Exploiting Ultrasound for the synthesis of nanomaterials: effect on particle dispersion, morphology and crystallinity

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Ultrasound (US) are mechanical waves above 20 kHz of frequency employed in sonochemistry, namely the chemistry branch that exploits acoustic cavitation phenomena. When considering the application of US in the preparation of nanomaterials, cavitation induces mechanical effects, that if properly tuned, strongly influence the materials during their synthesis. For example, the US-induced turbulence can improve mass transfer with respect to mechanical stirring [1] and can be exploited for the dispersion of metal nanoparticles on heterogeneous surfaces [2-4]. Moreover, acoustic cavitation can play a role in the crystallinity of the produced materials, indicating extremely fast cooling rates as a factor with pivotal influence on structural organization [5]. Depending on the nature of the employed precursors, bubbles collapse can result in two different outcomes. On one hand, when volatile precursors (e.g. organometallic compounds) are employed, reactions predominantly take place in the gas phase (the inner part of the bubble) and amorphous materials are generally produced, given the absence of conditions (e.g. adequate cooling rates) functional to structural organization. Conversely, when the employed precursors are non-volatile (e.g. metallic salts), reactions happen in the outer part of the bubble (liquid-phase). Whether the products will be amorphous or crystalline can be determined by the temperature of the interface region [6,7]. Here, the shockwaves produced from bubbles collapse are thought to deeply influence crystalline growth, resulting in nanocrystalline materials or (depending on the temperature) nano-amorphous materials. As a matter of fact, the use of US is strategic for rapid industrialization, since known materials with novel properties (e.g. smaller particle dimension, peculiar morphology) can be easily synthesized.
In this contribution, some representative case studies dealing with the US-assisted synthesis of nanomaterials for applications in the fields of catalysis and drug delivery are described. The aim is to establish correlations between the effect of some US parameters (frequency, power, sonication time, reactor design) and (i) the dispersion of metal nanoparticles, (ii) the particle morphology and (iii) the crystallinity of the obtained materials.

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