The 2006 Ernest Orlando Lawrence Award Ceremony

An award
given by the U.S. Department of Energy

March 28, 2007
National Academy of Sciences Building
2100 C Street, N.W.
Washington, D.C.

Welcome

The Honorable Samuel W. Bodman
Secretary of Energy

welcomes you to the

presentation of the

2006 Ernest Orlando Lawrence Award

to

A. Paul Alivisatos
University of California at Berkeley
and Lawrence Berkeley National Laboratory
Malcolm J. Andrews
Los Alamos National Laboratory
Moungi G. Bawendi
Massachusetts Institute of Technology
Arup K. Chakraborty
Massachusetts Institute of Technology
My Hang V. Huynh
Los Alamos National Laboratory
Marc Kamionkowski
California Institute of Technology
John M. Zachara
Pacific Northwest National Laboratory
Steven John Zinkle
Oak Ridge National Laboratory

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Reception immediately following the ceremony

2006 Award Laureate Citations

A. Paul Alivisatos, *Materials Research*
For chemical synthesis and characterization of functional semiconducting nanocrystals, also known as quantum dots.

Malcolm J. Andrews, *National Security and Non-Proliferation*
For pioneering contributions in the area of fluid instabilities and turbulent mixing, with expertise spanning the realms of theory, numerical simulation, and experiment.

Moungi G. Bawendi, *Materials Research*
For chemical synthesis and characterization of functional semiconducting nanocrystals, also known as quantum dots.

Arup K. Chakraborty, *Life Sciences*
For his groundbreaking theoretical work leading to an understanding of the dynamics and function of the immunological synapse.

My Hang V. Huynh, *Chemistry*
For her seminal contributions in the design of new materials using coordination chemistry, including green primary explosives that contain no lead, no mercury, and no perchlorate, and for the creation of a new class of polyazido compounds with no carbon-carbon bonds that transcend the carbon-carbon bond paradigm and can be used to prepare novel ultra-pure nanomaterials, such as carbon nanospheres and high-nitrogen carbon nitrides.

2006 Award Laureate Citations *(Continued)*

Marc Kamionkowski, *High Energy and Nuclear Physics*
For his theoretical analyses demonstrating that precise observations of the cosmic microwave background can lead to deep understanding of the origin and evolution of the universe, thereby motivating a series of increasingly precise cosmological experiments.

John M. Zachara, *Environmental Science and Technology*
For his seminal and continuing scientific contributions to understanding geochemical and microbiologic factors that are critical to the fate and transport of metals and radionuclides in the environment.

Steven John Zinkle, *Nuclear Technologies (Fission and Fusion)*
For significant contributions to the scientific basis for understanding the effects of radiation on the properties of materials, and for applying this understanding to the establishment of performance limits of materials in radiation environments.

A. Paul Alivisatos

University of California at Berkeley
and Lawrence Berkeley National Laboratory

Materials Research

Professor A. Paul Alivisatos has demonstrated that advanced properties of solid-state electronic materials can be duplicated in colloidal nanocrystals produced by simple and accessible synthetic chemistry approaches. Through a combination of synthesis and spectroscopy, Dr. Alivisatos has played a seminal role in creating the field of colloidal nanocrystal science. He developed key concepts for the production of high quality, narrow size distribution, shape-controlled colloidal nanocrystals with monolayer protected surfaces; he employed structural techniques and studies of solid-solid phase transitions to demonstrate their high quality and purity; he investigated their fundamental optical and electrical characteristics; and he demonstrated their applications in a wide range of disciplines. He provided the earliest comprehensive view of the photophysics of this important class of material. This work culminated in a seminal paper in the development of the field of nanocrystals, "Semiconductor Clusters, Nanocrystals, and Quantum Dots," (*Science* 271 (5251): 933-937).

Dr. Alivisatos has been a leader in the field of structural and thermodynamic properties of nanocrystals. He demonstrated that pressure induced transformations generally will proceed by only one nucleation event per nanocrystal, since the time for a reaction front to move a few nanometers is generally much faster than the rate of nucleation. Further, the shape change of a nanocrystal as it passes from one phase to another can reveal important details concerning the mechanisms of solid-state transformations. Finally, he has shown that it is possible to determine fundamental kinetic parameters such as the activation energy and activation volume of structural transformations in nanocrystals, while it is intrinsically impossible to do so in extended solids. This work will prove to be of lasting value in solid-state chemistry and physics and in the geological sciences, and it has been far ahead of its time.

Alivisatos has continued to make major contributions to the chemistry of nanocrystal synthesis in the decade since, inventing many widely used techniques. He has demonstrated the method of "size distribution focusing," he introduced the concept of "delayed nucleation," and, in a remarkable series of papers, Dr. Alivisatos has shown that it is possible to reproducibly make "branched nanocrystals" such as tetrapods, inorganic denrimers, and hyper-branched tree-like nanocrystals. Recently, Alivisatos has studied chemical reactions in which whole nanocrystals are transformed: he developed a general approach to the creation of hollow nanocrystals. Applications showed that nanocrystals can be superior fluorescent labels for many biological imaging experiments when compared to conventional organic fluorosphores; and that colloidal nanocrystals can find important applications in areas of high-volume low-cost electronics, focusing on the use of semiconductor polymers to create light emitting diodes, solar cells and transistors.

Dr. Alivisatos has also provided important leadership to the scientific community. One example is his role in establishing the Molecular Foundry, the new Department of Energy Nanoscale Science Research Center at Lawrence Berkeley National Laboratory. Dr. Alivisatos is the founding editor-in-chief of the American Chemical Society's *Nano Letters*, which has rapidly become the flagship journal for the field. He also is a scientific founder of two of the most active and dynamic companies to emerge in the nanotechnology arena, Quantum Dot Corporation and Nanosys.

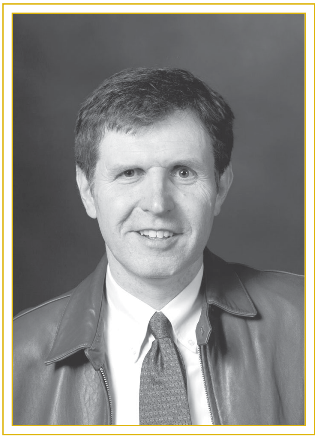
A. Paul Alivisatos was born in 1959 in Chicago, IL. He received his B.A. in Chemistry from the University of Chicago (1981); and his Ph.D. in Chemical Physics from the University of California, Berkeley (1986). He was a Postdoctoral Fellow at AT&T Bell Labs (1986-1988). He has spent his career at the University of California at Berkeley, where he is currently the Larry and Diane Bock Professor of Nanotechnology, as well as Professor of Chemistry and Materials Science. At Lawrence Berkeley National Laboratory, he is Director of the Materials Science Division and Associate Laboratory Director for Physical Sciences.

His honors include election to the National Academy of Sciences (2004); the Rank Prize Award (2006); the ENI-Italgas Prize for Energy and the Environment (shared with Alan Heeger, 2007); and the American Chemical Society Award for Colloid and Surface Science (2004).

Professor Alivisatos is a member of the American Chemical Society and the Materials Research Society, and a Fellow of the American Physical Society and of the American Association for the Advancement of Science.

Malcolm J. Andrews

Los Alamos National Laboratory



National Security and Non-Proliferation

Dr. Malcolm J. Andrews is a world renowned expert on Rayleigh-Taylor mixing and unstable or turbulent fluid flow processes that are critical to the predictive quality of the nation's stockpile stewardship and thus to the nation's security.

Over the past decade, he has made a broad and penetrating set of contributions in buoyancy driven mixing (Rayleigh-Taylor mixing in ICF capsules, oil-trapping salt domes, turbine blade cooling, Bridgeman crystal growth, fuel spray disintegration, and supernovas). He has spun many insights from this field, leading to other significant contributions across several allied fields, including heat transfer (heat exchangers, radiators), and multiphase flows (insights and algorithms for multiphase flow, sprays, deposition, and homogenization of physical representations on scales varying from nano- to micro-). Buoyancy effects are dominant processes in many important and diverse physical phenomena, such as clear air turbulence, internal wave breaking in the oceans, and thermal plumes in the atmosphere. In addition, buoyancy effects often play a major role in materials science when there are significant variations of temperature and density. However, buoyancy effects are challenging to address experimentally.

Dr. Andrews' strong mathematical background enables him to attack apparently diverse research areas, often in ways that unify them. He has developed a world-class laboratory for buoyancy driven mixing research, and is one of the leading individuals in obtaining closure between theory, computation, and experiment in this field. His laboratory has collaborated with other leading laboratories at the California Institute of Technology, Cambridge University, and Aldermaston.

Dr. Andrews' expertise and capabilities are extensive. He investigated optimal ship navigation and sound wave propagation under the Arctic (1982); developed a length-scale transport equation for the advancement of Rayleigh-Taylor mixing (1986); formulated advanced mathematical models for internal combustion engine sprays (1988); created the first large-scale simulations of heat exchangers (1994); developed and applied the first statistically steady experimental facility to investigate Rayleigh-Taylor mixing (1995); created (with Dr. P.J. O'Rourke) the MP-PIC computational method, designed to implicitly predict dense particulate flows (1996); developed carbon black-latex mixer for continuous production of rubber (1998); designed mathematical models and conducted related experimental correlations for the preprogrammed release of microencapsulated therapeutic drugs (2005); invented a new gas-channel experiment for statistically Rayleigh-Taylor mixing to investigate large-density differences and diffusion processes relevant to national security (2005); and is now project leader for the Multi-Shocked-Fluids experiment, presently being performed at Los Alamos National Laboratory, to collect data about high-Mach-number-driven turbulence associated with ICF implosion (2007).

Malcolm J. Andrews was born in 1958 in Coventry, England. He received his B.A. and M.A. degrees in mathematics from Oxford University in 1980, and his Ph.D. in Mechanical Engineering from Imperial College, London, in 1986. He became a U.S. citizen in 1997. Dr. Andrews was a member of the Professional Research Staff, lecturer, and Head of the Computational Group in the Princeton University Engine Laboratory at Princeton University from 1986 to 1991, when he moved to Texas A&M

University. Currently, he is the National Security Fellow at Los Alamos National Laboratory and Professor of Mechanical Engineering at Texas A&M University, College Station.

He has published more than 160 peer-reviewed journal articles, book chapters, and conference papers, and he holds four patents. He is associate editor of the American Society of Mechanical Engineer's *Journal of Fluids Engineering* and is an Associate Fellow of the American Institute of Aeronautics and Astronautics.

His honors include the Plenary Lecture, National Academy of Engineers Southwest Regional Conference (2004); elected Associate Fellow, American Institute of Aeronautics and Astronautics (2003); elected Fellow, Texas Engineering Experiment Station (2003, 2005); listed in *Who's Who in Fluids and Flow Engineering* (2002); Professional Engineer (PE-TX) , Chartered Mechanical Engineer (CENG) in the United Kingdom, and European Engineer (EUR ING).

Moungi G. Bawendi

Massachusetts Institute of Technology

Materials Research

Professor Moungi G. Bawendi is a world leader in the development of semiconductor nanocrystals, also known as quantum dots, and has made many seminal contributions to this field. Semiconductor nanocrystals, in large part due to Bawendi's efforts, have become one of the most studied systems in all of materials chemistry.

Moungi Bawendi burst onto the materials chemistry scene at the Massachusetts Institute of Technology when he developed a synthesis of single crystal semiconductor nanocrystals that enabled precise control of their size (*Journal of the American Chemical Society*, 1993, 115, 8706). This seminal publication represents the beginning of a whole new subfield of materials chemistry – the study of defined semiconductor nanocrystals. Using the Bawendi synthesis, nanocrystals are now routinely made to order and, depending on the materials, their optical properties can be tuned from the UV all the way to telecommunication wavelengths at 1.5 microns and further.

The initial nanocrystals were not robust, and their fluorescence degraded rapidly. In order to stabilize them, Bawendi demonstrated and characterized a complete size series of emissive nanocrystals encapsulated with a second semiconductor with a larger band-gap, where the larger band-gap material on the outside effectively prevents detrimental quenching of the particle's emission. In the formation of precise nanocrystals, Bawendi further determined that these materials can assemble into crystalline structures with the quantum dots packed in superlattices. Well defined semiconductor nanocrystals are now simply a part of a modern materials chemist's tool box.

In addition to being an excellent materials chemist, Bawendi is a practitioner of physical chemistry at the highest levels. Bawendi rigorously established the nature of the observed excited electronic states in semiconductor nanocrystals. Through experimental observations on single semiconductor nanocrystals, Bawendi was able to first observe that these particles display strong spectral diffusion and blinking. Most recently, he has been conducting extremely interesting studies involving multiple excitations in single quantum dots by exciting them with intense laser pulses.

In addition to developing the fundamental science of semiconducting nanocrystals, Bawendi has also been a leader in developing their technologies. He demonstrated chemical linkages to the nanocrystals that allow conjugation to biological species, which was the basis of a company, Quantum Dot Corporation (acquired by Invitrogen), that Bawendi co-founded with Dr. Paul Alivisatos. Bawendi's work has also been incorporated into another startup company, Nanosys. More recently, with collaborator Dr. Vladimir Bulovic, he has demonstrated high efficiency electroluminescence in self-assembled close-packed monolayers of quantum dots assembled between organic electron and hole conductors. This later invention is now the base technology of a new company, QDVision. In collaboration with Dr. John Frangioni and other doctors at Beth Israel Hospital, Bawendi has extended these systems to image lymph nodes associated with malignant tumors. This new technology promises to create new advances for the treatment of cancer.

Moungi G. Bawendi was born in 1961 in Paris, France, and he became a U.S. citizen in 1982. He received his A.B. in Chemistry from Harvard University in 1982, his A.M. in Chemical Physics from Harvard in 1983, and his Ph.D. in Chemistry from the University of Chicago in 1988. He began his career as a Postdoctoral Member of the Technical Staff at AT&T Bell Laboratories (1988-1990). In 1990, he began teaching at MIT, where he is currently Professor of Chemistry.

Among his honors are the MIT School of Science Teaching Prize (1997); the Coblentz Award for Molecular Spectroscopy (1997); the Wilson Prize, Chemistry Department, Harvard University (2000); the Raymond and Beverly Sackler Prize in the Physical Sciences (2001); and the University of Chicago Chemistry Department Young Alumnus Award (2001). He is a Fellow of the American Association for the Advancement of Science and a Fellow of the American Academy of Arts and Sciences.

Arup K. Chakraborty

Massachusetts Institute of Technology

Life Sciences

Professor Arup K. Chakraborty has applied statistical mechanical methods to shed light on the molecular mechanisms that regulate the activation of T lymphocytes that orchestrate the immune response. His theoretical work has had widespread impact on experimental cellular and molecular immunology.

Higher organisms, including humans, have an adaptive immune system that enables them to respond to infectious pathogens. At the same time, many autoimmune disorders arise from the failure of the immune system to discriminate between “self” and “non-self.” Dr. Chakraborty recognized that T cell signaling and activation is an emergent property arising from collective dynamical processes involving many components. Thus, he built and applied statistical mechanical models to study T cell signaling and activation with a view toward elucidating the collective dynamical processes involving molecular components in the cell membrane and the cytoplasm.

In 2001, Chakraborty (with junior collaborators, S. Qi and J. Groves) published the first mechanistic model that explained the forces driving synapse formation. They showed that topological size differences between the receptor-ligand pairs and the finite bending rigidity and interfacial tension of cell membranes created the conditions for receptors and ligands of different sizes to separate into two phases. This intrinsic tendency to spatially segregate different components to different parts of the intercellular junction is amplified by active processes involving the cellular cytoskeleton. These ideas have become the basis for numerous papers from other research groups—both theoretical and experimental—as evidenced by the fact that Chakraborty's original paper has already been cited a large number of times in a short period.

In late 2003, Chakraborty (with junior collaborators, A. Dinner and S. Raychaudhuri, and experimental collaborators) published a paper in Science (cited unusually highly) on how intracellular signaling dynamics is influenced by different spatial patterns of the membrane receptors. These studies showed that the synapse could both amplify and attenuate signaling depending upon circumstances. Many predictions emerging from this model have been verified by experiments carried out principally in Professor Andrey Shaw's laboratory at Washington University. Again, this work is an example of Chakraborty's ability to develop models for complex biological systems whose predictions can be tested directly by genetic, biochemical, and imaging experiments.

In the long term, Dr. Chakraborty's most important contributions to immunology may be his current work that seeks to understand how T cells detect the presence of minute amounts of antigen with extraordinary sensitivity. Recent single molecule experiments carried out in the laboratory of Professor Mark Davis at Stanford University have shown that T cells can be fully activated by ten or fewer antigen-derived pMHC molecules in a sea of 30,000 endogenous molecules. In close collaboration with the Davis laboratory, Chakraborty's group has developed computational and analytical models of membrane-proximal signaling in T cells that shed light on the molecular mechanisms that underlie the amazing ability of T cells to discriminate between "self" and "non-self" with such exquisite precision. The first paper resulting from the collaboration between Chakraborty and Davis was published in *Nature Immunology* in 2004. One testament of its impact is that the mechanism presented therein will appear in the forthcoming edition of a popular immunology textbook.

Dr. Chakraborty's work in immunology, his contributions to understanding DNA microarrays, and his work on pattern recognition are beautiful examples of using field-theoretic methods, renormalization group theory, and computer simulations to address mechanistic questions in complex biological systems. The work is distinguished by its direct impact on experimental biologists.

Arup K. Chakraborty was born in 1961 in Calcutta, India. He received his Bachelor of Technology in Chemical Engineering from IIT, Kanpur in 1983 and his Ph.D. in Chemical Engineering from the University of Delaware in l988. He did postdoctoral work at the University of Minnesota (1987-1988). He became a U.S. citizen in 1998.

Professor Chakraborty began his career at the University of California at Berkeley, where he was Assistant Professor of Chemical Engineering (1988-1993); Associate Professor of Chemical Engineering (1993-1997); Professor of Chemical Engineering and Professor of Chemistry (1997-2001); Warren and Katherine Schlinger Distinguished Professor, Chair of Chemical Engineering, Professor of Chemistry (2001-2005); and Head, Theoretical and Computational Biology, Lawrence Berkeley National Laboratory (2004-2005). He is currently the Robert Haslam Professor of Chemical Engineering, Chemistry, and Biological Engineering at the Massachusetts Institute of Technology.

His honors include election to the National Academy of Engineering (2004); the NIH Director's Pioneer Award (2006); the Colburn and Professional Progress Awards from the AIChE; and more than 170 invited lectures on his research (including several named lectures). He has published more than 115 papers.

My Hang V. Huynh

Los Alamos National Laboratory

Chemistry

Dr. My Hang V. Huynh's interdisciplinary research represents a breakthrough approach, both metaphorically and chemically, to the conventional framework and conceptualization represented by transcending the carbon-carbon bond paradigm. Dr. Huynh has designed and synthesized an array of "Organic Polyazido High-Nitrogen Compounds – Caged Tigers" that are composed primarily of nitrogen atoms and have no carbon-carbon bonds. These caged tigers are the most endothermic organic compounds known to date. Their myriad of applications ranges from powerful extrudable explosives, to efficient feedstock for preparing carbon-based and carbon-nitride-based nanomaterials, and to the creation of hosts that can be used to deliver medicines and to detect pathogens.

Dr. Huynh's caged tigers can be simply and controllably pyrolized at various patterns of temperatures to prepare ultra-pure carbon nano-spheres and nano-polygons, as well as a series of nitrogen-rich carbon nitride nano architectures (nano-clusters, nano-leaves, nano-sheets, nano-dendrites, nano-sponge, nano-layers, and nano-foam). These nano-materials have controllable morphologies, particle sizes, pore sizes, and layers that are unobtainable by other precursors, regardless of the technological means employed. Using these caged tigers also circumvents complicated pre-treatments, convoluted preparative processes, lengthy separation, and elaborate purifications; more importantly, they release nitrogen gas as the only byproduct. They avoid expensive and toxic synthetic steps, greatly lowering the production-costs for carbon nano-materials and nitrogen-rich carbon nitride nano architectures.

Dr. Huynh's versatility in pushing synthetic frontiers by using inorganic chemistry as the vehicle for achieving new regimes of reactivity has solved many industrial and environmental problems. Dr. Huynh is the pioneer for groundbreaking discovery of "Inorganic Non-toxic Primary Explosives – Green Primaries" that is the solution of a nearly four centuries-old problem in energetic materials. Green primaries meet all required criteria for modern primaries and have suitable explosive performance to replace lead-based primary explosives. They are safer to manufacture, handle, and transport because their explosive sensitivities can easily be suppressed by wetting with water. Universally, their use in initiation devices are broadly in military and civilian applications, ranging from primers for small arms ammunition to detonators for mining, excavation, and demolition.

The preparation of green primaries is advantageous and cost-effective from many perspectives because they are prepared in water or ethanol, give quantitative yields without purification or re-crystallization, generate non-hazardous waste, can be chemically tailored to give a plethora of green primaries with diverse explosive performance, reduce liability insurance costs, eradicate the need for specialized safety equipment, and release harmless gases and non-toxic byproducts upon detonation. With Dr. Huynh's discovery of Green Primaries, the environment no longer will be contaminated by lead residue, and both military and civilian personnel will be protected from lead aerosol intake.

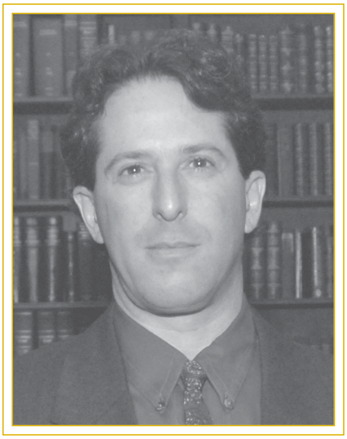
Dr. Huynh's passion for coordination chemistry extends to "High-Nitrogen Transition Metal complexes" in which transition metals are coordinated by organic high-nitrogen compounds. She invented and synthesized many different types of transition metal complexes that can be used either as gas-generators or as precursor for both metal and alloy nano-foams. With high-nitrogen content, these complexes easily and rapidly undergo self-thermal propagation to give low-density, high-surface metallic nano-foams with a diversity of morphologies, pore-sizes, and grain-sizes that cannot be accessed by other nanotechnologies. Owing to their ultra-low density and high-surface areas, they are suitable for applications that fall within the Department of Energy's missions, including hydrogen storage, oil refinement, catalyses, silver biotic filters, and targets for inertial-confinement fusion experiments.

My Hang V. Huynh was born in 1962 in Saigon, Vietnam, and she became a U.S. citizen in 1991. She received her B.S. in Chemistry and B.A. in Mathematics from the State University of New York at Geneseo in 1991 and her Ph.D. in Coordination Chemistry from the State University of New York at Buffalo in 1998. She was a Postdoctoral Research Associate at the University of North Carolina at Chapel Hill (1998-2000), a Postdoctoral Research Associate at Los Alamos National Laboratory (2000), and a Director-Funded Postdoctoral Fellow also at Los Alamos National Laboratory (2001-2002). Since 2002, she has been a Synthetic and Organic Chemist in high-nitrogen energetic materials in the Dynamic Experimentation Division, Materials Dynamics Group, at Los Alamos National Laboratory.

In addition to her peer-reviewed publications, Dr. Huynh has four patents and six pending. Her honors include the International Medal of Honor Awarded for Intellectual and Vocational Excellence (2007); R&D 100 Awards (2005 and 2006); listing as one of the Outstanding Scientists of the Twenty First Century (2006); the Twenty First Century Award for Achievement (2005); listing as one of 2000 Outstanding Scientists of the Twenty First Century (2005); listing as one of 2000 Outstanding Intellectuals of the Twenty First Century (2004); the Living Science Award for Services to Research, Application, Healthcare, and Education in All Scientific Fields (2004); Best-in-Class Pollution Prevention DOE/NNSA P2 Award (2007); and the National Registry of Environmental Professionals (NREP) Pollution Prevention Award in Health and Safety (2006). She is listed in *Who's Who in the World, Dictionary of International Biography*, *Who's Who in America*, *Who's Who in Science and Engineering*, *Who's Who in American Women*, *Who's Who in Medicine and Healthcare*, and *Who's Who in American Colleges and Universities*. Her two peer-reviewed papers on green primaries published in the *Proceedings of the National Academy of Sciences* have resulted in 13 international (Russia, Italy, England, France, Germany, Australia, and Canada) and 25 national media highlights since March 2006.

Marc Kamionkowski

California Institute of Technology



High Energy and Nuclear Physics

Professor Marc Kamionkowski is a leading theoretical physicist and astrophysicist who has described how the observations of the microwave background radiation – the Cosmic Microwave Background (CMB) – can be translated into understanding the behavior of the universe.

In 1994, Kamionkowski, with collaborators David Spergel and Naoshi Sugiyama, first pointed out that the geometry of the Universe could be measured through measurements of the small-scale temperature anisotropy of the cosmic microwave background. Shortly after, in a landmark paper with Gerard Jungman, Arthur Kosowsky, and Spergel, Kamionkowski elucidated in detail how both the geometry and the fundamental nature of the contents of the Universe would be encoded in the CMB.

These papers inspired a new generation of experiments that have since revolutionized cosmology. As a result of this work, we now know that the

Universe has a flat geometry, that it is composed primarily of exotic forms of matter and energy never detected in a laboratory, and that it very likely was spawned from a sub-nuclear volume by a process of super-luminal "Inflation."

Even as the experiments inspired by those insights were being developed, Dr. Kamionkowski and collaborators made another enormous leap. In 1997, Kamionkowski, with Kosowsky and Albert Stebbins, showed that the Cosmic Gravitational-wave Background (CGB) that would have been produced during Inflation would leave a signature in the polarization of the CMB.

In this and subsequent papers, Kamionkowski and his collaborators laid out how one might use the special symmetry properties of the polarization to separate this very faint signature from the more prosaic form of CMB polarization that has already been detected by several experiments. The possibility of using this technique to probe the epoch of Inflation has now inspired yet another generation of very sophisticated experiments that have begun the search for the signature of the CGB.

Dr. Kamionkowski's other research interests include the dark-matter problem, the problems posed by the accelerated expansion of the Universe, the physics of the early Universe, galaxy formation, and some problems in stellar astrophysics. His 1996 review article (with Jungman and Kim Griest) on supersymmetric dark matter remains a standard reference. He recently identified (with Robert Caldwell and Nevin Weinberg) a new possible end fate for the Universe, the "Big Rip," in which the Universe stretches to infinite size in finite time, tearing everything in the Universe apart as it does so.

Marc Kamionkowski was born in 1965 in Cleveland, Ohio. He received his B.A. from Washington University in 1987 and his Ph.D. from the University of Chicago in 1991. He was a Member of the Institute for Advanced Study in Princeton (199-1994), and he taught at Columbia University (1994-1999). Since 1999, he has been Professor of Theoretical Physics and Astrophysics at the California Institute of Technology, and in 2006, he was named the Robinson Professor of Theoretical Physics and Astrophysics, his current position.

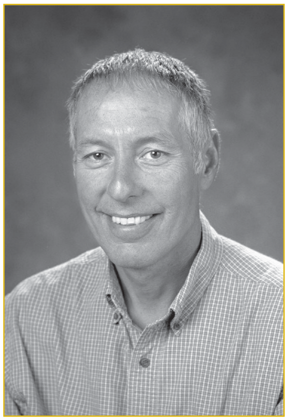
He is the Principal Investigator for Caltech's recently established Moore Center for Theoretical Physics and Cosmology and serves as the

Astrophysics Editor of *Physics Reports*. He is a member of the American Physical Society and the American Astronomical Society.

Among Dr. Kamionkowski's honors are Outstanding Junior Investigator, Department of Energy, (1998-1999); Helen B. Warner Prize, American Astronomical Society (1998); Alfred P. Sloan Foundation Fellow (1996-1998); and the SSC National Fellowship (1991-1993).

John M. Zachara

Pacific Northwest National Laboratory



Environmental Science and Technology

Dr. John M. Zachara is perhaps the most influential subsurface contaminant environmental geochemist in the world today. The Department of Energy's Hanford site in Washington state, the focus of Dr. Zachara's work at the Pacific Northwest National Laboratory, is a legacy waste site of large size and tremendous complexity in terms of released wastes and subsurface geochemical, geologic, and geohydrologic conditions. Contaminants have been in the ground for 40 to 50 years, allowing for progress of slow, poorly understood, physical, chemical, and microbiologic processes. Hanford has been described as one of the most contaminated sites worldwide, and is the focus of one of the largest and most complex environmental remediation activities ever attempted by mankind. Effective environmental solutions devised for Hanford will have worldwide applications.

Dr. Zachara has brilliantly combined principles of geochemistry, mineralogy, microbiology, and hydrogeology to understand the mystery of how DOE legacy contaminants including radionuclides and metals with complex chemistry (e.g., uranium, cesium, technetium, chromium) travel in the subsurface environment. He and his team have investigated some of DOE's most extreme subsurface contamination sites, providing insights and understanding of vexing migration patterns. His research has combined innovative laboratory experimentation with molecular spectroscopy and microscopy, geochemical and transport modeling at different scales and astute field observations to gain this understanding.

An exceptional aspect of his work has been the use of new generation chemical, biological, physical imaging tools on *real* environmental samples to determine contaminant form and processes controlling subsurface fate and transport. In particular, his use of varied molecular science techniques at DOE's Environmental Molecular Sciences Laboratory (EMSL) and DOE synchrotron radiation facilities to investigate contaminant dynamics in mineral suspensions and contaminated subsurface sediments has been seminal in transforming the way scientists conceptualize the linkage between biogeochemical reaction and physical transport processes at the microscopic scale. The use of DOE user facilities by environmental scientists has grown tremendously in the last decade, and Dr. Zachara's work in this area has set the "gold standard" for integrating results from multiple facilities as needed to understand the exceedingly complex behavior of contaminants in natural materials.

Beyond his personal research accomplishments, Dr. Zachara has led a number of multidisciplinary, multi-organizational research teams directed at larger environmental science issues. Since 1999, he has served as Principal Scientist for the Hanford Science and Technology Program. This program has coordinated more than fifty individual research groups with the goal of providing fundamental science in support of improved contaminant transport and fate projections and Hanford cleanup decisions. More recently, Dr. Zachara and a longtime colleague initiated the EMSL Biogeochemistry Grand Challenge. This highly focused, detailed science effort involves four PNNL and eleven university research groups striving to resolve the molecular mechanisms of electron transfer between bacteria and mineral surfaces using EMSL and other DOE user facilities.

John Zachara was born in 1951 in Hackensack, N.J. He received his B.S. in Chemistry from Bucknell University in 1973, his M.S. in Soil/

Watershed Chemistry from the University of Washington in 1979, and his Ph.D. in Soil Chemistry from Washington State University in 1986.

His professional affiliations include the American Association for the Advancement of Science, American Geophysical Union, American Chemical Society, Clay Minerals Society, and the Geochemical Society of America.

Among Dr. Zachara's distinctions are membership on the American Geophysical Union Groundwater Hydrology Advisory Panel (1991-1992 and 1994-1998); Associated Western Universities Distinguished Lecturer (1994); principal scientist for the Department of Energy's Subsurface Science Program Co-Contaminant Chemistry Research (1994-1998); Associate Editor of the *Journal of Contaminant Hydrology*; member of the Stanford University Synchrotron Radiation Laboratory (SSRL) peer review panel (1994-present) and science advisory committee (2006); member of the National Academy of Sciences/National Research Council study panel on "Intrinsic Remediation of Groundwater" (1997-1999); lead scientist in Hanford Science and Technology and the Remediation and Closure Science Projects (1999 - present); and member of DOE's Office of Biological and Environmental Research/Natural and Accelerated Bioremediation Research Scientific Advisory Panel. He is a Fellow of the American Association for the Advancement of Science.

Steven John Zinkle

Oak Ridge National Laboratory

Nuclear Technologies (Fission and Fusion)

Dr. Steven J. Zinkle is widely acknowledged as the foremost international expert on radiation effects on materials, in particular in the area of effects of irradiation damage on the behavior of the materials for next generation power-producing fission and fusion reactors and for space reactor technologies. His detailed research on a wide range of metallic and ceramic materials has utilized a variety of experimental and modeling tools to determine controlling fundamental mechanisms. For example, he used transmission electron microscopy, electrical resistivity, and mechanical property measurements to demonstrate the similarity in the defect production “source term” for fission, fusion, and spallation neutrons. This demonstrated the appropriateness of using existing fission reactors for the initial screening of materials for fusion research and spallation systems. He has used these seminal experiments and modeling along with analyses of published data to develop physically based models of materials behavior in extreme radiation environments. His research is characterized by an ability to meld materials science, solid-state physics, and nuclear engineering concepts to resolve challenging materials issues for fusion and fission applications.

ITER, the international experimental fusion reactor, reflects Dr. Zinkle's definition of the effects of neutron irradiation on the copper alloys used in high heat flux components and the stainless steel structure. An early design consideration of the use of a vanadium base alloy was rejected largely based on his demonstration of a previously unknown embrittlement mechanism operating at the projected temperature of the water-cooled ITER. He also conducted the definitive experiments that showed existing state-of-the-art ceramics could be used as insulators in critical applications in ITER plasma diagnostic and heating systems. As a result of his work, pessimistic predictions of permanent electrical degradation in ceramics based on less carefully controlled, limited experiments from other countries were corrected.

Dr. Zinkle led a team that evaluated a broad range of refractory metal and other alloys for in-core components in high-temperature fusion and fission reactors. One focus was on the fast-spectrum fission reactor designs under consideration for NASA space exploration missions. Based on his fundamental understanding of the alloy systems and radiation effects phenomena, he identified critical areas in the projected dose-temperature-stress service space and performed experiments and modeling to map the response of the materials needed for the selection of the concept and design.

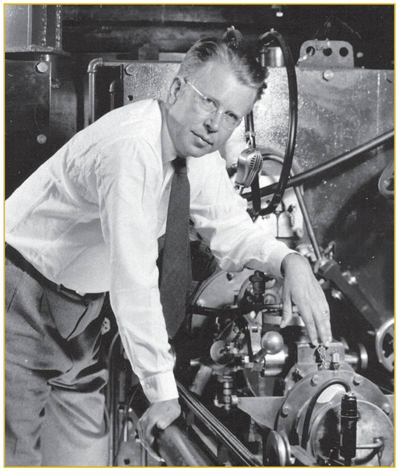
His work on advanced steels, silicon carbide ceramic composites, and other advanced materials has been used to identify realistic operating windows for Generation IV fission applications, directly influencing the engineering design of these and other advanced fission reactor concepts. His understanding of the physics of controlling mechanisms coupled with limited experimental data led to developing dose-temperature-stress "windows" for satisfactory operation. These are used in the development of the design and in defining additional research needed to validate design assumptions. He has been a leading advocate for the utilization of advanced steels and other recently developed high-performance materials in Gen IV fission reactor concepts.

Dr. Zinkle has been a leader and spokesperson for fusion's international advanced materials program and represents the U.S. in several international collaborations on materials for fusion systems. He has worked tirelessly to bridge the gap between materials science and engineering design of practical fission and fusion systems by effectively communicating and prioritizing materials and engineering technology issues.

Steven John Zinkle was born in 1958 in Prairie du Chien, Wisconsin and grew up on a dairy farm near Wauzeka, Wisconsin. He was educated at the University of Wisconsin, Madison, receiving his B.S. in Nuclear Engineering in 1980, an M.S. in Nuclear Engineering in 1982, and another M.S. in Materials Science, and his Ph.D. in Nuclear Engineering (with a minor in Physics) in 1985. He began his career at Oak Ridge National Laboratory as a Eugene P. Wigner Fellow in 1985. Now a UT-Battelle Corporate Fellow, he is Director of the ORNL Materials Science and Technology Division.

He is also a Fellow of ASM International (formerly known as the American Society for Metals) and the American Ceramic Society, and received the 1992 Fusion Power Associates Excellence in Fusion Engineering Award. He has won three professional society best paper awards, the American Nuclear Society Materials Science and Technology Division's 2005 Outstanding Achievement Award, and numerous ORNL awards including ORNL Technical Achievement (R&D Accomplishment) Awards in 1991, 1997, 1999, and 2002. He has written over 200 peer reviewed papers published in scientific journals and conference proceedings.

The Life of
Ernest Orlando Lawrence



Ernest Orlando Lawrence's scientific accomplishments and influence on science are almost unique in his generation and rank among the most outstanding in history. His cyclotron was to nuclear science what Galileo's telescope was to astronomy. A foremost symbol of the rise of indigenous American science in the twentieth century, Lawrence, perhaps more than any other man, brought engineering to the laboratory, to the great benefit of scientific progress. He originated a new pattern of research, of the group type and on the grand scale, which has been emulated the world over. Rarely, if ever, has any person given so many others, in such a small span of years, the opportunity to make careers for themselves in science. Lawrence was a leader in bringing the daring of science to technology, in wedding science to the general welfare, and in integrating science into national policy.

Lawrence was born in Canton, South Dakota, on August 8, 1901, the son of educated Norwegian immigrants. He received his B.S. degree from the University of South Dakota and his M.A. in physics from the University of Minnesota. He continued his studies at the University of Chicago for two years, then transferred to Yale, where he received his Ph.D. in 1925. In 1928, Lawrence went to the University of California as an associate professor, and in 1930, at the age of 29, he became the youngest full professor on the Berkeley faculty.

His doctoral thesis was in photoelectricity. Later, he made the most precise determination, to that time, of the ionization potential of the mercury atom. With J.W. Beams, he devised a method of obtaining time intervals as small as three billionths of a second, and he applied this technique to study the early stages of electric spark discharge. He originated a new and more precise method for measuring e/m, which was perfected by F.G. Dunnington.

In 1929, Lawrence, who for some time had been contemplating the problem of accelerating ions, chanced, while scanning the literature, upon a sketch in a German publication. He formulated, within minutes, the principles of the cyclotron and the linear accelerator and so set himself upon a course that was to fundamentally influence scientific research and human events. Between the brilliant, simple concept and operating machines lay engineering barriers not previously encountered. Lawrence's willingness to tackle new engineering problems and his success in solving them, as he reached for successively new energy ranges, was a departure in scientific research that is an important part of his contribution. The hard road he chose was recognized when W.D. Coolidge, presenting Lawrence with the National Academy of Sciences' valued Comstock Prize in 1937, said, "Dr. Lawrence envisioned a radically different course ... [which] called for boldness and faith and persistence to a degree rarely matched." By 1936, the scale of research and supporting engineering development was so large that the Radiation Laboratory was created at the University of California. The prototype of the big laboratory had been born.

Lawrence championed interdisciplinary collaboration: he strongly encouraged physicists to work with biologists, and he set up his own radioisotope distribution system, supplying isotopes to hundreds of doctors and numerous institutions in the prewar period. With his brother John, director of the University's medical center, he used the cyclotron to irradiate malignant tissues with neutrons.

In July 1958, Lawrence traveled to Geneva to take part in developing an agreement on means for detecting nuclear weapon tests. In the midst of negotiations, he became ill and was forced to return to Palo Alto, California, where he died on August 27, 1958.

Lawrence received many awards during his lifetime, including the 1939 Nobel Prize in Physics, the Hughes Medal of the Royal Society, the Medal for Merit, the Faraday Medal, the American Cancer Society Medal, the very first Enrico Fermi Award, and the first Sylvanus Thayer Award. He was a member of the National Academy of Sciences and the American Philosophical Society and recipient of many honorary degrees and memberships in foreign societies.

This biography was excerpted from "E. 0. Lawrence: Physicist, Engineer, Statesman of Science," by Glenn T. Seaborg, The Institute of Electrical and Electronics Engineers, Inc., Nuclear and Plasma Science, 5 Society News, June 1992.

The Ernest Orlando Lawrence Award

The Ernest Orlando Lawrence Award was established in 1959 in honor of a scientist who helped elevate American physics to world leadership.

E. O. Lawrence was the inventor of the cyclotron, an accelerator of subatomic particles, and a 1939 Nobel Laureate in physics for that achievement. The Radiation Laboratory he developed at Berkeley during the 1930s ushered in the era of "big science," in which experiments were no longer done by an individual researcher and a few assistants on the table-top of an academic lab but by large, multidisciplinary teams of scientists and engineers in entire buildings full of sophisticated equipment and huge scientific machines. During World War II, Lawrence and his accelerators contributed to the Manhattan Project, and he later played a leading role in establishing the U.S. system of national laboratories, two of which (Lawrence Berkeley and Lawrence Livermore) now bear his name.

Shortly after Lawrence's death in August 1958, John A. McCone, Chairman of the Atomic Energy Commission, wrote to President Eisenhower suggesting the establishment of a memorial award in Lawrence's name. President Eisenhower agreed, saying, "Such an award would seem to me to be most fitting, both as a recognition of what he has given to our country and to mankind, and as a means of helping to carry forward his work through inspiring others to dedicate their lives and talents to scientific effort." The first Lawrence Awards were given in 1960.

The Lawrence Award honors scientists and engineers, at mid-career (defined as within 20 years of receiving a Ph.D.), showing promise for the future, for exceptional contributions in research and development supporting the Department of Energy and its mission to advance the national, economic and energy security of the United States.

The 2006 Lawrence Award is given in each of the following seven categories: Chemistry, Materials Research, Environmental Science and Technology, Life Sciences (including Medicine), Nuclear Technologies (Fission and Fusion), National Security and Non-Proliferation, and High Energy and Nuclear Physics. The Lawrence Awards are administered by the Department of Energy's Office of Science.

Each Lawrence Award category winner receives a citation signed by the Secretary of Energy, a gold medal bearing the likeness of Ernest Orlando Lawrence, and $50,000; if there are co-winners in a category, the honorarium is shared equally.

The Ernest Orlando Lawrence Award Laureates

2004:
Nathaniel J. Fisch
Bette Korber
Claire E. Max
Fred N. Mortensen
Richard J. Saykally
Ivan K. Schuller
Gregory W. Swift

2002:
C. Jeffrey Brinker
Claire M. Fraser
Bruce T. Goodwin
Keith O. Hodgson
Saul Perlmutter
Benjamin D. Santer
Paul J. Turinsky

1998:
Dan Gabriel Cacuci
Joanna S. Fowler
Laura H. Greene
Steven E: Koonin
Mark H. Thiemens
Ahmed H. Zewail

1996:
Charles Roger Alcock
Mina J. Bissell
Thom H. Dunning, Jr.
Charles V. Jakowatz, Jr.
Sunil K. Sinha
Theofanis G. Theofanous
Jorge Luis Valdes

1994:
John D. Boice, Jr.
E. Michael Campbell
Gregory J. Kubas
Edward William Larsen
John D. Lindl
Gerard M. Ludtka
George F. Smoot
John E. Till

1993:
James G. Anderson
Robert G. Bergman
Alan R. Bishop
Yoon I. Chang
Robert K. Moyzis
John W. Shaner
Carl Wieman

1991:
Zachary Fisk
Richard Fortner
Rulon Linford
Peter Schultz
Richard E. Smalley
J. Pace Vandevender

1990:
John J. Dorning
James R. Norris
S. Thomas Picraux
Wayne J. Shotts
Maury Tigner
F. Ward Whicker

1988:
Mary K. Gaillard
Richard T. Lahey, Jr.
Chain Tsuan Liu
Gene H. McCall
Alexander Pines
Joseph S. Wall

1987:
James W. Gordon
Miklos Gyulassy
Sung-Hou Kim
James L. Kinsey
J. Robert Merriman
David E. Moncton

1986: James J. Duderstadt
Helen T. Edwards
Joe W. Gray
C. Bradley Moore
Gustavus J. Simmons
James L. Smith

1985: Anthony P. Malinauskas
William H. Miller
David R. Nygren
Gordon C. Osbourn
Betsy Sutherland
Thomas A. Weaver

1984: Robert W. Conn
John J. Dunn
Peter L. Hagelstein
Siegfried S. Hecker
Robert B. Laughlin
Kenneth N. Raymond

1983: James F. Jackson
Michael E. Phelps
Paul H. Rutherford
Mark S. Wrighton
George B. Zimmerman

1982: George F. Chapline, Jr.
Mitchell J. Feigenbaum
Michael J. Lineberry
Nicholas Turro
Raymond E. Wildung

1981: Martin Blume
Yuan Tseh Lee
Fred R. Mynatt
Paul B. Selby
Lowell L. Wood

1980: Donald W. Barr
B. Grant Logan
Nicholas P. Samios
Benno P. Schoenborn
Charles D. Scott

1977: James D. Bjorken
John L. Emmett
F. William Studier
Gareth Thomas
Dean A. Waters

1976: A. Philip Bray
James W. Cronin
Kaye D. Lathrop
Adolphus L. Lotts
Edwin D. McClanahan

1975: Evan H. Appelman
Charles E. Elderkin
William A. Lokke
Burton Richter
Samuel C. Ting

1974: Joseph Cerny
Harold Paul Fourth
Henry C. Honeck
Charles A. McDonald
Chester R.Richmond

1973: Louis Baker
Seymour Sack
Thomas E. Wainwright
James Robert Weir
Sheldon Wolff

1972: Charles C. Cremer
Sidney D. Drell
Marvin Goldman
David A. Shirley
Paul F. Zweifel

1971: Thomas B. Cook
Robert L. Fleischer
Robert L. Hellens
P. Buford Price
Robert M. Walker

1970: William J. Bair
James W. Cobble
Joseph M. Hendrie
Michael M. May
Andrew M. Sessler

1969: Geoffrey F. Chew
Don T. Cromer
Ely M. Gelbard
F. Newton Hayes
John H. Nuckolls

1968: James R. Arnold
E. Richard Cohen
Val L. Fitch
Richard Latter
John B. Storer

1967: Mortimer M. Elkind
John M. Googin
Allen F. Henry
John O. Rasmussen
Robert N. Thorn

1966: Harold M. Agnew
Ernest C. Anderson
Murray Gell-Mann
John R. Huizenga
Paul R. Vanstrum

1965: George A. Cowan
Floyd M. Culler
Milton C. Edlund
Theodore B. Taylor
Arthur C. Upton

1964: Jacob Bigeleisen
Albert L. Latter
Harvey M. Pratt
Marshall N. Rosenbuth
Theos J. Thompson

1963: Herbert J.C. Kouts
L. James Rainwater
Louis Rosen
James M. Taub
Cornelius A. Tobias

1962: Andrew A. Benson
Richard P. Feynman
Herbert Goldstein
Anthony L. Turkevich
Herbert F. York

1961: Leo Brewer
Henry Hurwitz, Jr.
Conrad L. Longmire
Wolfgang K. H. Panofsky
Kenneth E. Wilzbach

1960: Harvey Brooks
John S. Foster, Jr.
Isadore Perlman
Norman F. Ramsey, Jr.
Alvin M. Weinberg

The 2006 Ernest Orlando Lawrence Award Ceremony

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http://www.sc.doe.gov/lawrence/