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**Probing plutonium dioxide nanoparticles with various synchrotron methods**

Plutonium is one of the most complicated element among actinides. It can exist in four different oxidation states (III, IV, V, VI) under environmental conditions. Due to the small value of standard electrode potentials among these linked oxidation states plutonium can change its oxidation state easily. Moreover, plutonium may exist in several oxidation states simultaneously, which makes its chemistry even more complex.

It was previously shown that plutonium migrates in colloidal form in the subsurface environment with the distance of several kilometers. It turned out that so called “colloidal Pu(IV) polymers” are in fact aggregates of PuO2 nanoparticles with diameters ~ 2 nm. However, the certain structure and stoichiometry of these colloids, as well as presence of other oxidation states but Pu(IV) is still debated.

This contribution will show results of plutonium oxide nanoparticle studies at the large-scale facility – The European Synchrotron (ESRF) by complementary methods that used X-rays in different regimes to probe the Pu oxide nanoparticles. Samples were prepared by rapid chemical precipitation using precursors in the different oxidation states (Pu(III), Pu(IV), Pu(V) and Pu(VI)). These precursors were obtained by chemical reduction or oxidation of Pu stock solution. The obtained nanoparticles were characterized at the different beamlines at the ESRF. It gives the opportunity to study our samples with various techniques: X-ray diffraction (XRD), pair distribution function analysis (PDF), and several types of spectroscopies: high energy resolution fluorescence detection (HERFD) at L3 and M5-edges, X-ray emission spectroscopy (XES) and extended X-ray absorption fine structure (EXAFS) spectroscopy. The applying multifold synchrotron methods benefits to discover features, which may be unclear or even indistinguishable, these approach is also crucial to confirm results, obtained with individual methods.

It was found that small (2 nm) nanoparticles are formed from the Pu(III), Pu(IV), Pu(V) aqueous solutions, with the crystal structure close to PuO2, without any other Pu-O contributions or oxidation states of Pu except Pu(IV).