High performance red/deep-red emitting phosphors for white LEDs

Marikumar Rajendran and Sivakumar Vaidyanathan*

Department of Chemistry, National Institute of Technology Rourkela, India.

Journal: New Journal of Chemistry (Ms. Ref. No.: NJ-ART-01-2020-000086.R2)

Supplimentry section- Date of acceptance 04-03-2020

Characterization

The X-ray diffraction of all the synthesized phosphors was recorded from the Rigaku ULTIMA IV, Japan with Cu-Kα1 radiation for generation of X - rays. The Rietveld refinement data's were collected from Co-Kα1 radiation for generation of X - rays and the Rietveld refinements were executed by using the JANA 2006 package with the step width of 0.01. The crystal structure was drawn by using Diamond software. The SEM images were acquired by a JEOL JSM 6480LV scanning electron microscope (SEM). The Fourier transform infrared spectroscopy (FTIR) was carried out in the range of 400 – 4000 cm-1 by PerkinElmer Spectrum Version 10.4.00. Diffuse reflection spectra were recorded by a scanning-type UV–visible spectrophotometer (Shimadzu UV-3600) with $BaSO_4$ as a reference. The photoluminescence (excitation and emission) spectra, lifetime and internal quantum efficiency (IQE), were recorded by using Edinburg Spectrofluorometer FS–5 instruments with attaching SC – 10 modules and SC – 30 integrating sphere module. For IQE measurement BaSO4 was used as a reference. A pulsed xenon lamp was used as the excitation source, and the signals were noticed with a photomultiplier. Temperature-dependent PL spectra were measured by using the spectrometer (Edinburgh FS5) equipped with a temperature controller. The CIE color coordinates were calculated from the emission spectral data of synthesized the phosphors by using MATLAB software. All the measurements were carried out in the room temperature.

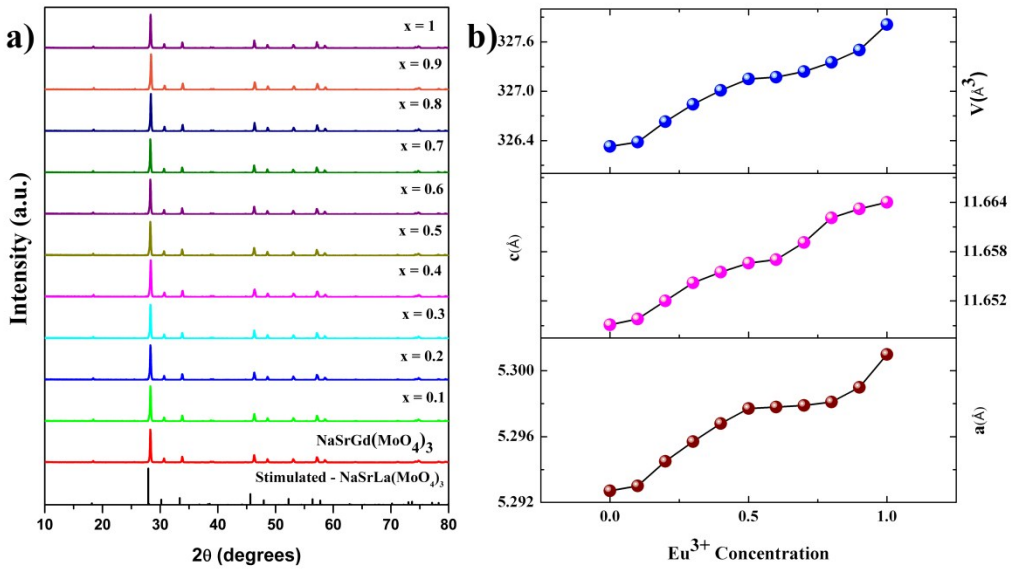

Fig. S1 a and b) X-ray diffraction patterens and lattice parameters of the NSGM:Eu^{3+} phosphors.

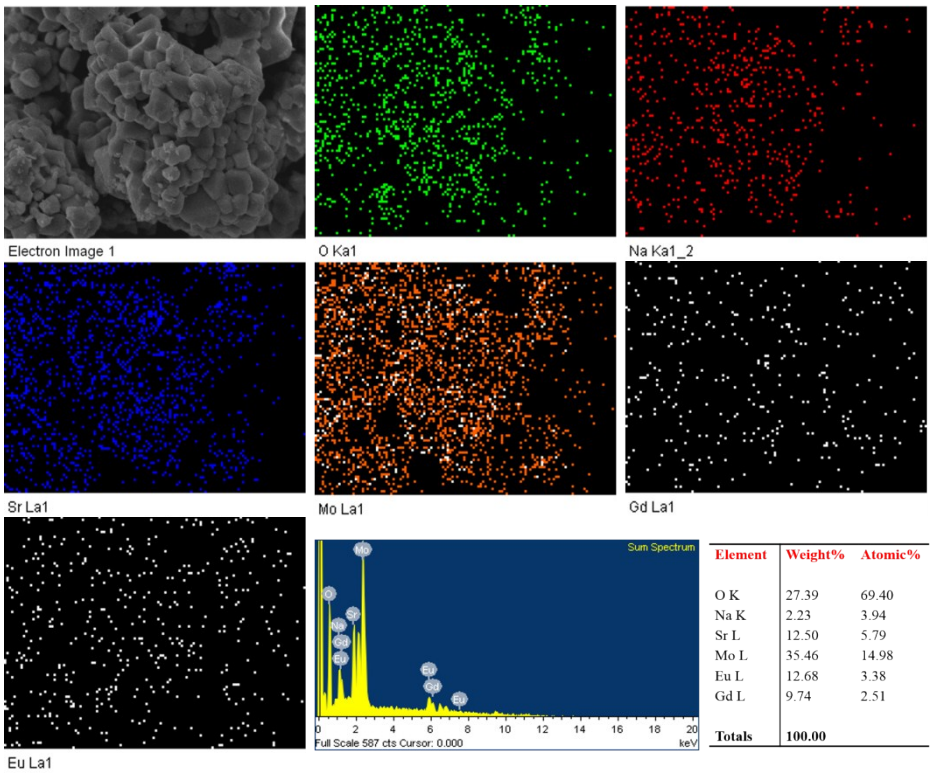

Fig. S2 Elemental mapping and EDX spectrum of the NSGM:$_{0.5}Eu^{3+}$ sample.

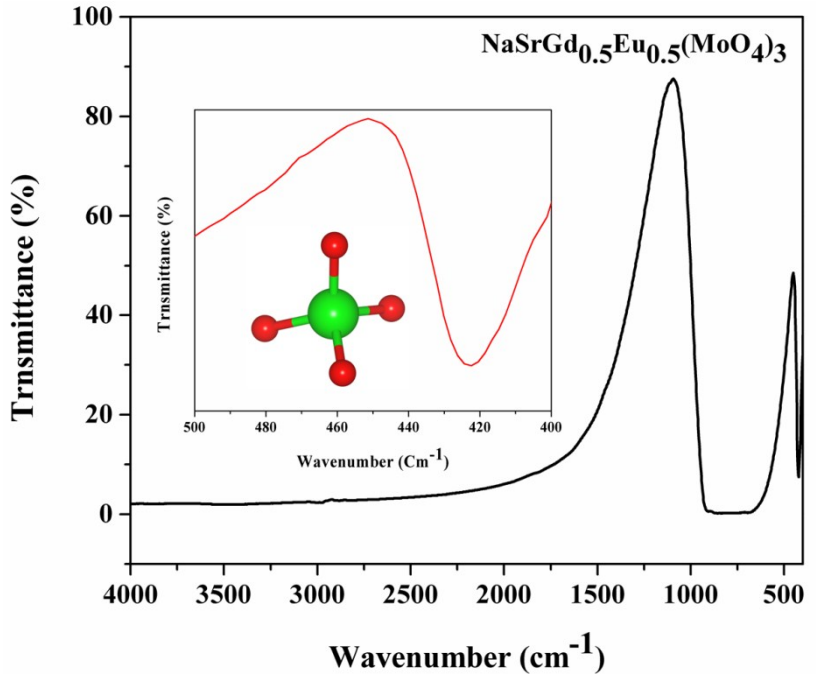

Fig. S3 FT-IR spectrum of $NSG_{0.5}Eu_{0.5}M$ phosphor (inset enlarge region 400-500 cm^{-1}).

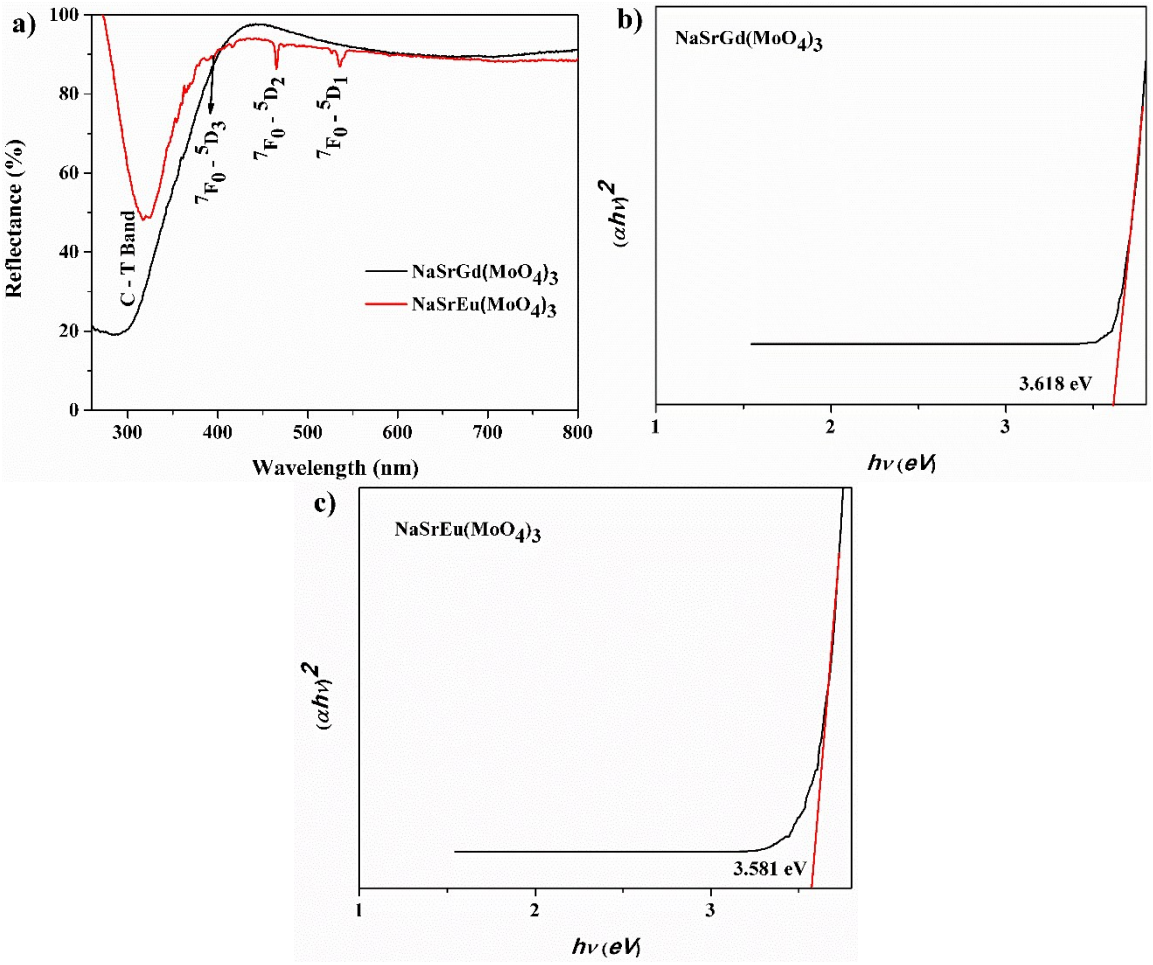

Fig. S4 (a) DRS spectrum, and band gap of NSGM (b) and NSEuM (c) phosphors.

Table ST1

Judd – Ofelt Parameters of NSGM:Eu^{3+} phosphor.

Concentration of Eu^{3+}	Judd – Ofelt Parameters		A_{0-1} in S^{-1}	A_{0-2} in S^{-1}	A_{0-4} in S^{-1}
	Ω_2 (10^{-19} cm^2)	Ω_4 (10^{-20} cm^2)			
0.1	1.1098	3.4889	50	909.9482	139.3687
0.2	1.1136	4.15524	50	913.1220	166.1569
0.3	1.1351	3.9354	50	930.7621	157.3542
0.4	1.1596	4.1278	50	950.8119	164.3748
0.5	1.1816	4.2203	50	968.8154	168.1610
0.6	1.1591	4.4705	50	950.3990	178.7762
0.7	1.1274	4.8263	50	924.4099	193.0073
0.8	1.1041	4.3904	50	905.3066	175.2396
0.9	1.1074	4.5623	50	907.9829	182.4610
1	1.1138	4.1984	50	913.2586	167.8937

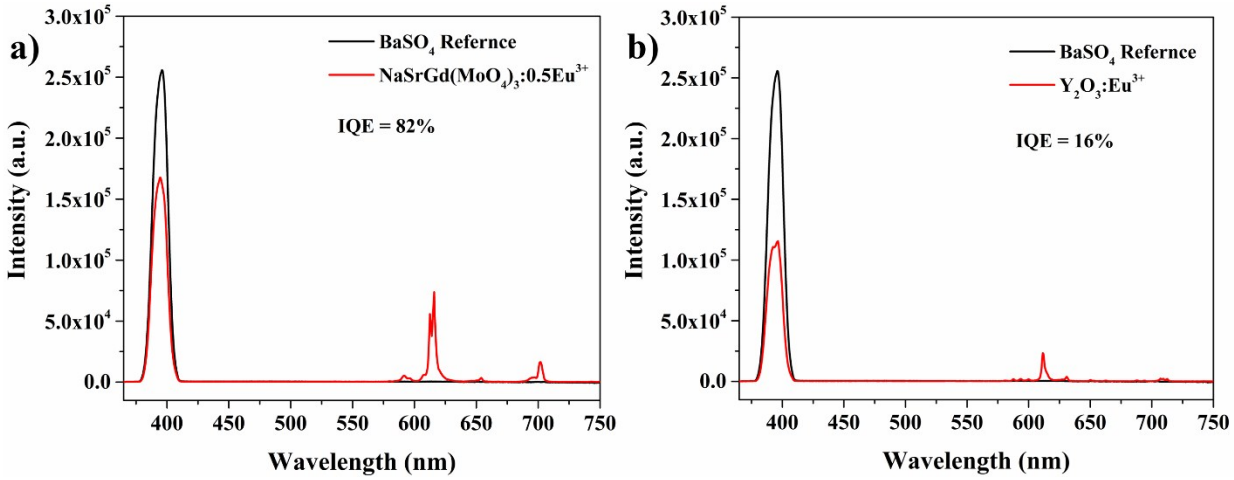

Fig. S5 Internal quantum efficiency (IQE) measurement of (a)NSGM:$_{0.5}Eu^{3+}$ and (b)Y_2O_3:Eu^{3+} red phosphors.

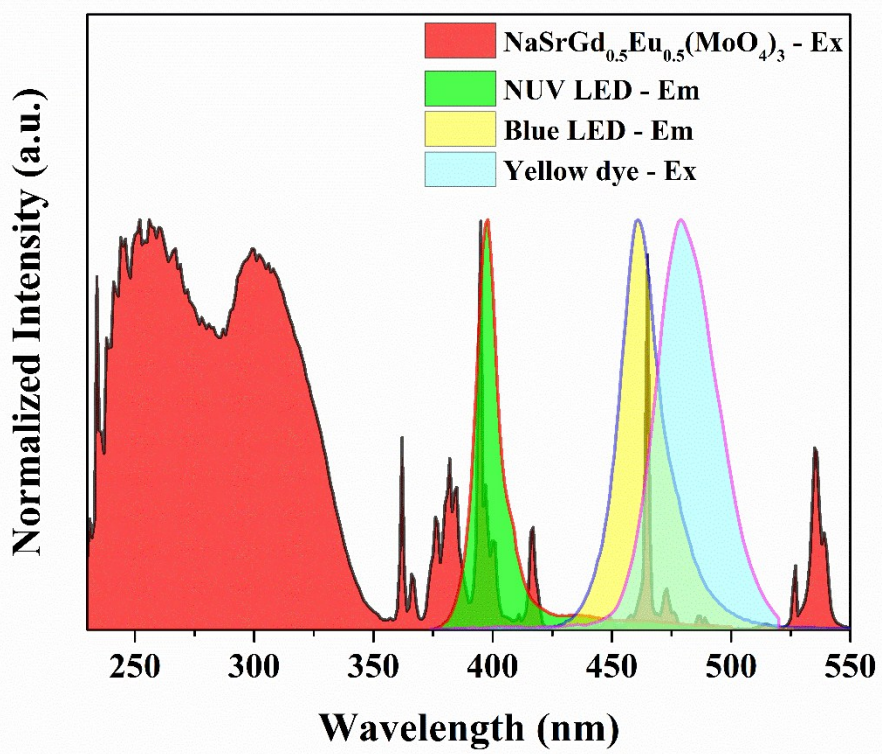

Fig. S6 Excitation and emission spectrum of $NSG_{0.5}Eu_{0.5}M$ red phosphor, yellow dye, NUV LED and Blue LEDs.

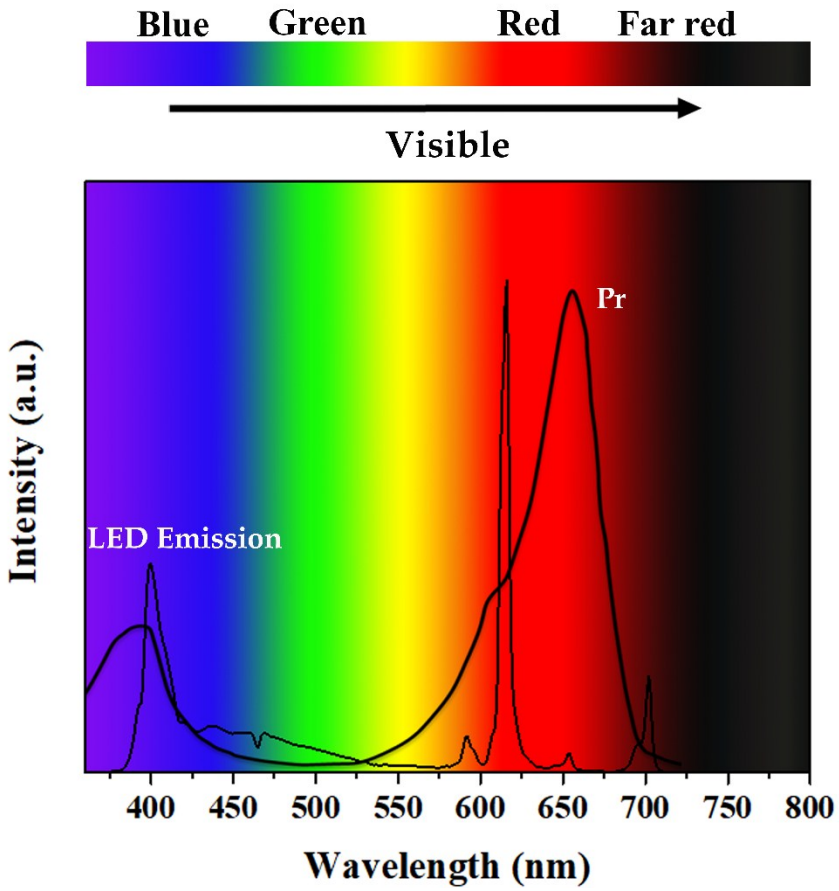

Fig. S7 EL spectrum (NSGM:0.1Sm^{3+}, 0.05Eu^{3+}) of the red LED merging with Pr absorption lines.

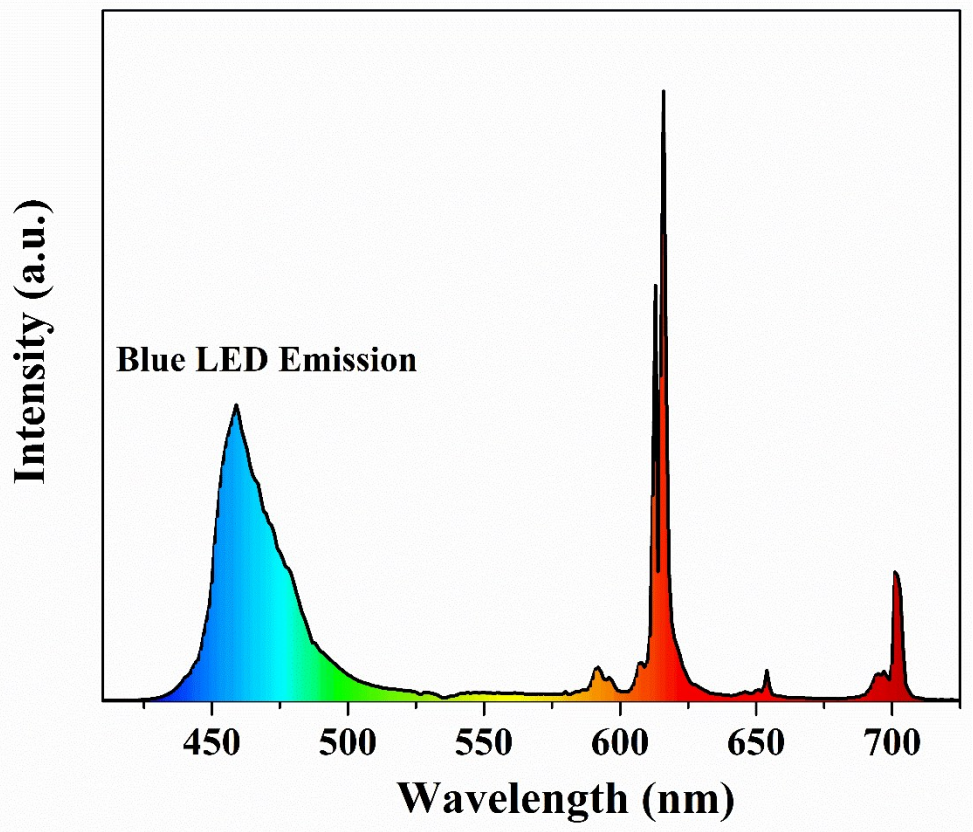

Fig. S8 EL spectrum of red LED with the combination of blue LED with $NSG_{0.5}Eu_{0.5}M$ red phosphor.

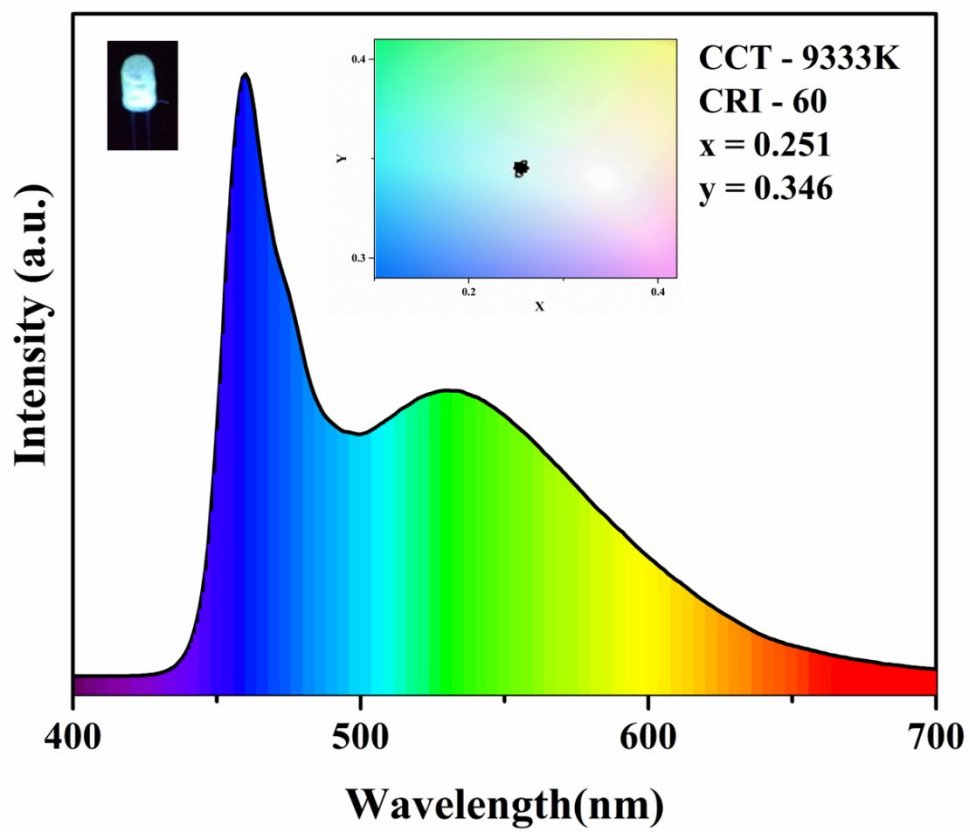

Fig. S9 EL spectrum of white LED by using blue LED with yellow organic dye.

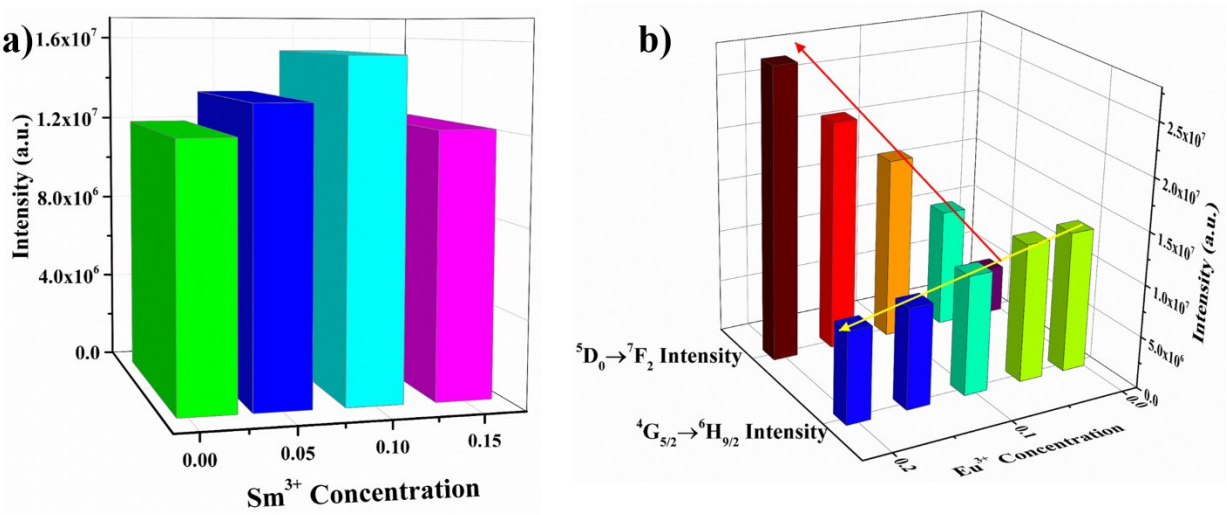

Fig.S10 a) Concentration *vs* intensity plot, b) changes in emission intensity of Eu (616 nm) and Sm (645 nm) ions with respect to the Eu^{3+} concentration.

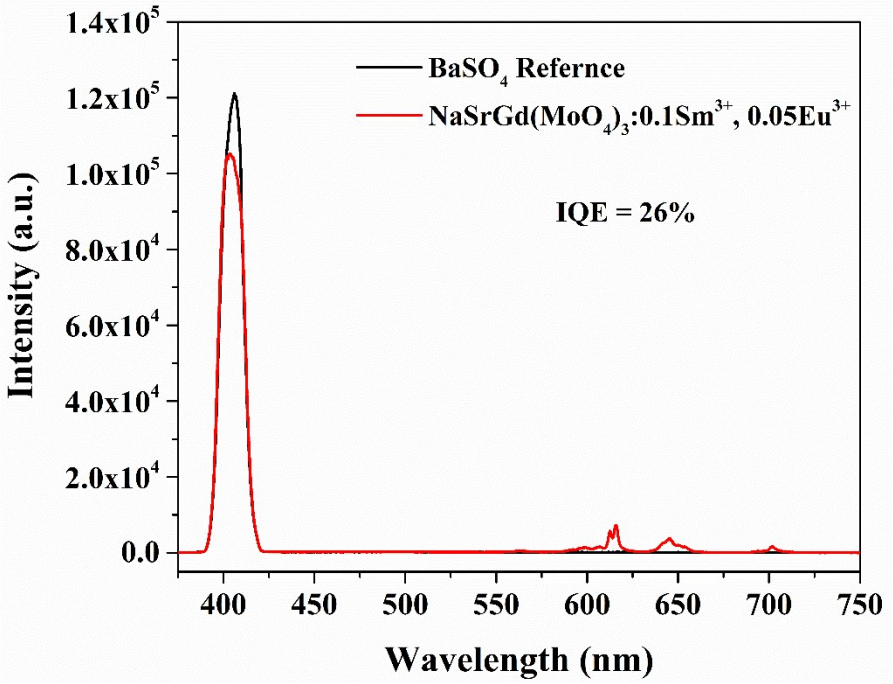

Fig. S11 Internal quantum efficiency (IQE) measurement of NSGM:0.1Sm^{3+}, 0.05Eu^{3+} phosphors.