Thin Actinide Targets

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Stewardship Science Academic Programs (SSAP) is supporting a research project to investigate novel approaches for the preparation of actinide targets that are isotopically pure, cost-efficient, reliable, robust, and highly uniform with controlled thicknesses. The project started on October 1, 2018 and presently involves three graduate students (Stefania Dede, Cyclotron Laboratory of Texas A&M; Ashabari Majumdar and Jordan Roach, University of Notre Dame (Notre Dame)) and one undergraduate student (Jacob Galden, Notre Dame).

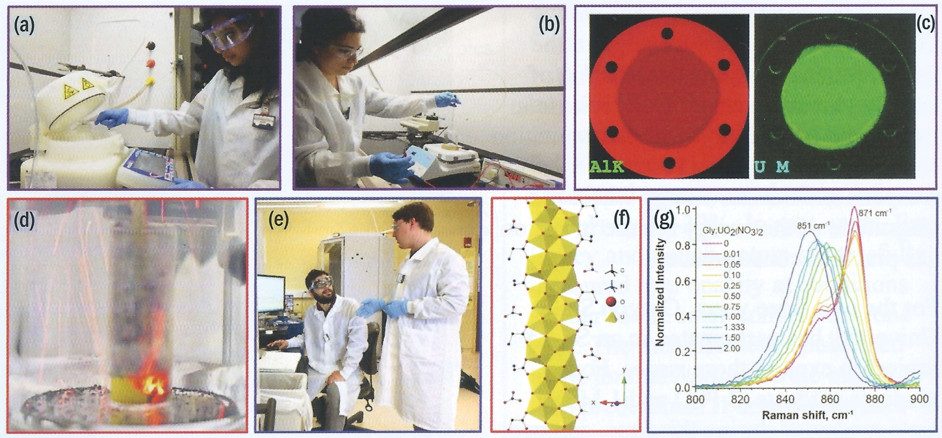

Figure 1. Shows preparation of thin actinide films by CS in combination with the spin coating (a) and spraying (b). X-ray fluorescence imaging of a target prepared by CS and spin coating (c). Investigation of the CS process in bulk solutions (d). X-ray crystallographic analysis of intermediates (e). The structure of the glycine-uranyl coordinate compound (f). Raman spectra of reactive solutions with different glycine-uranyl nitrate molar ratios (g).

The principal investigator of the project, is Ani Aprahamian, Professor of Physics at Notre Dame. This project brings together expertise from material science, radiochemistry, and nuclear science. The aim of the project is to develop new ways to prepare thin actinide targets for research in nuclear science and stockpile stewardship. This grant provides exciting opportunities for carrying out cutting-edge research while educating the next generation of STEM scientists capable of exploiting the techniques that are developed. This project expands the scope with novel techniques and the training of new personnel that can satisfy national needs at both Los Alamos and Lawrence Livermore National Laboratories.

The nuclear science and stockpile stewardship components rely on experiments to extract key nuclear cross-section and structure information. Typically, thin, uniform films of radionuclides with thicknesses in the range of from few to several hundreds of nanometers are deposited on a backing. Current target preparation techniques are based on decades-old approaches that do not take advantage of recent developments in materials science. This project develops revolutionary new approaches for the preparation of actinide targets.

The novelty relies on the use of combustion synthesis (CS) reactions between actinide metal nitrates (or metal-oxide clusters) with different organic compounds. CS of thin-film targets involves deposition of reactant solutions on backings using spin coatings (Figure 1a) and spraying processes (Figure 1b) followed by short periods of heating, resulting in rapid exothermic chemical reactions in thin solution layers. The result is the formation of crystalline actinide oxide films with desired tunable thicknesses. For example, Figure 1c shows an X-ray fluorescence image of a thin uranium oxide film formed on an aluminum backing. The distribution of Aluminum K and Uranium M X-ray lines indicate that the uranium layer is distributed uniformly on the substrate. The project also is utilizing an array of spectroscopic, electron microscopic, and ion beam analysis methods to investigate the effectiveness of the process parameters on the composition, uniformity, adhesion, and other characteristics of the thin films.

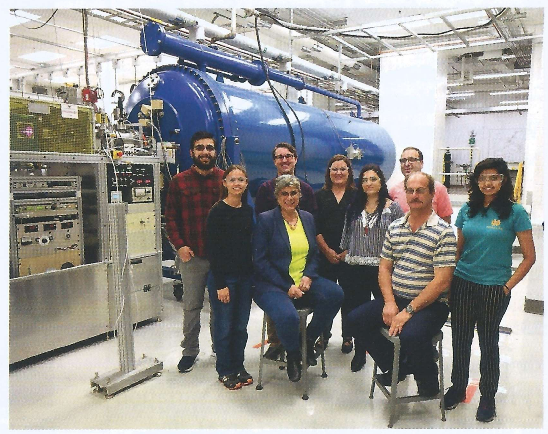

Figure 2. Team members of the project, from left to right: Jacob Galden, Dr. Ginger Sigmon, Jordan Roach, Prof. Ani Aprahamian, Jennifer Szymanowski, Stefania Dede, Dr. Khachatur Manukyan, Prof. Peter Burns (Director, NNSA Actinide Center of Excellence), and Ashabari Majumdar.

The research program also investigates CS (Figure 1d) in a bulk solution to establish relations between processing conditions and characteristics of the resulting products. Students utilize X-ray crystallographic methods (Figure 1e) to investigate intermediate products of the reactions to reveal the chemical mechanisms of these processes. For example, recently a glycine-uranyl coordinate compound (Figure 1f) was isolated from reactive solutions. The exothermic thermal decomposition of this compound can be the driving force of the CS process. Currently, this research is being complemented by in-depth investigations of reactive solutions using Raman spectroscopy (Figure 1g) and other methods to reveal the mechanism of chemical reactions that govern thin film deposition for nuclear target preparation.

The training of a diverse student body with interdisciplinary skills is an essential part of the project (see Figure 2). The students are being exposed to a wide range of experimental techniques related to actinide chemistry, preparation of targets, characterization of actinide materials by ion beam analysis and X-ray based techniques, vibration spectroscopy, electron microscopy, and other methods. Such a cross-disciplinary program prepares the next-generation of leaders in nuclear science that can be integrated into the workforce of the national laboratories.