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Editorial

Proceedings of the Plutonium Futures—The Science 2006 Conference Pacific Grove, California, USA, 9–13 July 2006

1. History

The waters of the Pacific Ocean off the Monterey Peninsula in California made a dramatic backdrop for the 2006 Plutonium Futures—The Science Conference, which took place July 9–13 at the Asilomar Conference Grounds in Pacific Grove. This special issue of the Journal of Alloys and Compounds constitutes the Proceedings of the 2006 Conference. The conference was the fourth in a series of important international conferences focused on plutonium and other actinides that was initiated in 1997 to enhance the international dialogue among scientists on the fundamental properties of plutonium and their technological consequences. This series was also intended to recapture the spirit of cooperation that was originally established in the "Plutonium" conferences that started in 1960 following President Eisenhower's "Atoms for Peace" speech.

Co-organized by Lawrence Livermore National Laboratory and Los Alamos National Laboratory, the Plutonium Futures Conference was cosponsored by the American Nuclear Society, Quantum Design Company, and the FEI Company.

Previous conferences were:

- Plutonium Futures—The Science 1997, August 25–27, 1997, Santa Fe, New Mexico, USA.
- Plutonium Futures—The Science 2000, July 10–13, 2000, Santa Fe, New Mexico, USA.
- Plutonium Futures—The Science 2003, July 6–10, 2003, Albuquerque, New Mexico, USA.

2. Venue

The Asilomar Beach and Conference Center, part of the California State Parks System, was itself one highlight of the conference. The name is derived from two Spanish words: "asilo," meaning refuge, and "mar," meaning sea. The Center encompasses 107 acres of coniferous forest separated from the ocean by sand dunes affording a significant ecological reserve. Conference participants walking through early morning fog encountered numerous birds, raccoons, deer, and warnings of mountain lions sighted in the area.

3. The challenges of Plutonium

In 1940 Seaborg, McMillan, Kennedy, and Wahl synthesized plutonium, element 94, in a cyclotron at the University of California at Berkeley. The following year Seaborg, Kennedy, Wahl, and Segre demonstrated that the plutonium isotope with mass number 239 was fissionable with low energy neutrons. When plutonium-239 undergoes fission, the nucleus releases enormous amounts of energy. One kilogram of this metal, when fissioned, is equivalent to about 22 million kWh of heat energy. The controlled release of this energy can be fruitful and fearsome. Plutonium fission in nuclear power reactors is used to provide large amounts of electricity globally and is the basis for many nuclear weapons. It is clear that the plutonium challenge is not only scientific, but also political and socioeconomic as well. Sixty-seven years after its discovery, the solid-state physics and chemistry of plutonium pose extraordinary challenges that continue to demand the attention of scientists around the world.

The physical and chemical behavior of plutonium is arguably the most complex of any element. This complexity derives from its position in the actinide series where the 5f electrons transition from de-localized to localized behavior. Plutonium joins with virtually every other element to make compounds, complexes, or alloys. The aqueous chemistry of plutonium is complicated by its existence simultaneously in four oxidation states. Plutonium metal exhibits six solid-state phase transformations, more than any other element. Density changes that are large and poorly understood occur as it transitions through these phases. Hence, recent research for both the chemical and solid-state aspects of plutonium were presented and discussed at the Conference.

4. Attendees

The international interest in the conference was reflected in its attendance statistics. Twenty-six countries were represented at the conference and over 270 papers were presented in oral and in poster sessions. Of the 359 registered attendees, 43% were from the host country, the United States. Other countries with substantial representation included Russia 14%, France 14%, the United Kingdom 10%, Japan 5%, and Germany 4%.

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5. Conference program

Plutonium Futures—The Science 2006 provided opportunities to examine present knowledge of the chemical and physical properties of plutonium and other actinides in complex media and materials; to discuss the current and emerging science (chemistry, physics, materials science, nuclear science, and environmental effects) of plutonium and actinides relevant to enhancing global nuclear security; and to exchange ideas. This international conference also provided a forum for illustrating and enhancing capabilities and interests, and assessing issues in these areas. U.S. and international scientists, engineers, faculty, and students from universities, national laboratories, and DOE's nuclear complex were encouraged to participate and make technical contributions.

The Conference ran from Sunday, July 9 through Thursday, July 13. A popular aspect of the conference was the opening tutorial session on Sunday afternoon intended for students and scientists new to the area of plutonium research. The tutorial was well attended by novices and veterans alike, and featured such diverse topics as: plutonium metallurgy, plutonium in the environment, and international arms control and nonproliferation. Beginning Monday, two plenary lectures began each morning and each afternoon session and highlighted the breakout sessions on coordination/organometallic chemistry, solid-state physics, environmental chemistry, materials science, separations and reprocessing, advanced fuels and waste forms, phase transformations, solution and gas-phase chemistry, compounds and complexes, electronic structure and physical properties, and more.

5.1. Chemistry highlights

The papers included in these proceedings describe progress in a broad range of plutonium and actinide chemistry from gas phase and solution thermodynamics, to new separation, analytical, and theoretical methods, to environmental stewardship. Progress is presented in developing inert matrix and other fuels for nuclear reactors, advanced separations processes for partitioning of spent nuclear fuel, and improved waste forms. The complex redox chemistry of plutonium in aqueous solution alluded to above is discussed in a number of papers from the identification of reaction mechanisms and intermediate products, including Pu(III), in the PUREX process, to the thermodynamics of PuO_{2+x}, to the evidence for a new oxidation state of plutonium in aqueous solution, Pu(VIII). Advances in understanding the aqueous and non-aqueous solution chemistry of plutonium and other actinides are described in many contributions including experimental and theoretical approaches. In the area of nuclear forensics, case histories of nuclear materials confiscation and the successes of applying forensics protocols to determine attribution and possible intention are provided. The understanding of environmental transport mechanisms of plutonium is shown to be important at sites around the world including Rocky Flats in the U.S., the Yenisei River in Russia, and the Chernobyl Site Object Shelter in the Ukraine. We hope the reader will find the progress presented in this proceedings useful and the challenges remaining intriguing.

5.2. Solid-state and materials highlights

Plutonium solid-state and materials research is represented in these proceedings by a wealth of leading edge discovery class research. The breadth of this research is reflected in the topics covered:

- solid-state,
- materials science,
- superconductivity,
- phase changes, phonons, and entropy,
- electronic structure and physical properties,
- surface science and corrosion,
- radiation effects, defects, impurities, and property changes.

Indeed the scientific challenge and excitement of plutonium can best be highlighted by quoting the tutorial prospectus of Drs. Sarrao and Schwartz. "Plutonium has long been recognized as a complex and scientifically rich metal. The challenge of Pu derives from the fact that its 5f electrons are neither fully localized nor fully itinerant. The resulting low energy scales lead to competing interactions and important entropic and lattice considerations as well. As a consequence, plutonium is on the verge of magnetic order and can be stabilized in a variety of crystal structures. The past several years have seen a renaissance in plutonium materials research. Despite significant progress and important breakthroughs, metallic plutonium remains a mystery at the frontier of materials research . . .." As we hope you will discover, much progress is being made that is reflected in these proceedings. More importantly however, is that the papers herein also inspire new experiments and theoretical approaches that we trust will not go unnoticed by the reader.

5.3. Other highlights

Lively roundtable discussions were held on Monday and Tuesday evenings with expert panelists, focused on Legacy Issues and New Strategies for Advanced Nuclear Fuel Cycles. Three poster sessions with a total of 180 presentations were held on Monday and Tuesday evenings and Wednesday afternoon and added greatly to the technical exchanges among the conference participants.

On Wednesday, the Conference Banquet and two thought-provoking lectures by Drs. Gerry Lander and Siegfried Hecker addressing "Plutonium Science Futures" and "Plutonium World Futures" followed an evening bonfire on the beach. Later, Lander and Hecker were recognized for their outstanding contributions to plutonium science and their leadership in fostering this conference series. After the talks, the conference committees and staff were recognized for their hard work and the Best Student Poster Awards were presented. The most coveted of the Student Poster Awards, sponsored by Springer Publishers, was a copy of the five-volume set of *The Chemistry of the Actinide and Transactinide Elements* (see Actinide Research Quarterly, first/second

quarters 2006). The volumes were premiered and released at the Conference. The editors of this useful compendium were present as were numerous coauthors of the many chapters.

6. Pu Futures—the Science, 2008

Plutonium is the linchpin of any future nuclear energy strategy. It is a byproduct from "burning" uranium. Next generation nuclear reactors are designed to efficiently use and recycle nuclear fuels in order to conserve precious resources. Safety and waste management, as well as resistance to proliferation, are issues that will be addressed internationally to enable long-term sustainability of nuclear power. A combination of technologies is currently being developed in order to achieve these long-term goals and further efforts are required in fundamental research particularly in the scientific field related to element 94, plutonium. The study of plutonium is a 21st Century Grand Challenge for chemists, materials scientists, and solid-state physicists. Each Plutonium Futures Conference presents another opportunity to bring these communities together.

The next Plutonium Futures—The Science Conference will be in July 2008 in Dijon, France (http://www.pu2008.org/index.html). It will be cosponsored by the Atomic Weapons Establishment (AWE), United Kingdom; the Commissariat à l'Energie Atomique (CEA), France; and European Commission, Joint Research Center, Institute for Transuranic Elements (ITU), Germany, in collaboration with Los Alamos National Laboratory and Lawrence Livermore National Laboratory. We feel this is a further acknowledgement from our international community of the value of this conference series. We look forward to working with them to prepare for another successful conference.

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