Measurement of low-dose irradiation effects in PTFE using differential scanning calorimetry

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Uranium centrifuge enrichment is inherently a dual-use technology, and verification of the production histories of such facilities may be required as part of non-proliferation agreements. Currently, there are no forensic measurement techniques that can be performed to reconstruct enrichment histories quantitatively. However, a method based on differential scanning calorimetry (DSC) may be able to capture historical information left in uranium-facing components through low-dose radiation damage by the alpha-decay of uranium. This work focuses on the first steps in development of this technique for the polymer polytetrafluorethylene (PTFE), a common material for gaskets. Through investigating the sensitivity of the material and the instrument to radiation effects, the usefulness of the technique can be determined and the limitations understood.

We irradiated PTFE with helium ions at energies and fluences comparable to those expected from enriched uranium in the envisioned application. Because such conditions are based on the radioactive decay of uranium isotopes, these conditions represent extremely low doses. DSC measurements revealed changes to the melting and crystallization behaviour of the polymer, which is attributable to chemical changes in the material. Analysis shows a correlation between enthalpies of the reactions and fluences at centrifuge-relevant doses. These results are further improved by elimination of systematic variation through iterations of the experiment. Having taken these firsts steps towards developing DSC as a forensic technique, the lessons learned will guide further development of the experimental technique and influence investigations of new materials.