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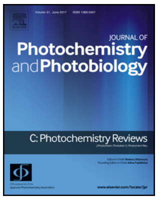

Lanthanide complex-derived white-light emitting solids: A survey on design strategies

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ABSTRACT

Solid-state materials with tunable light emission characteristics offer an attractive prospect. Unique luminescence features of trivalent lanthanide (Ln^{III}) ions—sharp characteristic emission in the visible and near-infrared (NIR) spectral regions, exceptional color purity, long luminescence lifetimes, high quantum yield and large Stokes shifts—afford them as promising white-light source materials. The review provides an overview of the recent developments in the Ln- complex-based solid-state white-light emitters with particular emphasis on different design strategies and photoluminescence features to augment the foundations of factual knowledge further. The approaches adopted in the lanthanide coordination complexes—logical codoping of Ln^{III} in various compositions, lanthanide encapsulation in MOF pores, infinite coordination particles, and lanthanide incorporated composites—to attain tunable white-light emission, will be discussed. The pros and cons of different adopted strategies in term of further processing of the materials into real-world applications as well as the imminent challenges are also reviewed and put in prospect.

Contents

Abbreviations: Ln, lanthanides; NIR, near-infrared; MOF, metal-organic framework; SSL, solid-state lighting; PL, photoluminescence; LED, light emitting diode; WLED, white-light emitting diode; OLED, organic light emitting diode; CIE, commission Internationale d'Eclairage; CCT, correlated color temperature; CRI, color rendering index; LCMD, light-conversion molecular device; ISC, intersystem crossing; ET, energy transfer; IC, internal conversion; RGB, red Green Blue; PXRD, powder X-ray diffraction; LC, ligand centric; MLCT, metal-ligand charge transfer; ICP, infinite coordination polymer; LMWG, low molecular weight gelator; CPG, coordination polymer gel; RET, resonance energy transfer; PLED, polymer light emitting diode; LCD, liquid crystals display; FWHM, full width at half maximum; MCCP, metal-containing conjugated polymer; AC, aminoclay.

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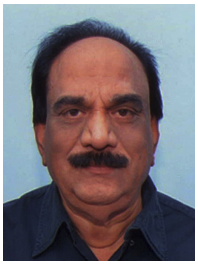

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1. Introduction

The nature and application of solid-state lighting (SSL) materials have evolved rapidly in recent years. Solid-state white-light emitting materials, thanks to their exciting prospects such as long operation lifetime and excellent energy saving, have emerged as a prolific topic with spurring research activities [1]. These materials find utility in a gamut of applications spanning from large-panel displays to mood-sensitive lightings [2]. Currently employed white-light sources are incandescent and mercury-based fluorescent materials; the white composite photoluminescence (PL) of the latter type relies on the emission of mercury vapor to stimulate semiconductor phosphors [3]. However, the adverse effects of mercury on both health and environment paved the way for a concerted worldwide effort longing for greener, safer and energy efficient white phosphor materials as white LEDs (WLEDs). The SSL sources are prepared with either inorganic (LED) or small molecule organic (OLED) semiconductors. With their facile synthesis and possibly large scale processing, OLEDs are advantageous in developing energy efficient and inexpensive lighting materials [4]. Nevertheless, many of these materials based on the inorganic/organic platform cover only a part of the visible spectrum and lacks the required superior efficacy of 150–200 Lm/W for white-light, to displace fluorescent lamps [5]. Facile methods and novel materials are, hence, required to address the issues pertaining to the efficiency and the emission colors if the materials are to be explored for general-purpose lighting. (Fig. 1)

The review gives an overview of the concepts and designs adopted to realize tunable white-light emitting materials based on lanthanide coordination complexes, and also some reflections on the efficiency and sensitization of lanthanide luminescence (Scheme 1). Besides the well-studied strategy of codoping metal ions in crystalline framework materials, single component systems, as well as lanthanide-based hybrid materials, also will be mentioned. The classification of hybrid material is interpreted rather roughly in this review and encompasses the Ln-composites attained by the supramolecular approach, and also by incorporating Ln-complexes into polymer/clay matrixes. For dedicated information on the photoluminescence aspects of Ln^{III} and their applications, the reader is referred to the available books [6] and reviews [7–10].

2. White-light emission and characteristics

White-light, ideally, is composed of two (blue and yellow) or three (blue, green, and red) component colors and covers the whole visible range of the electromagnetic spectrum (from 400 to 700 nm). Apparently, two main approaches are adopted to generate white-light:

a) Mixing red, green, and blue (RGB) or yellow and blue sources proportionally and precisely.

b) Up-conversion of infrared (IR) light or down-conversion of ultraviolet (UV)/blue light using suitable phosphors into specific compositions of red, green and blue, or yellow and blue.

The traditional methods of physical mixing of primary colors from different emitting sources to obtain white-light could hamper their practical utility because of the possible phase separation and stability issues. Single-component systems, in contrast, offer greater stability, better reproducibility and no phase separation, further to their simpler fabrication processes [11,12]. Presently, the blue InGaN LEDs that excite a yellow-emitting YAG:Ce phos-