High pressure / High temperature Microfluidics: Unique tools with multiple applications

Anaïs Cario[1], Olivier Nguyen[1], Cyril Aymonier,[1] Carole Lecoutre[1], Yves Garrabos[1] and Samuel Marre[1*]

[1]*CNRS, Univ. Bordeaux, ICMCB, UMR 5026, F-33600 Pessac, France*

Keywords: high pressure/ high temperature, microfluidics, thermodynamics, materials synthesis, CO_2 geological storage

*e-mail: samuel.marre@icmcb.cnrs.fr

1. Introduction

Over the past 20 years, microfluidics has advanced biological and chemical research, in particular through the integration of analytic techniques [1] with cell handling [2], biochemical assays, chemical synthesis [3] and micro-nanostructures synthesis [4]. However, these tools were so far generally confined to ambient pressure and temperature conditions. Being able to reach high pressure and high temperature conditions with microdevices could open avenues towards process intensification, fast screening and *in situ* investigation for many high pressure applications, which could benefit from the advantages of microfluidics.

2. Results and discussion

Microfluidics exhibit several advantages over conventional macroscale devices. Indeed, microreactors offer a solution to feedback control of temperature, feed streams, reproducibility, flexibility in design to control hydrodynamics, *in situ* reaction monitoring using sensor integration, rapid screening of parameters, fast mass and heat transfer and low reagent consumption during optimization. Additionally, such small, controlled reaction volumes enable reactions to be performed under more aggressive conditions (confining for example small amount of hazardous products). The combination of the size reduction, the use of small quantities of products, the online single and/or multi-phase flows and the improved reliability of the process, can be registered in a sustainable development policy. The recent development of high pressure high temperature (HP / HT) microreactors has offered additional advantages by considerably expanding the synthesis / applications space (typically up to 800 K and 30 MPa). This led to a substantial enlargement of the set of solvents, precursors and surfactants available for chemical reactions, materials synthesis, geological applications and microbiology in extremes conditions, which will be detailed in this talk.

After highlighting the main strategies used to develop high pressure / high temperature compatible microsystems, some applications of HP/HT microreactors will later be presented. In particular, we will focus on:

(i) The development of microfluidics platform for investigating phase diagrams for a quick access to complex mixtures thermodynamic,
(ii) The use of Geological Labs on Chips (HP/HT porous micromodels) for investigating mechanism related to CO_2 geological storage,
(iii) The process of organic materials in particular semi-conducting polymer P3HT and their use for organic electronics and their use in organic electronics,
(iv) The synthesis of inorganic nanostructures nano-materials at supercritical conditions in microreactors. The synthesis of nanomaterials in supercritical microreactors is indeed a versatile approach that takes advantages of the fast heat transfers provided by the microfluidic devices, while benefiting from the high supersaturations occurring at supercritical conditions, leading to high quality nanocrystals.

3. Conclusions

In conclusion, HP/HT microreactors open new experimental routes to get insights in high pressure processes at lab scale. The main interest stands in the ability to easily implement and combine *in situ* and real time characterization techniques, both in flow and in batch mode. The microfabrication provides flexibility in design compared to conventional high pressure tools, while safety is improved thanks to the small volumes. We will eventually introduce some perspectives of the use of HP/HT microreactors in particular in life sciences and geosciences.

Acknowledgments: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 725100 [5].

[1] De Mello, A.J. (2006) Control and detection of chemical reactions in microfluidic systems, *Nature*, **422**, 394-402.
[2] El-Ali J., Sorger P.K., Jensen, K.F. (2006) Cells on chips, *Nature*, **442**, 403-411.
[3] Hartman R.L., Jensen, K.F. (2009) Microchemical systems for continuous-flow synthesis, *Lab on a chip*, **9,** 2495-2507.
[4] Marre S., Jensen K.F. (2010) Synthesis of micro and nanostructures in microfluidic systems, *Chemical Society Reviews*, **39**, 1183-1202.
[5] http://www.erc-bigmac.cnrs.fr/