onset of bulk oxide formation. This work has attracted wide-spread attention, with several theory groups going after the electronic, structural, and kinetics aspects of our work. The reader is referred to recent publications from our group for more background material on this topic. See, for example: Reconstruction Kinetics of a Stepped Metallic Surface: Step Doubling and Singling of Ni(977) Induced by Low Oxygen Coverage, L. Niu, D.D. Koleske, D.J. Gaspar, S.F. King and S.J. Sibener, Surface Science 356, 144 (1996). Other papers synopses appear later in this report.

Tom Pearl also used the STM as a spatially localized source of electrons, attempting to elucidate further information on how electrons synergistically enhance metallic oxidation. This encompasses both nucleation issues as well as the actual electron attachment process. Here we used an electrically biased STM tip to locally inject electrons as a function of energy, and then to image the resulting electron-modified interface. Preliminary experiments have confirmed the feasiblility of such measurements. These experiments will extend our work on electron stimulated oxidation, experiments which have received widespread attention in both the metallic oxidation and semiconductor patterning communities. The reader is referred to recent work from our group for more details: (1) Electron Stimulated Oxidation of Ni(111) at Low Temperature, Wei Li, M.J. Stirniman, and S.J. Sibener, Surface Science Letters 329, L593 (1995); (2) Inelastic Electron Scattering Study of Metallic Oxidation: Synergistic Effects Involving Electrons During the Low Temperature Oxidation of Ni(111), Wei Li, M.J. Stirniman, and S.J. Sibener, J. Vacuum Science and Technology A. 13, 1574 (1995); (3) Electron Stimulated Oxidation of the Ni(111) Surface: Dependence on Substrate Temperature and Incident Electron Energy, M.J. Stirniman, Wei Li, and S.J. Sibener, J. Chemical Physics 103, 451 (1995).

4.1b Interaction of Energetic Oxidants Including Atomic Oxygen with Metals

Julie Slezak, who has also received substantial salary support from this AASERT grant, has now completed construction of her intense atomic oxygen plasma beam source. It was placed into the beamline of our combined neutral beam scattering/electron energy loss surface spectroscopy facility. This atomic oxygen beam source sucessfully generated intense beams of excited oxidants, such as $O(^3P)$, $O(^1D)$, and $O_2(^1\Delta)$. Such a plasma beam source was originally developed by the PI for work in gas phase kinetics, and has been successfully duplicated by other groups over the past decade. Using a low-intensity version of this beam source, we have already seen remarkable changes in the surface oxygen overlayers and rate of oxygen migration into the bulk when switching from O_2 to $O(^3P)$ dosing. Most recently we have demonstrated remarkable differences in the oxidation of Ni(111) when using atomic oxygen rather than molecular species. A synopsis of this follows in the Publications Section.

Ben Zion, Aubrey Hanbicki, and Julie Slezak have also explored kinetic energy effects in metallic oxidation. We have quantitatively examined the oxidation kinetics of the Ni(111) surface utilizing kinetic energy selected supersonic beams of molecular oxygen. Using *in situ* high-resolution electron-energy-loss spectroscopy, we have observed notable differences in the oxidation mechanism for this interface as a function of incident beam kinetic energy. Exposure of a 300 K surface to a relatively low energy 60 meV O_2 beam leads to oxidation kinetics which follow an island growth model, qualitatively similar to what is seen with simple ambient gas dosing. In contrast to this, exposure to a relatively high energy 600 meV O_2 beam yielded fundamentally different oxidation behavior: the kinetics of oxidation no longer follow an island growth model but rather behave with a Langmuir-like sticking model, implying key differences in the nucleation stage for interface oxidation. Cryogenically cooled Ni(111) could not be oxidized using either of these incident beam conditions, indicating that the energetic constraints needed to move from oxygen chemisorption to actual metallic oxidation cannot be simply overcome using incident O_2 kinetic energy. For further information please see our recent manuscript: Kinetic Energy Effects on the Oxidation of Ni(111) Using O2 Molecular Beams, B. D. Zion, A. T. Hanbicki, and S. J. Sibener, published in Surface Science.

4.1c. Electrochemistry

Another aspect of our atomic force microscopy imaging program deals with the electrochemical corrosion of metals under different types (tensile and compressive) and levels of stress. We have succeeded, unambiguously, in demonstrating that externally applied stresses can influence the electrochemical corrosion of metals. Specifically, the electrochemical corrosion of aluminum 2024-T3 and of pure nickel were explored by anodizing metal surfaces under stress. Statistical analyses of AFM images yields information on etch pit size and shape distributions produced under compressive and tensile stress. Etch pits created under tensile stress are bigger, deeper and denser than those formed under compressive stress. This effect is systematically enhanced as the amount of applied stress is increased. Etch pit morphologies are also being examined with AFM. This work has now been published.

4.1d. Polymer Thin Film Coatings

Our work on polymer thin film morphology has also come to fruition during the past year. Here we have performed the first measurements of how individual defects in cylinder-forming diblock copolymers move and topologically evolve, including defect annihilation events, during polymer annealing. This has been accomplished for cylinder-forming polystyrene-block-polymethylmethacrylate films using atomic force microscopy. We now know that this evolution takes place through relinking, joining, clustering, and annihilation of defects. Such processes form the basis for predicting structural change in polymer films. For further details please see our recent manuscript: Defect Evolution in Ultrathin Films of PS-b-PMMA Diblock Copolymers Observed by Atomic Force Microscopy, J. Hahm and S. J. Sibener, now published in the Journal of Chemical Physics.

Further details of the aforementioned projects, as well as others which have benefitted from our new STM and AFM imaging capabilities, can be found in the Final Technical Report for AFOSR-F49620-96-1-0084, "Surface Chemistry, Vibrational Dynamics, and Structural Stability". Background information can be found in prior reports for that grant, as well as prior reports associated with the now expired project AFOSR-F49620-93-1-0423, "Scanning Tunneling Microscopy Studies of the Morphology and Kinetic Pathways for Corrosion Reactions of Stressed Materials".

4.2 Titles and Abstracts of Publications

1. Silicon Nitride Membrane Substrates for the Investigation of Local Structure in Polymer Thin Films, T.L. Morkved, W.A. Lopes, J. Hahm, S.J. Sibener, and H.M. Jaeger, Polymer (Communication) 39, 3871 (1998).

We describe the fabrication of silicon nitride membrane substrates and their use in studies of polymer thin films. As an integral part of a wafer, these membranes are both self-supporting and transparent for transmission electron microscopy (TEM). Therefore, the same polymer film can be spin-cast on the substrate and, without being removed, studied by a variety of techniques, including TEM, and atomic force microscopy (AFM). To demonstrate the utility of these substrates in characterizing both global and local film morphology, we present experimental results on polystyrene-polymethylmethacrylate diblock copolymers in the ultrathin film limit, using optical microscopy together with combinations of AFM and TEM at the same location. We also discuss the addition of microfabricated structures to these substrates, such as planar electrodes.

2. Inelastic Multiphonon Helium Scattering from a Stepped Ni(977) Surface, Daniel J. Gaspar, Aubrey T. Hanbicki, and S. J. Sibener, J. Chem. Phys. 109, 6947-6955 (1998).

The multiphonon energy exchange between a neutral He atom and a stepped Ni(977) surface has been measured in order to examine how the presence of a regular array of atomic-scale steps on a surface modifies energy exchange in the classical multiphonon scattering regime. At elevated substrate temperatures, we compare the multiphonon scattering with the predictions of a classical theory that has previously been used by others for assessing energy exchange involving a smooth surface. There is a significant discrepancy between the theoretical predictions and our experimental data, which we attribute to differences between a smooth and stepped surface. Specifically, changes in the vibrational modes and associated surface density of states due to the presence of extended surface defects have a fundamental impact on the details of the energy exchange mechanism.

3. Defect Evolution in Ultrathin Films of Polystyrene-block-Polymethylmethacrylate Diblock Copolymers Observed Using Atomic Force Microscopy, J. Hahm, W. A. Lopes, H. M. Jaeger, and S. J. Sibener, J. Chem. Physics (Communication) 109, 10111-10114 (1998).
We track individual defects in the microdomain patterns of cylinder-forming polystyrene-block-polymethylmethacrylate films with atomic force microscopy to elucidate the evolution of diblock domain topology during annealing. This evolution takes place through relinking, joining, clustering, and annihilation of defects. Such processes form the basis for predicting structural change in polymer films.

4. Kinetic Energy Effects on the Oxidation of Ni(111) Using O_2 Molecular Beams, B. D. Zion, A. T. Hanbicki, and S. J. Sibener, Surf. Sci. Letters 417, L1154-L1159 (1998).
The oxidation kinetics of the Ni(111) surface have been quantitatively examined utilizing kinetic energy selected supersonic beams of molecular oxygen. Using *in situ* high-resolution electron-energy-loss spectroscopy, we have observed notable differences in the oxidation mechanism for this interface as a function of incident beam kinetic energy. Exposure of a 300 K surface to a relatively low energy 60 meV O_2 beam leads to oxidation kinetics which follow an island growth model, qualitatively similar to what is seen with simple ambient gas dosing. In contrast to this, exposure to a relatively high energy 600 meV O_2 beam yielded fundamentally different oxidation behavior: the kinetics of oxidation no longer follow an island growth model but rather behave with a Langmuir-like sticking model, implying key differences in the nucleation stage for interface oxidation. Cryogenically cooled Ni(111) could not be oxidized using either of these incident beam conditions, indicating that the energetic constraints needed to move from oxygen chemisorption to actual metallic oxidation cannot be simply overcome using incident O_2 kinetic energy.

5. High Density Adsorbed Oxygen on Rh(111) and Enhanced Routes to Metallic Oxidation Using Atomic Oxygen, K. D. Gibson, Mark Viste, Errol C. Sanchez, and S.J. Sibener, J. Chem. Phys. (Communication) 110, 2757(1999).
Exposure of Rh(111) to atomic oxygen leads to the facile formation of a full-coverage and ordered (1x1)-O monolayer which is stable at room temperature. This result differs markedly from the half-coverage (2x1)-O overlayer which forms at saturation when using molecular oxygen. This demonstrates that kinetic rather than thermodynamic constraints inhibit the formation of dense oxygen overlayers when O_2 is the oxidant. We also report that O absorption into the bulk proceeds much more readily when using O rather than O_2, a finding with direct implications for enhanced methods of low-temperature metallic oxidation. These results demonstrate that there are important fundamental differences in the way in which low-energy beams of atomic and molecular oxygen interact with metals.

6. Enhanced Oxidation Rate of Ni(111) by Atomic Oxygen, J.A. Slezak, B.D. Zion, and S.J. Sibener, Surf. Sci. Lett. 442, L983-988 (1999).
The oxidation of the Ni(111) surface by a supersonic atomic oxygen beam has been quantitatively studied using *in situ* high-resolution electron-energy-loss spectroscopy. For a room temperature substrate, a drastically different oxidation rate for atomic oxygen induced oxidation than for molecular oxygen based oxidation is observed. This rate was found to be two orders of magnitude higher than that of molecular oxygen. The reaction on a 110 K substrate indicated oxygen uptake only to the chemisorption saturate with no further oxidation. This later finding agrees with previous results for low surface temperature oxidation using molecular oxygen, implying that the inhibiting step in low temperature Ni oxidation is not molecular oxygen dissociation, but a more fundamental property of the metallic substrate. The chemisorption region of the atomic oxygen reaction was found to saturate at the same (2x2) overlayer as results from exposure to molecular oxygen, i.e., a dense (1x1) overlayer as has been seen on other metals does not form on Ni(111).

7. Rational Design of Interfacial Structure: Adsorbate-Mediated Templating, S.B. Darling, A.T. Hanbicki, T.P. Pearl, and S.J. Sibener, J. Phys. Chem. B 103, 9805-9808 (1999).
In this letter we show that it is possible to guide the formation of a novel non-close-packed xenon structure on a stepped nickel surface using an intentionally atomically-patterned substrate. By first defining the symmetry and desired dimensions of the underlying superlattice, we successfully template the targeted rare gas overlayer. Such templating effects, in which the corrugation and structure of the interface can be tuned by prior adsorption of an adsorbate, should be a general route to the formation of new self-organizing interfacial nanoscale structures.

8. Physical and Chemical Properties of High-Density Atomic Oxygen Overlayers Under UHV Conditions: (1x1)-O/Rh(111), K.D. Gibson, M. Viste, E.C. Sanchez, and S.J. Sibener, J. Chem. Phys. 112, 2470 (2000).
In this paper, we elaborate on our previous communication of high coverages of oxygen on Rh(111) (J. Chem. Phys. **110**, 2757 (1999)). When dosing with O_2, half of a monolayer of O is adsorbed. Higher coverages can be achieved when exposing the surface to O atoms. As the quantity of adsorbed O increases from a half to a full monolayer, the overlayer structure undergoes several distinct phase changes. At a full monolayer, the (1x1)-O structure is stable at surface temperatures less than ~400 K. Continued dosing with O atoms results in the rapid migration of O into the bulk. We also report on the chemical reactivity of this densely oxygen-covered surface with CO, H_2, and propene.

9. Proximity Heater for the Elevated Temperature *In Situ* Vacuum Scanning Tunneling Microscopy of Metal Surfaces, T.P. Pearl and S.J. Sibener, Rev. Sci. Instrum. 71, 124-127 (2000).
The design and application of a radiant heater assembly for elevated temperature scanning tunneling microscopy (STM) in ultra-high vacuum (UHV) is presented. The proximity heater is a non-invasive modification to an existing commercial room-temperature microscope and is capable of radiatively heating samples up to 650 K *in situ*. Imaging at higher temperatures should be readily accessible with other microscope construction designs. It is demonstrated that this heater is well suited for enabling an STM to capture surface morphological transformations such as the motion of atomic steps on metal surfaces at elevated temperature. Various design issues and solutions related to variable temperature UHV-STM are also discussed. We believe the approach described to be general in nature, offering a direct route to adapting UHV-STM designs for elevated temperature imaging.

10. Stress Effects in the Electrochemical Pitting Corrosion of Aluminum 2024-T3 and Pure Nickel Using Atomic Force Microscopy, Applied Surf. Sci., 161, 375-384 (2000).

In this paper we demonstrate that externally applied tensile and compressive stresses can systematically modify the electrochemical surface reactivity of pure and alloyed metals. Atomic force microscopy is used to statistically characterize the extent and nature of interface change for nickel and aluminum alloy 2024-T3 subjected to electrochemical conditions under various levels of stress. Statistical analysis of AFM images reveals that the extent of electrochemical reactivity is significantly enhanced when subjecting the sample to tensile as opposed to compressive stress; this enhancement increases monotonically as the level of applied stress is systematically increased. Surface morphologies differ on the pure nickel and alloyed aluminum samples, with the nickel interfaces exhibiting facetted features which are aligned 120° from one another while the surface features on aluminum alloy 2024-T3 are circular pores. These results unambiguously indicate that the kinetics for electrochemical metallic processes, which nucleate at surface defects and grain boundaries, can be significantly modified by the presence of external stress fields.

5. Personnel Supported and Associated with This Program

Personnel receiving partial or full support from this AASERT grant during the past 3 years include US citizen graduate students:

*Tom Pearl
*Julie Slezak
Dan Gaspar
Mark Viste
Ben Zion
(* indicates graduate students with most connection to this AASERT grant)

Others who benefitted from this grant (without receiving AASERT salary support):

Steven J. Sibener, Professor and PI
Graduate Students: Seth Darling, Jongin Hahm, Bill Isa, Errol Sanchez
Postdoctoral Fellow: Aubrey Hanbicki
Research Scientist: Kevin Gibson
Undergraduates: Shoshana Gourdin, Patrick Yu, and Gillian Zacharias
N.B.: Graduate Students Terry Morkved and Ward Lopez from Prof. Jaeger's group also benefitted from scanning probe microscopy instrumentation and imaging expertise developed in our group under the auspices of this grant.

6. Publications

6A. List of Publications

1. Silicon Nitride Membrane Substrates for the Investigation of Local Structure in Polymer Thin Films, T.L. Morkved, W.A. Lopes, J. Hahm, S.J. Sibener, and H.M. Jaeger, Polymer (Communication) 39, 3871 (1998).

2. Inelastic Multiphonon Helium Scattering from a Stepped Ni(977) Surface, Daniel J. Gaspar, Aubrey T. Hanbicki, and S. J. Sibener, J. Chem. Phys. 109, 6947-6955 (1998).

3. Defect Evolution in Ultrathin Films of Polystyrene-block-Polymethylmethacrylate Diblock Copolymers Observed Using Atomic Force Microscopy, J. Hahm, W. A. Lopes, H. M. Jaeger, and S. J. Sibener, J. Chem. Physics (Communication) 109, 10111-10114 (1998).

4. Kinetic Energy Effects on the Oxidation of Ni(111) Using O_2 Molecular Beams, B. D. Zion, A. T. Hanbicki, and S. J. Sibener, Surf. Sci. Letters 417, L1154-L1159 (1998).

5. High Density Adsorbed Oxygen on Rh(111) and Enhanced Routes to Metallic Oxidation Using Atomic Oxygen, K. D. Gibson, Mark Viste, Errol C. Sanchez, and S. J. Sibener, J. Chem. Phys. (Communication) 110, 2757 (1999).

6. Enhanced Oxidation Rate of Ni(111) by Atomic Oxygen, J.A. Slezak, B.D. Zion, and S.J. Sibener, Surf. Sci. Lett. 442, L983-988 (1999).

7. Rational Design of Interfacial Structure: Adsorbate-Mediated Templating, S.B. Darling, A.T. Hanbicki, T.P. Pearl, and S.J. Sibener, J. Phys. Chem. B 103, 9805-9808 (1999).

8. Physical and Chemical Properties of High-Density Atomic Oxygen Overlayers Under UHV Conditions: (1x1)-O/Rh(111), K.D. Gibson, M. Viste, E.C. Sanchez, and S.J. Sibener, J. Chem. Phys. 112, 2470 (2000).

9. Proximity Heater for the Elevated Temperature *In Situ* Vacuum Scanning Tunneling Microscopy of Metal Surfaces, T.P. Pearl and S.J. Sibener, Rev. Sci. Instrum. 71, 124-127 (2000).

10. Stress Effects in the Electrochemical Pitting Corrosion of Aluminum 2024-T3 and Pure Nickel
Using Atomic Force Microscopy, Applied Surf. Sci., 161, 375-384 (2000).

7. Interactions/Transitions

7.1. Invited Presentations of the PI at meetings, conferences, seminars, etc.

1996

UCLA, Department of Chemistry, Los Angeles, CA
Univ. of Penn., Department of Chemistry, Philadelphia, PA
DARPA Meeting on Chemical Corrosion and Coatings, San Diego, CA
Modern Trends in Chemical Dynamics - 60th Birthday Fest for Yuan T. Lee,
Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, R.O.C. (Dec. 1996).

1997

Univ. of Utah, Department of Chemistry, Salt Lake City, UT
March Meeting of the APS, Kansas City, KS
U. of Chicago/Argonne Natl. Lab Meeting on Collaborative Research, Oakbrook, IL
1997 Conference on the Dynamics of Molecular Collisions, Gull Lake, MN
Gordon Research Conference on Dynamics of Gas-Surface Interactions, Andover, NH
DARPA/AFOSR Conference on Aircraft Coatings and Corrosion, Annapolis, MD

1998

National ACS Meeting (March 1998), Dallas, Texas; Symposium on Interfacial Water
National ACS Meeting (August 1998), Boston, MA; Symposium on Structure and Electronic
Properties of Materials by Scanning Probe Microscopy
DARPA/AFOSR Conference on Aircraft Coatings and Corrosion, Annapolis, MD

1999

Univ. of Illinois at Chicago, Department of Chemistry, Chicago, IL
Wayne State University, Department of Chemistry, Detroit, MI
Univ. of Pittsburgh, Department of Chemistry, Pittsburgh, PA

7.2a. Connections with DoD

- Graduate student Mike Stirniman participated in the "Joint AFOSR-AFMC/EN Aging Aircraft Conference" [Workshop on Aging Aircraft Research] that was held from 27-28 April 1993 at Georgia Tech in Atlanta, GA.
- Professor Sibener was an invited participant at the "Second Air Force Aging Aircraft Conference" that was held from 17 May to 19 May at the Oklahoma City Air Logistics Center, Tinker AFB, OK. His talk was entitled "The Initial Stages of Metallic Oxidation", and stimulated much discussion with the participants and sponsors.
- Professor Sibener was also an invited speaker at the AFOSR/URI Meeting on "Corrosion, Tribology, Lubrication, and Materials Fatigue Under Extreme Conditions" that was held from 17-18 August 1994 at the Beckman Institute at the Univ. of Illinois/Urbana-Champaign. His presentation was entitled "The Initial Stages of Metallic Oxidation", and was presented at a much higher technical level than the overview talk presented earlier at Tinker AFB.
- Professor Sibener was an invited speaker at the DARPA Meeting on Chemical Corrosion and Coatings, November 19-21, 1996 in San Diego, CA
- Professor Sibener was an invited speaker at the DARPA/AFOSR Conference on Aircraft Coatings and Corrosion, September 15-18, 1997 in Annapolis, MD
- Professor Sibener was an invited speaker at the DARPA/AFOSR Conference on Aircraft Coatings and Corrosion, Annapolis, MD

7.2b. DoD Consulting of the PI

The PI was a charter member of the Defense Science Study Group of the Institute for Defense Analyses. He is currently a consultant for IDA.

7.3. Transitions

1. Title: Electronics for High-Impedance STM Imaging
   Purpose: Circuitry needed for STM imaging of molecular overlayers
   Recipient: Mark Greenbaum, Topometrix Corporation (708-717-0566)

2. Title: Ultra-High Vacuum Technology for Atomic Traps
   Purpose: Generation of ultra-low temperature atomic beams for atomic/synchrotron physics and small-scale pattern deposition
   Recipient: Bruce Zabransky, Argonne National Lab (630-252-4046)

3. Title: Multiple Supersonic Molecular Beam Methods of Materials Growth
   Purpose: Improved growth of advanced semiconductors
   Recipient: Dr. Hiroshi Kajiyama/Dr. Hrvoje Petek
   Advanced Research Laboratory, Hitachi Ltd., Japan

4. Title: Electron Enhanced Oxidation of Materials
   Purpose: Improved oxidation and patterning of semiconductors
   Recipient: Dr. Wilson Li, Intel Corp., (408-765-2837) [now at Lucent Technologies]

5. Title: Technology for Generating Supersonic Molecular Beams
   Purpose: Intense sources of cooled atoms for synchrotron experiments in atomic physics
   Recipient: Dr. Linda Young, Argonne National Laboratory, (630-252-8878)

6. Title: Advanced Methods of Electron Stimulated Materials Oxidation
   Purpose: Improved oxidation, patterning, and passivation of materials
   Recipient: Dr. Michael Stirniman, Seagate Technology (510-353-4935)

8. New Discoveries, Inventions, or Patent Disclosures

None (see Section 4 for new scientific findings).

9. Honors/Awards

Elected Fellow, American Physical Society (November, 1997).
Appointed Director, Materials Research Science and Engineering Center (MRSEC) at The University of Chicago, July 1997-.
Chairman, Div. of Chemical Physics, American Physical Society, 1996-97; Chair-Elect (1995-96); Vice-Chair (1994-95).
Visiting Fellow, Joint Institute for Laboratory Astrophysics, Univ. of Colorado, Boulder, 1992-93.
Marlow Medal of the Faraday Division of the Royal Society of Chemistry, 1988.
Chairman, 1987 Gordon Conference on the Dynamics of Gas-Surface Interactions; Vice-Chair 1985.
Charter Member, Defense Science Study Group--Institute for Defense Analyses (1985-1988).
IBM Faculty Development Award, 1984-86.
Alfred P. Sloan Foundation Research Fellow, 1983-87.
Camille and Henry Dreyfus Young Faculty in Chemistry Award, 1980.
Gulf Oil Research Fellow, University of California, Berkeley, 1977.
American Institute of Chemists Award, University of Rochester, 1975.
Phi Beta Kappa, University of Rochester, 1975.

END DOCUMENT