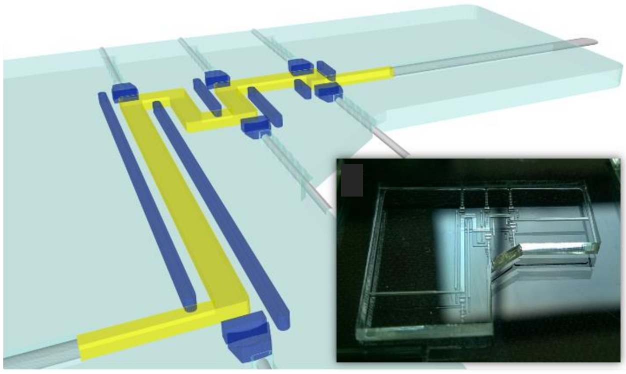
Proposition for a post-doctorate position

"Optofluidics integrated on microchips in a nuclear environment"



Context: The project described here is part of the work carried out by the CEA concerning present and future processes for the treatment/recycling of spent nuclear fuels. The study and development of these processes require many steps, from design in the laboratory through to setting up on an industrial scale. In all of these steps, analysis and instrumentation are key points. For scientific reasons (small-scale studies, control of phenomena, etc.) but also as regards minimizing costs, risks, and waste, such developments are increasingly carried out by the CEA teams on CEA milli/microfluidic devices. The logic is the same for the analyses associated with their follow-up and their interpretation. Due to this, over the last few years the CEA Marcoule has been designing and developing analysis devices on opto/microfluidic systems adapted to the different processes (dissolution, liquid/liquid extraction, precipitation, etc.) studied there. The post-doctorate work proposed is part of this approach.

Project description: The main part of the techniques implemented at the CEA Marcoule are based on optofluidic systems integrating optical measurement devices on microfluidic chip. Most of them have come from past developments [1]. Among the optic methods assessed at this stage, we can mention: absorption spectrophotometry [2, 3], the use of evanescent waves [4], thermal lenses [5] and also fluorescence. All these techniques have advantages and drawbacks. However, at present absorption spectrophotometry remains the most polyvalent and the most efficient to quantify the species of interest present in solution. For example, the first trials carried out in a microfluidic chip with this technique on uranium (VI) showed that it was easy to cover ranges of concentration adapted to monitoring processes (from 0.1 to 200 g L^{-1}) with just 3 microliters of solution. This post-doctorate project is intended to take the earlier work further via three development axes:

"Choice of techniques and materials". The first trials were performed with microchips in PDMS (Polydimethylsiloxane) specially fabricated by CEA teams [6] but other materials could be envisaged, for example glass (cf. the company FEMTOprint), plexiglass (material worked in machining by teams at CEA Saclay), etc. The first task to perform will be an in-depth benchmarking of the advantages and drawbacks of these different materials, following a comparison grid including the optical properties (collimation of integrated lenses, transport of light, etc.), resistance to different liquids (HNO_3, Solvent), and exposure to ionizing radiation, as well as the material's ability to be easily used [7] in a hostile environment (within a glove box, etc.).

"Signal processing and microchip design optimization" To date, the only trials completed have concerned the measurement of U(VI) in aqueous solution. Obviously this is not the only species of interest when monitoring processes. Once the technology has been decided on, the second task will therefore be to study the performances of adsorption spectrophotometry on microfluidic chips for the species U(IV), U(VI), Pu(IV), and Pu(III), alone or in a mixture, in an aqueous phase (HNO_3) and in an organic phase (diluted solvent), knowing that these elements give high levels of spectral interference. At this stage, the different methods for spectrum processing and deconvolution developed by the CEA will need to be adapted to any special features of measurements which involve a microfluidic device. Microanalysis coupling and integration in microfluidic systems to enable the study of different processes will therefore also be part of the objectives for this development task.

"Integration of optical components" The last point to study concerns the complete integration of light sources and detectors onto the optofluidic device. For several years, optofluidic systems have included mirrors, lenses and even wave guides [8]. More recently, some teams have shown that it is possible to integrate a light source, a wave guide and a detector on a single system [9]. In the post-doctorate described here, the interest and the potential of these approaches for the strictly-contained environments used in the nuclear industry will be examined via a scientific watch. This will involve identifying the most promising work and contacting the research teams concerned with a view to establishing collaborations.

Work on these three aspects must be carried out in close association with the Marcoule teams in charge of separation process R&D (dissolution, liquid-liquid extraction, precipitation). The experiments should take place as much as possible in association with trials run by these teams.

Profile sought: PhD in science or doctor-engineer, in the field of micro/millifluidics, preferably applied to analyses and instrumentation. The applicant must have a solid background in physics (optics) and in instrumentation, and master microfluidics tools, their use and possibly their design/fabrication. Ideally, more specific knowledge in process engineering will be appreciated, but is not indispensable. Good communication skills are required in order to add value to the work via participation in international congresses and in publications.

Host team: The host laboratory is the **L**aboratoire de **G**énie **C**himique et **I**nstrumentation (Chemical Engineering and Instrumentation Laboratory) of the CEA Marcoule (LGCI). The LGCI carries out the design, development and the reliability testing of technologies and processes related to the nuclear fuel cycle. Its research domains include:

1. The development of technologies associated with individual chemical engineering operations: liquid-liquid extraction, solid-liquid separation, dissolution/digestion, thermal treatment (calcination and fusion), gas treatments…
2. The development and/or nuclearization of prototypes (chemical engineering apparatus, microsystems, etc.) for hostile environment R&D studies.
3. Modeling (chemical engineering, fluid mechanics, etc.) for upscaling from laboratory scale to industrial scale.
4. The development of special instrumentation as supports for small scale trials and for modeling.

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Initial bibliography

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