Modelling and characterisation of microcapsules

Dr Salsac’s research focuses on the dynamics and mechanical behaviour of microcapsules and their subsequent interactions under the presence of an external flow when placed in suspension. This is an exciting field with potent applications to biofluids and vascular mechanics (e.g., flow of red blood cells in the microcirculation), and to the encapsulation of active substances (e.g., pharmaceuticals, cosmetics). The ability to model and characterise artificial microcapsules could hold the key to optimising drug delivery to specific cells or tissues.

Undoubtedly, the most challenging aspect of generating efficient microcapsules is to ensure their stability, by controlling their deformation in fluid environments.

Microencapsulation is the process of enclosing a core substance within a micrometric-sized particle. Microcapsules are liquid droplets protected by a thin, deformable membrane with elastic properties whose size can vary from a few micrometres to millimetres for the largest ones. The reticulated membrane governs the deformation of the capsule when it is placed in suspensions, and controls the exchanges between the internal and external fluids.

THE IMPORTANCE OF MICROCAPSULES

Micro-encapsulation is a prominent means of protecting a liquid internal medium and allowing its subsequent controlled release if desired – through adaptation of the membrane’s mechanical properties and porosity. Even though this is a well-known technique – in fact, the first microencapsulation procedure was published back in 1931 – recent technological developments have allowed microencapsulation to become a very significant part of scientific research with a number of industrial applications.

CHALLENGES FOR AN OPTIMISED USE OF MICROCAPSULES

Undoubtedly, the most challenging aspects of generating efficient microcapsules is to ensure their stability, and control their deformation in external fluid environments. This requires controlling the deformability of the capsules as well as their dynamics when in suspension.

Owing to the strong fluid–structure interactions with the confined fluid flows, the capsules can be deformed in a complex way under the formidable hydrodynamic stresses. In order to deeply understand their dynamics, there is a need to generate numerical models that predict the behaviour of capsules under hydrodynamic stress.
and to conduct microfluidic experiments.

The other challenge is to design tech to characterise the mechanical properties of entire capsule populations and even that they have the desired behaviour in situ. Micropipette aspiration or indentation by atomic force microscopes have the drawback of necessitating the manipulation of individual particles, which is cumbersome.

The development of microfluidics has new techniques of characterisation been devised: the membrane resistance is determined from the flow of capsule suspensions in microchannels, provided one can numerically model the capsule deformation under the exact same flow conditions as those prevailing in the microsystem.

This concept of combining highly complex numerical modelling with microfluidic experiments is exactly what Dr Anne-Virginie Salsac’s work in the Micro-Mechanics & Bioengineering Laboratory of Université de Technologie de Compiègne intends to achieve. This will, in turn, allow for the design and fabrication of microcapsules, specifically customised to satisfy the demands of each industrial application.

MICROCAPSULE FABRICATION USING MICROFLUIDICS

With the possibility of using photolithography to create microfluidic systems with an infinite number of designs, new techniques of microcapsule production have been designed. Dr Salsac’s group has developed a microfluidic technique (Figure 1) that allows for the fabrication of finely calibrated microcapsules, both in terms of size and mechanical properties.

It relies on a flow-focusing system to first generate droplets, around which a capsule forms. It relies on a flow-focusing system to first generate droplets, around which a capsule forms. The development of microfluidics has allowed the fabrication of microcapsules, both in terms of size and mechanical properties. The development of microfluidics has allowed the fabrication of microcapsules, both in terms of size and mechanical properties.

Dr Salsac’s pioneering research in the characterisation of microcapsules has the capacity to provide the scientific community with a greater insight on a field that has many industrial applications.

Why did you first become interested in this area of research?

Being specialised in biofluids applied to vascular mechanics, I am interested in the understanding of the blood flows from microcirculation to the haemodynamics in large blood vessels. Microcapsules, which are models of natural cells, provide an insight into the behaviour of red blood cells and open the way to the study of blood microcirculation.

What applications are there for microcapsules in general?

Over the last decades, small-scale encapsulation has become ubiquitous. Besides its classical use in cosmetics and personal care products, it is at the source of innovative applications, many of them appearing in the fields of biotechnologies (encapsulation of drugs for drug therapy or cells for artificial organ generation), food industry (encapsulation of aromas, nutrients, or active substances to produce nutraceuticals), agriculture (encapsulation of fertilizers) or energy storage (encapsulation of phase-change substances for new insulation technologies).

Can you give an example of how the knowledge gained from your research could be applied?

The beauty is that the research combines very fundamental aspects (advanced numerical models of the microfluidic fluid-structure interactions of micro-objects) and very practical applications: for instance, it enables prediction of the behaviour of microcapsules upon injection, and determination of their mechanical properties using in batch technologies.

What are the next steps for this research?

The next step is to further study the processes of release of the encapsulated medium and its interactions with the capsule flow and deformation.

International collaborations constitute a real strength and a source of mutual enrichment.

RESEARCH OBJECTIVES

Dr Salsac’s research focuses on the dynamics and mechanical behaviour of microcapsules and their interactions with an external flow when placed in suspension. Her latest research has looked at modelling and characterising microcapsules under hydrodynamic stresses.

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BIO

After graduating from UC San Diego in 2005 with a PhD in Biofluids, Anne-Virginie Salsac spent two years at University College London as a Lecturer. She was recruited by the CNRS in 2007 and joined the Microfluidics and Bioengineering Laboratory at UTC (Fonds). In 2014, she was nominated Visiting Professor at Queen Mary University of London.

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