# Aerosol synthesis of phosphor particles based on $Eu^{3+}$ activated gadolinium oxide matrices



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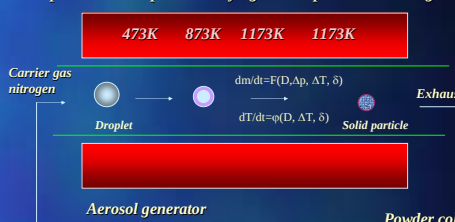
**ABSTRACT**

The designs of advanced phosphor materials effort emphasize the ultrafine powder synthesis control ability. Particularly, when spherical, aggregate-free, uniformly sized particles are considered, luminance and resolution give an improved behavior on their application abilities compared with conventional coarse grained phosphors. Aerosol synthesis as a dispersion phase powder processing method was applied to synthesize the rare earth system Eu - activated gadolinium oxide matrices, commonly used as red phosphors in cathodoluminescence. The process involves aerosol formation ultrasonically (aerosol generator operating at 1.7 MHz) from the precursor salt solutions and control over the aerosol decomposition in a high-temperature tubular flow reactor at the temperatures up to 1173K. Consequently, spherical, solid, agglomerate-free, submicronic particles with the mean particle size below 900nm are obtained. The particle morphology, phase and chemical structure are revealed in accordance to various analysis methods (XRD, DTA, SEM-EMAX) and discussed in terms of precursor chemistry, process parameters and luminescent properties.

*Evaporation- Precipitation- Drying- Decomposition-Sintering*

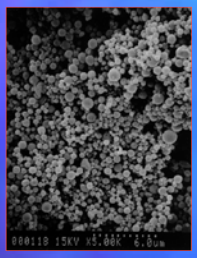


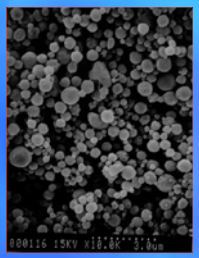

- *Solution characteristics, c = 0.1 mol/dm³*

$Gd(NO_3)_3 nH_2O$ (n=5.92) and

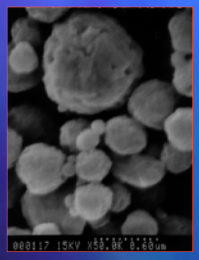
$Eu(NO_3)_3 nH_2O$ (n=5.42)

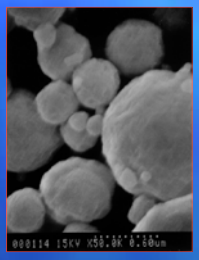
*Phosphor particles*
**$Gd_2O_3$ : Eu**

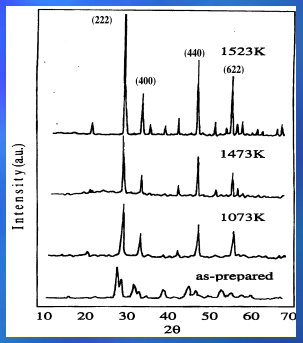




*$Gd_2O_3$: Eu as-prepared particles*
*gas flow rate: 120 l/h*
*residence time: 25.5 s*







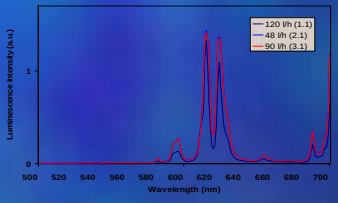

*XRD of the as-synthesized powders : cubic $Gd_2O_3$ phase (space group Ia3, file card 43-1014) and a phase that is structurally similar with cubic $Gd_2Te_2O_{15}$ (space group Fm3m, file card 37-1400).*

*Red emission for the as-prepared powders, two dominant peaks at 615 and 624nm. The sharp emission band at 612nm is evident in all investigated samples annealed in the range from 1073-1473K.*

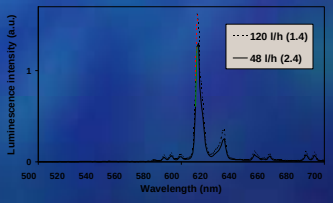
Table I. Synthesis conditions and characteristics of $Gd_2O_3$:Eu phosphor particles

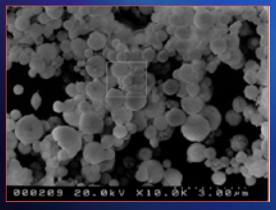
| Sample | Flow rate (l/h)/ Residence time (s) | Particle size (nm) / Specific surface area ($10^6$ $m^2/m^3$) | Annealing temperature (K) / time (h) | Crystallite size (nm) / lattice microstrains (Scherrer eq[12]; Voight function modeling[13*]) | |
|---|---|---|---|---|---|
| F1.1 | 48 / 63.1 | 770 / 8.74 | As-prepared | 17.10 / 102.6 | |
| F1.2 | | | 1073 / 10 | 25.66 / 45.57 | |
| F1.3 | | | 1073 / 24 | 68.46 / 6.4 | |
| F1.4 | | | 1473 / 8 | 136.85 / 1.6 | |
| F2.1 | 90 / 34.3 | 800 / 8.18 | As-prepared | - | |
| F2.2 | | | 1073 / 10 | 82.12 / 4.45 | |
| F2.3 | | | 1473 / 8 | 136.87 / 1.6 | |
| F3.1 | 120 / 25.5 | 890 / 7.5 | As-prepared | 14.66 / 139.6 | 5.9* |
| F3.2 | | | 1073 / 10 | - | |
| F3.3 | | | 1073 / 24 | 17.18 / 102.5 | 9.5* |
| F3.4 | | | 1473 / 8 | 136.81 / 1.60 | 15.2* |

Influence of the gas flow rate

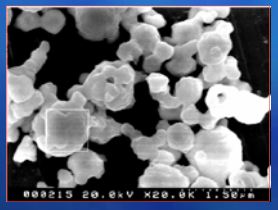



Influence of the flow rate (annealing temperature 800C)



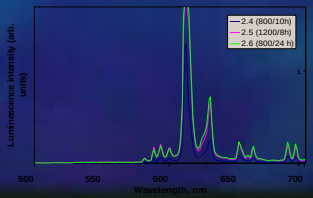



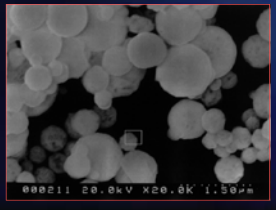
*$Gd_2O_3$: Eu particles*
*gas flow rate: 120 l/h*
*annealed at 1073K /10h*

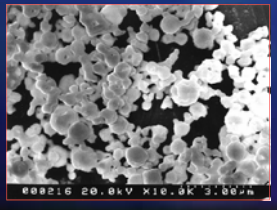


*$Gd_2O_3$: Eu particles*
*gas flow rate: 90 l/h*
*annealed at 1473K /8h*

Influence of the annealing temperature





## CONCLUSIONS

**Aerosol synthesis was used for the preparation of red phosphor particles based on cubic $Gd_2O_3$ :Eu. As-prepared particles are spherical, nonagglomerated, submicronic (<900 nm), comprised of nanocrystallites (~6nm). In order to control the particles crystal structure and to establish the conditions for stabilization of the low-temperature gadolinia cubic phase, the process parameters such as temperature distribution, gas flow rate and annealing temperatures were adopted. It was shown that the phase content influences luminescence causing the appearance of two dominant peaks at 615 and 624 nm for as-prepared particles when a two-phase particle structure is established. However, the sharp emission band at 612 nm is associated with single cubic gadolinium oxide. Particle morphology affects luminescence properties implying that particle aggregation and/or sintering caused the decrease of luminescence intensity.**

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