

## Nanostructured Materials Prepared with Ultrasound

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Recent advances in nanostructured materials have opened up new opportunities for diverse applications ranging from electronics, spintronics, and energy to biology, which would have been unimaginable in the past. A variety of nanostructured materials have been prepared so far with different synthetic approaches. One could claim that selecting an appropriate synthetic route ultimately determines the success or failure of nanostructured materials synthesis, because the physical properties and applications of nanostructured materials are heavily dependent upon their synthetic method. As a result, there have been tremendous efforts toward the development of new synthetic methodologies for several decades. Among these efforts, the utilization of ultrasound for materials synthesis has been extensively examined. By virtue of its exceptional success, ultrasound now positions itself as one of the most powerful tools for nanostructured materials synthesis.

Sonochemistry and ultrasonic spray pyrolysis (USP) are the most successful examples of the utilization of ultrasound in synthesis.<sup>1-13</sup> In particular, both methods have a superior ability to create nanocomposites compared to other synthetic methods. Often, sacrificial template materials are used as one of the components of the composites in the preparation of nanostructured materials. In this research, using carbon nanoparticles as a spontaneously removable template, nanosized hollow hematite is sonochemically prepared.<sup>14</sup> In addition, nanostructured ZnS:Ni<sup>2+</sup> photocatalysts are produced via USP using a silica template, and it has been demonstrated that the USP produced ZnS:Ni<sup>2+</sup> nanoparticles are an excellent photocatalyst for hydrogen evolution because of their well-balanced crystallinity and surface area.<sup>15</sup>

Despite the usefulness of the pre-structured template materials (e.g., silica or carbon), it would be desirable to develop new template materials which are not subject to tedious, time-consuming removal procedures. In the USP-assisted synthesis of titanium nitride, the simple addition of zinc nitrate into precursor solutions as a source of an *in situ* generated template leads to a dramatic change in the pore structure of titanium nitride.<sup>16</sup> Not only does this newly devised synthetic route eliminate the use of a pre-structured template, but also requires no additional template-removal procedure. Another example of the *in situ* generated template is found in the synthesis of porous carbons. The decomposition of alkali halocarboxylates via USP produces various forms of porous carbon spheres.<sup>12</sup> In this synthesis, metal salts are generated *in situ*, introducing porous structures into the carbon spheres. These porous carbons were examined as fuel cell electrode materials, demonstrating that the inclusion of the carbon spheres is an effective way to facilitate mass transport during fuel cell operation.<sup>17</sup>

USP has proven to be an excellent method to produce organic-inorganic hybrid materials. Nanoporous silica spheres incorporated with various organic dyes are synthesized by USP and utilized in colorimetric sensing arrays for the identification of aliphatic amines.<sup>18</sup> Further usefulness of USP is demonstrated in quantum dot synthesis. Previously, using organic precursor solutions containing high boiling point liquids, highly luminescent CdSe and CdTe quantum dots were prepared.<sup>10</sup> In this study, this novel synthetic route is further extended to prepare far-red and near-IR emitting ternary quantum dots.<sup>19</sup>

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