

Nuclear Forensics: Deciphering nuclear device components within post-detonation materials

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Nuclear Forensics is defined as “the technical means by which nuclear materials, whether intercepted intact or retrieved from post-explosion debris, are characterized (as to composition, physical condition, age, provenance, history) and interpreted (as to provenance, industrial history, and implications for nuclear device design).” Detailed investigation of post detonation material (PDM) is critical in preventing and/or responding to nuclear-based terrorist activities/threats. However, accurate identification of nuclear device components within PDM typically requires a variety of instrumental approaches and sample characterization strategies; the latter may include radiochemical separations, mass spectrometry, decay counting measurements, microscopy, and expertise from various fields, such as chemistry, geology, and physics. Cleverly designed approaches can simultaneously provide insight into a material’s “age” (i.e., time elapsed since last purification), actinide concentrations, and relevant isotopic ratios/enrichment values. Consequently, these signatures are invaluable in determining the origin, processing history, and intended purpose of a nuclear material, and are data that will be used by pertinent law enforcement agencies.

The ultimate technical objective of nuclear forensic analysis is to determine the source attributes of the pertinent radioactive specimens, which for the purposes of this lecture shall be limited to PDMs. Specifically, the results and discussion presented in this chapter shall focus on recent, detailed, *in-situ* (micron-scale) investigations of ‘*Trinitite*’; the PDM resulting from the first atomic weapon test ‘*Trinity*’ conducted on the White Sands Proving Grounds (south of Alamogordo, NM) at 5:29:45 a.m. on July 16, 1945. PDMs from historic test sites, such as trinitite, provide an excellent opportunity to establish and verify forensic protocols, as the nature of the device components employed are relatively well documented. Timely forensic investigations of PDMs are needed to reveal the elemental and isotopic compositions of the device and associated components so that source attribution can be made rapidly and accurately. Deciphering the chemical/isotopic composition of a nuclear device from PDMs in a relatively rapid manner will also serve as a strong deterrent to nuclear terrorism. However, factors that complicate forensic analysis of PDMs include the inherent heterogeneity (mineralogical, chemical, isotopic) of the materials present at ground zero, and possible overlapping signatures of the natural and anthropogenic (device) components. Moreover, traditional investigative methods for post-detonation are time-consuming, and those involving bulk sample digestion followed by chemical separation tend to homogenize (average) the chemical and isotopic signatures; hence obliterating valuable forensic information present at the micron-scale.

To date, my research team has focused its efforts into the detailed, micron-scale mineralogical, chemical, and isotopic characterization of ~70 samples of trinitite. Most of the results presented in this chapter were obtained using extra thick (~70 to 100 microns) standard petrographic thin sections of trinitite; in contrast, gamma spectroscopy experiments were conducted using bulk trinitite samples. Results reported here were obtained from various *in-situ*, microanalytical

techniques that provide relatively *rapid*, spatially resolved chemical and isotopic data of trinitite; several are based on laser ablation- inductively coupled plasma mass spectrometry (LA-ICP-MS). Of importance, these *in-situ* results document the inherent and significant chemical/isotopic variability present within individual trinitite samples at the 10s to 100s micron scale.