Synthesis of ZnS nanoparticles by spray pyrolysis: Morphology control using the same precursors in different reactor systems

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Nanoparticles of zinc sulfide, a II-VI semiconductor with large band gap in the near UV region[1], have potential applications in solar cells, displays, photocatalysts and other emerging technologies[2,3]. We have prepared ZnS nanoparticles through spray pyrolysis of zinc acetate and thiourea. These two precursors have been used by other groups to prepare ZnS nanocrystals in solution, or to deposit ZnS thin films[4-6]. For the same precursors, we used different reactor systems to produce nanoparticles with different size and properties.

In one system (system 1), the precursors were premixed and heated together in a single reaction line, as shown schematically in Figure 1. In this system, the two precursors react within the liquid droplets rather than evaporating and reacting in the gas phase. The size of the particles produced in this system ranged from tens to hundreds of nanometers in diameter. The particles were porous, as a result of the release of solvent and vapor-phase byproducts during reaction. Powder x-ray diffraction (XRD) shows that the particles consist of cubic ZnS, with no evidence of production of any other crystalline phases.

Although the two precursors can produce ZnS nanoparticles, the overall particle size is relatively large, and is related to the size of the droplets entering the reactor system. Much smaller particles could be formed by direct nucleation from the vapor phase. Thermo gravimetric analysis (TGA) showed that both precursors can evaporate or decompose to volatile products below 400°C. Hence, to achieve particle nucleation from the vapor phase, we have used another reactor system in which the precursors are delivered and evaporated separately. In it, two atomizers and reaction lines have been used, as shown schematically in Figure 2. In this system, the two precursors were separated and heated in different lines and were then mixed after evaporation. Smaller particles (below 20nm) with irregular geometry were obtained in this system. However, after sufficient residence time in the separate lines, thiourea decomposed and zinc acetate produced ZnO at the temperature used (beyond 400°C). Contact with vapor-phase sulfur-containing compounds sulfided the ZnO to yield ZnO_xS_y nanoparticles. The composition of these nanoparticles could be controlled by the relative amounts of the precursors delivered to the reactor.

References:

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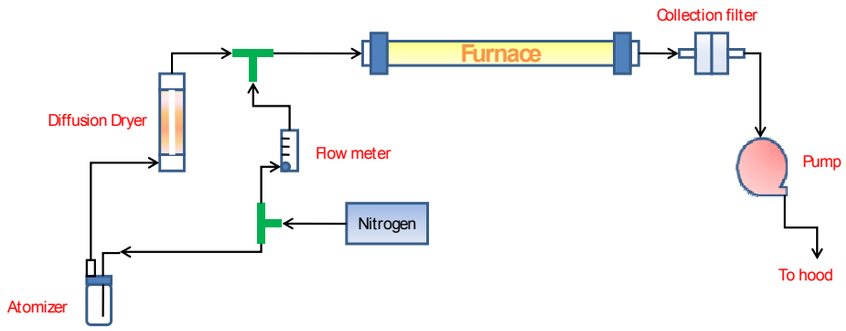

Figure 1. Schematic drawing of the reactor system 1 for synthesis of ZnS nanoparticles by spray pyrolysis.

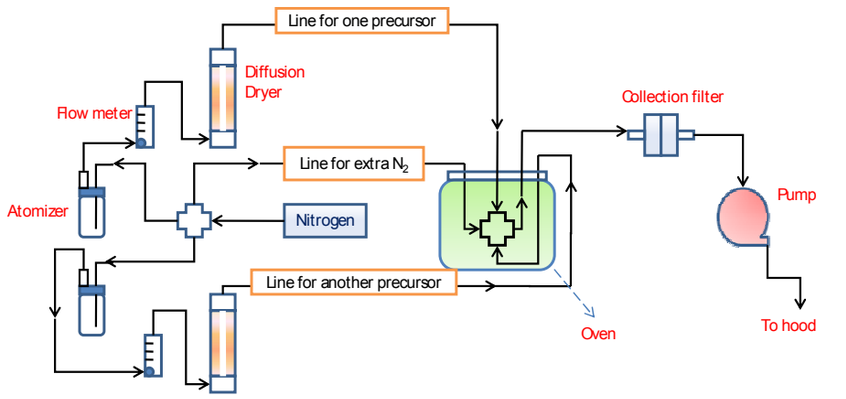

Figure 2. Schematic drawing of the reactor system 2 for synthesis of ZnS nanoparticles by spray pyrolysis.