Chapter 8

Perspectives of Hydrothermal Synthesis of Fluorides for Luminescence Applications: Fluorides Phosphors for Luminescence

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ABSTRACT

Hydrothermal synthesis is an easy, portable, less-hazardous, and low-cost synthesis method. Various researchers across the globe are worked on the synthesis of different materials via this route. Practically, fluorides are difficult to synthesize due to their hygroscopic nature by conventional methods. But, the hydrothermal synthesis is used to prepare several compositionally optimized fluoride-based materials using closed-system physical and chemical processes in an aqueous solution at low temperatures and pressures. The silent features of the hydrothermal method over conventional methods of materials processing are a crystallization of materials, crystal growth, in the processing of a wide range of materials not only the bulk crystals but fine particles with a controlled size and morphology. Therefore, in order to place its numerous recent developments, past and current research come together in this chapter. This chapter is a recent clocking update for synthesis, materials, and their applications.

INTRODUCTION

The term Hydrothermal was coined from two words, “hydro” means water and “thermal” means heat and describe the action of water at elevated pressure and temperature (Byrappa, 2001). It is a method used to produce different materials by closed-system physical and chemical processes in an aqueous solution at temperatures above 100 °C and pressures above 1 atm. However, there is no definite lower limit for the temperature and pressure conditions. Hydrothermal synthesis is an advanced material pro-
cessing technique, which has numerous advantages than other methods. With the help of aforementioned method, one can prepare high-quality crystals of materials which are even unstable near the melting point. Homogeneous materials of pure phase are obtained, offers high diffusivity, low viscosity, and mass transport. By tailoring the chemical environment, it gives control over the shape and size of the crystals, consumes less energy, less reaction time and is a safe method with no environmental hazards as it’s a closed system processing technique. There are various other terms preferred by chemists like solvothermal which means a chemical reaction in the presence of a non-aqueous solvent or solvent in supercritical or near supercritical conditions. Similarly, several other terms like glycothermal, alco-thermal, ammonothermal, carbonothermal and lyothermal are also used (Yoshimura, 2008). Among the various synthesis techniques, a hydrothermal synthesis route is a simple approach for synthesizing various inorganic materials with controllable morphologies and architecture (Jia, 2009; Xu, 2010). The temperature in hydrothermal synthesis is low compared to most traditional melt techniques of synthesis. A great variety of materials like metal oxides, silicates, hydroxides, sulfides, carbonates, phosphates, tellurides, nitrides, selenides, KTiOPO 4 (Bierlein, 1976), tungstates (Reis, 1990), Ti- superconductors (Chen, 1994), layered compounds (Sugita, 1990), artificial gems (Zhao, 1997; Hosaka, 1991), intercalation compounds (Whittingham, 1995) and zeolites (Barrer, 1982) have been synthesized using the hydrothermal technique. A wide variety of combinations of aqueous and solvent mixture systems can be used in hydrothermal processing. Moreover, compared to solid state processes, the possibility for acceleration of diffusion, higher dispersion, controlled morphology, better nucleation, high reactivity, adsorption, reaction rate and crystallization in the liquid is more (Yoshimura, 2000). The hydrothermal process is a method of forming ceramic powders by heating and pressurizing solutions or suspensions of metal salts, oxides, hydroxides or metal powders in water or in other solvents. The process is conducted in a pressure vessel called an autoclave. Normally, as the mixture is heated in this closed system, the pressure rises and these conditions result in the formation of submicron particles with controlled size and shapes. This route has been used to prepare a variety of monodispersed powders, materials with specific particles with controlled size and shapes, crystalline phases and frequently at temperatures lower than those required in normal processing procedures. The formation of monodispersed spheres by providing the appropriate conditions needed for homogeneous nucleation which only assisted by the hydrothermal process. For example, using heat and pressure in an autoclave, monodispersed metal oxide powders are formed by homogeneous nucleation of metal hydroxide particles, which are produced by forced hydrolysis of metal alkoxides. By controlling the release of precipitating ion, forced hydrolysis is normally achieved. The advantage of the hydrothermal process is that low-quality reactants can be used because metallic impurities remain in solution. Also, a variety of reaction conditions such as pH, temperature, and pressure controls the particle size. The relatively low reaction temperature, around 300 °C and ability to use impure reactants are attractive features for commercial exploitation of this technique. In recent times, hydrothermal synthesis has been used for preparing fluoride phosphors (You, 2002).

Hydrothermal synthesis is typically the chemical reactions in water/solvents conducted above the ambient temperature and pressure in a sealed or closed system. It is a special type of chemical transport reaction that relies on the liquid-phase transport of reactants to form the desired product. Under autogenus conditions, water functions both as a pressure-transmitting medium and as a solvent. In a sealed vessel, as the temperature increases, the vapor pressure of water increases below its critical temperature but above its boiling temperature (Rabenau, 1969). The hydrothermal technique has its place in several branches of science and technology today where its roots attached to the appearance of several other related techniques. In the last few years many luminescent materials have been discovered and applied.