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**Original research papers**  
**Luminescence Characteristics of Polymer  
Passivized Strontium Aluminate Phosphor**

**ABSTRACT**

Trivalent Europium ions doped strontium aluminate as the host and passivized by Polyvinyl pyrrolidone (PVP), polyvinyl alcohol (PVA) and carboxyl methyl cellulose (CMC) shows luminescence arising from various  $^5D_2$  and  $^5D_0 \rightarrow ^7F_4$  transition of  $Eu^{3+}$  ion upon excitation at 285nm. The influence of the varied polymers concentration on crystal structures and optical properties was studied by means of X-ray diffraction (XRD) and photoluminescence (PL) spectrometer. XRD pattern revealed a dominant phase characteristics of orthorhombic strontium aluminate compound at 1000°C with an average crystal sizes of the phosphors calculated to be ~39nm – 42nm. Photoluminescence emission spectral showed a broad peak at 648nm with PVP sample having the highest luminescence intensity. These materials are likely to have high efficiency of conversion in the LED and display industries without a significance changes in the crystal sizes within the various phosphor samples.

*Keywords: CMC, Phosphors, Optical properties, PL, PVA, PVP, Strontium Aluminate*

**1. INTRODUCTION**

Photoluminescent material with long afterglow is a kind of energy storage material that can absorbs both ultraviolet (UV) and visible lights from sunlight, and gradually releases the energy in the dark at a certain wavelength. These sorts of materials have great potential for various device applications and have been widely studied by many researchers<sup>1</sup>. Phosphorescence, called afterglow, refers to a luminescence with delayed radiative return that is caused by the trapping of photo-generated electrons and/or holes at intrinsic or extrinsic defect sites of the material<sup>2,3</sup>; hence, when freed by thermal energy, these trapped charge carriers recombine at the ionized luminescent centers. Phosphorescence in other words, is a thermoluminescence with de-trapping at room temperature<sup>4</sup>.

Strontium aluminate in recent years has attracted numerous researches globally due to their excellent properties like high quantum, efficiency, chemical and thermal stability and long persistence of phosphorescence<sup>5</sup>.

Strontium Aluminate phosphors doped with rare earth metal ions have emerged as materials with great potential especially europium ion<sup>6</sup>. The mechanism of photoluminescence properties appears to depend mainly on the doping elements<sup>7</sup>. The rare earth metal europium has a strong red emission when doped in different matrices<sup>8,9,10</sup> the prominent is 612nm arising from electric dipole moment allowed transition<sup>11</sup>.

The intensity and duration of the phosphorescence of  $\text{SrAl}_2\text{O}_4$  (especially  $\text{Eu}^{2+}, \text{Dy}^{3+}$  doped) makes it possible to envisage a continuous light emission; the materials with larger size are prepared using solid-state reaction techniques<sup>2,12</sup>.

To obtain much smaller particles, larger phosphor particles need to be further grinded, but this can introduce additional defects easily, hence luminescence efficiency reduction<sup>3</sup>. Different synthetic routes are employed to achieve high purity, homogenous single phase, thermally stable and radiation resistant fine particle powders<sup>13</sup>. The light output is affected by particle size distribution as well as the particle shape<sup>14</sup>.

Since nanoparticles have extremely high tendency of adhesion and high level of aggregation, it is of great importance to develop relevant techniques to control the dispersive/aggregation phenomena of nanoparticle to apply them into materials that are functional; Hence the choice of suitable passivating agents (PVP, PVA and CMC) which has been capped with ZnS and ZnO majorly but less attention of its function was given to capping it with  $\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$  phosphor.

Newer technologies developed to solve this challenge include, reverse micro emulsion<sup>6</sup>, combustion technique<sup>15</sup>, sol-gel and co-precipitation were employed to prepare  $\text{SrAl}_2\text{O}_4$  phosphors. The importance of these research findings involving different polymers as passivating agents on  $\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$  phosphor is to verify their influence on the crystals sizes and luminescence emission characteristics at the excitation of 285nm.

## 2. EXPERIMENTAL DETAILS

### 2.1 Synthesis of $\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$ -(PVP; CMC; PVA) Phosphors

$\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$  passivated by PVP, CMC and PVA were synthesized by direct combustion technique using analytical grade of  $\text{Sr}(\text{NO}_3)_2$ ,  $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ,  $\text{EuCl}_2 \cdot 6\text{H}_2\text{O}$  and  $\text{CH}_4\text{N}_2\text{O}$  as a starting materials. Stoichiometric amount of starting materials was dissolved in 5mL of de-ionised water, stirred continuously for 20mins until clear solution was obtained. The doping concentration of  $\text{Eu}^{3+}$  ions was 0.2mol %. This solution was kept aside and labeled Sol A. In another section, 0.3M of PVP or CMC or PVA was dissolved in 5mL of de-ionised water and rigorously stirred until clear solution was formed, this solution was also kept aside and labeled Sol B. Sol A and Sol B were added together, mixed, stirred on a magnetic stirrer for 30mins till clear solution of the precursors was formed. The mixed solution was oven dried at 80°C for 20hrs. The fluffy form of material obtained after cooling (Fig.1b) was crushed and 0.309g of  $\text{H}_3\text{BO}_3$  was added as a reflux<sup>16</sup> and further annealed at 1000°C for 2hrs. Fig. 1b photograph was obtained under the same condition (same order of preparation, calcination temperature & time, and characterization). Within few minutes, reaction starts giving yellowish flame, this continues for few seconds and it is over. The mixture froths and swells forming foams, which rupture with a flame and glows to incandescence. The white powder obtained was crushed into powder for characterizations. A flow diagram describing the preparation is shown in Figure 1a.

The phase identification of synthesized powder samples was carried out using X'PertPro, PANalytical XRD spectrometer ( $\text{CuK} \alpha: 1.541\text{\AA}$ ) at 40kv, 40mA and a scan rate of 0.02°/s in the 2 hours range from 10° to 70° for the verification of the crystal structure and the average size of the particles at Sheda Science and Technology Complex, Abuja-Nigeria. The photoluminescence emission and excitation measurement was done using

78 Photoluminescence Spectrometer, Perkin-Elmer LS-55 Fluorescence at CSIR Pretoria,  
 79 South Africa.

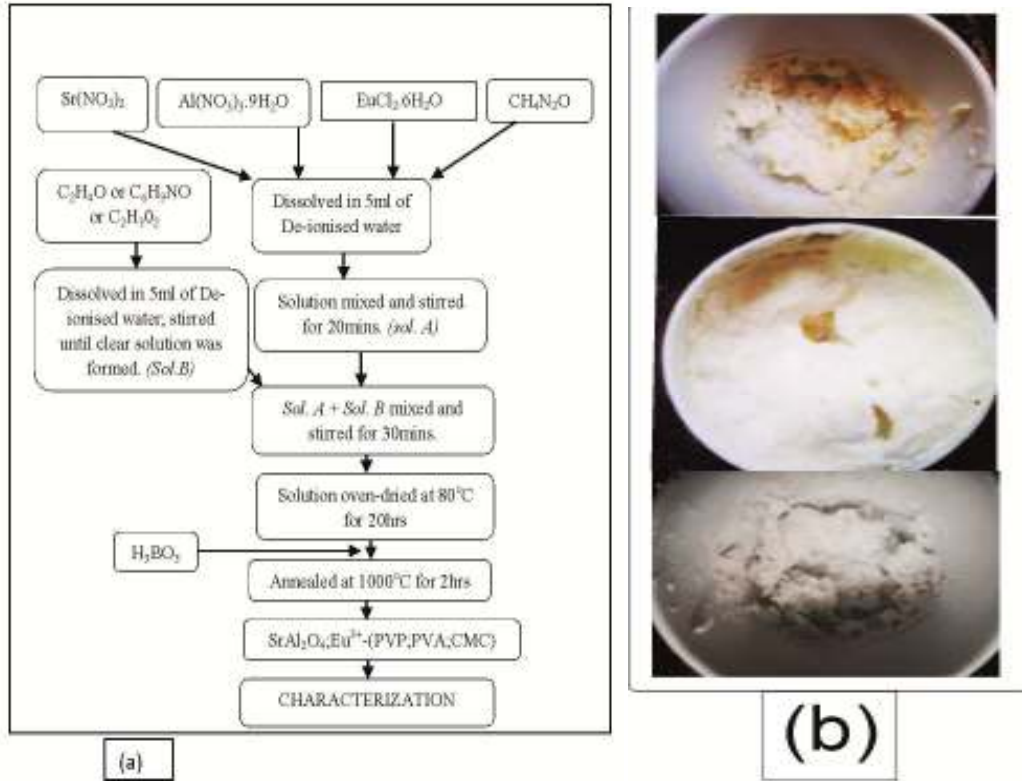
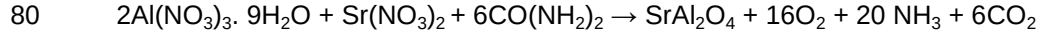


Fig 1. Schematic diagram showing synthesis of  $\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$ -(PVP; PVA; CMC) phosphors

### 3. RESULTS AND DISCUSSION

#### 3.1 Crystallinity of the Samples

Fig.2 illustrates the combined X-Ray Diffraction (XRD) patterns of the different passivized strontium aluminate samples. Sample(s) was ground to fine powder, and powder X-ray diffraction was taken with X'PertPro, PANalytical made in Netherland XRD with  $\text{CuK}\alpha(1.541\text{\AA})$  radiation. All the peaks could be indexed to orthorhombic phase of strontium aluminate<sup>15,16</sup>. The XRD pattern of PVP passivized nanoparticles has reflection of (021), (121), (211) and (311) planes<sup>15</sup>. The reflection planes for CMC and PVA are (210), (211), (112), (113).

The average grain size of the powder was estimated using the Scherrer's formula:

$$d = \frac{0.89\lambda}{\beta \cos\theta}$$

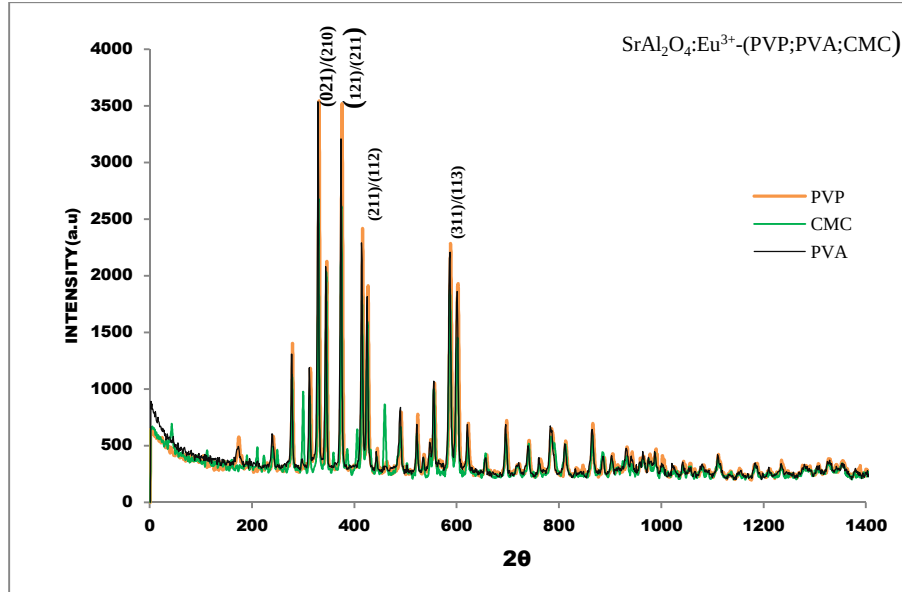
where  $d$  is the average grain size,

$\lambda$  is the wavelength of  $\text{Cu K}\alpha$  ( $\lambda=0.154056\text{nm}$ ),

$\beta$  is the full width at half maximum intensity

(FWHM), and

102  $\theta$  is the Bragg's angle. All conversion was done in  
 103 radian.  
 104 The grain size calculated from Sherrer formula was 42.01nm, 41.45nm and 38.64nm for  
 105 PVP, PVA and CMC respectively agreed with that by Nathan *et al* 2015<sup>15</sup>.  
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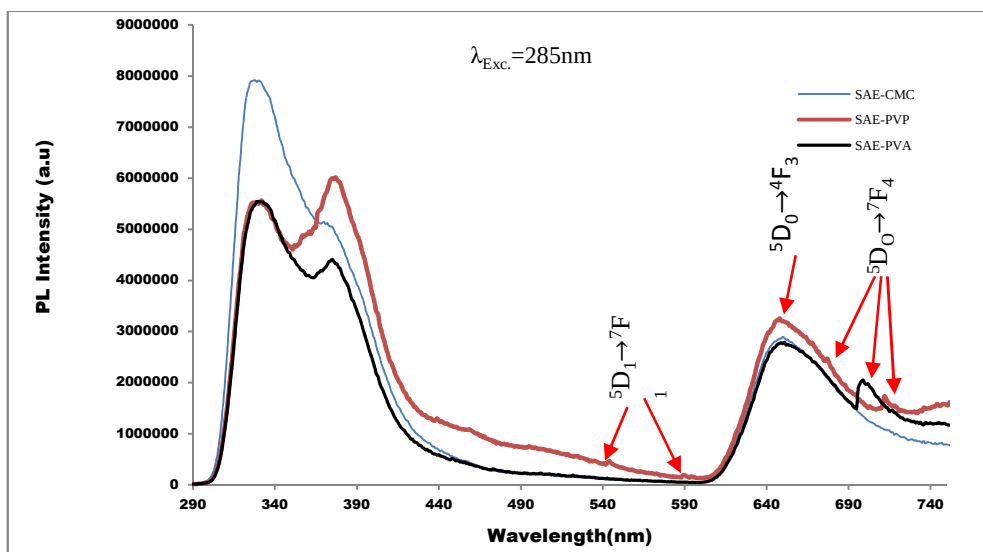
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 109  
 110 Fig 2.XRD of  $\text{SrAl}_2\text{O}_4:\text{Eu}^{3+}$ -(PVP;CMC;PVA)sample prepared by chemical combustion  
 111 reaction.  
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### 113 3.2 Luminescence Studies

114  
 115 Fig.3 shows emission spectra of the three samples under consideration synthesized by  
 116 direct chemical combustion techniques. The emission characteristics were recorded at  
 117 285nm wavelength excitation. Five observed emission peaks associated to PVP are 541nm,  
 118 592nm, 648nm, 674nm, and 712nm basically within the yellow-red colour band. Sample  
 119 passivized by PVA shows broad emission at 648nm and 699nm; CMC passivized sample  
 120 only has a broad emission peak at 648nm. The intensity of PVP at 648nm peak relative to  
 121 the other at that emission wavelength is the highest<sup>15</sup>. **PVP sample which has the highest  
 122 crystal size of 40nm also gave the highest luminescence intensity, indicating it's more  
 123 luminous for LED and other display usage under the said conditions.**

124 These PL spectra results confirmed the incorporation of europium in the strontium aluminate  
 125 lattice within the +3 state.  $\text{Eu}^{3+}$  transition are given by  $^5\text{D}_0 \rightarrow ^7\text{F}_J$  ( $J=0,1,2,3,4$ ) are undoubtedly  
 126 pronounced in these spectra<sup>17</sup> but these relative intensities of  $\text{Eu}^{3+}$  transition varied from  
 127 sample to sample. The emission peak at 648nm which is the major peak in these spectral,  
 128 ascribed to the  $^5\text{D}_0 \rightarrow ^7\text{F}_3$  transition, which operates by electric dipole interaction<sup>18</sup>. The other  
 129 peaks at 541nm and 590nm ( $^5\text{D}_1 \rightarrow ^7\text{F}_1$ ) having a very weak intensity sensitive to ligand  
 130 environment of the magnetic dipole; 674nm, 699nm and 712nm ( $^5\text{D}_0 \rightarrow ^7\text{F}_4$ ) are electric dipole  
 131 transition<sup>18,19</sup>.

132 The trivalent europium ion is non-degenerate ground state  $^7F_0$  and non-overlapping  $^{2S+1}L_J$   
 133 multiplets<sup>20</sup>. These emission wavelengths are all in the red light region. The crystal fields are  
 134 affected by these transitions.  
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 138

139 Fig 3. PL emission spectra ( $\lambda_{exc.}$  285nm) of polymer passivized strontium  
 140 Aluminate synthesized through combustion techniques and annealed at 1000°C  
 141  
 142

## 143 CONCLUSION

144 Trivalent Europium activated polymer passivized Strontium Aluminate nanoparticle having  
 145 ~39.00nm -42.00nm crystal size was successfully prepared by direct combustion methods.  
 146 These exhibit broad emission bands at 648nm with PVP having the highest luminescence  
 147 intensity. These materials are likely to have a high efficiency of conversion in the LED and  
 148 display industries.  
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