Surface Functionalization for Solvent-free Capture and Release of Molecules

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A microfluidic platform for solvent-free extraction and preconcentration of pollutants from water has been developed. A microfluidic channel with embedded pillar array is functionalised with a thermo-responsive polymer. This sorbent enables capturing and releasing the analytes by changing the temperature. This technology is fit for analytical methods where the use of an organic solvent is prohibited, such as immunoassays.

Efficient and rapid capture and release of molecules are required in many fields, in particular for the development of grown cell films, clean-up, and biosensing applications. However the biological working environment often prohibits the use of organic solvents in the processing steps, as they can cause damage to the structure of the biological elements.

In this project, we focused on the preconcentration of molecules for their analysis in water samples using bioassays. Preconcentration is often required to bridge the gap between actual levels and limit of detection in the analytical method. It is usually performed by applying solid phase extraction techniques. The sample is flushed through a sorbent in which the analytes have an affinity. The target molecules are then desorbed using an appropriate solution of a given volume. Preconcentration is achieved when the final volume is smaller than the sample. However, this method often requires the use of organic solvents in the desorption step, which is not directly compatible with a detection method involving biological elements.

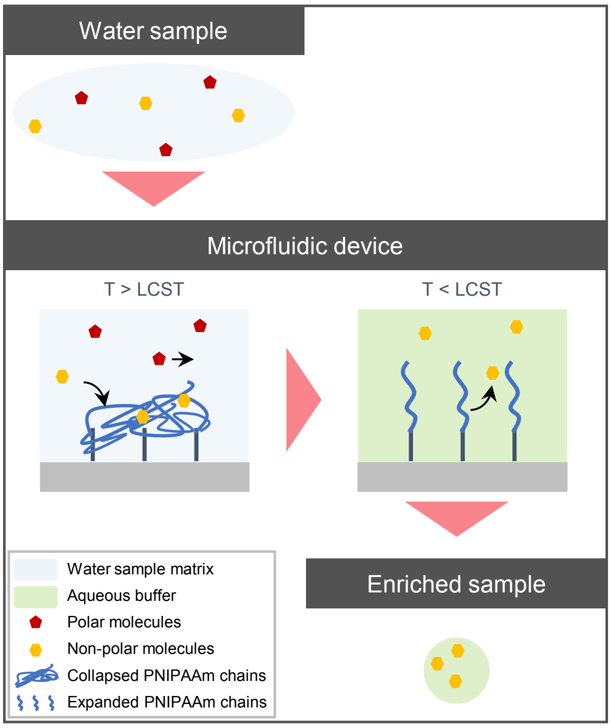

Figure 1: Illustration of the solvent-free extraction and release principle using the thermo-responsive polymer PNIPAAm, where T is the temperature in the microfluidic device and Ts is its switching temperature.

Here we developed a surface coating to enable solvent-free capture and release of molecules from aqueous media. Thermo-responsive polymers are macromolecules that undergo a change of conformation around their lowest critical solution temperature (LCST). Above this temperature, the polymer chains aggregate and become hydrophobic, while they expand in water (hydrophilic behavior) below this value. Such a polymer could be used to replace traditional hydrophobic sorbents.

Figure 1 illustrates the principle of sample preconcentration using a thermo-responsive polymer. Hydrophobic molecules will adsorb on the hydrophobic polymer film on the surface of the fluidic channel when heating above the LCST, while salts, ionic and polar molecules will not. The hydrophobic molecules could then desorb in a fresh aqueous buffer upon cooling below the LCST. High preconcentration factors could be achieved by applying this method in a microfluidic device, enabling the control of tiny volumes of solution.

A polydimethylsiloxane (PDMS) microfluidic device was fabricated and functionalized with Poly(N-isopropylacrylamide) [1] whose LCST is about 32°C. The functionalization consists of the in-situ polymerization of the monomers. The microfluidic channel has embedded micropillars to increase the surface area. The film coating was observed by confocal microscopy as shown in Figure 2. The film density is homogeneous along the pillar walls. A capture and release proof of concept study was performed using a fluorescently labeled IgG biomolecule (IgG*) in phosphate buffer saline (PBS). The molecule successfully adsorbed at T>LCST and desorbed in fresh PBS for T<LCST (Figure 2).

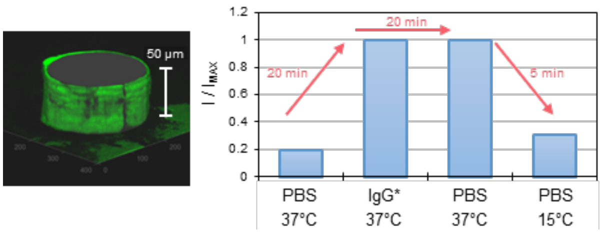

Figure 2: 3D image of a coated micropillar after the injection of IgG, obtained by confocal microscopy, and results of the capture and release study, with I/I_{MAX} the relative fluorescence intensity.*

The application of this method for smaller molecules in environmental samples will be investigated. New copolymers films will be explored to optimize the transition speed and the switching temperature. This project contributes to the development of new green analytical methods for environmental monitoring applications.

[1] S. Heub, X. Mao, P.S. Dittrich, L. Barbe, "A functionalized poly(dimethylsiloxane) chip for solvent-free, temperature actuated solid phase extraction", Proc. of the 19th micro-TAS conference, 2015