Chapter – II

Phosphor Synthesis

CHAPTER -2

PHOSPHOR SYNTHESIS

Introduction:

In this chapter, the detailed synthesis processes of barium magnesium aluminates [BAM] phosphors are discussed. The solid state diffusion method was used for the synthesis of Eu, Nd, Pr, Ce and Mn doped BAM phosphors The different parameters like, purity of raw materials, raw material blend ratio, flux used and particle size control plays important role in the synthesis of phosphors. The characterization techniques used in the present work to study inorganic powder phosphors are: Fluorescence spectrofluorophotometer for studying emission and excitation spectra and windows based Thermoluminescence reader which is discussed in the chapter 3 apart from XRD characterization of the BAM phosphors.

Solid State Diffusion Process

Theory:

The phase transformation between two solids takes place via decomposition, synthesis and subsituational reactions. The two solids if they are in powder form will react only when they are in close proximity and usually when intimately mixed and heated. Thus, the degree of dispersion and mixing of one reacting solid with another is important to the overall mechanism of solid-state reaction. When A reacts with B and vice versa, a phase boundary is formed at each interface i e. between A and B and between AB and B This boundary grows outward as shown in Fig. 2.1. Once a phase boundary is established, then each reaction species must diffuse through the phase AB to reach it's opposite phase boundary, in order to react. A diffuse through the right phase of AB while B diffuses to the left. Thus the overall solid state reaction is dependent upon the rate of diffusion of the two species. These two rates may or may not be the same. The AB has certain ordered structure and so A and B do not react in the middle.

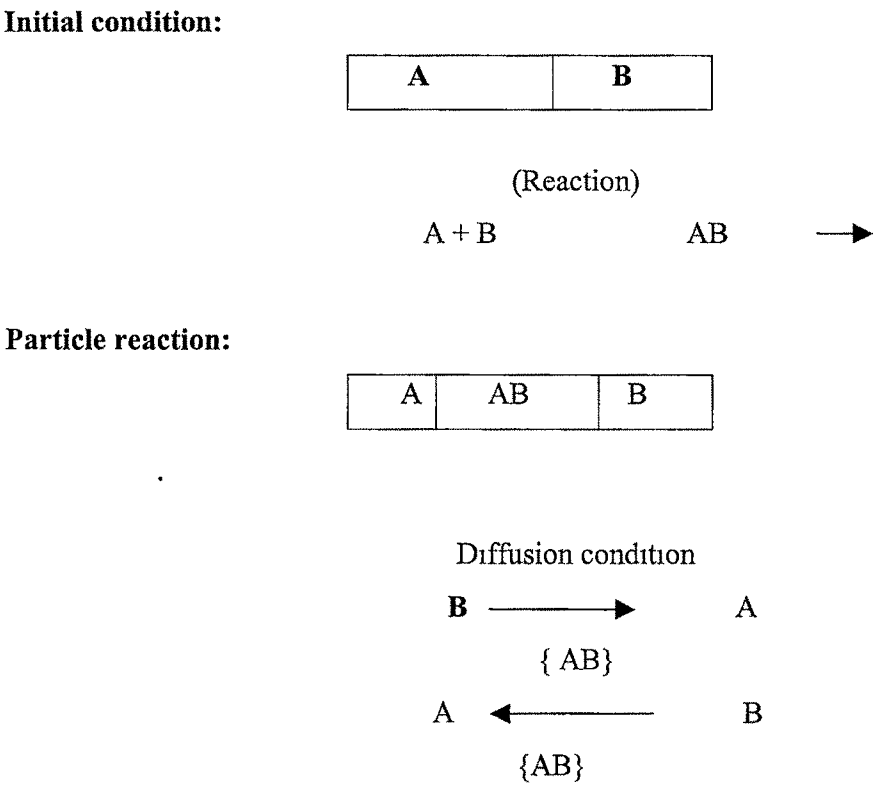


Fig. 2.1: Formation of a phase boundary during diffusion process

The rate of solid state reaction depends on the number of nuclei produced per unit volume. A nucleus is a point where the atoms or ions have reacted and begun formation of the product structure. The nuclei formation is of three types. (I) Phase boundary controlled (II) nuclei growth and (III) diffusion controlled. In diffusion process interchange of atoms takes place by (a) vacancy hopping (b) interstitial movements and (c) dissociative exchange. In 1932, Fick formulated the laws, which described the diffusion processes in solids Consider a lattice as shown in Fig 2.2. With this three dimensional it is easy to see that there are six ways for an atom (ion) in x-plane to move to the y-plane.

$$J_{x \rightarrow y} = 1/6 \, .1/\tau \, .n_A \, .Ra \text{ -----------------(1)}$$

Thus the concentration of A-atoms in the y-plane will be

$$N_{a(y)} = n_A + a \, dn_A / dx \text{ -----------------(2)}$$

Combining equation (1) and (2)

$$J_{x\rightarrow y} = (n_A + a\, dn_A / dx) - (aR / 6\tau) \text{ ---(3)}$$

τ = time of stay at a given site
$1/\tau$ = Frequency of jumps
n_A = number of A-atoms per unit volume
R = cross-sectional area of a given plane
a = lattice vector
$J_{x\rightarrow y}$ = number of jumps per unit time from x-plane to y-plane

If we assume that $J_{y\rightarrow x}$ is also valid, then we have

$J = J_{x\rightarrow y} - J_{y\rightarrow x}$

Where J→ total number of jumps that occurs.

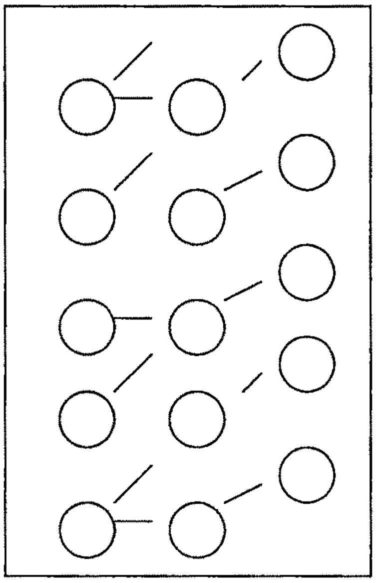


Fig. 2.2 . Three-dimensional lattice structure

Thus $J = aR.\, n_A/6\tau - (n_A + a\, dn_A/dx).\, (aR/6\tau) = -a^2 R/6\tau \,.\, dn_A/dx$ --------- ------(4)

Now, diffusion coefficient is defined as

$D = a^2/6\tau$ or $\alpha a^2/6\tau$ (interstitial)

Where α is the number of interstices in the lattice, for the interstitial case.

Therefore, $J = -DR \,.\, dn_A/dx$ ----------(5)

Let concentration $c = R.\, n_A$ so that $dc/dx = R dn_A/dx$

Then $J = -D\, dc/dx$ -------------(6)

Which is the Fick's first law of diffusion. Here it is assumed that discrete jumps take place and there are no concentration gradients between the planes. If such exists then dc/dx= constant, and we must subtract the two different jump rates.

$J_1 - J_2 = -\Delta x \,.\, (dc/dt)$ ------------------(7)

If the last term is taken only in respect to the x-dimension then

$(dc/dt)x = d[D\, dc/dx\,] = D d^2c/dx^2$ ---------------(8)

This is Fick's second law. We can also show that the diffusion coefficient "D" is temperature dependent and we can fit it to an Arrhenious equation $D = D_0 \exp(-E/KT)$

or $$E_D = - K_1 d\,(1nD)/(1/\tau) \quad \text{---------(9)}$$

Now the reciprocal of the time of stay is the jump frequency. And we can write

$$D = a^2/6\tau = \alpha a^2/\tau = \alpha\omega a^2$$

This jump frequency can be related to the free energy of the lattice via a Boltzman distribution. Using a series of manipulations we get

$$\omega = \omega_0\, \alpha \exp(-\Delta G_0/ r\, t) \;\; \omega_0\, \alpha \exp(-\Delta S/R - \Delta H/RT) \quad \text{---------(10)}$$

It turns out that the ω_0 is the atomic vibrational frequency or the zero phonon mode of the lattice and that $\omega_0 = 1/2\pi \,.\, \sqrt{K}/m$ where 'k' is the elastic constant of the lattice and 'm' is the reduced mass of the atoms composing the lattice. There are three types of diffusion reactions, (I) simple diffusion (II) phase boundary controlled and (III) material transport.

All diffusion motion occurs by defect movement in the lattice. Fig.2.3 shows the mechanism of self-diffusion. Self-diffusion can occur at least by two mechanisms, vacancy and interstitial. Both are ' hopping ' motions. The rate of diffusion differs depending on the diffusing species. If we compare electron and vacancy, the diffusion of former will be very fast while that of latter will be very slow. The Kirchendall effect deals with this manifestation [1].

For simple diffusion controlled reaction we can write

$$X^2 = 2D\, c_o\, t\, V_M + (a)^{1/2} \quad \text{-----------------------------(11)}$$

Where c_o = concentration of constituents at interface, V_M = volume of the product AB per mole of the reactants, a = surface layer thickness at the interface when t=0. It is also well to note that the final volume of the product may be the same as that of the reactant.

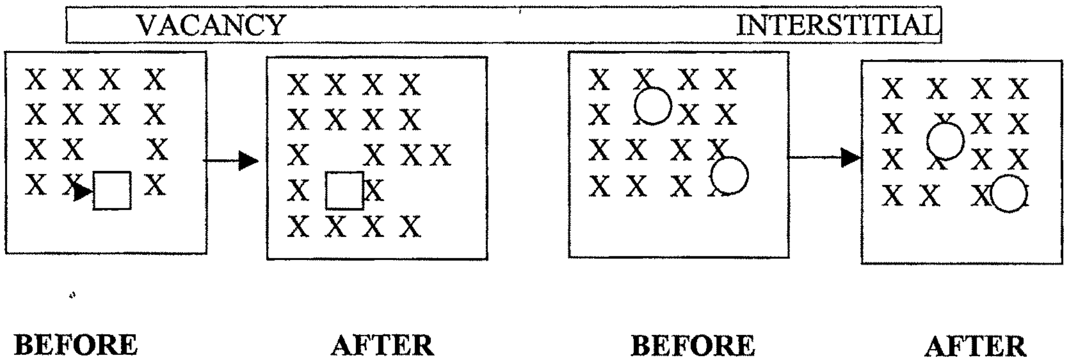


FIGURE : 2.3 Mechanism of self diffusion

The phase boundary controlled reactions are slow so that the diffusing species pile up. That is the reaction to rearrange the structure is slow in relation to the arrival of the diffusing ions or atoms. Thus a phase boundary focus exists which controls the overall rate of the solid state reaction. This rate may be given as

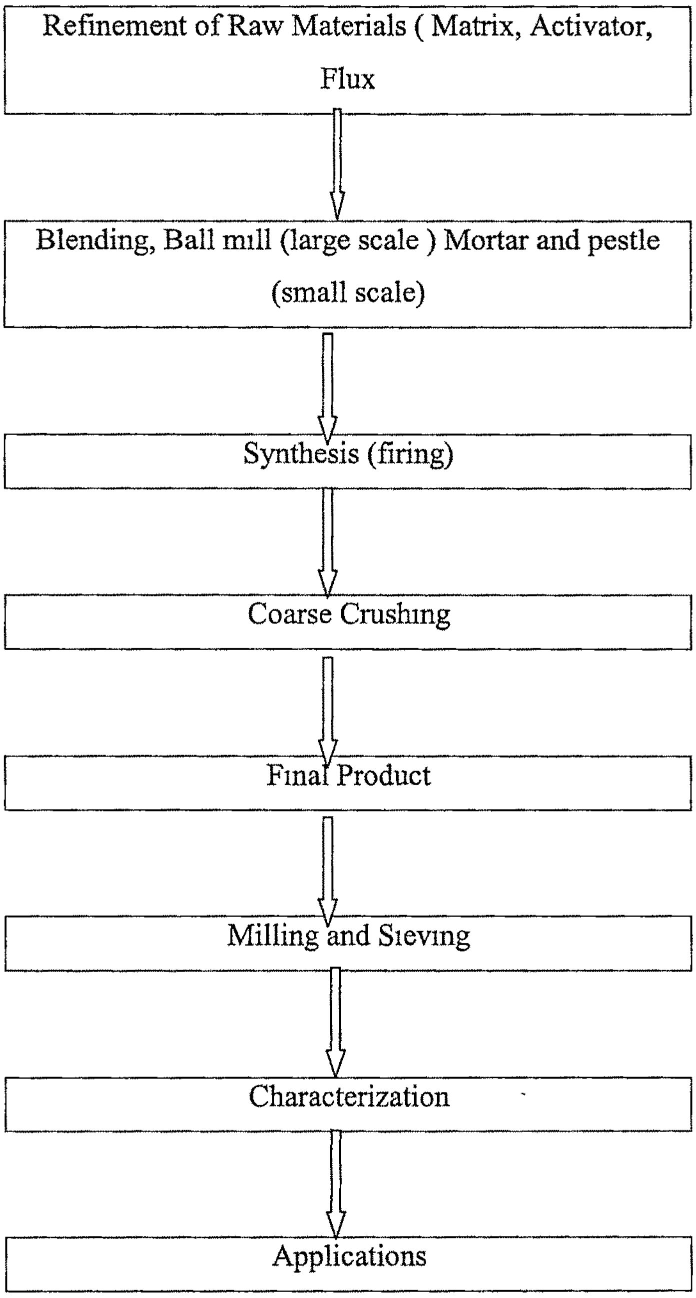
$$dx/dt = k_1 (S_t / V_0)$$

Where S_t → instantaneous surface area; V_0 → original volume of particles reacting. Material transport frequently involves an external gaseous phase and a general formula has not yet evolved.

Synthesis:

Almost all rare earth activated phosphors are synthesized by solid state diffusion reaction between the raw materials at high temperature. Although the basics of the industrials scale phosphor synthesis were well established decade ago, however the process of optimization is still continuing because of the importance for phosphor efficiency required in different applications, the production cost and hence market share. The synthesis of a phosphor with reproducible efficiency and chromaticity requires careful control on the purity, stoichiometry and particle size of the starting raw materials. Fig. 2.4 gives the generals concept of phosphor synthesis process. First the high purity materials of the host crystal, activators, and the fluxes are blended, mixed and then fired in a container. As the product obtained by firing is more or less sintered, it is crushed, milled and then sorted to remove coarse and excessively crushed particles. In some cases the product undergoes surface treatment also.

Fig.2.4 Flow chart of phosphor synthesis process



Phosphor Parameters

Purity of raw materials:

Even a small amount of impurities sometimes change phosphor characteristic drastically, therefore the raw materials used must be of high purity. One must exercise all cautions to choose pure raw materials to form the phosphor and prevent further contamination from occurring during the processing to form the phosphor. For example in case of Y_2O_3. the most frequently used rare earth compound, the rare earth other than 'Yttrium' should be kept below 10 ppm and the total amount of heavy metals below 10 ppm. In the present work the rare earth oxides used are procured from Indian Rare Earth's Limited and were of 99.9% purity and other chemicals from Chemical Center and Ducat chemicals, Baroda.

Raw materials blend ratio:

The completeness of the solid state reaction depends on the relative diffusion rate of the reacting species. The rate of reaction between the two solids is an exponential one, rapid in the beginning but slowing as the components are used up. An asymptote is gradually approached but the reaction never becomes 100 % complete. Thus we always end up with an un reacted components. Any such impurity affects the efficiency of the so-produced phosphor. Therefore in formulating a phosphor composition, one always employs a small excess of the anion reactant so as to avoid the presence of strongly absorbing cationic species in the end product. The excess components either vaporize during the firing or are consumed to create byproduct. They can sometimes be washed away after the reaction and we get the resulting phosphors very closed to the stoichimetric composition.

Use of flux:

The substance that is added to the raw material mixture to help crystal growth and necessitates the required chemical reaction is called as a flux. It does so by providing a liquid phase for transport of the materials including ions, so as to increase the crystallinity and the size of the particles so produced. When the flux melts, the surface tension of the liquid helps the particles to coagulate. The melt also makes it easier for particles to slide and rotate, provide chances of particle-particle contacts and promote crystal growth. However, the firing temperature and firing time are always a cause of concern in synthesis of these phosphors In the present preparation the flux used is $BaCl_2$ and AlF_3 around 0.5 gm.

Crucibles and atmosphere:

In phosphor industry, quartz and silicon carbide are the most frequently used container materials for firing the phosphors. In the present work, samples were prepared using alumina / silica crucibles. Firing carried out in air. The firing temperature is 1200 °C for four hours.

Furnace for Heating the Specimens:

A muffle furnace of muffle sizes 50 X 50 X 50 cm is used for preparing the phosphors. The sample of synthesized phosphor were heated up to 1200°C for three hours in a furnace made by 'Alfa Furnaces, Baroda. The furnace has a very precise temperature controller of 'ADI' make, with a resolution of ±1°C at 1200 °C.

Synthesis of the Barium Magnesium Aluminates Phosphor (BAM)

The doping of $BaMgAl_{10}O_{17}$ (BAM) with Eu^{2+}, Mn^{2+} yields highly efficient luminescence phosphors which are widely used as display phosphors mostly in PDP's, Mercury low pressure and Xe low pressure discharge lamps. The excellent stability of the BAM phosphors makes it possible to develop very high loading fluorescent lamps such as compact fluorescent lamps (CFL's) and high loading photocopying lamps [11].

By considering the application potential the BAM phosphors are prepared and studied for its luminescence characteristics. The chemical composition of BAM originally proposed as $BaMg_2Al_{16}O_{27}$, but a true single phase was later found to take the form $BaMgAl_{10}O_{17}$. The later showed better maintenance performances, both in lamp manufacturing process and in lamp operation By considering the application potential of these phosphors (BAM) with different dopant concentrations the present work was under taken for this thesis. Since the CFL's are the present day energy saving lamps which are widely used globally therefore it is considered the present phosphor synthesis will help the local industry to use the indigenously developed materials

The phosphors i.e. $BaMgAl_{10}O_{17}$: Eu, Mn, Pr, Ce, Nd were prepared using high temperature solid state reaction method with different Eu, Mn, Pr, Ce, Nd concentrations. High reaction temperature and long processing time is always a bit problem with solid state diffusion process, therefore required quantities of $BaCl_2$ and AlF_3 were used as a flux in the synthesis of the phosphors. The work presented in this thesis consists of the phosphors synthesized in the laboratory and are indexed in the table no 2.1 (Samples No 1-27).

The rare earths are costly but have proved the benefits for phosphor industry which justify their use in the display industry. Because of the demand for rare-earth phosphors for television, X-ray excited materials and fluorescent lamps, the chemical technology for preparation and purification of these compounds has been improved greatly, providing consistent and reliable materials in purity levels required for efficient phosphor absorption and emission.

The blending and mixing procedures of RE, NRE and RE:NRE activated Barium Magnesium Aluminate materials, were prepared using solid state reaction . Stoichiometric proportion of raw materials namely; Barium Nitrate[$Ba(NO_3)_2$], Magnesium Nitrate [$Mg(NO_3).6H_2O$], Aluminum Nitrate[$Al(NO_3$ $9H_2O$], with Eu_2O_3, Ce_2O_3 , Nd_2O_3 , Pr_2O_3 and MnO_2 impurities were grinded in an agate motor and pestle and mixed and transferred into alumina /silica crucible . The resulting material has been fired at 1200°C temperature for four (04) hours Subsequently, the phosphors have been cooled to room temperature. The materials thus obtained have been grinded further to get uniform powder specimen. These powder specimens have been used for different experimental measurements.

The general formula of present phosphor is **Ba_{1-x} $MgAl_{10}O_{17}$: Y_x**

Where Y indicates the different activators like Eu , Mn, Ce , Pr and Nd

X Indicated the activator or Co-activator concentration.

The following are the concentrations of the raw materials used for the preparation of the phosphor i.e 0.5,1.0 and 1.5 molar percentage of the single and double dopants.

Preparation of $BaMgAl_{10}O_{17}$: Eu

Mole Weight of the raw material

$BaCO_3$:- 197.35, $MgCO_3$:- 84.313,Eu_2O_3 :- 351.97, Al_2O_3 :- 101.96
$BaCl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:-
$BaCO_3 + MgCO_3 + 5\ Al_2O_3 \rightarrow BaMgAl_{10}O_{17} + 2CO_2$

[1] Sample A-1(a) :- $BaMgAl_{10}O_{17}$: Eu (0.5%)

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + Eu_2O_3 \rightarrow BaMgAl_{10}O_{17}$ Eu

Weight of $BaCO_3$ = 1.99 gm
Weight of $MgCO_3$ = 0.854 gm
Weight of Eu_2O_3 = 0.01774 gm
Weight of Al_2O_3 = 4.1314 gm

[2] Sample A-1(b) :- $BaMgAl_{10}O_{17}$: Eu (1%)

Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Eu_2O_3 = 0 03519 gm
Weight of Al_2O_3 = 4.1314 gm

[3] Sample A-1(c) :- $BaMgAl_{10}O_{17}$: Eu (1.5%)

Weight of $BaCO_3$ = 1.97 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Eu_2O_3 = 0.0527 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Ce

Mole Weight of the raw material

$BaCO_3$:- 197 35,$MgCO_3$:- 84.313,CeO_2 :- 172.12,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + CeO_2 \rightarrow BaMgAl_{10}O_{17}$ Ce

[4] Sample A-2(a) ·- $BaMgAl_{10}O_{17}$: Ce (0.5%)
Weight of $BaCO_3$ = 1.99 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.00867 gm
Weight of Al_2O_3 = 4.1314 gm

[5] Sample A-2(b) :- $BaMgAl_{10}O_{17}$: Ce (1%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.01712 gm
Weight of Al_2O_3 = 4.1314 gm

[6] Sample A-2(c) :- $BaMgAl_{10}O_{17}$: Ce (1.5%)
Weight of $BaCO_3$ = 1.97 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.02576 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Nd

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84.313,Nd_2O_3 :- 336.48,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + Nd_2O_3 \rightarrow BaMgAl_{10}O_{17}\ Nd$

[7] Sample A-3(a) :- $BaMgAl_{10}O_{17}$: Nd (0 5%)
Weight of $BaCO_3$ = 1.99 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Nd_2O_3 = 0.016gm
Weight of Al_2O_3 = 4.1314 gm

[8] Sample A-3(b) :- $BaMgAl_{10}O_{17}$: Nd (1%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Nd_2O_3 = 0 033gm
Weight of Al_2O_3 = 4.1314 gm

[9] Sample A-3(c) :- $BaMgAl_{10}O_{17}$: Nd (1.5%)
Weight of $BaCO_3$ = 1.97 gm
Weight of $MgCO_3$= 0 854 gm
Weight of Nd_2O_3 = 0.05gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Pr

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84.313,Pr_2O_3 :- 329.817,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.
Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + Pr_2O_3 \rightarrow BaMgAl_{10}O_{17}$ Pr

[10] Sample A-4(a) :- $BaMgAl_{10}O_{17}$: Pr (0.5%)
Weight of $BaCO_3$ = 1.99 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Pr_2O_3 = 0.01662 gm
Weight of Al_2O_3 = 4.1314 gm

[11] Sample A-4(b) :- $BaMgAl_{10}O_{17}$: Pr (1%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Pr_2O_3 = 0.03298 gm
Weight of Al_2O_3 = 4.1314 gm

[12] Sample A-4(c) :- $BaMgAl_{10}O_{17}$: Pr (1.5%)
Weight of $BaCO_3$ = 1.97 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Pr_2O_3 = 0.04937 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Mn

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84.313,MnO_2 :- 86.4,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + MnO_2 \rightarrow BaMgAl_{10}O_{17}$ Mn

[13] Sample A-5(a) :- $BaMgAl_{10}O_{17}$: Mn (0.5%)
Weight of $BaCO_3$ = 1.99 gm
Weight of $MgCO_3$= 0 854 gm
Weight of MnO_2 = 0.00435 gm
Weight of Al_2O_3 = 4.1314 gm

[14] Sample A-5(b) :- $BaMgAl_{10}O_{17}$: Mn (1%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of MnO_2 = 0.00864 gm
Weight of Al_2O_3 = 4.1314 gm

[15] Sample A-5(c) :- $BaMgAl_{10}O_{17}$: Mn (1.5%)
Weight of $BaCO_3$ = 1.97 gm
Weight of $MgCO_3$= 0.854 gm
Weight of MnO_2 = 0.01293 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Ce,Mn

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84.313,CeO_2 :- 172.12,MnO_2 :- 86.4 ,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:-$BaCO_3 + MgCO_3 + 5\ Al_2O_3 + CeO_2 + MnO_2 \rightarrow BaMgAl_{10}O_{17}$ Ce,Mn

[16] Sample A-6(a) :- $BaMgAl_{10}O_{17}$: Ce,Mn (0.5%, 0.5%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.008634 gm
Weight of MnO_2 = 0.004332 gm
Weight of Al_2O_3 = 4.1314 gm

[17] Sample A-6(b) :- $BaMgAl_{10}O_{17}$: Ce,Mn (1%, 1%)
Weight of $BaCO_3$ = 1.96 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.016032 gm
Weight of MnO_2 = 0.008048 gm
Weight of Al_2O_3 = 4.1314 gm

[18] Sample A-6(c) :- $BaMgAl_{10}O_{17}$: Ce,Mn (1.5%, 1.5%)
Weight of $BaCO_3$ = 1.94 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.02537 gm
Weight of MnO_2 = 0.01274 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Ce,Eu

Mole Weight of the raw material

$BaCo_3$:- 197.35,$MgCO_3$:- 84.313,CeO_2 :- 172.12,Eu_2O_3 :- 351.97,Al_2O_3 :- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + CeO_2 + Eu_2O_3 \rightarrow BaMgAl_{10}O_{17}$ Ce,Eu

[19] Sample A-7(a) :- $BaMgAl_{10}O_{17}$: Ce,Eu (0.5%, 0.5%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.01 gm
Weight of Eu_2O_3= 0.02 gm
Weight of Al_2O_3 = 4.1314 gm

[20] Sample A-7(b) :- $BaMgAl_{10}O_{17}$: Ce,Eu (1%, 1%)
Weight of $BaCO_3$ = 1.96 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.02 gm
Weight of Eu_2O_3= 0.03495 gm
Weight of Al_2O_3 = 4.1314 gm

[21] Sample A-7(c) :- $BaMgAl_{10}O_{17}$: Ce,Eu (1.5%, 1.5%)
Weight of $BaCO_3$ = 1.94 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.03 gm
Weight of Eu_2O_3= 0.05190 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Ce,Nd

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84.313,CeO_2 :- 172.12,Nd_2O_3 :- 336.48,Al_2O_3 :- 101.96
Bacl$_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + CeO_2 + Nd_2O_3 \rightarrow BaMgAl_{10}O_{17}$ Ce,Nd

[22] Sample A-8(a) :- $BaMgAl_{10}O_{17}$: Ce,Nd (0.5%, 0.5%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.01 gm
Weight of Nd_2O_3= 0.02 gm
Weight of Al_2O_3 = 4.1314 gm

[23] Sample A-8(b) :- $BaMgAl_{10}O_{17}$: Ce,Nd (1%, 1%)
Weight of $BaCO_3$ = 1.96 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.02 gm
Weight of Nd_2O_3= 0.03 gm
Weight of Al_2O_3 = 4.1314 gm

[24] Sample A-8(c) :- $BaMgAl_{10}O_{17}$: Ce,Nd (1.5%, 1.5%)
Weight of $BaCO_3$ = 1.94 gm
Weight of $MgCO_3$= 0.854 gm
Weight of CeO_2 = 0.03 gm

Weight of Nd_2O_3= 0 05 gm
Weight of Al_2O_3 = 4.1314 gm

Preparation of Ba $MgAl_{10}O_{17}$: Eu,Mn

Mole Weight of the raw material

$BaCO_3$:- 197.35,$MgCO_3$:- 84 313,Eu_2O_3 :- 351.97,MnO_2 :- 86.4, Al_2O_3 .- 101.96
$Bacl_2$ and AlF_3 are added 0.5 gm respectively as flux.

Reaction:- $BaCO_3 + MgCO_3 + 5\ Al_2O_3 + Eu_2O_3 + MnO_2 \rightarrow BaMgAl_{10}O_{17}$ Eu,Mn

[25] Sample A-9(a) :- $BaMgAl_{10}O_{17}$: Eu,Mn (0 5%, 0.5%)
Weight of $BaCO_3$ = 1.98 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Eu_2O_3 = 0.02 gm
Weight of MnO_2= 0.00432 gm
Weight of Al_2O_3 = 4.1314 gm

[26] Sample A-9(b) :- $BaMgAl_{10}O_{17}$. Eu,Mn (1%, 1%)
Weight of $BaCO_3$ = 1.96 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Eu_2O_3 = 0 03 gm
Weight of MnO_2= 0.01 gm
Weight of Al_2O_3 = 4.1314 gm

[27] Sample A-9(c) :- $BaMgAl_{10}O_{17}$: Eu,Mn (1.5%, 1.5%)
Weight of $BaCO_3$ = 1.94 gm
Weight of $MgCO_3$= 0.854 gm
Weight of Eu_2O_3 = 0 05 gm
Weight of MnO_2= 0.01 gm
Weight of Al_2O_3 = 4.1314 gm

Table.No.2.1

The prepared phosphors are Indexed as follows

Serial Number	Sample Number	Sample Name
1	A-1 (a)	Ba $MgAl_{10}O_{17}$–Eu (0.5%)
2	A-1 (b)	Ba $MgAl_{10}O_{17}$-Eu (1%)
3	A- 1 (c)	Ba $MgAl_{10}O_{17}$ Eu (1.5%)
4	A – 2 (a)	Ba $MgAl_{10}O_{17}$-Ce (0.5%)
5	A – 2 (b)	Ba $MgAl_{10}O_{17}$-Ce (1%)
6	A – 2 (c)	Ba $MgAl_{10}O_{17}$-Ce (1.5%)
7	A – 3 (a)	Ba $MgAl_{10}O_{177}$-Nd (0.5%)
8	A – 3 (b)	Ba $MgAl_{10}O_{17}$-Nd (1%)
9	A - 3 (c)	Ba $MgAl_{10}O_{17}$-Nd (1.5%)
10	A - 4 (a)	Ba $MgAl_{10}O_{17}$-Pr (0.5%)
11	A – 4 (b)	Ba $MgAl_{10}O_{17}$-Pr (1%)
12	A – 4 (c)	Ba $MgAl_{10}O_{17}$-Pr (1.5%)
13	A – 5 (a)	Ba $MgAl_{10}O_{17}$ -Mn (0.5%)
14	A – 5 (b)	Ba $MgAl_{10}O_{17}$-Mn (1%)
15	A – 5 (c)	Ba $MgAl_{10}O_{17}$-Mn (1.5%)
16	A – 6 (a)	Ba $MgAl_{10}O_{17}$-Ce,Mn (0.5%, 0.5%)
17	A – 6 (b)	Ba $MgAl_{10}O_{17}$-Ce,Mn (1%,1%)
18	A – 6 (c)	Ba $MgAl_{10}O_{17}$-Ce,Mn (1.5%,1.5%)
19	A – 7 (a)	Ba $MgAl_{10}O_{17}$-Ce,Eu (0.5%,0.5%)
20	A – 7 (b)	Ba $MgAl_{10}O_{17}$-Ce,Eu (1%,1%)
21	A – 7 (c)	Ba $MgAl_{10}O_{17}$-Ce,Eu (1.5%,1.5%)
22	A – 8 (a)	Ba $MgAl_{10}O_{17}$-Ce,Nd (0.5%,0.5%)
23	A – 8 (b)	Ba $MgAl_{10}O_{17}$-Ce,Nd(1%,1%)
24	A – 8 (c)	Ba $MgAl_{10}O_{17}$-Ce,Nd (1.5%,1.5%)
25	A – 9 (a)	Ba $MgAl_{10}O_{17}$-Eu,Mn (0.5%,0.5%)
26	A – 9 (b)	Ba $MgAl_{10}O_{17}$-Eu,Mn (1%,1%)
27	A – 9 (c)	Ba $MgAl_{10}O_{17}$-Eu,Mn (1.5%,1.5%)

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