Effect of Mg substitution in Sr$_2$SiO$_4$:Eu$^{2+}$ nanophosphors for blue and white emission at near UV excitation

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**Key words:** Photoluminescence; Nanophosphor; (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$; Charge transfer band; FESEM,

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**Abstract**

Nanophosphors of (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ (x=0, 0.18, 0.38, 0.58 and 0.78) were prepared through low temperature solution combustion method and their luminescence properties were studied. The emission peak for Eu$^{2+}$ doped Sr$_2$SiO$_4$ nanophosphor is observed at ~490 nm and ~553 nm corresponding to two Sr$^{2+}$ sites Sr(I) and Sr(II) respectively for 395 nm excitation but the addition of Mg$^{2+}$ dopant in Sr$_2$SiO$_4$ leads to suppression of ~553 nm emission peak due to absence of energy levels of Sr (II) sites which results in a single broad emission at ~460nm. It was shown that the emission peak blue shifted with increase in Mg concentration which may be attributed to change in crystal field environment around Sr(I) sites. Therefore the
(Mg$_{0.78}$Sr$_{0.20}$Eu$_{0.02}$)$_2$SiO$_4$: Eu$^{2+}$ nanophosphor can be used for blue emission and the Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ for green-yellow emission at 395 nm excitations. The CIE coordinates for mixed powders of (Mg$_{0.78}$Sr$_{0.20}$Eu$_{0.02}$)$_2$SiO$_4$ and Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ (in 1: 1 ratio) fall in the white region demonstrating the possible use of the mixture in white light generation using near UV excitation source.

**Introduction**

Nanophosphor typically solid inorganic materials have become popular from the last decade due to their extraordinary and unique physical, chemical and optical properties. Nanophosphors are also preferable in white LED applications due to lower scattering loss as compared to larger particle sized phosphors. Phosphor based white LEDs is an efficient source of light because of its excellent properties such as high brightness, low power consumption, fast response time and long life time. One can’t realize a phosphor based white LED without blue excitation source or blue emission phosphor. The utilization of near ultraviolet (UV) radiation as excitation source for blue emitting phosphor is beneficial as human eye is not very sensitive to the wavelengths range ~380 to ~ 400 nm and also, the utilization of near-UV excitation source for blue emission will provide greater efficiency because stokes shift is small; hence lesser energy is converted into heat. Therefore, use of phosphors that can be excited in near UV region is the basis of research nowadays.

Rare earth doped Strontium Silicate based hosts (Sr$_2$SiO$_4$) have been studied in details to provide greater efficiency compared to the conventional YAG:Ce based white LED. Divalent Europium(Eu$^{2+}$) is a popular rare-earth element which on doping in hosts like phosphates, silicates, aluminates, shows parity-allowed 4f-5d energy level transition from ultraviolet to red based on host lattice and co-valence in the host. The Eu$^{2+}$ doped Sr$_2$SiO$_4$ is widely being used
for producing yellow light using blue or UV LEDs excitation source. The Sr$^{2+}$ in Sr$_2$SiO$_4$ have two cation sites Sr(I) and Sr(II) which are ten and nine coordinated by oxygen atoms respectively. Thus doping of Eu$^{3+}$ ions in Sr$_2$SiO$_4$, results in two emission bands at ~490 nm and ~560 nm. These two transitions are attributed to $^4f_{5d} \rightarrow ^4f_7$ transition of Eu$^{2+}$. The preference of Eu$^{2+}$ for Sr(I) or Sr(II) in Sr$_2$SiO$_4$ at different excitation wavelengths was also reported in the literature. The effects of Mg$^{2+}$ doping in Sr$_2$SiO$_4$:Eu$^{2+}$ was studied at 365 nm excitation and its influence on the two emission bands i.e. ~459 nm and ~564 nm has also been reported. The silicate based blue phosphor (Sr$_x$Mg$_{1-x}$ Eu$_{0.02}$)$_2$Si$_{1.02}$O$_{4.08}$ prepared by solid state route for 400 nm excitation, showed two emission bands at ~460 nm and ~570 nm for x = 0.6 and above Sr doping concentrations for 400 nm excitation. However, no studies have yet examined the photoluminescence characteristics of nano sized (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ phosphor for near UV excitation. Thus, this work is carried out to investigate the effects on photoluminescence (PL) characteristics of (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ nanophosphor by varying Mg doping concentrations.

**Experimental**

Nano powders of (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ (x=0, 0.18, 0.38, 0.58 and 0.78) were synthesized by combustion method. Nitrate solutions, Sr(NO$_3$)$_2$, Mg(NO$_3$)$_2$ and Eu(NO$_3$)$_3$ were prepared based on stoichiometric ratios using carbonates of Sr and Mg, and Eu$_2$O$_3$ respectively. Tetraethoxysilane (TEOS) solution was mixed with nitrate solution. The solution was stirred for 2 hours and Glycine was added into the solution which acts as fuel in the combustion. The solution was heated at 500°C for combustion. The powder obtained from combustion was calcined at 900°C in a reducing atmosphere (90% N$_2$+ 10% H$_2$) for two hours to get desired phase.
The confirmation of phase of the synthesized phosphors was done using Rigaku X-Ray diffractometer (Powder-XRD) with Cu Kα1 (λ= 0.15405 nm) radiation. The particle size and morphology of phosphors were observed by field emission scanning electron microscopy (FESEM; ZEISS-SIGMA). The PL and photoluminescence-excitation (PLE) spectra were measured using a FLS920-S steady state Fluorometer, Edinburgh Instruments Ltd. The standard light source used for excitation is a 450W ozone free xenon arc lamp.

Results

The XRD Patterns of the as-prepared (Sr_{0.98-x}Mg_{x}Eu_{0.02})_2SiO_4 phosphors were shown in figure 1a. The diffraction peaks of the prepared samples were indexed using JCPDS file (39-1256) which confirms the proper phase formation of Sr_2SiO_4:Eu^{2+}. The pure Sr_2SiO_4:Eu^{2+} belongs to the orthorhombic phase of α-Sr_2SiO_4. The replacement of Sr by Mg is also reflected in XRD pattern. The (Sr_{0.98-x}Mg_{x}Eu_{0.02})_2SiO_4 remains in orthorhombic phase with small percentage of β-Sr_2SiO_4 upto x = 0.58, [confirmed from the existence of the peak at 32.8° according to JCPDS file 38-0271 (marked with circle in the XRD pattern of figure 1a)]. Furthermore, we observed shifting of diffraction peaks towards higher 2θ value due to doping of Mg (as shown in figure 1b). This may be due to the substitution of Sr^{2+} ions by smaller Mg^{2+} ions, which results in shrinkage of lattice parameter of Sr_2SiO_4. The XRD pattern of (Sr_{0.20}Mg_{0.78}Eu_{0.02})_2SiO_4 shows more extra peaks in addition to XRD peaks of Sr_2SiO_4. These peaks are assigned to (021), (101), (111) and (002) planes of orthorhombic Mg_2SiO_4 (JCPDS: 78-1371). This confirms separate phase formation of Mg_2SiO_4 along with Sr_2SiO_4 orthorhombic phase for x = 0.78. Moreover we found one extra small peak at 28.2° in all diffraction patterns which may be due to unconverted phase of Eu^{3+}.15
The particle size and morphology of the prepared powders were analyzed using FE-SEM. The particles appear to be nearly spherical for Sr$_2$SiO$_4$ and no significant change has been observed in its morphology with subsequent doping of Mg in it (figure 2). The particles sizes were found to be in the range of ~20-80 nm. The deviation from spherical shape is due to nature of synthesis i.e. combustion method, where control over particle size and shape is very difficult. The inset figures are enlarged images of small nano particles. Some large particles along with small nano particles were observed in SEM images and close observation reveals that these large particles are agglomerated blocks of small particles.

The PLE spectra of $(\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4$ phosphor are shown in figure 3 which were obtained by placing detector at 460 nm. The PLE spectra confirm that the sample can be excited using broadband excitation from 250 to 400 nm. A broad peak at 313nm is observed in PLE spectrum of Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ (figure 3) and the single broad peak splits into two broad peaks at ~280 nm and ~340nm due to doping of Mg$^{2+}$. Therefore we have investigated luminescence properties of the phosphors at 280 and 340nm excitation. We also studied the PL properties of these nanophosphors at 395 nm. Although the 395 nm does not correspond to typical excitation peak in PLE spectra but near UV LED of this wavelength is easily available.

The PL spectrum of Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ excited at 395 nm is shown in figure 4 which shows an asymmetric broad spectrum with two broad peaks at ~480 and ~553 nm. The peak at ~553 nm is found to be more intense than the peak at ~480 nm The PL spectra for $(\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4$ ($x=0.18, 0.38, 0.58$ and $0.78$) show a symmetric broad peak at ~460 nm (figure 4). It is also observed that the emission peak is blue shifted with increase in concentration of Mg$^{2+}$ dopant. Maximum PL intensity observed for $(\text{Sr}_{0.20}\text{Mg}_{0.78}\text{Eu}_{0.02})_2\text{SiO}_4$ nanophosphor
The PL spectra for all compositions for 340 nm excitation are shown in figure 5. The emission peaks were blue shifted with subsequent increase in Mg dopant concentrations in (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ ($x=0.18$, $0.38$, $0.58$ and $0.78$). In case of Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$, an asymmetric broad emission spectrum was observed. The emission peak at $\sim$490 nm for Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ dominated in the broad spectrum but the emission peak at $\sim$550 nm was suppressed (figure 5). The smaller intensity peaks at $\sim$575 and $\sim$622 nm were also observed which may be due to very small unconverted Eu$^{3+}$ presence in the calcined sample.

The emission spectra of all compositions excited at 280 nm are shown in figure 6. The emission range was reduced i.e. from 375 to 540 nm in order to avoid second order diffraction peaks. The Sr$_2$SiO$_4$:Eu$^{2+}$ shows broad emission centered at 489 nm while peaks at 459, 461, 466 and 471 nm were observed for (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ corresponding to $x=0.78$, $0.58$, $0.38$ and $0.18$ respectively for 280 nm excitation.

**Discussion**

The excitation spectrum of Sr$_2$SiO$_4$:Eu$^{2+}$ shows a broad absorption band centered at 313 nm when PL monitored at 460 nm. In Sr$_2$SiO$_4$:Eu$^{2+}$ the 4f$^6$5d$^1$ electron state strongly interacts with neighbouring anion ligands and forms a broad absorption band called charge transfer bands (CTBs). So broad excitation band is observed due to the electronic transition to these CTBs of Eu$^{2+}$ ions (4f$^7$→4f$^6$5d$^1$). Since broad excitation spectrum has been observed (from 250 nm to 400 nm) the phosphor can be excited by near UV region (i.e. 370-400 nm). The excitation spectrum of Mg doped Sr$_2$SiO$_4$:Eu$^{2+}$ shows splitting of broad peak into two peaks due to addition of Mg. These splitting of broad peak may be ascribed to CTBs associated with Sr(I) and Sr(II) sites in Sr$_2$SiO$_4$. 

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The broad PL emission centred at ~490 nm and at ~553 nm for Sr$_2$SiO$_4$:Eu$^{2+}$ under the excitation of 395 nm, is ascribed to the electric dipole-allowed transition of the Eu$^{2+}$ ions from the lowest level of the 5d excited state (CTBs at two different Sr$^{2+}$ sites) to the 4f ground state. The shorter wavelength emission band (~495 nm) and the longer wavelength emission band (~553 nm) correspond to Sr(I) and Sr(II) site respectively. It was observed that the broad band at ~553 nm associated with Sr(II) disappears due to increase in Mg doping [i.e. in (Sr$_{0.98-x}$Mg$_x$Eu$_{0.02}$)$_2$SiO$_4$ ($x$=0.18, 0.38, 0.58 and 0.78) with increase in $x$) and the blue shifting of broad band at ~476 nm was also observed with increase in concentration of Mg in Sr$_2$SiO$_4$.

The ionic radius of Eu$^{2+}$ (~0.131 nm) is very similar to Sr$^{2+}$ (~0.132 nm) and much larger than Sr$^{2+}$ (0.054 nm), makes way for Eu$^{2+}$ ions to substitute Sr$^{2+}$ ions in the crystal lattice. The covalence of the Sr–O bonds in the lattice gets decreased when a part of Sr$^{2+}$ ion is substituted by Mg$^{2+}$ ions. So, the covalence of Eu–O bonds doped at the Sr$^{2+}$ (I) site gets decreased. This causes the difference between the 4f and 5d energy level to become larger since less negative charge transfers to the Eu$^{2+}$ ion. This makes the emission energy increased, which results in a blue-shift of the emission spectra.

According to the crystal field theory in the host lattice of Sr$_2$SiO$_4$, the size of Sr(II) site is larger than that of Sr(I) Substitution of Sr$^{2+}$ ions by smaller Mg$^{2+}$ ion decreases the bond length. The Mg$^{2+}$ ion may prefer for the Sr(I) site because the Mg$^{2+}$ ion is much smaller than Sr$^{2+}$. Hence, the crystal field strength could be improved more for Sr(I) when Mg$^{2+}$ ions are doped. Similarly, the symmetry of ligand ions surrounding Eu$^{2+}$ in the Sr(II) site maybe distorted due to large site size. Thus the crystal field effect cannot be efficiently exerted for this Sr(II) site which results in suppression of emission band at ~553 nm (related to Sr (II) sites).
Although, all the emission peaks were similar in case of Mg doped Sr₂SiO₄:Eu₀.₀⁴²⁺ for 280, 340 nm and 395nm excitation but for pure Sr₂SiO₄:Eu₀.₀⁴²⁺ the emission band is different for 395 nm excitation compared to excitation at 280 and 340 nm. An asymmetric broad emission band centred at ~490 nm has been observed for pure Sr₂SiO₄:Eu₀.₀⁴²⁺ since the intensity of ~553nm peak decreases substantially for 280nm and 340nm excitation. This shows that for shorter wavelength UV excitation the luminescence due to Sr(I) site is dominant than Sr(II) site.¹¹,¹³

The variation of the Commission International de L’Eclairage (CIE) chromaticity coordinates of the phosphors with different Sr:Mg ratio are calculated based on the corresponding PL spectrum upon 395 nm excitation, and the results are summarized in figure 7 and Table 1. The CIE coordinates for Sr₂SiO₄:Eu₀.₀⁴²⁺ were found to be in greenish-yellow region and with increase in Mg:Sr ratio the graph shifted from green yellow to deep blue. Similarly the CIE diagram for 340 nm excitation was studied, and the results are summarized in figure 8 and Table 2. It was found that with increase in Mg:Sr ratio the graph shifted from green towards deep blue. The white light for 395 nm excitation is obtained by mixing equal amount of blue (Sr₂SiO₄:Eu₀.₀⁴²⁺) and yellow-green emitting phosphor (Mg₀.₇₈Sr₀.₂₀Eu₀.₀₂)₂SiO₄ (figure 9). Therefore these phosphors can be used in generation of white light using commercially available 395 nm excitation sources.

Conclusions

In the present work, (Sr₁-ₓMgₓEu₀.₀₂)₂SiO₄ (x=0, 0.18, 0.38, 0.58 and 0.78) nanophosphors were prepared by combustion method. The formation of orthorhombic α-Sr₂SiO₄ phase was confirmed for Sr₂SiO₄:Eu²⁺ nanophosphor; while orthorhombic α-Sr₂SiO₄ along with few percentage of monoclinic β-Sr₂SiO₄ was obtained for Mg²⁺ doped Sr₂SiO₄:Eu₀.₀⁴²⁺. FE-SEM analysis showed particles to be nearly spherical for Sr₂SiO₄ and no significant change in its morphology was
observed with subsequent doping of Mg. In Sr$_2$SiO$_4$ the Eu$^{2+}$ dopant occupies two different Sr$^{2+}$ sites (Sr (I) and Sr (II)) which will lead to two emission bands i.e. at ~490 and ~553 nm for 395 nm excitation respectively. However, an asymmetric broad emission band centred at ~490 nm could be seen for Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ at 280 and 340 nm excitation. This confirms that the luminescence from Sr(I) site is dominant than Sr(II) site for shorter wavelength excitation. Addition of Mg$^{2+}$ ions in Sr$_2$SiO$_4$:Eu$^{2+}$ leads to shifting of emission peak to shorter wavelength ~460 nm (blue region) for at 395nm excitation which attributed to preference of Mg for Sr(I) site. Therfore Mg doped Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$ nanophosphor can be used as blue emitting phosphor for near-UV excitation. The CIE coordinates for mixture of blue (Mg$_{0.78}$Sr$_{0.20}$Eu$_{0.02}$)$_2$SiO$_4$ and yellow-green (Sr$_2$SiO$_4$:Eu$_{0.04}^{2+}$) with 1: 1 ratio lies in white region for 395 nm excitation which indicates great potential of these nano phosphors for white light generation.

Acknowledgement

We are thankful to Mr. Ashish Kumar Singh, NFM Laboratory, LMDDDD, RRCAT, Indore, for his help in synthesis of phosphors. Authors also would like to thank Mr. Gopal Mohod for his help in infrastructure development for experimental setups.
Tables:

Table 1. CIE chromaticity coordinates (x,y) for (Sr\textsubscript{0.98-x}Mg\textsubscript{x}Eu\textsubscript{0.02})\textsubscript{2}SiO\textsubscript{4} phosphors excited at 395nm

| Sample no. | Sample Composition            | CIE Coordinates(x,y) |
|------------|-------------------------------|----------------------|
| 1          | (Mg\textsubscript{0.78}Sr\textsubscript{0.20})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1402,0.0714)     |
| 2          | (Mg\textsubscript{0.58}Sr\textsubscript{0.40})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1395,0.0780)     |
| 3          | (Mg\textsubscript{0.38}Sr\textsubscript{0.60})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1371,0.1185)     |
| 4          | (Mg\textsubscript{0.18}Sr\textsubscript{0.80})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1333,0.1725)     |
| 5          | Sr\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+}              | (0.3644,0.4783)     |

Table 2. CIE chromaticity coordinates (x, y) for (Sr\textsubscript{0.98-x}Mg\textsubscript{x}Eu\textsubscript{0.02})\textsubscript{2}SiO\textsubscript{4} phosphors excited at 340nm

| Sample no. | Sample Composition            | CIE Coordinates(x,y) |
|------------|-------------------------------|----------------------|
| 1          | (Mg\textsubscript{0.78}Sr\textsubscript{0.20})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1435,0.0668)     |
| 2          | (Mg\textsubscript{0.58}Sr\textsubscript{0.40})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1384,0.0923)     |
| 3          | (Mg\textsubscript{0.38}Sr\textsubscript{0.60})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1425,0.1057)     |
| 4          | (Mg\textsubscript{0.18}Sr\textsubscript{0.80})\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+} | (0.1412,0.1595)     |
| 5          | Sr\textsubscript{2}SiO\textsubscript{4}:Eu\textsubscript{0.04}\textsuperscript{2+}              | (0.1914,0.3021)     |
Figure captions:

**Figure 1.** (a) XRD patterns of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors \((0 \leq x \leq 0.78)\); (b) Magnified XRD pattern of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors \((0 \leq x \leq 0.78)\);

**Figure 2.** FE-SEM images of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors \([(A) \ x=0.78, (B) \ x=0.58, (C) \ x=0.38, (D) \ x=0.18, (E) \ x=0]\). Inset figures show zoomed images of nano particles.

**Figure 3.** PLE spectra \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors. The inset shows the PLE spectra of \((\text{Sr}_{0.80}\text{Mg}_{0.18}\text{Eu}_{0.02})_2\text{SiO}_4\) nanophosphor.

**Figure 4.** PL spectra of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors for 395nm excitation. The inset shows the PL spectra of \((\text{Sr}_{0.80}\text{Mg}_{0.18}\text{Eu}_{0.02})_2\text{SiO}_4\) phosphor.

**Figure 5.** PL spectra of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors for 340nm excitation.

**Figure 6.** PL spectra of \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors for 280nm excitation. The inset shows the PL spectra of \((\text{Sr}_{0.80}\text{Mg}_{0.18}\text{Eu}_{0.02})_2\text{SiO}_4\) phosphor.

**Figure 7.** CIE chromaticity diagram of prepared \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors for 395nm excitation \((A= (\text{Mg}_{0.78}\text{Sr}_{0.20}\text{Eu}_{0.02})_2\text{SiO}_4, \ B= (\text{Mg}_{0.58}\text{Sr}_{0.40}\text{Eu}_{0.02})_2\text{SiO}_4, \ C= (\text{Mg}_{0.38}\text{Sr}_{0.60}\text{Eu}_{0.02})_2\text{SiO}_4, \ D= (\text{Mg}_{0.18}\text{Sr}_{0.80}\text{Eu}_{0.02})_2\text{SiO}_4, \ E= \text{Sr}_2\text{SiO}_4:\text{Eu}^{2+})\).

**Figure 8.** CIE chromaticity diagram of prepared \((\text{Sr}_{0.98-x}\text{Mg}_x\text{Eu}_{0.02})_2\text{SiO}_4\) phosphors for 340nm excitation \((A= (\text{Mg}_{0.78}\text{Sr}_{0.20}\text{Eu}_{0.02})_2\text{SiO}_4, \ B= (\text{Mg}_{0.58}\text{Sr}_{0.40}\text{Eu}_{0.02})_2\text{SiO}_4, \ C= (\text{Mg}_{0.38}\text{Sr}_{0.60}\text{Eu}_{0.02})_2\text{SiO}_4, \ D= (\text{Mg}_{0.18}\text{Sr}_{0.80}\text{Eu}_{0.02})_2\text{SiO}_4, \ E= \text{Sr}_2\text{SiO}_4:\text{Eu}^{2+})\).

**Figure 9.** CIE chromaticity diagram for combined \((\text{Mg}_{0.78}\text{Sr}_{0.20}\text{Eu}_{0.02})_2\text{SiO}_4\) and \((\text{Sr}_2\text{SiO}_4:\text{Eu}^{2+})\) nano phosphors indicating white point for 395nm excitation.
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Figure 1

(a) XRD Pattern of (Mg$_2$Sr)$_2$SiO$_4$:Eu$^{2+}$

(b) XRD Pattern of (Mg$_2$Sr)$_2$SiO$_4$:Eu$^{2+}$

- Sr$_2$SiO$_4$
- (Mg$_{0.16}$Sr$_{0.80}$)$_2$SiO$_4$
- (Mg$_{0.38}$Sr$_{0.62}$)$_2$SiO$_4$
- (Mg$_{0.62}$Sr$_{0.38}$)$_2$SiO$_4$
- (Mg$_{0.96}$Sr$_{0.04}$)$_2$SiO$_4$
- (Mg$_{1.32}$Sr$_{0.68}$)$_2$SiO$_4$

Impurity peaks indicated.
Figure -2
Figure 3

Excitation Scan $(\text{Mg, Sr})_2\text{SiO}_4$:Eu$^{2+}$ detector at 460nm
Figure 4

Emission Scan \((\text{Mg}, \text{Sr})_2 \text{SiO}_4 : \text{Eu}^{2+}\) for 395nm excitation

Intensity (arbitrary units)

| Compound                      | Emission Peaks | Wavelength (nm) |
|-------------------------------|----------------|-----------------|
| \(\text{Sr}_2 \text{SiO}_4\)  | 476, 589, 615  | 450, 500, 550   |
| \((\text{Mg}_{0.18} \text{Sr}_{0.82})_2 \text{SiO}_4\) | 460, 461, 467 | 500, 550, 600   |
| \((\text{Mg}_{0.38} \text{Sr}_{0.62})_2 \text{SiO}_4\) | 476            | 550             |
| \((\text{Mg}_{0.58} \text{Sr}_{0.42})_2 \text{SiO}_4\) | 553            | 600             |
| \((\text{Mg}_{0.78} \text{Sr}_{0.22})_2 \text{SiO}_4\) |                | 650             |

with 2% Eu
Figure 5

Emission Scan $(\text{Mg}_x\text{Sr}_y)_2\text{SiO}_4:\text{Eu}^{2+}$ for 340nm excitation

Intensity (arbitrary units)

wavelength (nm)

- $\text{Sr}_2\text{SiO}_4$
- $(\text{Mg}_{0.18}\text{Sr}_{0.82})_2\text{SiO}_4$
- $(\text{Mg}_{0.38}\text{Sr}_{0.62})_2\text{SiO}_4$
- $(\text{Mg}_{0.58}\text{Sr}_{0.42})_2\text{SiO}_4$
- $(\text{Mg}_{0.78}\text{Sr}_{0.22})_2\text{SiO}_4$

with 2% Eu
Emission Scan $(\text{Mg}, \text{Sr})_2\text{SiO}_4:\text{Eu}^{2+}$ for 280nm excitation

- $\text{Sr}_2\text{SiO}_4$
- $(\text{Mg}_{0.18}\text{Sr}_{0.82})_2\text{SiO}_4$
- $(\text{Mg}_{0.38}\text{Sr}_{0.62})_2\text{SiO}_4$
- $(\text{Mg}_{0.53}\text{Sr}_{0.47})_2\text{SiO}_4$
- $(\text{Mg}_{0.78}\text{Sr}_{0.22})_2\text{SiO}_4$

Intensity (arbitrary units)

wavelength (nm)

459, 461, 466, 471, 490
Figure-7

Chromaticity coordinates for 395 nm excitation
