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Influence of ammonium sulfate on YAG nanopowders and Yb:YAG ceramics synthesized by a novel homogeneous co-precipitation method

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Abstract: Homogeneous and dispersed $Y_3Al_5O_{12}$ (yttrium aluminum garnet, YAG) nanopowders were synthesized via a homogeneous co-precipitation method from the mixed solutions of yttrium nitrate, aluminum nitrate and a small amount of ammonium sulfate using hot urea as the precipitant. The method has the superiorities that co-precipitation of cations is ensured and continuous decomposition of the hot urea is achieved to obtain the narrow size distribution particles. The addition of small amount of ammonium sulfate surfactant, although has no influence on YAG garnet phase formation, has significant effect on dispersion, particles distribution and sinterability of the resultant YAG and Yb:YAG powders. Compared with the undoped sample, the green body of Yb:YAG doped with ammonium sulfate has higher total shrinkage, linear shrinkage rate and relative density through sintering at 1600 °C. The resultant Yb:YAG powders can be sintered into transparent ceramics at 1700 °C through vacuum sintering. The influence of the sulfate ions on characteristics of the resultant powders was thoroughly studied.

Keywords: homogeneous co-precipitation method; $(NH_4)_2SO_4$; homogeneous powders; Yb:YAG; Rare earths

1. Introduction

Yttrium aluminum garnet ($Y_3Al_5O_{12}$ or YAG) has attracted widespread attention owing to its good optical properties and thermal stability. Dy, Ce or Eu doped YAG ceramics are significant inorganic phosphors, which can be applied to the field of emission displays (FEDs), scintillators and so forth. Yb or Nd doped YAG crystals are excellent solid-state laser materials[1-6]. Polycrystalline transparent YAG ceramics have the advantages of high dopant concentration, ease of fabrication and low cost, making them promising substitute for single crystalline YAG. Compared with Nd:YAG, Yb:YAG has the advantages of no concentration quenching, low thermal loading, long fluorescence lifetime and high quantum efficiency and so on[7,8].

In recent years, more and more effort has been committed to the fabrication of YAG powders, transparent ceramics and YAG composite ceramics. Various kinds of wet chemical synthesis routes were applied to ceramics preparation instead of traditional solid reaction process[9-13], such as precipitation method, combustion method, and microwave method, which have the advantages of low YAG phase formation temperature, well mixing of the initial substances and fine chemical homogeneity of the resultant powders. Among which, the co-precipitation method is a potential synthetic technique. Nevertheless, in the co-precipitation method, pH value of the mixed solutions varies with adding the cation salts. Ultimately, the resultant powders are probable to have broad particle size distribution. In the homogeneous precipitation technique, the aluminum ions preferentially precipitated, while yttrium ions precipitated on the aluminum rich precipitates on account of the discrepancy of solubility product of the Y^{3+} and Al^{3+}, which leads to low uniformity and low sintering activity of the resultant products.

Homogeneous, dispersed and high sintering activity powders are key to the manufacture of YAG transparent ceramics and high performance phosphors[14]. In order to resolve the impurity induced lattice defects in traditional solid-state technique, and the broad particle size distribution and differential precipitation of cations in the wet chemical synthesis process, a novel homogeneous co-precipitation method is proposed in this paper to produce well homogeneous YAG powders. The technique, adopted dropwise addition of cations solutions into hot urea solutions with the existence of small amount of ammonium sulfate, has the advantages of stable pH value during precipitation

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