Chapter 6
White Light Emitting Phosphors for Solid State Lighting

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ABSTRACT
Phosphor materials are an integral and important part in the white light generation in LEDs and have participated in the global warming reduction significantly. In this chapter, the authors focus on different types of phosphor materials belonging to a family of apatites, fluoroapatites, silicates, oxides, phosphates, and borates with different crystal structures. The detailed investigations on their crystal chemical structure, synthesis, and photoluminescence properties are briefly discussed. The improved optical properties make the phosphor potential candidate for smart panel displays and white light emitting diodes (including solid state lighting). The crystal structure has a great influence on the chemical and luminescence properties of any phosphor; hence, a great change of activator ion (Eu²⁺, Ce³⁺, Mn²⁺, and Tb³⁺) concentrations can be achieved in the phosphor performances. The chapter correlates the structure-compositions-property of the phosphor materials with special emphasis on white LEDs.

INTRODUCTION
In past two decades, research on inorganic luminescent materials have gained significant attention, due to emerging technology with the lighting industry as well as their wide spectral applications, such as cathode ray tubes (CRTs), light emitting diodes (LEDs), field-emission displays (FEDs), vacuum fluo-

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Rescent displays (VFDs), and plasma display panels (PDPs) (Wang, 2013; Xie, 2004; Liu, 2013; Hoppe, 2009; Dai, 2011; G. Li, 2014; K. Li, 2016). Especially significant revolution has occurred in the field of lighting industry (starting from the incandescent bulb to the current era of energy efficient white light emitting diodes (WLEDs). Increasing global energy demand and carbon emission pushes the use of renewable energy or energy saving smart devices. The energy efficient devices or smart displays play vital role in reducing the cost of the energy by half. The discovery of blue LED or solid state lighting based white LEDs considered as a triumph in the field of materials chemistry and subsequently awarded Nobel prize in physics 2011 (Sivakumar & Kasturi, 2017).

The cool white LEDs have successfully replaced the existing florescent lamps as due to their improved performances and lifetime. Further, as time goes the compact fluorescent lamps (CFLs) have been surpassed by the warm white LEDs. In the solid state lighting (SSL) devices (including LEDs), violet, blue, and green LEDs are based upon InGaN semiconductors, while the red and amber LEDs are based upon AlInGaP semiconductors (Phillips, 2007; Krames, 2007; Schubert, 2005). To overcome the disadvantages generated from InGaN and AlInGaP LEDs the use of down converted phosphor or inorganic luminescent materials came into scenario to be used for generating the yellow and green light for highly efficient white LEDs. There has been wide research and development for phosphors used in CFLs, cathode-ray tubes (CRTs), and X-ray films but the most of the traditional phosphors do not meet the need for the LED applications. Since, it fails to absorb either in the near UV or blue region, where the LED emission occurs. There are several ways; one can produce white light from the LED. The selective methods based on phosphor + LEDs are depicted in Figure 1.

The understanding of energy transfer behavior between the sensitizer (D) and activator (A) is important task, as it involves in the overall improvement of the phosphor quantum efficiency as well as the LED performance.

Figure 1. Schematic diagram of LED fabrication with (a) RGB and (b) single host white phosphor