Chapter 3
Principles and Advantages of Microwave-Assisted Methods for the Synthesis of Nanomaterials for Water Purification

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ABSTRACT

Nanomaterials are the pillars of nanoscience and nanotechnology and to realize their full potential in various potential applications, synthetic methodologies/routes need to be established that are simple, fast and cost-effective. Wet-chemical approaches for nanomaterial synthesis have proven to be among the most versatile and effective routes to finely tailor nanocrystals with varying compositional and architectural complexity. Microwave-assisted solution route represents an efficient wet-chemical
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approach for the synthesis of nanomaterials that offers additional advantages, such as rapid volumetric heating, high reaction rates, size and shape control by tuning reaction parameters, and energy efficiency. In addition, the homogenous heating of the reactants in microwave synthesis minimizes thermal gradients and provides uniform nucleation and growth conditions that leads to the formation of nanomaterials with uniform size distribution. This chapter deals with the basics of microwave chemistry and its applications towards the synthesis of nanomaterials for catalytic applications.

The prefix ‘nano’ which means one billionth of something is derived from the Greek word ‘nanos’ meaning dwarf. A nanometre (nm) is an SI (International System of Units) unit of length and is equal to one-billionth of a metre, $10^{-9}$ m. Nanoscience and nanotechnology thus deals with the study of phenomena, design and manipulation of matter having dimensions of the order of a billionth of a metre. One of the fundamental issues in nanoscience is to achieve control over size and morphology of nanostructures to tailor their physical and chemical properties. Since the discovery of size-dependent behavior in nanoscale matter, colloidal inorganic nanocrystals have been developed more rapidly than other classes of nanomaterials owing to the high degree of control on geometric and compositional engineering in the synthesis stage and to the versatility with which they can be incorporated into a number of technologically valuable applications (Baghbanzadeh et al. 2011).

Colloidal nanocrystals are synthesized from the reaction of molecular precursors (metal-organic compounds, metal salts and metal–ligand complexes) in a liquid reaction medium heated to a suitable temperature, often in the presence of some stabilizing organic agents, such as ligands and surfactants, that can influence their growth to bring out different morphologies with distinctive properties. Wet-chemical approaches have proven to be among the most versatile and effective routes to finely tailor the size and shape of nanocrystalline materials. The traditional form of heating using heating plates/mantles is rather a slow and inefficient method for transferring energy to a reaction mixture, since it depends on convective currents and on the thermal conductivity of the various compounds or materials that have to be penetrated, and often results in the temperature of the reaction vessel being higher than that of the reaction medium (Galema, 1997). In contrast, microwave (MW) irradiation leads to efficient internal “in core” volumetric heating (that is, the temperature is raised uniformly throughout the whole liquid volume) by direct coupling of MW energy to the molecules present in the reaction medium (Lidström et al. 2001). This volumetric heating has particular implications in nanomaterial synthesis as it leads to a rapid and homogeneous heating of the reaction mixture, that minimizes thermal gradients and provides uniform nucleation and growth conditions.

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