IS ULTRASOUND AND MICROWAVE COUPLING A VIABLE SOLUTION FOR PROCESS INTENSIFICATION?

CALINESCU Ioan, VINATORU Mircea

[1]*University POLITEHNICA of Bucharest, Faculty of Applied Chemistry and Material Science*

**Corresponding author: ioan.calinescu@upb.ro*

Keywords: microwave, ultrasound, process intensification

Introduction: The use of microwave energy in chemical laboratories was first described in 1986 by Gedye [1] and by Giguere [2] in organic synthesis and by Ganzler [3] in the extraction of biological matrices for the preparation of analytical samples. Because the microwave radiation is nonionized, the interaction with materials occurs by their heating. Some advantages of microwave heating over conventional systems are[4]:

- Volumetric heating: heating does not take place by transfer from a surface but to the volume of the reaction mixture;
- Selective heating - the components of a heterogeneous system can heat up differently even if the size of the components is very small;
- Rapid energy transfer - very high-power densities can be obtained which produce very high heating rates.

Because of these particularities, microwave heating is increasingly used in the synthesis and processing of materials. However, the overall process rate is often limited by mass transfer and here comes the ultrasound which can improve the mass transfer and overcome this limitation. Power ultrasound besides improving mass transfer can influence chemistry and processing, generating cavitation bubbles when passes through the liquid. There are many thousands of such bubbles in the liquid some of which are relatively stable, but others expand further to an unstable size and undergo violent collapse to generate temperatures of about 5000°K and pressures of the order of 2000 atm. If the bubble collapses occur close to a solid surface the collapse is not symmetrical and results in microjets of liquid being directed towards the surface of the material at speeds of up to 200 m/s. These jets are, of course, the underlying reason why ultrasounds are so effectives in increasing mass transfer.
The combination of these two types of irradiations – electromagnetic and mechanical – and their application to chemical reactions is of high interest, but scientific articles are quite few [4, 5].

Conclusions: Both microwave and ultrasound irradiation meet the Process Intensification guidelines for: the improvement of energy transfer; the reduction of energy consumption; the reduced volumes of reactors/plants; the improved product quality; the ease of process automation; as well as remote reaction control [6].
The main question about the combined technology is how the two separate technologies can be combined. There are two approaches:

- Use separate reactors one using ultrasound and another using MW with a recirculating pump to allow the liquid to be transferred from one reactor to another.
- Use a single reactor with both US and MW inside.

The challenges are related to the types of processes that can be intensified by applying US and MW, considering that each of these processes requires restrictive conditions to produce good results.
The paper describes the main types of equipment that make possible the simultaneously use of ultrasounds and microwaves. Some results obtained using this type of equipment are also presented.

The authors acknowledge the financial support received from the Competitiveness Operational Programme 2014-2020, Action 1.1.4: Attracting high-level personnel from abroad in order to enhance the RD capacity, project: P_37_471, „Ultrasonic/Microwave Nonconventional Techniques as new tools for nonchemical and chemical processes”, financed by contract: 47/05.09.2016

References:

1. Gedye, R., et al., *The use of microwave ovens for rapid organic synthesis.* Tetrahedron Letters, 1986. **27**(3): p. 279-282.
2. Giguere, R., T. Bray, and S. Duncan, *Application of comercial microwaves ovens to organic synthesis.* Tetrahedron Letters,, 1986. **27**(41): p. 4945-4948.
3. Ganzler, K. and I. Szinai, *Effective sample preparation method for extracting biologically active compounds from different matrices by a microwave technique.* Journal of Chromatography, 1990. **520**: p. 257-262.
4. Leonelli, C. and T.J. Mason, *Microwave and ultrasonic processing: Now a realistic option for industry.* Chemical Engineering and Processing: Process Intensification, 2010. **49**(9): p. 885-900.
5. Gude, V.G., *Synergism of microwaves and ultrasound for advanced biorefineries.* Resource-Efficient Technologies, 2015. **1**(2): p. 116-125.
6. Vinatoru, M., T.J. Mason, and I. Calinescu, *Ultrasonically assisted extraction (UAE) and microwave assisted extraction (MAE) of functional compounds from plant materials.* TrAC Trends in Analytical Chemistry, 2017. **97**: p. 159-178.