Ultrasound-driven chemical processes: from lab scale to commercial applications

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Ultrasound is sound waves above 20 kHz, i.e., beyond the upper human audible limit. When coupled with a certain power (usually above several Watts per liter), ultrasound creates non-negligible physico-chemical effects in a liquid or in a mixture containing liquids. These effects include, among others, macro shear rates, micro-mixing, acoustic cavitation, micronization, and surface erosion (when solids are present), which results in improved mass transfer and, to a minor extent, heat transfer [1]. These effects can be leveraged to make mechanical and chemical processes more efficient. As such, ultrasound is generally classified as a Process Intensification (PI) approach, this latter comprising a pool of innovative technologies that aim at short-circuiting mass and heat transfer limitations, eventually resulting in equipment that has a lower volume footprint and reduced energy requirements. PI provides opportunities to make processes modular and electrifiable with clean energy, thus contributing to energy transition and reducing emissions [2].

Neverthelss, ultrasound, like most PI technologies, is contoured by uncertainties inherent to its scale-up. This is due to several factors including the lack of success stories, know-how and the complex fluid-dynamics enacted by ultrasound, which change with the shape of the vessel and physico-chemical properties of the materials treated [1]

In this talk I will present the basics of the effects that ultrasound can enact when utilized to power a chemical process, as well as typical (over-the-counter) and less typical (custom-made) ultrasound equipment.

I will also demonstrate methods to map acoustic pressure and cavitation zones on the lab, as well to quantify the radicals generated by ultrasound. Together with examples of commercial applications, recommendations on scale-up strategies will also follow.

[1] Meroni, D. et al., Chem. Rev. 2022, 122, 3, 3219–325
[2] Boffito D., Chem. Eng. Proc. 2925, June 2025, 110275