Chemical Engineering Journal 210 (2012) 461–466

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Direct synthesis of spherical YAG:Ce phosphor from precursor solution containing polymer and urea

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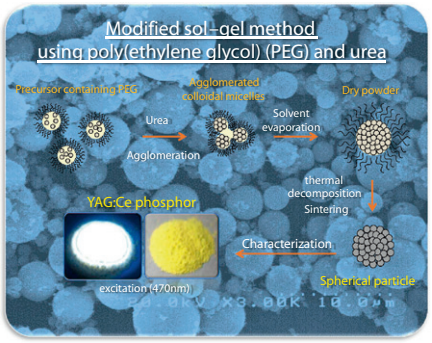
HIGHLIGHTS

- This is the first repot on the direct synthesis of a spherical YAG:Ce phosphor.
- The spherical phosphor were prepared by a sol–gel method using PEG and urea.
- The mechanism of the particle formation are proposed based on experimental results.
- PEG caused micelle formation and urea acted as an agglomeration promoter.
- The presented method is a direct preparation and produces large amounts of product.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 1 June 2012
Received in revised form 28 August 2012
Accepted 4 September 2012
Available online 21 September 2012

Keywords:
Phosphor
Yttrium aluminum garnet
Spherical particle
Photoluminescence
Sol–gel
Micelle

ABSTRACT

In this study, spherical cerium-doped yttrium aluminum garnet (YAG:Ce) phosphor particles were directly synthesized by a modified sol–gel method using poly(ethylene glycol) (PEG) and urea. In the absence of PEG and urea, only irregularly shaped particles were obtained through aggregation and sintering after solvent evaporation. In contrast, adding both PEG and urea to the precursor solution resulted in the formation of spherical particles. The spherical morphology was attributed to micellization by PEG and micelle agglomeration by urea in a liquid phase. Scanning electron microscopy and X-ray diffraction analyses revealed that the spherical particles were of size around 5 μm, and the obtained crystal was pure a YAG phase. The emission band of the YAG:Ce phosphor prepared at 1600 °C for 2 h was observed at 530 nm under excitation at 470 nm, and the maximum internal quantum efficiency was found to be 57.6%.

1. Introduction

Cerium- or rare-earth-doped yttrium aluminum garnet (YAG:Ce/RE) is a well-known phosphor material used in white-light-emitting diodes because of its relatively high absorption efficiency of blue excitation radiation, high quantum efficiency, and good stability in high-temperature and high-humidity environments [1,2]. In the preparation of YAG:Ce phosphor particles, the formation of spherical particles is very important for high brightness and high resolution because these particles have lower scattering of evolved light and higher packing densities than those of irregularly shaped particles prepared by conventional solid-state reaction methods [1,3].

According to previous research, spherical YAG:Ce phosphor particles can be synthesized using spray [2,4–6] and solvothermal methods [7,8]. The particles prepared by spraying are generally spherical and rel-

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http://dx.doi.org/10.1016/j.cej.2012.09.033

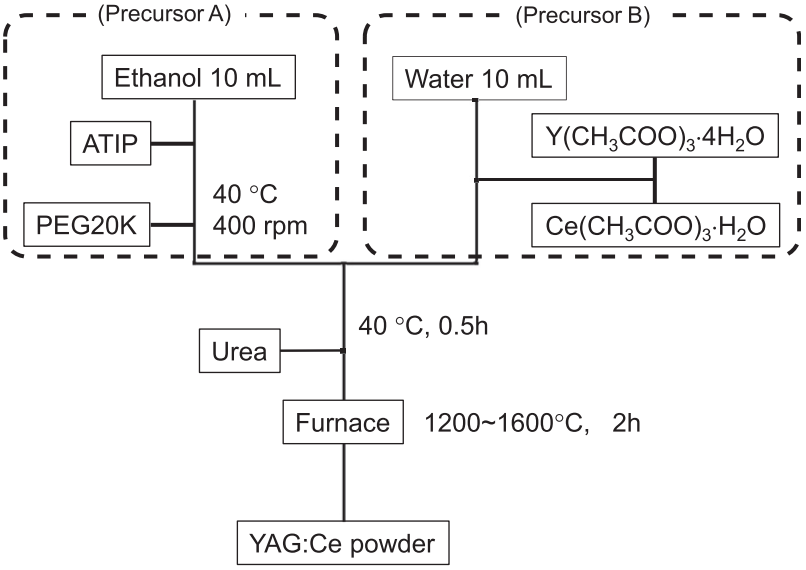

Fig. 1. Flow diagram for the synthesis of spherical YAG:Ce phosphor particles.

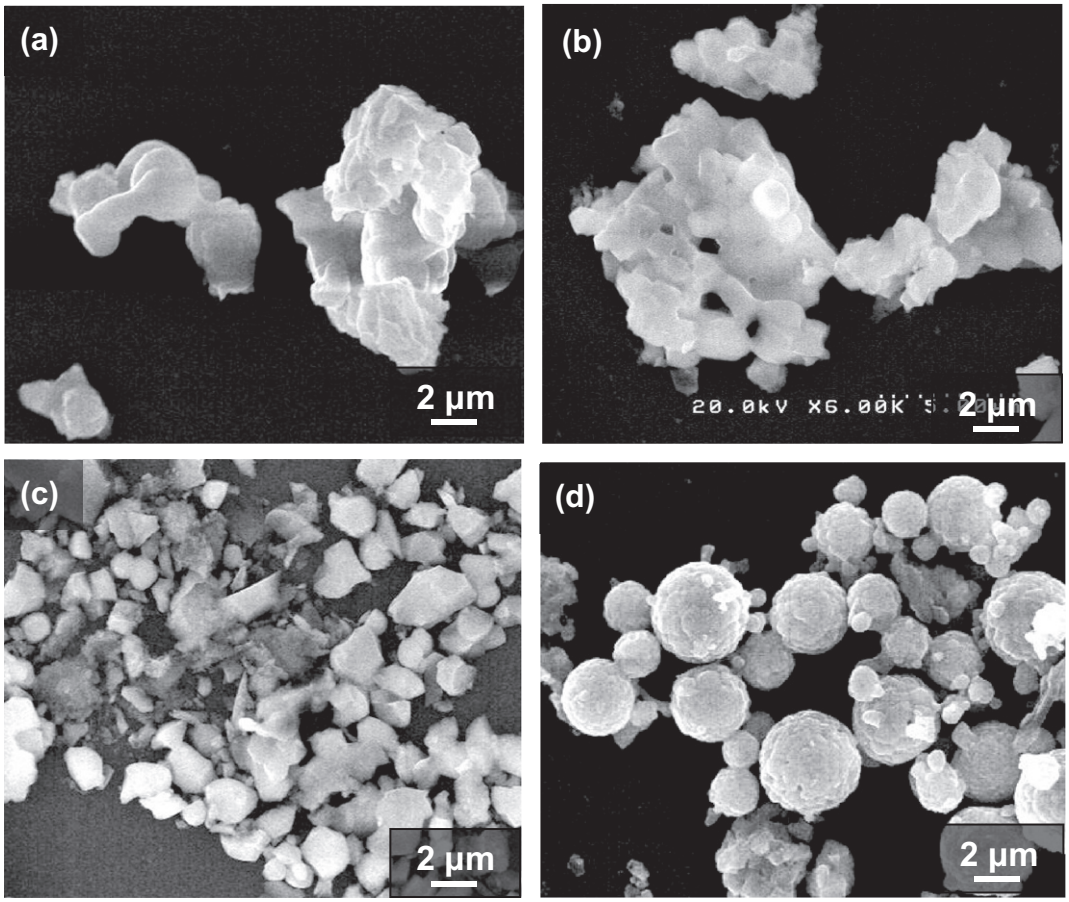

Fig. 2. SEM images of samples prepared at 1400 °C with various PEG and urea contents: (a) without PEG/without urea, (b) without PEG/with urea, (c) with PEG/without urea, and (d) with PEG/with urea.

atively uniform in size and composition. However, the production rate for this process is relatively low and reheating treatment is sometimes needed to obtain a pure YAG structure [4,6,9,10]. In solvothermal synthesis, high pressures (40–100 MPa) are essential for forming a single-phase YAG [8]. From the industrial point of view, preparation processes under atmospheric conditions are preferable. Large-scale, one-step synthesis of spherical YAG:Ce phosphor particles is an area of ongoing research.

Sol–gel processes have the potential to avoid the above-mentioned problems; they provide a direct method of synthesizing