Actinide behavior in biphasic alpha contaminated waste package

HOTLAB 2019

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I. Industrial context
Industrial context: Initial waste characterization

- Intermediate Level – Long-Lived alpha contaminated waste

- Materials used in glove boxes of MOx production and spent fuel reprocessing plants (operations, maintenance, dismantling...)

- Incompatible with existing treatment processes without prior separation due to the heterogeneous nature of the waste (metallic and organic components)
Industrial context: Objectives of the study

- Conditioning of the initial waste in a package acceptable for deep geological disposal in National French Radioactive Waste Management Agency ANDRA facilities.

- Long term stability (destruction of the organic material).

- Volume reduction.

- Containement of radionuclides.

- No pre-treatment.
Industrial context: Qualification

Inactive laboratory trials
- Parametric study
- Gateway study

Actinide surrogate data collection

Laboratory-Technology Gateway: Upscaling surrogate behavior

Active-inactive gateway: Surrogate representativeness

Radioactive trial
- Parametric study with U
- Pu and U study (distribution and data)

Technological trials

Actinides localization in PIVIC waste package
Industrial context: PIVIC process

- Innovative one step thermal treatment process
- Coupling of existing technologies: plasma incineration and low-frequency induction melter
- Organic matter destroyed by incineration
- Ashes digested in glass fraction
- Metal components melted
- In-can process: no need of pouring system
Industrial context: Final waste package

- Compact bi-phasic metal glass package
- Strong volume reduction
- Metallic fraction below
- Glass fraction above containing ashes and actinides
- Clear demarcation between the phases
- Concrete added for the purpose of the can cutting
II. Radioactive waste and vitrification process research laboratory
Radioactive waste and vitrification process research laboratory: Missions

MISSIONS
- Studies on the incorporation mechanisms of radionuclides in nuclear waste conditioning matrices (glasses and glass-ceramics).
- Studies on the radiation effects on nuclear materials (conditioning matrices, spent nuclear fuel, corium...).
- Long-term behavior model development of nuclear waste material under interim storage or deep geological disposal conditions.
- Support to the dismantling/decommissioning activities by the characterization of highly radioactive materials.

ACHIEVEMENTS
- 2002: 1st study on $^{238}$Pu doped ceramic
- 2006: Contribution to the scientific report for the “Bataille” act
- 2009: Synthesis of the 1st $^{241}$Am and $^{244}$Cm doped glass-ceramics
- 2012: 1st leaching experiment under environmental disposal conditions and alpha radiolysis
- 2017: 1st leaching experiment on prototypical corium to support the Fukushima site
- 2019: 1st electronic microprobe mapping on High Level Waste for dismantling-decommissioning activities
Radioactive waste and vitrification process research laboratory: C18/C19 Hot cells

LEACHING TESTS
- Dynamic mode ( Soxhlets )
- Static mode ( Autoclave )
- $^{60}$ Co irradiator
- Furnace (1150°C)
- Gas phase chromatography

PHYSICAL MEASUREMENTS
- Optical microscopy
- RAMAN spectrometry
- Gamma scanning
- Mechanical properties measurements ( hardness, Young modulus )
- Density measurements

PHYSICO-CHEMICAL ANALYSIS
- Calorimetry ( thermal power, heat capacity )
- Thermal treatment furnaces (1500°C)

SAMPLE PREPARATION
- Cutting
- Embedding
- Polishing
- Grinding
- Sieving
- Micro core drilling

MATERIAL SYNTHESIS
Calcination/Vitrification process
High temperature furnace (1500°C)
Radioactive waste and vitrification process research laboratory: L29 Solid characterization laboratory

SEM-EDS mapping Prototypical Corium
- X-Ray Diffraction
- Scanning Electron Microscope-EDS
- Electron Probe Micro-Analysis

EPMA mapping Glass-ceramic
Radioactive waste and vitrification process research laboratory: L30 Leachate and solutions analysis laboratory

LEACHATE ANALYSES LABORATORY

- ICP AES
- Radiometry ($\alpha$, $\beta$, $\gamma$)
- Kinetic Phosphorescence Analyzer (U)
- Ionic chromatography
- UV visible spectrometry
- Gas phase chromatography
- Chemiluminescence
- Carbon measurements
- Leaching tests in inert atmosphere
### III. Actinide behavior

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<tr>
<th>Element</th>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Mass Number</th>
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### Periodic Table of Elements

[Periodic Table Image]
Actinide behavior: Non-radioactive mockup

- Elaboration parameters determined during numerous tests
- Base for comparison with radioactive sample
- Hafnium simulates the behavior of Uranium and Cerium simulates Plutonium
Actinide behavior: Thermal elaboration in hot cells

- Mixed metals + glass powder + MOx powder
- Proportions have been determined in non radioactive trials
- Melted at 1400°C under inert atmosphere
Actinide behavior : Sample preparation

- Multi phasic material : sampling difficult due to separation of phases during cutting

- 2 samples have been isolated, embedded and polished :
  - Glass fraction on top
  - Bottom of the crucible containing metal, glass and crucible interactions
- First optical images of the samples
Conclusions and prospects

- New IL-LL waste required an innovative solution for treatment and long term disposal.

- In-can Vitrification Incineration Process in development as a collaboration between Orano, CEA and ANDRA

- First radioactive sample with Uranium and Plutonium has been prepared.

- Radioactive samples are now being characterized to compare with surrogate behaviors
  - RAMAN spectroscopy and X-ray diffraction will help identify the different phases
  - Optical and scanning electron microscopy will determine the microstructure of those phases
  - Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy and electron microprobe analysis will be performed to chemically map the samples
Thanks

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