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Application of composite phosphor ceramics by tape-casting in white light-emitting diodes

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Abstract: Composite phosphor ceramics were fabricated for white light-emitting diodes (LEDs) employing the tape-casting. Benefiting from the superposition of different emission spectrum, wider emission spectra of composite ceramics were reached, result in a higher color rendering index (CRI) of ceramic-based WLED. The composite structure and fluorescent property of composite ceramics were analyzed and the optical properties of ceramic-based WLED were tested. A ceramic-based WLED with a maximum CRI value of ~83 was reached when (Ce,Gd):YAG and (Ce,Pr):YAG were employed for the composite ceramics.

Key words: transparent ceramics; light-emitting diodes; tape-casting.

1. Introduction

The dominant solution in commercial white light-emiting diodes (WLEDs) is the phosphor-based one, in which one or several InGaN blue LED chips were combined with yellow phosphor powders by silicone glue to input white light. Though easy to fabricate, its poor thermal and photonic stability would cause severe carbonization and therefore deteriorate the luminous efficiency as well as induce perceivable color shifting [1,2], limiting their lifetime and restricting their application. To solve this problem, polycrystalline Ce:YAG ceramics have been developed and reported, which has several advantages as the phosphor converter: excellent heat resistant, promising optical property and easy formability [3-6]. However, some drawbacks such as high fabrication cost, poor homogeneity of optical performance are still preventing the commercialization of ceramic-based LEDs. In addition, on the consideration of light quality, the spectral ranges of the yellow emission of ceramics are always not wide enough to cover the red part, which may lead to excessive high correlated color temperature (CCT) as well as low color rendering indices (CRI) — neither of them is favorable in the application of in-door lighting [7-9].

Tape-casting, a well-established technique for molding ceramics that is being widely used in large-scale production of multilayer structure [10,11], may be a suitable candidate for avoiding the aforementioned drawbacks for the following reasons: Firstly, The thickness of the phosphor ceramics layer can be precisely controlled at the micron level by adjusting the blade height, which ensures consistency in thickness among products and, therefore, the optical homogeneity of ceramic-based WLED. Secondly, those ceramics samples molded by tape-casting are free from extra processes of polishing and cutting (pre-cutting in tape-casting process), which means a great reduction in the fabrication cost. Lastly and most importantly, tape-casting shows great potential in the fabrication of multilayer composite ceramics. The high precision of the thickness of every single layer and the bonding between different layers ensure excellent microstructure. High CRI and appropriate CCT of ceramic-based WLEDs can be obtained by stacking and laminating different phosphor layers, whose emission peaks range from 480~780 nm, depending on a desired ratio. Significant progress has been made in the fabrication of multilayer composite laser ceramics by tape casting [12-14]. However, so far there have no been relevant reports on the application of tape-casting on the fabrication of phosphor ceramics for LED.

In this letter, we employed the low-cost tape-casting in fabrication of phosphor composite ceramics for WLEDs. Both Single-layer phosphor ceramics and multilayer composite