

Preface

The idea for this book on actinide nanoparticle research was born during the “Russian–German Symposium on Actinide Nanoparticles” held in May 2009 in Moscow and organized by the Institute Department of Chemistry of the Lomonosov Moscow State University (MSU) and the Institute of Nuclear Waste Disposal at the Karlsruhe Institute of Technology (KIT-INE). The symposium itself is a milestone in a cooperation between MSU and KIT-INE, the Helmholtz-Russian Joint Research Group entitled “Actinide Nanoparticles: Formation, Stability, and Properties Relevant to the Safety of Nuclear Waste Disposal” funded by the German Helmholtz Society and the Russian Foundation for Basic Research.

The research interest in actinide nanoparticles is multifaceted. An obvious interest lies in their importance for safety research related to nuclear waste disposal and assessment of actinide-contaminated sites, as the formation and transport of actinide nanoparticles is an environmental concern that is vital not only to our generation but also to future generations. There are other aspects of more basic character, which are a driving force behind actinide nanoparticle research. This research belongs to a distinct realm of nanoscience, but with a history longer than other areas of today’s conventional nanoscience. Modern nanoscience, as a presently well-funded, “sexy” research area, has actually joined the ranks of the area of nanoscience referred to for decades as colloid chemistry or colloid research, including macro- and supramolecular chemistry.

Our endeavors in actinide nanoparticle research entail much more than being simply classified as a sector of nanoscience, however. We are clearly tackling the grand challenge of understanding the behavior of these heavy elements as nanoclusters and nanoparticles with inherent special behavior, reactivity, and structure. Part of this challenge lies in the radioactivity of actinide-containing systems investigated, requiring specialized expertise and infrastructure. It is not always a trivial task equipping instrumentation for nanoparticle characterization to make safe studies of radioactive systems possible and only a limited number of laboratories worldwide have the capability and licensing for working with transuranium actinide elements. Certainly an exceptionally challenging aspect is the

theoretical description of heavy actinide elements. Experimental observation and interpretation on the nanoscale is driving instrumentation and method development and the thrust to couple experiments on actinide systems with quantum chemical calculations is promoting advances in theory. Theoretical, computational description of 5f element systems must deal with numerous electrons in (5f, 6d, 7s, and 6p) orbitals close in energy, requiring scalar and often spin-orbit relativistic effects or electron correlation effects.

Many chapters of this book, but not all, are an extension or overview of presentations given at the Russian–German Symposium on Actinide Nanoparticles. The first chapter Actinide Nanoparticles – Generation, Stability, and Mobility is a summary of the presentation given by Professor Horst Geckeis at the symposium and is an excellent discourse on the state of knowledge and the importance of environmental actinide nanoparticle behavior. The remaining chapters of this book are divided into four sections dealing with different aspects of actinide nanoparticle research, in a manner similar to the structure of the symposium: Methods, Modeling, Surface Reactivity and Environmental Behavior. In the Methods section, we have included imaging, spectroscopic and separation techniques covering overviews of previous studies (STXM, FFF, and MS), newer results (STEM), and a chapter on a newer spectroscopy offering great potential for direct characterization of actinide nanoparticle bulk electronic structure (RIXS). The Modeling section includes not only a treatise on modeling of colloid-mediated actinide transport in the environment but also a chapter on the outlook of quantum chemical strategies for computing actinide nanoparticle structures. This is followed by a section on Interfacial Phenomena and Formation of Actinide Nanoparticles. The interfacial phenomena are addressed in three separate chapters, one reporting new results from an investigation of actinide ion interaction with silica nanoparticles, the second chapter on well-defined thin films produced under controlled sputtering conditions as models for reactive surfaces, especially spent fuel but potentially applicable for advancing our understanding of actinide nanoparticles with inherent large surface to bulk ratios. The third chapter in this section deals with novel structures of uranium selenate clusters, which can serve as models for formation and reactivity of certain classes of actinide nanoparticles. The last section presents results from previous and new investigations of actinide nanoparticle environmental behavior. Four of this section's chapters deal with anthropogenic actinide contamination legacies; the last chapter reports new results of X-ray tomography investigations with nanoscale resolution and techniques offering a potentially encouraging outlook for future research activities.

Ultimate goal in actinide nanoparticle research of attaining a level of understanding, which permits us to predict and ultimately control actinide behavior in systems covering the entire size-scale range – from ion, to nanoclusters, to nanoparticles and microparticles, up to bulk, condensed systems – is not only a noble ambition necessary for providence of modern society, it is at the forefront of research. Potential applications include synthesis of actinide systems targeted toward novel structures, as well as selected chemical and physical characteristics, and reliable prediction of actinide mobility in geochemical milieus on a long-term

timescale necessary for safety assessment of nuclear waste disposal concepts and strategies for eliminating/minimizing risks associated with contamination legacies. This is indeed a grand challenge. This humble endeavor, as the first book published on the subject of actinide nanoparticle research, represents one step in our exciting journey into the fascinating domain of the multifarious actinide nanoscopic world.

Karlsruhe, Germany
Moscow, Russia
February 2011

Melissa A. Denecke
Stepan N. Kalmykov

Actinide Nanoparticle Research

Kalmykov, S.N.; Denecke, M.A. (Eds.)

2011, XIX, 440 p., Hardcover

ISBN: 978-3-642-11431-1