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Europium complex doped luminescent solar concentrators with extended absorption range from UV to visible region

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Abstract

In this paper, a europium complex, $Eu(TTA)_3Dpbt$ (TTA = thenoyltrifluoroacetonate, Dpbt = 2-(N,N-diethylanilin-4-yl)-4,6-bis(3,5-dimethylpyrazol-1-yl)-1,3,5-triazine), with extended absorption range is incorporated into polyvinyl-butyral (PVB) to fabricate luminescent solar concentrators (LSCs) on the face of K9 glass. This kind of LSC can absorb the light in the UV and the blue region and is free of self-absorption. External quantum efficiency of the LSC is measured at different wavelength. Under a solar simulator (AM1.5G), efficiency of $Eu(TTA)_3Dpbt$ doped LSC is 11% higher than that of $Eu(TTA)_3Phen$ doped LSC (0.176%), resulting from the absorption of $Eu(TTA)_3Phen$ which is limited within UV region. It can be seen from this result that extending absorption region of lanthanide complexes can be used to further enhance efficiency of lanthanide complex doped LSC, besides these complexes are without self-absorption because of their large Stokes shift.

Keywords: Luminescent solar concentrators; Europium complex; Visible light sensitization; *I–V* characteristics; Self-absorption

1. Introduction

Recently, luminescent solar concentrators (LSCs) have attracted much interest as an optical precursor device for photovoltaic (PV) cell (Mulder et al., 2009; Rowan et al., 2008; Goldschmidt et al., 2009a,b; McIntosh et al., 2007). The sunlight of relatively short wavelength can be shifted to long wavelength light through the photoluminescence process of the fluorophore, and the re-emit light can be concentrated by total internal reflection (TIF) in the optical wave guide construction. With the increase of geometric gain, intensity of the light from side of the waveguide has been enhanced and becomes much larger than the sunlight. Therefore, cells attaching to LSC can generate more electric power than conventionally used. By means of LSCs, the production cost of electric power by solar cell can be decreased (Currie et al., 2008). Otherwise, both direct and diffuse incident light of the sun can be concentrated by this system, therefore, the tracking device is not required which make it convenient to integrate on building surface.

To date, three kinds of fluorophores have been used in LSCs: (i) fluorescent organic dyes (Goldschmidt et al., 2009a,b); (ii) quantum dots (QDs) (Gallagher et al., 2007; Kennedy et al., 2009); (iii) lanthanide complexes (Kawano et al., 1997). The former two fluorophores, which have high fluorescence quantum yield (FQY) and tunable, wide absorption range, have been investigated frequently. However there is one intractable problem concerning the

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small Stokes shift of them, which results in serious self absorption effect within the waveguide structure of LSC.

Organic lanthanide complexes have many advantages such as: good dissolvability and compatibility to polymer like PMMA, stable and high FQY caused by efficient intramolecular energy transfer (Moudam et al., 2009). Moreover, unique superiority is its large Stokes shift. In 2010, Wilson et al. reported their work about simulating self-absorption by Monte Carlo ray tracing method and the results indicated that in the case of LSC with large scale, higher efficiency can be acquired by employing lanthanide complexes in contrast to organic dyes (Wilson et al., 2010). However, in that work, the absorption of lanthanide complexes and the spectrum of sunlight were not taken into consideration.

The disadvantage of lanthanide complexes which restricts their use is the narrow absorption range. Most lanthanide complexes have absorption only within UV region, this would lead up to low utilization ratio of the sunlight. Thus, extending the absorption range is the key problem to be solved.

In this paper, an UV light sensitized and a visible light sensitized Eu complex are prepared and incorporated into PVB on the face of K9 glass to construct planar waveguide LSCs, respectively. The performances of these LSCs in practical application are investigated and compared with each other, and emphases are paid on their absorption of the LSCs in sunlight spectrum given by a solar simulator.

2. Experimental

Compelxes, $Eu(TTA)_3Phen$ and $Eu(TTA)_3Dpbt$ (TTA =thenoyltrifluoroacetonate, Phen = 1,10-phenanthroline, Dpbt = 2-(N,N-diethylanilin-4-yl)-4,6-bis(3,5-dimethylpyr-azol-1-yl)-1,3,5-triazine), were synthesized according to the processes in the literature (Melbyn et al., 1964; Yang et al., 2004). The chemical structures of them are shown in Fig. 1. PVB (PVB = Polyvinyl-butyral) was selected as host material

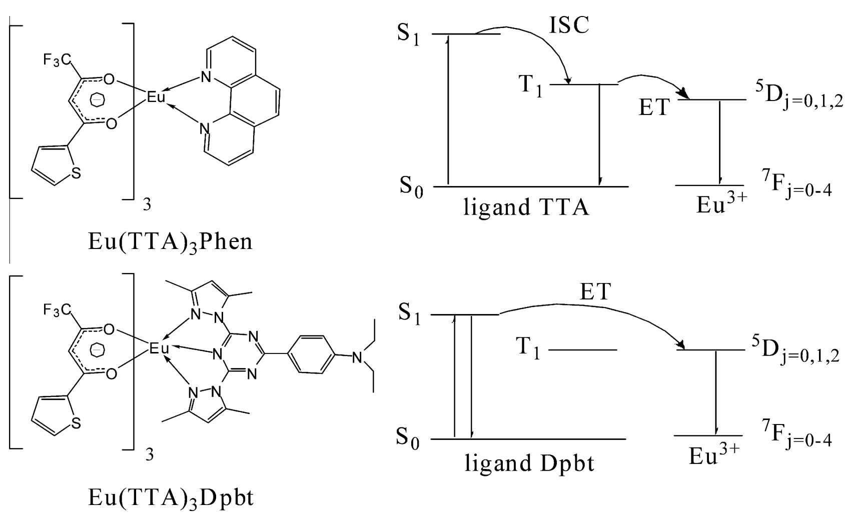

Fig. 1. Molecular structures of Eu complexes and their luminescence mechanism. The energy transfer is from the triplet state of TTA to Eu^{3+} ion, and for Dpbt, the sensitive energy level is singlet state.

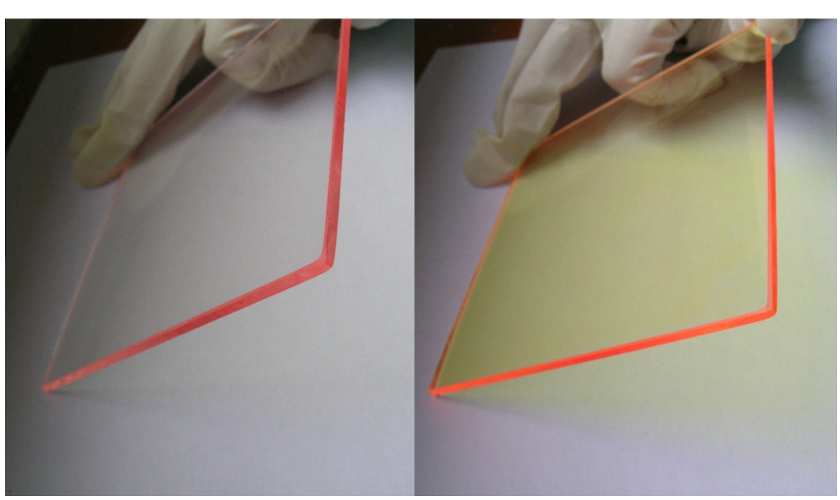

Fig. 2. Photographs of LSCs doped with $Eu(TTA)_3Phen$ (left) and $Eu(TTA)_3Dpbt$ (right) under natural day light next to window.