Luminescence of the Green-Emitting $Ca(La,Gd)_4(SiO_4)_3O:Tb^{3+}$ Phosphors with VUV Excitation

Chia-Chin Wu (吳佳蓁)[1], Bing-Ming Cheng (鄭炳銘)[2], and Teng-Ming Chen (陳登銘)[1]

[1]Department of Applied Chemistry, National Chiao Tung University, Hsinchu, Taiwan
[2]National Synchrotron Radiation Research Center, Hsinchu, Taiwan

We have investigated the synthesis, VUV photoluminescence spectra, optical properties, and chromaticity of hexagonal $Ca(La_{1-x-y}Tb_xGd_y)_4Si_3O_{13}$ phosphors by using synchrotron radiation in the VUV spectral range. The VUV PLE and PL spectra and the correlation among VUV PL intensity, λ_{em}, and Tb^{3+} and Gd^{3+}-content have been established.

To investigate the VUV luminescence performance, we have measured the PLE spectra for $CaLa_4Si_3O_{13}$, $CaGd_4Si_3O_{13}$, and $CaM_4Si_3O_{13}$ (M = La, Gd, or both La and Gd) doped with 5% of Tb^{3+}, respectively. We compare the PLE spectra of $CaLaSi_3O_{13}$with $CaGdSi_3O_{13}$ in the upper section in Figure 1. The broad band from 170-220nm in curve a is host-related absorption. When La^{3+} is replaced by Gd^{3+}, shown in curve b, the band becomes broader, because the transitions ($^8S_{7/2}\rightarrow{}^6G_J$, $^8S_{7/2}\rightarrow{}^6F_J$) within Gd^{3+} ions overlap the host absorption. Besides, the narrow peaks at 273 and 276nm are attributed to $^8S_{7/2}\rightarrow{}^6I_J$ transition. When doping Tb^{3+} ions, other broad bands in curve c, d, and e which are resulting from the *f-d* transitions of Tb^{3+} in the host lattices are observed. The electrons configuration of Tb^{3+} is $4f^8$, so the ground state is $^7F_6$ and there are two kinds of spin states, ^9D_J and ^7D_J, within the $4f^75d$ excitation levels. For this reason, Tb^{3+} in a specific host exhibits two groups of *f–d* transitions, spin-allowed with high-energy and spin-forbidden with lower energy. From 190 nm to 250 nm in curve c is a strong broad band and it is assignable to the spin-allowed transitions ($^7F_6\rightarrow{}^7D_J$) of Tb^{3+} while another weak broad, from 240 nm to 270 nm, is assigned to the spin-forbidden transitions. However, the intensity of the *f-d* transitions within Tb^{3+} reduces in curve d. Here also saw the $^8S_{7/2}\rightarrow{}^6I_J$ transition, at 274nm, within Gd^{3+}ions, indicating the existence of the energy transfer from Gd^{3+} to Tb^{3+} in $Ca(Gd_{0.95}Tb_{0.05})_4Si_3O_{13}$. If Gd^{3+} ions only substitute half of La^{3+} ions, there is no significant change occurring, except for slight red shift of the peaks which belong to the *f–d* transitions, as shown in curve e.

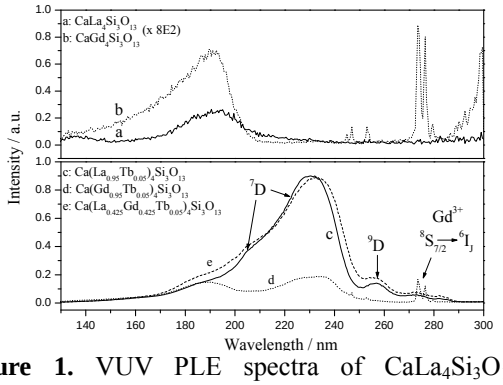

Figure 1. VUV PLE spectra of $CaLa_4Si_3O_{13}$ (a), $CaGd_4Si_3O_{13}$ (b), $Ca(La_{0.95}Tb_{0.05})_4Si_3O_{13}$ (c), $Ca(Gd_{0.95},Tb_{0.05})_4Si_3O_{13}$ (d), and $Ca(La_{0.425}Gd_{0.425}Tb_{0.05})_4Si_3O_{13}$ (e).

To improve the absorption efficiency of phosphors in the VUV spectral region, we have also investigated the VUV PL spectra of $Ca(La_{0.9}Gd_yTb_{0.1})_4Si_3O_{13}$ as a function of doped Gd^{3+} content under VUV excitation at 147 and 172 nm and the results are represented in Figures 2(a) and 2(b), respectively. The existence of the $^8S_{7/2}\rightarrow{}^6I_J$ transition, at 274 nm, within Gd^{3+} ions reveals that the energy transition from Gd^{3+} to Tb^{3+} happening. Consequently, we found that the PL spectra for the $Ca((La_{0.9-y}Gd_yTb_{0.1})_4Si_3O_{13}$ phosphors increases with increasing Gd^{3+} content from y = 0 to 0.90, reaching an optimal dopant value at 0.90 under both excitation conditions.

Furthermore, as indicated by a comparison of VUV PL spectra excited by 147 and 172 nm, we observed that under VUV excitation the PL intensity of our phosphor $Ca(Gd_{0.9}Tb_{0.1})_4Si_3O_{13}$ is 33 % (*i.e.*, excited at 147 nm) or 67 % (*i.e.*, excited at 172 nm) of that for commodity P1-G1S from Kasei Optonix. These observations hint that $Ca(Gd_{0.9}Tb_{0.1})_4Si_3O_{13}$ might serve as a promising substitute for P1-G1S as a green-emitting PDP phosphor.

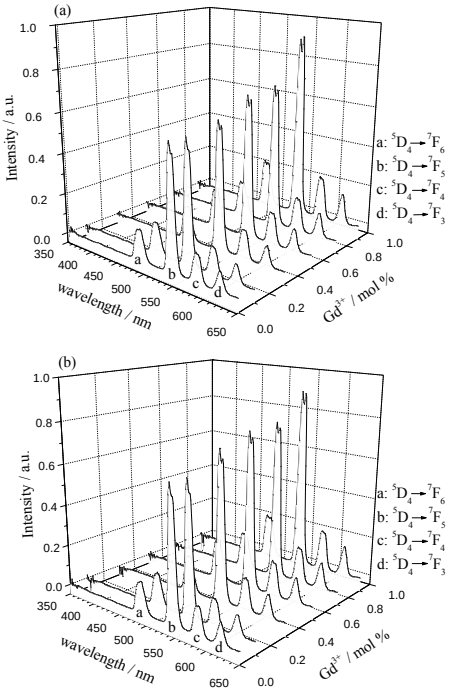

Figure 2. VUV PL intensity of $Ca(La_{0.9-y}Gd_yTb_{0.1})_4$ Si_3O_{13} as a function of Gd^{3+} content: λ_{ex} = (a) 147 nm and (b) 172 nm.