Process Intensification using Microwaves and Ultrasound

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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. Due to the fact that 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. Ultrasound can be used to improve the mass transfer. Power ultrasound which is capable of influencing chemistry and processing, generates 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 close to or on a solid surface the collapse is not symmetrical and results in a microjet 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 really interesting.
Both microwave irradiation and ultrasound definitely meet the Process Intensification rules through 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
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 paper describes the main types of equipment that make it possible to simultaneously use of ultrasounds and microwaves.

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