Design and fabrication of miniaturized extraction devices for sample purification hyphenated to elemental and isotopic analysis

One of the research topics of the Nuclear, Isotopic, and Elemental Analytical Development Laboratory (LANIE) at the French Atomic Energy and Alternative Energies Commission (Saclay center), is the miniaturization of analytical methods and techniques. In line with our objective, we are focused on downscaling the sample purification steps performed by solid-phase extraction chromatography. These steps are commonly carried out using prepackaged columns with resin-based particles in order to isolate actinide fractions prior to their elemental and isotopic analysis by mass spectrometry (Figure 1). Our strategy is based on the implantation of functionalized polymeric monoliths within the channels of microsystems made of cyclic olefin copolymer (COC), material known to be easy to process but chemically inert. The methodology for the synthesis and *in situ* anchoring of actinide-specific monoliths in hundred-micrometer-scale channels is currently being improved, using commercial COC chips of simple geometry (Figure 1).

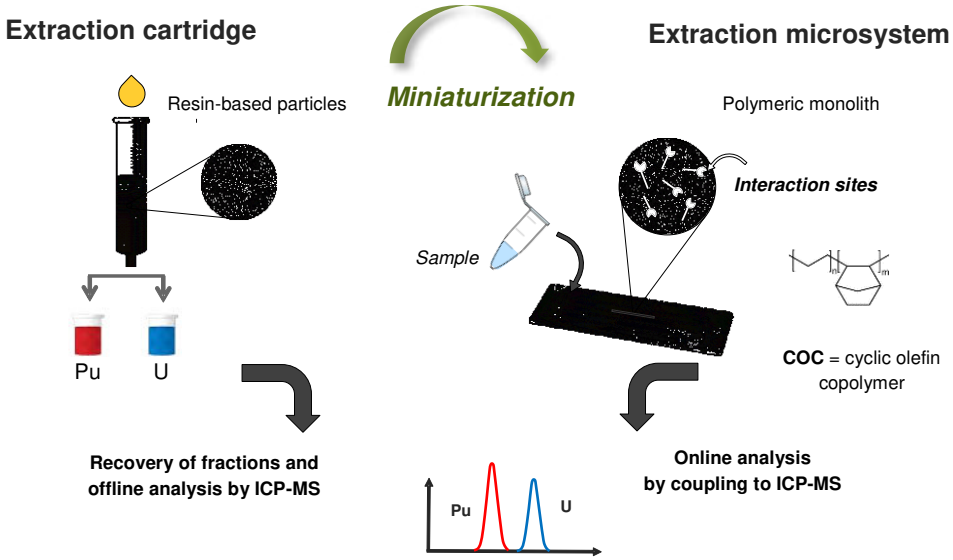

Figure 1: *Proposed approach for the downscaling of the solid phase extraction chromatography sample purification steps*

Once this key step is validated, this project aims to set up a comprehensive analytical pipeline in the laboratory, starting from the design, prototyping, and manufacturing of integrated miniaturized extraction devices, up to their de facto implementation for the reduced-scale analysis of samples for monitoring in nuclear facilities, treatment processes, environmental inquiries, and forensic issues.

The candidate will be in charge of:

- **Microfluidic device design and micro-fabrication:** first, custom-integrated miniaturized devices, having more complex geometry than commercial straight-channel chips, will be designed using computer-assisted design tools (Solidworks, VisualCADCAM). These integrated devices will comprise the extraction microsystem based on monolithic supports, the associated connectors and holders for easy control and connection to the auxiliary instruments. The second step will involve prototyping these miniaturized devices and manufacturing them based on the final design. To this end, a state-of-the-art CNC micro-milling machine and 3D printer will be used to produce and optimize the modeled devices.

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- **Surface functionalization:** the actinide-specific polymeric monoliths developed in the laboratory will be first synthesized and anchored *in situ*, in the channels of commercial microfluidic chips to control their implantation in COC material. Based on the same protocol, the robustness of the *in situ* covalent anchoring of these monoliths will then be validated in the channels of the extraction microsystems custom-engineered in the laboratory.
- **Instrumental and analytical chemistry**: the integrated miniaturized extraction devices will be set up to develop and validate the downscaling of sample purification steps. First of all, these devices will be connected to inductively coupled plasma mass spectrometry (ICP-MS) in a conventional laboratory, for the separation and online elemental and isotopic characterization of small quantities of U, Th, and Sm, that function as actinide analogs. The methodology will then be transferred to the downscaling of U- and Pu-based samples in a restricted area, using instruments installed in glove boxes.

The candidate will benefit from the laboratory's skills in micro-machining, microfluidics, and analytical chemistry in the field of high-precision elemental and isotopic characterization and coupling of separation techniques to mass spectrometry. He/she will also benefit from the state-of-the-art analytical instruments, micro-fabrication tools as well as the material characterization techniques available within the laboratory and the institute. He/she will be expected to interact with other CEA laboratories on the Marcoule site. The work will be substantiated by communications, publications, or patents.

The skills and experience acquired by the candidate will be a valuable asset for his/her professional profile in a growing field of analytical techniques, microfluidic technology, and microfabrication. He/she will be able to extend his/her knowledge to analysis of various samples originating from numerous areas such as recycling of valuable materials, nuclear sector, environment, toxicology, biomedical, food, fraud-prevention, and cultural heritage.

Required profile:
PhD in Analytical Chemistry/Microfluidics/Polymer Chemistry
Previous experience with surface functionalization and analytical chemistry would be considered a valuable asset.
Strong interest in experimental work, autonomous, rigorous and creative force.
Teamwork, and interdisciplinary research.
Strong writing, communication, and organizational skills.

Keywords: micro-fabrication, microfluidics, surface functionalization, solid phase extraction chromatography, instrumental analysis, elemental and isotopic mass spectrometry, coupling

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Starting date: April/May 2024, for 24 months

Please send your CV\Resume\Motivation letter to: carole.bresson@cea.fr