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Washington University
Campus Box 1054
One Brookings Drive
St. Louis, MO 63130 -4862

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INVESTIGATOR(S):

Name: Rajan Chakrabarty
Email: chakrabarty@wustl.edu
Phone Number: 3149356054
Principal: Y

Organization: **Washington University**
Address: Campus Box 1054, St. Louis, MO 631304862
Country: USA

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Final Report for Period Beginning 01-Jul-2015 and Ending 30-Jun-2016

Title: Exploration Workshop: Recent Advances in Characterization of Aerosols

Begin Performance Period: 01-Jul-2015 **End Performance Period:** 30-Jun-2016

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Submitted By: Rajan Chakrabarty Email: chakrabarty@wustl.edu
Phone: (314) 935-6054

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Major Goals: Motivation

Aerosols influences the earth's radiation balance and climate, atmospheric chemistry, visibility, and the health of living beings including humans on scales ranging from local to global. Recent studies indicate that aerosols present in the earth's atmosphere are multi-component in their chemical make-up, and their microphysical properties and behaviors become very complicated to study. Given the impacts of particle composition on atmospheric chemistry and the radiation balance, understanding the nature of multi-component aerosol systems is fundamental to our understanding of their roles in the atmosphere. The ability to accurately measure and characterize these aerosols is also important in defense contexts for the detection of aerosolized biological and chemical weapons agents.

The workshop proposed here will review the current knowledge of measurement and characterization techniques for aerosol systems and investigate what research directions are most likely to advance its capabilities. Examples of topics to review include mass spectrometry, electron microscopy, photoacoustic and nephelometry, laser-induced fluorescence, polarimetry, holography, and mobility spectrometers. This review will then enable general discussions between the workshop participants exploring coordinated research efforts intended to advance the field.

Participants

The workshop will be small-scale, involving approximately 25 attendees. Roughly one third of the attendees will be experts in the fields of aerosol physics and chemistry, and will be invited to present review talks. These speakers will be selected from academic institutions and government laboratories including the Army and Naval Research Laboratories. The remaining two thirds of the attendees will be invited from academic institutions and will consist of scientists and advanced graduate students and post-docs actively conducting research related to these fields. Rajan Chakrabarty of Washington University in St. Louis (WUStL) will be the organizer of this workshop and will be responsible for distributing announcements and issuing invitations to prospective participants. The method of announcement will be email, phone conversations, and mailing of workshop brochures to institutions.

Workshop format

The department of Energy, Environmental and Chemical Engineering at WUStL has been selected as the venue for this meeting based on its central US location and comparatively low cost for accommodations. The workshop will occur from 8 am to 6 pm on July 14th and the morning of July 15th. Participants will arrive on July 15th and depart in the afternoon of July 15th. These dates are ideal as many of the participants will be university professors and this time roughly corresponds to the summer break period. The first day of the workshop will include review talks such that all participants are exposed to general ideas of the multiple topics covered. Then break-out sessions will be held where participants can have in-depth discussion with the experts and other participants in a smaller-group format. The objective in these break-out sessions will be to identify areas of research that will improve our understanding of aerosol properties and its measurement and characterization. The whole group will then meet at the end of the second day to discuss the conclusions of the break-out sessions and identify the most important avenues for future research.

Army relevance
Instrumentation capable of sensing aerosolized biological and chemical weapons agents has been a long-standing objective for Army research and development efforts. Some notable progress has been made toward this end, but overall, the complexity of the particle medium involved has largely prevented the realization of this goal. Realistically, a successful point-sensor concept will necessarily combine multiple particle-characterization techniques. Since the meeting proposed here will bring together experts in these and other fields with other scientists, it is possible that valuable research concepts emerge that could benefit the Army's long-term interests. It is also likely that attendees of the workshop will form research collaborations and apply for funding under the Multidisciplinary University Research Initiative (MURI) administered by the Office of Naval Research.

Accomplishments: US ARMY RESEARCH OFFICE MURI TOPIC IDENTIFIED AND SUBMITTED: Characterization of Electromagnetic Wave Interaction With Complex Particulate Systems

Background: Interaction of electromagnetic (EM) fields with particulate systems dispersed in the gas phase results in redistribution of energy via the fundamental processes of scattering, absorption and emission. The EM fields and particulate systems may vary widely; ranging from sunlight interacting with atmospheric ice crystals to coherent laser radiation interacting with engineered nanoparticles. From a broad perspective, the interest in studying the nature of EM interaction with a complex system of particles lies in the important ability to infer information–i.e., physical and chemical properties–about the particulate system in real-time. In situ optical characterization techniques pose a distinct and significant advantage over other characterization techniques, such as offline microscopy and spectroscopy.

Gap Identified: The chemical and physical form of the particulate system determines the nature of its EM interaction. However, decoding this measurable interaction to infer particle characteristics has been a major challenge. This is especially the case for complex particles such as those of non-spherical shape and/or inhomogeneous chemical composition. In other words, there is a gap in our understanding of the quantitative relationship between the observables and the actual particle properties. This so-called "inverse problem" could be attributed to a number of factors including: (i) inherent loss of information in the measurement process, which typically includes the phase of the scattered EM field; (ii) lack of or incomplete particle characterization techniques beyond certain size ranges; (iii) lack of novel theoretical analysis techniques of the measured observables; and (iv) the dynamic nature of the system that leads to properties being altered at various timescales, hence complicating the measurements and inversion of the data

Recent Advances: Much work has been done to solve this inverse problem, ranging from formal analytical mathematics to controlled laboratory experiments. Yet despite this effort there has been little progress towards general techniques that can accurately characterize the properties of particulate systems using conventional intensity-based measurements. Fortunately, there have been tremendous recent advances in measurement and computational hardware. The capabilities of optoelectronic detectors, such as intensified charged coupled device cameras, have improved vastly in the past decade. The availability and compact nature of light sources such as solid state lasers and light emitting diodes also has been an asset for measurements. Access to high performance computing systems and powerful personal computers are now widely available and the numerical simulations used to study and analyze EM scattering and absorption by particles have benefited from extensive optimization, with many of these codes being freely available.

Objectives: The aim of this MURI topic is to support basic theoretical and experimental research in EM interaction with complex particulate systems, with the global objective of solving the inverse problem for particles. This will require an understanding of the fundamental connection between the measured observables of a field and the characteristics of a particulate system. Possible questions to address are: What observables are needed? What specific information about the particulate system do they provide? How are the measurements performed? What are inherent, technological and conceptual limitations of the measurement and analytical techniques?

Research Concentration Areas: The topics of interest may include, but are not limited to, numerical and analytical modeling of scattering, absorption and emission from realistic particulate systems; controlled laboratory measurements of such systems, which may include photoacoustic spectroscopy, whispering-gallery microresonators, photopolarimetry, holography, spectral techniques such as laser induced fluorescence; and novel analysis techniques to interpret the measured observables. The research activities are expected to be multidisciplinary and highly coordinated. Of specific interest are investigations that combine both theoretical and experimental efforts in a complimentary mode and that leverage the substantial recent advances in computation and measurement technologies.

Impact: The in situ characterization of particulate systems using EM waves is highly important in both scientific and applied contexts. Instrumentation and analysis techniques that can discriminate between possible disease-transferring aerosols or bioterrorism agents and naturally occurring aerosols, such as black and organic carbon aerosols, are of great interest to the Army. A variety of application areas such as bioterror agent detection and destruction, natural and artificial fires/combustion processes, engineered nanomaterials for sensing applications, and others of relevance to the Army could be advanced by the unraveling study of the fundamental “inverse-problem”. A thorough understanding of the potential of particle-EM interaction could also enable future low-cost means of rapidly acquiring particle information.

Training Opportunities: Nothing to Report

Results Dissemination: 1) A YouTube channel "CASE Workshop 2015" has been published. This channel has most of the talks presented during the workshop for public viewing.
https://www.youtube.com/playlist?list=PLixkdczTQr9EVUdKw2G68cl44o2liGroc

2) A MURI whitepaper and presentation, resulting from the workshop, was prepared and delivered to the program manager, Dr. James Parker.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Rajan Chakrabarty
Person Months Worked: 1.00
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International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

July 14–15, 2015

Innovations in Aerosol Physics and Chemistry

Organized by Center for Aerosol Science and Engineering (CASE)

Washington University in St. Louis

eece.wustl.edu/CASEWorkshop2015

Brauer Hall

Washington University in St. Louis
School of Engineering & Applied Science

Welcome to Washington University!

The School of Engineering & Applied Science is a top-ranked, dynamic school with 87 tenured and tenure-track professors, 40 additional full-time faculty, 1,300 undergraduate students, 560 master's students, 380 doctoral students, and more than 20,000 alumni. With approximately $28 million in annual sponsored research, the school focuses intellectual efforts through a new convergence paradigm, particularly as applied to medicine and health, energy and environment, entrepreneurship, and security.

In 2006, Washington University became the first university in the world to create a Department of Energy, Environmental & Chemical Engineering (EECE) by bringing together faculty involved in the interdisciplinary Environment Engineering Science graduate program and the Department of Chemical Engineering.

Innovations in Aerosol Physics & Chemistry

PREFACE

Aerosol physics and chemistry encompasses the basic principles that describe the formation, growth, and evolution of a system of particles suspended in a gaseous medium, and the measurement, characterization, and modeling of their properties. Advances in this cross-disciplinary area of research are pivotal for improving our understanding and estimation of climate forcing; ensuring air quality protection; detection and control of biological and chemical weapons agents; assessment of health impacts; and enablement of advanced material synthesis.

Over the years, findings of large variations in formation pathways, morphology, chemical composition and optical properties of aerosols have spurred a rapid growth of interest in this discipline. The purpose of this workshop is to bring together a group of researchers with diverse interests and expertise in nucleation, transport, growth, instrumentation, characterization, and multi-scale modeling of aerosols to discuss recent advances, current challenges, and new directions. A mix of early-career and established researchers, working at the cutting edge in areas related to aerosol science, from academia, industry, and national research-laboratories have been invited. The workshop will kick-off with an inaugural keynote presentation followed by four moderated sessions. Each of these sessions will be led by four invited subject matter experts to discuss state-of-the-art research and identify critical issues pertinent to the session. A group-style discussion will follow at the end of each session with the goal of formulating a visionary guide for future research directions.

On behalf of the organizing committee, we thank the United States Army Research Office and Washington University's Department of Energy, Environmental & Chemical Engineering for their sponsorship of this event. We are sincerely pleased that you could attend and participate in this meeting of experts. We hope that you will find the workshop to be fun, interesting, and productive. We also hope that you have an enjoyable and memorable stay at Washington University.

Rajan Chakrabarty and Pratim Biswas

Center for Aerosol Science and Engineering, Washington University in St. Louis

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Speaker abstracts & biographies

Workshop Schedule

Monday, July 13, 2015

All Day	Arrival and check in at the Charles F. Knight Center/Moonrise Hotel
6:00 p.m.	Welcome Reception & Networking Dinner

Tuesday, July 14, 2015

Each speaker will introduce the topical area by presenting state-of-the-art research and challenges. Following this, each speaker will identify the future directions and needs. It is anticipated that "white paper" documents will result from the discussions and will be compiled by the moderators

7:30 a.m.	Continental Breakfast (Brauer Hall, 12)
8:00 a.m.	Welcome Remarks — Rajan Chakrabarty
8:05 a.m.	Welcome by Dean — Aaron Bobick
8:10 a.m.	Remarks by Army Research Office — Sandra Collier and Jim Parker
8:20 a.m.	Overview of CASE — Pratim Biswas
8:30 a.m.	Keynote Presentation — Richard Flagan, Distinguished Professor, Caltech **"The Pursuit of the Ideal Aerosol Measurement"**

Session I — Aerosol Formation, Growth and Transport

(Moderator: Pratim Biswas; Student Assistants: Yang Wang and Tandeep Chadha)

9:00 a.m.	Renyi Zhang, Distinguished Professor, Texas A&M College Station **"Nucleation and Growth of Atmospheric Aerosols — Progress and Challenges"**
9:15 a.m.	Sergey Nizkorodov, Professor, University of California Irvine **"Photochemical and Dark Ageing Processes in Organic Aerosols"**
9:30 a.m.	Christopher Hogan, Assistant Professor, University of Minnesota **"Probing Heterogeneous Nanoparticle Growth at the Molecular Scale"**
9:45 a.m.	Amit Chakrabarti, Professor, Kansas State University **"Superaggregates in Cluster-dense Soot Aggregation"**
10:00 a.m.	Moderated Discussion
10:30 a.m.	Coffee Break

Workshop Schedule

Tuesday, July 14, 2015 (continued)

Session II — Advances in Aerosol Measurement I (Physical and Chemical)

(Moderator: Brent Williams; Student Assistants: Mike Walker and Jiaxi Fang)

11:00 a.m.	David Pui, Distinguished Professor, University of Minnesota **"Methods for Determining Length, Surface Area and Fractal Dimensions of Non-spherical Particles"**
11:15 a.m.	Juan Fernández de la Mora, Professor, Yale University **"Ion Mobility, Mass Spectrometry and Nucleation Tools"**
11:30 a.m.	Doug Worsnop, Vice President and Director, Aerodyne Research Inc. **"Mass Spectrometry of Atmospheric Aerosol: 1 nanometer to 1 micron"**
11:45 a.m.	Alexander Laskin, Senior Scientist, Pacific Northwest National Laboratory **"Chemical Imaging and Molecular Characterization of Atmospheric Aerosols"**
Noon	Moderated Discussion
12:30 p.m.	Lunch (Lopata Gallery) **Overview of CCCU and facility tour by Rich Axelbaum**

Session III — Advances in Aerosol Measurement II (Optical)

(Moderator: Rajan Chakrabarty; Student Assistants: Akshay Gopan and Apoorva Pandey)

2:15 p.m.	Chris Sorensen, Distinguished Professor, Kansas State University **"The Kansas State Interpretation of Light Scattering"**
2:30 p.m.	Kirk Knobelspiesse, Scientist, NASA Ames Research Center **"Multi-angle Polarimetry: The Once and Future King of Aerosol Remote Sensing"**
2:45 p.m.	Chris Zangmeister, Leader, Aerosol Metrology Program, NIST **"Supercontinuum Photoacoustic Spectroscopy"**
3:00 p.m.	Rebecca Washenfelder, Research Scientist, NOAA **"Absorption and Scattering by Atmospheric Aerosol"**
3:15 p.m.	Moderated Discussion
3:45 p.m.	Coffee Break and Student Posters
4:30 p.m.	Laboratory Tours (coordinated by Ben Kumfer)
6:00 p.m.	Networking Dinner (Knight Center)

Workshop Schedule

Wednesday, July 15, 2015

7:30 a.m.	Continental Breakfast (Brauer Hall, Room 12)

Session IV — Advances in Aerosol Measurement III (Single Particle)

(Moderator: Jay Turner; Student Assistants: Kelsey Haddad and Chris Oxford)

8:30 a.m.	Lan Yang, Professor, Washington University **“Whispering-Gallery Microresonators and Microlasers for Nanoscale Sensing: A New Technology for Aerosol Science”**
8:45 a.m.	Yongle Pan, Fellow and Senior Scientist, Army Research Lab **“Effects of Atmospheric Environments on the Properties of Single Bioaerosol Particles”**
9:00 a.m.	Matthew Berg, Asst. Professor, Mississippi State University **“Particle Characterization with Digital Holography”**
9:15 a.m.	Chuji Wang, Professor, Mississippi State University **“Advantages and Challenges in Single-Aerosol-Particle Spectroscopy”**
9:30 a.m.	Moderated Discussion
10:00 a.m.	Coffee Break

Session V — MURI Discussion and Concluding Remarks

10:30 a.m.	All Participants
11:45 a.m.	Lunch with continued discussion (Brauer Hall, Room 12)
2:00 p.m.	Check-out and Departure

Welcome Remarks

Rajan Chakrabarty
Assistant Professor
Department of Energy, Environmental & Chemical Engineering,
Washington University

Dean's Welcome

Aaron Bobick
Dean, School of Engineering & Applied Science
Washington University

Overview of CASE

Pratim Biswas
Department Chair and Lucy & Stanley Lopata Professor
Department of Energy, Environmental & Chemical Engineering,
Washington University

Keynote speaker

Richard C. Flagan

Irma and Ross McCollum-William H. Corcoran Professor of Chemical Engineering and Professor of Environmental Science & Engineering, California Institute of Technology

“The Pursuit of the Ideal Aerosol Measurement”

ABSTRACT

Aerosol science has advanced in fits and starts, with advances in instrumentation and experimental methods driving many of the advances. Early measurements probed the physical nature of the aerosol, and the dynamic processes leading to those properties. The focus of aerosol measurements has increasingly shifted from fundamental aerosol physics to the effects of aerosols on human health, climate, ecosystems, and the technologies in which they arise. With this shift, the nature of the ideal measurement has changed as well. The primary measurement being made to assess exposure to particulate pollution and its impacts on human health is PM2.5, but a growing body of evidence shows that a tiny mass of ultrafine particles can have profound health effects. Half the particles in the global atmosphere result from nucleation of vapor-phase precursors, impacting radiative forcing of climate after they have grown large enough to efficiently scatter sunlight or to act as cloud condensation nuclei. In aerosol technology, nucleation processes are central to the synthesis of engineered nanoparticles and structures. Though the same particles are involved in the first two arenas, and the same size range and physical mechanisms in all three, very different methods will be required to address the underlying science. Similarly, optical measurements of larger particles are central to our understanding of radiative forcing, and to the characterization of the aerosol burden on the global scale through remote sensing. The continued advance of aerosol science requires ongoing pursuit of improved measurement technology, but the directions for these improvements for different applications may diverge.

BIOGRAPHY

Professor Flagan focuses on aerosols, and includes studies of secondary organic aerosols in the atmosphere, of biological particles such as pollen and their health impacts, and of the formation of particles and clouds in the atmosphere of Titan. At the center of his work is the development of methods for the physical, chemical, and biochemical characterization of aerosol particles ranging from particles as small a 1 nm diameter to pollen grains that can exceed 100 µm in size. He also applies methods derived from aerosol science to the study of phase transitions in materials, and the development of separations technologies.

Speaker

Renyi Zhang

Harold J. Haynes Endowed Chair, University Distinguished Professor. Department of Atmospheric Sciences, College of Geosciences, Department of Chemistry, College of Science, Texas A&M University

"Nucleation and Growth of Atmospheric Aerosols — Progress and Challenges"

ABSTRACT

Atmospheric aerosols impair visibility and human health, alter cloud formation, and interfere with the Earth's radiative transfer. The major contributors include secondary sulfate and organic aerosols from anthropogenic and biogenic activities, which are produced through a multitude of complex multiphase atmospheric processes by photochemical oxidation of emitted sulfur dioxide and volatile organic compounds (VOCs) into less volatile forms and gas-to-particle conversion. Aerosol nucleation events have been frequently observed under various tropospheric conditions and account for a major fraction of the total aerosol population, but the fundamental chemical processes responsible for aerosol nucleation and growth remain poorly understood. New particle formation occurs in two distinct stages, i.e., nucleation to form the critical clusters and subsequent growth of the newly nucleated clusters by condensation or heterogeneous reactions to larger particles. Although sulfuric acid has been identified as a key species in aerosol nucleation and growth, it is commonly recognized that sulfuric acid alone is inefficient enough to explain measured atmospheric aerosol formation. Considerable uncertainty exists regarding the mechanisms and identity of other condensable species responsible for nucleation and growth of atmospheric aerosols. This talk focuses on nucleation and growth of aerosols in the atmosphere, focusing on the fundamental chemical processes at the molecular levels.

BIOGRAPHY

Renyi Zhang joined the faculty at Texas A&M University (TAMU) in 1997 and is Professor in the Departments of Atmospheric Sciences of College of Geosciences and Chemistry of College of Science. He earned a Ph.D. from MIT and completed postdoctoral work at Caltech/NASA Jet Propulsion Laboratory. He is holder of the Harold J. Haynes Endowed Chair in Geosciences and University Distinguished Professor at TAMU. His early research contributed to the understanding of stratospheric ozone depletion and formation of the "Antarctic Ozone Hole". His research at TAMU has led to important advances in several atmospheric fields—photochemical oxidation of hydrocarbons; formation, growth, and properties of aerosols; urban and regional air pollution; ambient measurements of trace gases and aerosols; and assessment of aerosol-cloud-climate interaction—and provided critical insights into the impacts of human activities on the environment, weather, and climate. He has published more than 180 papers in peer-refereed journals. Currently, Zhang is editor for Journal of the Atmospheric Sciences and senior editor for Oxford Research Encyclopedia - Environmental Science, Oxford University Press, and is a member of the International Commission on Atmospheric Chemistry and Global Pollution. He served as editor of the Journal of Geophysical Research–Atmospheres (2009-2013) and chaired the American Meteorological Society's Atmospheric Chemistry Committee (2010-2014). He has received several awards, including honorary professorships at Peking University and Fudan University, the Outstanding International Collaboration Researcher Award from the China National Science Foundation, The Association of Former Students Distinguished Achievement Award—Research at TAMU, the Bush Excellence Award for Faculty in International Research at TAMU, and the Cheung-Kong Distinguished Scholar Award from the Ministry of Education–China. He is an elected Fellow of the American Geophysical Union and American Meteorological Society.

Speaker

Sergey A. Nizkorodov

Professor, Department of Chemistry, University of California

"Photochemical and Dark Ageing Processes in Organic Aerosols"

ABSTRACT

Organic compounds make up a significant, and often dominant, fraction of the atmospheric particulate matter. Primary Organic Aerosol (POA) is emitted in the atmosphere directly by various sources, and the initial molecular make-up of POA usually reflects the specific environment it originated from. Secondary Organic Aerosol (SOA) is produced directly in the atmosphere as a result of oxidation of volatile organic compounds (VOC). One of the challenges in representing organic aerosols in climate and air pollution models is their astonishingly high degree of chemical complexity. Furthermore, the chemical composition of organic aerosols is highly dynamic and continuously changes as a result of various "ageing" processes, such as photolysis, hydrolysis, oligomerization, oxidation, and other reactions involving aerosol constituents and atmospheric gases. This presentation will discuss the recent advances and current challenges in our understanding of the effects light-induced and dark ageing reactions on the molecular level chemical composition of organic aerosols, with a strong emphasis placed on so called "brown carbon", organic aerosol that absorbs near-UV and visible radiation and plays a rather uncertain role in climate.

BIOGRAPHY

Sergey Nizkorodov received his undergraduate degree in biochemistry from Novosibirsk State University, Russia, in 1993 and graduate degree in chemical physics from Basel University, Switzerland, in 1997. After doing his postdoctoral research in chemical kinetics and reaction dynamics at the University of Colorado at Boulder, and in atmospheric chemistry at the California Institute of Technology, he joined the faculty of the Department of Chemistry, University of California, Irvine, in 2002. He teaches analytical, physical and atmospheric chemistry courses, and does research on chemistry of particulate matter in the ambient atmosphere and in indoor environments using state-of-the art spectroscopic and mass-spectrometric techniques. His primary areas of expertise are molecular spectroscopy, high resolution mass spectrometry, chemical reaction dynamics, and photochemistry. He has been a research mentor to 55 graduate, undergraduate and postdoctoral students including 30 female researchers. His research, education and public outreach work were recognized by several awards including Camille Dreyfus Teacher-Scholar Award, Ascent Award, Coblentz Award, and UCI Chancellor's Award for Excellence in Fostering Undergraduate Research

Speaker

Chris Hogan

Associate Professor, Department of Mechanical Engineering, University of Minnesota

"Probing Heterogeneous Nanoparticle Growth at the Molecular Scale"

ABSTRACT

New particle formation in the gas phase occurs when vapor phase precursors collide with and bind to one another without dissociating; vapor molecules binding in succession eventually leads to the formation of nanoparticles. Traditionally, particle formation rate predictions have been based on classical nucleation theory (CNT), in which the energy barrier to growth is based on the assumed validity of the Kelvin effect. However, in realistic chemically inhomogeneous systems, the energy barrier predicted by CNT is typically an upper limit; growth can occur much faster through heterogeneous pathways (i.e. the binding of vapor molecules which are chemically distinct from those already incorporated into the growing particle). This talk will present recent research results on probing heterogeneous vapor binding to clusters using ion mobility spectrometry-mass spectrometry (IMS-MS) with a parallel-plate differential mobility analyzer (DMA). It will be shown that by doping the sheath gas of the DMA with controlled amounts of vapor dopants, the shifts in mobility/collision cross section for chemically well-identified particles/clusters can be monitored, with shifts in mobility <2% (corresponding to the transient binding of a single vapor molecule) observable. Case study results for water binding to salt clusters as well as atmospherically relevant dimethylamine-sulfuric acid clusters will be presented. Direct comparison between measured mobility shifts and predictions based upon CNT derived models will additionally be provided; this comparison shows that such models do not appropriately describe heterogeneous nanoparticle growth

BIOGRAPHY

Chris Hogan is an associate professor in the department of mechanical engineering at the University of Minnesota. He received his bachelor's degree in Biological & Environmental Engineering from Cornell University in 2004, and a PhD degree in Energy, Environmental, & Chemical Engineering from Washington University in 2008. After studying as a Postdoctoral Associate at Yale University, he joined the faculty at the University of Minnesota in 2009. He is the recipient of the 2011 Sheldon K. Friedlander Award for "Outstanding PhD dissertation in a field of aerosol science and technology", and the 2013 Marian Smoluchowski Award for "Outstanding contributions in aerosol science". Currently, his laboratory group focuses on measurements and theory to explain the growth and transport of nanoparticles and ions in the gas phase (aerosols).

Speaker

Amit Chakrabarti

Professor, Physics, Kansas State University

"Superaggregates in Cluster-dense Soot Aggregation"

ABSTRACT

The concept of *superaggregates* in *cluster-dense* diffusion limited cluster-cluster aggregation (DLCA) was first developed at Kansas State University laboratories. From both large-scale computer simulations and experimental studies of heavily sooting flames, we have shown that soot aggregates in the cluster-dense regime have a hybrid morphology with a "traditional" fractal dimension of 1.8 at smaller length scales and a percolation fractal dimension of 2.5 at larger length scales. We have also characterized the crossover length scale in terms of an ideal gel point description. Subsequently, such hybrid soot morphology and a larger fractal dimension of 2.5 were observed in various other experimental studies. In the current work, we will address the percolation analogy for superaggregates in details both from the point of view of fractal dimension and shape of the clusters. Our work will focus on a scaling description of the DLCA clusters at the ideal gel point and the shape anisotropy of the clusters. A detailed comparison with static percolation clusters will be presented as well. We will also address the implication of hybrid morphology of DLCA clusters on the scattering properties of soot aerosols.

BIOGRAPHY

Amit Chakrabarti is currently the William and Joan Porter Professor and Head of Physics at Kansas State University. Chakrabarti received his PhD in Physics from University of Minnesota in 1987. After post-doctoral work at Temple and Lehigh Universities, Chakrabarti joined Kansas State in 1990 as an Assistant Professor. Chakrabarti is a soft matter physicist and has published over 150 peer reviewed articles. His current research interests are self-assembly of aerosols, colloids, nanoparticles, and proteins, and modeling light scattering from irregularly shaped particles. He has received Kansas State University's Commerce Bank Distinguished Graduate Faculty Award (2009) and Presidential Award for Excellence in Undergraduate Teaching (2002).

Speaker

David Y.H. Pui

Distinguished McKnight University Professor, Director of the Particle Technology Laboratory, Mechanical Engineering Department, University of Minnesota

"Methods for Determining Length, Surface Area and Fractal Dimension of Non-spherical Particles"

ABSTRACT

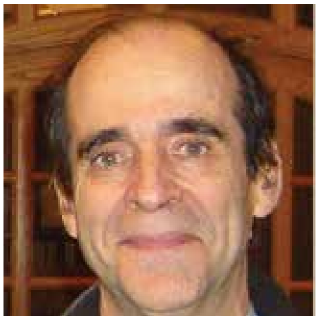
Instruments for measuring airborne particle size distributions are well established. Commercial aerosol instruments are available to measure size distributions from 2.5 to 1,000 nm with high resolution and wide concentration range. Most of these instruments deliver only equivalent particle size, e.g., mobility equivalent diameter or aerodynamic diameter of spherical particles. However, most of the real-life particles, such as Diesel soot and engineered nanoparticles, are non-spherical agglomerates. Information of agglomerates length, surface area and fractal dimension are important for toxicity assessment, for emission control of Diesel soot, and for quality control of engineered nanoparticles production.

We have developed methods for measuring length, surface area and fractal dimension of non-spherical particles. By combining a DMA (differential mobility analyzer) with a filter with uniform pores, namely a filter pre-separator, a new method for differentiating nanoparticles with different mass-mobility fractal dimensions was developed and validated experimentally and theoretically. It can also measure the effective length (or maximum projected length) of nanoparticles with irregular shapes. Another method involves incorporating a custom-built electrostatic precipitator in the existing NSAM (Nanoparticle Surface Area Monitor for lung deposited surface area). By varying voltages on the ESP to precipitate the charge particles and by dividing the classification in two regimes, a geometrical surface area monitor is developed and validated. Details of these developments, together with instrument calibration issues, will be discussed at the Workshop.

BIOGRAPHY

Professor David Y. H. Pui is Director of the Particle Technology Laboratory and of the Center Filtration Research at the University of Minnesota. He has a broad range of research experience in aerosol science and technology and has over 250 journal papers and 25 patents. He has developed several widely used commercial aerosol instruments. Dr. Pui has received many awards, including the Smoluchowski Award by the Gesellschaft fuer Aerosolforschung (1992), the Max Planck Research Award (1993), the Humboldt Research Award for Senior U.S. Scientists (2000), the David Sinclair Award by the American Association for Aerosol Research (2002), and the Fuchs Memorial Award (2010) -- the highest disciplinary award conferred by the American, German and Japanese aerosol associations.

Speaker



Juan Fernández de la Mora

Professor of Mechanical Engineering & Materials Science,
School of Engineering & Applied Science, Yale University

“Ion Mobility, Mass Spectrometry and Nucleation Tools”

ABSTRACT

Substantial measurement developments have taken place recently, driven by interest in new particle formation in the atmosphere, with ion mobility, mass spectrometry and condensation nucleation instrumentation having as a result greatly developed. There is a need to measure detailed rates of condensation, evaporation, charge evaporation, charge exchange, etc. Also to develop better and faster CPCs (for neutral and charged particles down to molecular sizes), to increase instrument resolving power, to develop improved size standards in the diameter range above 2 nm, to better interpret mobility information for spherical and non-spherical particles. Biological nanoparticles have also contributed substantially to some of these areas, being used as size and shape standards, while also offering promising biotech applications. A number of areas continue benefitting from gradual merging of physicochemical knowledge available for small molecules with more macroscopic information conventionally used in aerosol work. This unification process is, however, often difficult. Progress and obstacles in these various topics will be illustrated with recent studies at Yale and elsewhere.

BIOGRAPHY

Born in Madrid, 1952, Juan Fernández de la Mora studied Aeronautical Engineering (1975) and worked as an engineer at the aerodynamics department of the company Construcciones Aeronáuticas (Madrid, 1975, 1977). He received a Ph.D. at Yale under Prof. D.E. Rosner (Engineering and Applied Sciences, 1981), joined the UCLA group of Prof. Sheldon Friedlander as a Postdoctoral Scholar (1981), and has been on the Mechanical Engineering faculty at Yale since 1981. His core field of interest is Fluid Mechanics, with applications to nanoparticle separation by inertia, mobility and mass spectrometry. He has contributed to various nanoparticle separation, detection, ionization and atomization instruments, including DMAs, CNCs, impactors, and electrosprays. He has received the K. Whitby and the D. Sinclair Awards from the AAAR, and is a corresponding member of the Spanish Academy of Engineering.

Speaker

Doug Worsnop

Vice President, Director, Center for Aerosol and Cloud Chemistry
Aerodyne Research, Inc.

"Mass Spectrometry of Atmospheric Aerosol: 1 nanometer to 1 micron"

ABSTRACT

Despite much effort in the past decades, uncertainties in both climate impacts and health effects of atmospheric aerosols remain large. During the last ten years, aerosol mass spectrometry (AMS) has enabled size resolved measurement of sub-micron aerosol, showing that chemical composition is roughly 50:50 inorganic and organic worldwide. Elemental analysis (C, H, O, N, S; via time-of-flight mass spectrometry, ToFMS) has separated primary and secondary aerosol and shown that organics become highly oxidized on a time scale of days, with low volatility oxidized organic dominating remote aerosol organic loading. Global aerosol loading is dominated by photochemical production of inorganic and organic components. Parallel application of ToFMS to directly sample atmospheric ions has provided the first observation of molecular cluster ions involved in atmospheric nucleation. Chemical ionization mass spectrometry (CIMS), based on high pressure TOFMS, has extended detection to neutral molecules and clusters, detecting highly oxidized multifunctional organics in the gas phase. Ambient sampling and photochemical chamber experiments (Hyytiälä, Finland, and Cosmics Leaving OUtdoor Droplets (CLOUD) at CERN, respectively) have resolved the interaction of H2SO4 and low volatility organic vapors in nanoparticle particle nucleation and growth.

BIOGRAPHY

Doug Worsnop is a leading expert in the chemistry and heterogeneous reactions of atmospheric aerosols. He has pioneered the development of laboratory and field measurement techniques for investigating chemical interactions between atmospheric trace gases and aerosols, including water droplets. His expertise extends to the mechanisms of the formation of polar stratospheric clouds, and to measurements of the chemical composition of atmospheric aerosols. Dr. Worsnop is a recipient of the 2004 Benjamin Y. H. Liu Award (American Association for Aerosol Research) for his achievements in atmospheric composition measurement with the Aerodyne mass spectrometer system (AMS). He received the 2010 Yoram Kaufman (AGU Atmospheric Sciences) for Unselfish Cooperation in Research and is a Fellow of AAAS and AGU.

Speaker

Alexander Laskin

Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory, Richland, Washington

“Chemical Imaging and Molecular Characterization of Atmospheric Aerosols”

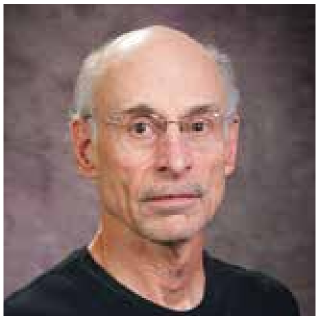
ABSTRACT

Fundamental understanding of the complex chemistry of atmospheric aerosols, their physico-chemical properties and environmental impacts is a challenging task because no single method of analytical chemistry is capable of providing the full range of analytical chemistry information. Electron microscopy and micro-spectroscopy approaches can visualize individual particles and their internal structures; however, they largely exclude molecular-level information, and are limited to elemental and chemical bonding characterization. Contemporary methods of high-resolution mass spectrometry can provide detailed information on the molecular content of organic aerosol, but these methods use bulk particle samples and provide no knowledge of the individual particle composition. Therefore, application of complementary analytical methods of chemical analysis is necessary for comprehensive characterization of aerosol properties ranging from bulk molecular composition of aerosol organic constituents to microscopy level details of individual particles. Combined assessment of the results provided by complementary analytical chemistry techniques offers unique insights to understand the composition and physico-chemical properties of aerosols determining their effects on air quality and climate. This presentation will give an overview of recent field and laboratory studies of atmospheric aerosols with an overall goal to understand fundamental relationship between chemical transformations of airborne particles and their environmental and climate impacts.

BIOGRAPHY

Alexander Laskin received his undergraduate (diploma) degree from the Polytechnical Institute, St. Petersburg, Russia, in 1991 in physics and his Ph.D. degree in physical chemistry from the Hebrew University of Jerusalem, in 1998. Following postdoctoral research appointments at the University of Delaware, Princeton University, and Pacific Northwest National Laboratory (PNNL), he became a staff scientist at PNNL in 2001. His present position at PNNL is a Senior Scientist (level V). He published over 120 research and review articles in the areas of the physical and analytical chemistry of aerosols, the environmental and atmospheric effects of aerosols, the chemical imaging and molecular level studies of aerosols, the micro spectroscopy and high-resolution mass spectrometry of aerosols, the study of combustion-related aerosols, combustion chemistry, and chemical kinetics.

Speaker



Chris Sorensen

Professor Physics, Kansas State University

"The Kansas State Interpretation of Light Scattering"

ABSTRACT

I will present an overview of light scattering by particles of any shape that takes the perspective that scattering starts at the wave diffraction limit and then adds the electromagnetic nature of light. The wave diffraction limit leads to the use of the scattering wave vector q as the angular variable, instead of the scattering angle, in an analysis method that we call the "Q-space analysis". The analysis uncovers power law descriptions of the scattering with quantifiable exponents and length scale dependent crossovers between the power laws for a wide variety of particles including Mie scattering by spheres, fractal aggregates, irregularly shaped particles such as dusts and perturbed spheres. A clear benefit of Q-space analysis is that it provides a simple and quantifiable description of light scattering that can be used to differentiate scattering by particles of different shapes. An unfolding benefit is that it leads to a new interpretation of what happens when light scatters from any object in terms of the convolution of diffraction and electromagnetism.

BIOGRAPHY

Christopher M. Sorensen is the Cortelyou-Rust University Distinguished Professor and a University Distinguished Teaching Scholar in the Departments of Physics and Chemistry (adjunct). His research work concerns particulate systems, light scattering, synthesis of nanoparticles and graphene, and soft matter physics. He has won numerous teaching awards including the 2007 CASE/Carnegie Foundation United States Professor of the year for doctoral universities. He is a Fellow of the American Association for Aerosol Research, the American Physical Society and the American Association for the Advancement of Science.

Speaker

Kirk Knobelspiesse

NASA Ames Research Center, Moffett Field, California

"Multi-angle Polarimetry: The Once and Future King of Aerosol Remote Sensing"

ABSTRACT

Although aerosols (and their interactions with clouds) are widely known to be one of the most uncertain components of the climate, they remain largely unconstrained in climate simulations. This is because global observations of all the parameters relevant to such simulations - quantity, size, shape, optical properties and chemical composition - are very difficult to simultaneously retrieve from existing remote sensing instruments. The problem can be addressed by maximizing the scene information gathered by a remote sensing instrument, by the use of (passive) multi-spectral, multi-angle and polarimetrically sensitive sensors. These observations, coupled with a radiative transfer model, can be inverted to solve for aerosol parameters. However, the choices to be made when designing such an observing system and retrieval algorithm are complex, and a variety of approaches have been undertaken by the scientific community.

I will review the various multi-spectral, multi-angle, polarimetric observation systems employed for aerosol remote sensing and their corresponding retrieval algorithms. This includes the French Polarization and Directionality of Earth Reflectance (POLDER) instrument, which has been the only such instrument successfully deployed in orbit thus far (most recently from 2004-2013), the NASA Aerosol Polarimetry Sensor (APS) on the ill-fated NASA Glory Mission (launch failure in 2011), potential or planned polarimeters on the NASA Aerosol-Cloud-Ecosystem (ACE) and Pre-Aerosol, Clouds and ocean Ecosystems (PACE) missions, and airborne prototypes from around the world.

BIOGRAPHY

Kirk Knobelspiesse began his academic career with an interest in photography (B.S., Rochester Institute of Technology), which evolved into a focus on optical remote sensing (M.S., Rochester Institute of Technology). After an interlude at the NASA Goddard Space Flight Center, where he worked with Ocean Color remote sensing on the SeaWiFS project, he returned to academia to obtain a Ph.D. in Applied Mathematics at Columbia University. His research, which was performed at the NASA Goddard Institute for Space Studies, dealt with the retrieval of aerosol optical properties from multi-angle passive polarimeters. He is now a physical scientist in the Atmospheric Science Branch at the NASA Ames Research Center in Moffett Field, CA. His primary interests are the optical remote sensing of parameters relevant to the Earth's climate, which requires expertise in radiative transfer computations, information content assessment, algorithm development, and field validation.

Speaker

Christopher Zangmeister

Leader, Aerosol Metrology Program, NIST

"Supercontinuum Photoacoustic Spectroscopy"

ABSTRACT

We have utilized a pulsed supercontinuum (SC) source coupled to a photoacoustic spectrometer (PAS) to measure absorption spectra across the visible and near-IR spectral regions. Using aerosol that is mobility diameter and mass selected allow the measurement of mass-specific absorption cross-sections across the complete spectrum. We will demonstrate the technique on nigrosin, fresh and hydrated flame generated soot, and engineered coated particles. The advantages of utilizing a short-pulse laser source for PAS data will be discussed.

BIOGRAPHY

Chris Zangmeister studied sea salt aerosol and ice chemistry in Jeanne Pemberton's group at the University of Arizona. In 2001 he became a National Research Postdoctoral Fellow at the National Institute of Standards at Technology in Gaithersburg, MD. In 2011 he became the Aerosol Metrology Program lead at NIST. The program focuses on developing new methods for measuring aerosol optical properties, assessing methods for particle classification and developing aerosol with known properties for future standards.

Speaker

Rebecca Washenfelder

Research Scientist, NOAA and University of Colorado

"Absorption and Scattering by Atmospheric Aerosol"

ABSTRACT

Aerosol scattering and absorption are still among the largest uncertainties in quantifying global radiative forcing. Brown carbon has a wavelength-dependent absorption that increases in the UV spectral region, and its major atmospheric sources include biomass burning, anthropogenic combustion of fossil fuels, and secondary organic aerosol. The rural southeastern U.S. is influenced by high biogenic emissions and varying concentrations of biomass burning aerosol, making it an ideal place to compare the relative contributions of these two sources to the brown carbon absorption budget. During the Southern Oxidant and Aerosol Study in summer 2013, we deployed a new field instrument that uses cavity enhanced spectroscopy with a broadband light source to measure aerosol optical extinction as a function of wavelength. I will discuss laboratory and field results from this work.

BIOGRAPHY

Rebecca Washenfelder is a scientist at NOAA in Boulder, Colorado. She received her Ph.D. in Environmental Science and Engineering with Paul Wennberg at Caltech in 2006. As a graduate student, she built an automated observatory to measure column concentrations of carbon dioxide and methane. Dr. Washenfelder began work at NOAA as a National Academies Postdoctoral Research Fellow in the Tropospheric Chemistry group, and has continued as a research scientist.

Dr. Washenfelder develops laboratory and field instruments to measure trace gases and aerosol using broadband cavity enhanced spectroscopy. BBCES is a sensitive and accurate technique that can achieve effective pathlengths of many kilometers in a cell with a physical length of 1 m. These optical cavities can be coupled to extremely high-power blue and ultraviolet LEDs. Currently, she is using these analytical methods to quantify the scattering and absorption by atmospheric aerosol particles.

Speaker

Lan Yang

Edwin H. & Florence G. Skinner Professor, Electrical & Systems Engineering, School of Engineering & Applied Science, Washington University in St. Louis

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"Whispering-Gallery Microresonators and Microlasers for Nanoscale Sensing: A New Technology for Aerosol Science"

ABSTRACT

Optical sensors based on Whispering-Gallery-Mode (WGM) resonators have emerged as front-runners for label-free, ultra-sensitive detection of nanoscale materials and structures due to their superior capability to significantly enhance the interactions of light with the sensing targets. A WGM resonator traps light in circular orbits in a way similar to a whisper, i.e., a sound wave, traveling along a circular wall, an effect found in the whispering gallery of St. Paul's Cathedral in London. The basis for resonator sensors is that the physical associations and interactions of nanomaterials on the surface of a high-Q optical WGM resonator alter the trajectory and lifetime of photons in a way that can be measured and quantified. I will first present a laser-assisted processing method to create Si-chip based optical WGM microresonators with Q-factors in excess of 100 million. I will then present a recent discovery of using ultra-high-Q microresonators and microlasers for ultra-sensitive self-referencing detection and sizing of single virion, dielectric and metallic nanoparticles. A case study of characterization of hygroscopic growth of aerosol particles using the new technology will be presented. I will also discuss using optical gains in a microlaser to improve the detection limit beyond the reach of a passive microresonator. These recent advancements in WGM microresonators will enable a new class of ultra-sensitive and low-power sensors for investigating the properties and kinetic behaviors of nanomaterials, nanostructures, and nanoscale phenomena. It will provide a new route to study and analyze chemical and physical properties of aerosols.

BIOGRAPHY

Lan Yang is the Edwin H. and Florence G. Skinner professor in the Preston M. Green Department of Electrical and Systems Engineering at Washington University. She received Ph.D. in applied physics from Caltech in 2005. Her current research interests include novel photonic materials and nano/micro photonic devices for energy, biomedical research, optical communication, environmental monitoring and sensing. She received NSF CAREER Award in 2010 for her work on single nanoparticle detection and sizing using an on-chip optical resonator for the first time. She is also the recipient of the 2010 Presidential Early Career Award for Scientists and Engineers (PECASE).

Speaker

Yongle Pan

Research Physicist, Environmental Sensing Branch, CISD, US Army Research Laboratory

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"Effects of Atmospheric Environments on the Properties of Single Bioaerosol Particles"

ABSTRACT

The effects of the atmospheric environment (gases, sunlight, and humidity) on the properties (size, concentration, viability, and fluorescence intensity and spectra) of bioaerosols were studied using both laboratory and field systems. Each system consists of: an aerosol generator; a clean air generator (which removes trace gases such as volatile organics, ozone, and NOx,); one or two rotating reaction chamber(s) (rotating at 1 rpm to keep particles aloft for long, multi-hour, studies); a single-particle fluorescence spectrometer (which measures fluorescence spectra excited at 263 nm and 351 nm); a UV-APS (which measures size, concentration and total fluorescence exited at 355 nm); and all-glass impingers (AGI) aerosol collectors. The laboratory system is used to systematically study changes in fluorescence, size and viability of aerosols exposed to different controlled conditions (ozone concentrations, humidities and temperature). The field system is used to study property changes of bioaerosol exposed to solar flux, ozone, humidity, and temperature etc. of various actual atmospheric environments. Measurements of single bioaerosol particles such as Octapeptide, BtK, E.Coli, BG, MS2 using the laboratory and field systems will be presented. Results and possible future research will be discussed. This research was supported by the Basic and Supporting Science--program of the Defense Threat Reduction Agency (DTRA) and ARL mission funds

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BIOGRAPHY

Yongle Pan is a Research Physicist at Environmental Sensing Branch, CISD, US Army Research Laboratory since 2009. He was elected to be a Fellow of the US Army Research Laboratory in 2013. His PhD is in Laser Physics and Optics from East China Normal University in 1993. From 1993 to 1998 he was an Assistant Professor, then Associate Professor at Fudan University. From 1997 to 2008 he was a Visiting Professor, then Senior Research Scientist at Yale University. He has been working on inventing real-time, in-situ bio-aerosol detection and characterization systems for years, mainly based on single particle fluorescence spectra, two-dimensional angular optical scattering patterns, and Raman spectroscopy. Some of the advancements have been transitioned to DARPA, DTRA, DHS, USAMIID, ARL, ITT, and SNL. He has over 80 refereed journal papers, 3 book chapters, and 6 patents, over 1900 citations. He has successfully completed more than 20 research projects supported by DARPA, DTRA, JBTDS, DHS, ARO, AFOSR, DOE as a principal investigator (PI), Co-PI, or key personnel.

Speaker

Matthew J. Berg

Assistant Professor, Department of Physics & Astronomy, Mississippi State University

"Particle Characterization with Digital Holography"

ABSTRACT

The recent availability of high resolution optoelectronic sensors has revived holography as a useful technique to study aerosol particles. By placing a two-dimensional detector in a collimated laser beam, the interference pattern produced by this light and that forward-scattered by a particle in the beam can be easily measured. This pattern is the particle's in-line hologram and information can be extracted from it directly. For example, applying a Fourier-transform operation to the hologram yields a silhouette-like image of the particle, thus revealing its size and shape without a priori information. In this sense, digital holography "solves" the classic inverse problem in applied light scattering. Moreover, this measurement can be done in situ and applied to flowing aerosol particles using pulsed illumination. In recent work, we have discovered there is also an inherent link between a particle's extinction cross section and the integral of the hologram. Using Mie theory, we have shown this relationship for a variety of spherical particles. The generality of the concept, however, suggests that it applies to nonspherical particles as well. In this presentation we will show that, indeed, the extinction cross section can be extracted from the holograms produced by such particles. Specifically, we investigate prolate and oblate spheroids and cubical particles in the wavelength-size range. Using both the discrete dipole approximation and the T-Matrix method, when applicable, we are able to simulate the holograms and then perform a simple integration to yield the cross sections. We will also present our ongoing experimental work applying this technique to coarse-mode aerosol particles.

BIOGRAPHY

Matthew J. Berg is an assistant professor of physics in the Department of Physics & Astronomy at Mississippi State University. He is also an appointed faculty member in the Center for Computational Sciences at the MSU High Performance Computing Collaboratory. Professor Berg received his Ph.D. in Physics from Kansas State University in 2008 and his B.Sc. in Engineering Physics from the Colorado School of Mines in 2003. Following graduate school, he received a National Research Council postdoctoral fellowship at the U.S. Army Research Laboratory (ARL) in Adelphi, Maryland, which he held from 2009-2010.

Speaker

Chuji Wang

Professor, Department of Physics and Astronomy, Mississippi State University

"Advantages and Challenges in Single-Aerosol-Particle Spectroscopy"

ABSTRACT

Recently-developed novel trapping and manipulating techniques made it possible to measure single aerosol particles in air using advanced laser spectroscopy such as Raman spectroscopy, cavity ringdown spectroscopy (CRDS) or their combination. Early work on laser-induced fluorescence (LIF) of single aerosol particles provided insightful information on chemical and biological properties of the particles, but the spectroscopic specificity are limited to the level of LIF-clusters due to the chemical complexity and broad band fluorescence signature. Recent studies have demonstrated single-aerosol-particle Raman spectra that offer more selective information on chemical compositions based on individual Raman bands. Single particle Raman has the unique features of minimum to no interference from surroundings and high spatial and temporal resolution. But the issues of weak Raman scattering signals and possible strong fluorescence need to be taken care. CRDS measures the total extinction (sum of scattering and absorption) of the particles at one wavelength at a time. Theoretically, single particle CRDS can lead to determination of both real and imaginary parts of refractive index of a particle as well as its chemical compositions in near-real time. CRDS measurements of single polystyrene beams and water droplets have been reported; however measurements of single airborne aerosol particles have not been much explored to date.

This talk gives a brief overview on advantages, status, and challenges of single-aerosol-particle trapping and its integration with Raman and CRDS techniques. We show our most recent results of Raman and CRDS measurements of single aerosol particles optically trapped in air. Future efforts are also discussed.

BIOGRAPHY

Chuji Wang is a Professor of physics, the founding director of the Laser Spectroscopy and Plasma Laboratory at Mississippi State University (www.wang.physics.msstate.edu). His research interests include breath analysis, sensors and sensing, plasma diagnostics, and measurements of single aerosol particles using cavity ringdown spectroscopy, laser induced fluorescence, Raman, or fiber loop ringdown. He holds seven US patents. He has authored or coauthored more than 80 peer-reviewed journal articles and three book chapters. He received his Ph.D. degree in Chemical Physics from University of Science and Technology of China in 1998.

Notes

Center for Aerosol Science and Engineering

Faculty Members

Center for Aerosol Science and Engineering (CASE) is operated by a core group of eight faculty in the School of Engineering & Applied Science and collaborates with faculty in other departments and schools across the university. In addition, CASE is connected to 28 other universities worldwide through the McDonnell Academy Global Energy and Environmental Partnership (MAGEEP).


Richard Axelbaum


Pratim Biswas


Rajan Chakrabarty


Rudolf Husar


Benjamin Kumfer


Elijah Thimsen


Jay Turner


Brent Williams

Washington University in St. Louis
SCHOOL OF ENGINEERING & APPLIED SCIENCE

center for aerosol science and engineering

Department of Energy, Environmental & Chemical Engineering

Campus Box 1180 • One Brookings Drive
St. Louis, MO 63130
(314) 935-6070

eece.wustl.edu