Long afterglow $CaAl_2O_4$ based phosphor for a fluorescence thermometer application

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The fiber-optic thermometer using fluorescence lifetime has attracted much attention, because it enables the temperature measurement in the severe electro-magnetic environments. In this thermometer system, the phosphors used as a sensor head is responsible for the accuracy and the sensitivity of the measurements. Ruby (Al_2O_3), spinel ($MgAl_2O_4$), $SrAl_2O_4$ and other phosphors have been studied as new sensor head materials in the fluorescence thermometer systems. In many phosphors, long afterglow phosphorescent $CaAl_2O_4$ based phosphors are found to be a useful sensor head material in the fluorescence thermometer because of its extremely long fluorescence lifetime. It has been recognized that the afterglow characteristics strongly depend on rare-earth element doped as auxiliary activators. A new type sensor head, in which the composite of $CaAl_2O_4$:Eu,Dy phosphor powders with a silicone attached at the top of the optical fiber, is developed through this study. In this paper, the afterglow characteristics and its temperature dependence have been systematically examined on the sensor heads using $CaAl_2O_4$ phosphors co-doped with Eu and 15 rare-earth elements as the auxiliary activators.

Time resolved photoluminescence spectrum and its time response were measured at temperatures from 300 K to 480 K under the excitation by third harmonic generation (λ=355 nm) from Q-switched YAG laser. The temperature dependence of fluorescence lifetime of the phosphors co-doped with 15 auxiliary activators was evaluated from the decay curves of PL time response. Sensor head equipped with the composite of $CaAl_2O_4$:Eu,Dy phosphor powders with a silicone attached at the top of the optical fiber is used as the specimens.

Strong blue fluorescence at wavelength of λ=442 nm is observed in all the specimens, indicating that auxiliary activators do not effect on the spectrum. However, it is noted that the temperature dependence of fluorescence decay dramatically varies with the auxiliary activator elements. The specimen co-doped with Dy ($CaAl_2O_4$:Eu,Dy) has a strong temperature dependence of the fluorescence lifetime. Decay curves of the $CaAl_2O_4$:Eu,Dy phosphor are composed of two exponential components in which slower decay time decreases linearly from 11.24 ms to 1.17 ms with temperature increasing from 30.5 K to 458 K. The temperature coefficient of this $CaAl_2O_4$:Eu,Dy phosphor is calculated to be -0.169 ms/K and is the largest in comparison with that of $CaAl_2O_4$ phosphor doped with other rare-earth elements as the auxiliary activators. This results indicate the potential of the application of $CaAl_2O_4$:Eu,Dy phosphor as a sensitive sensor head for the fluorescence thermometer.

In summary, we clarified that Dy is the most suitable rare-earth element as the auxiliary activators in the $CaAl_2O_4$:Eu phosphors system for the sensitive fluorescence thermometer. New type sensor head equipped with the composite of $CaAl_2O_4$:Eu,Dy phosphor powders with a silicone attached at the top of the optical fiber is potentially useful for the fiber-optic fluorescence thermometer system.

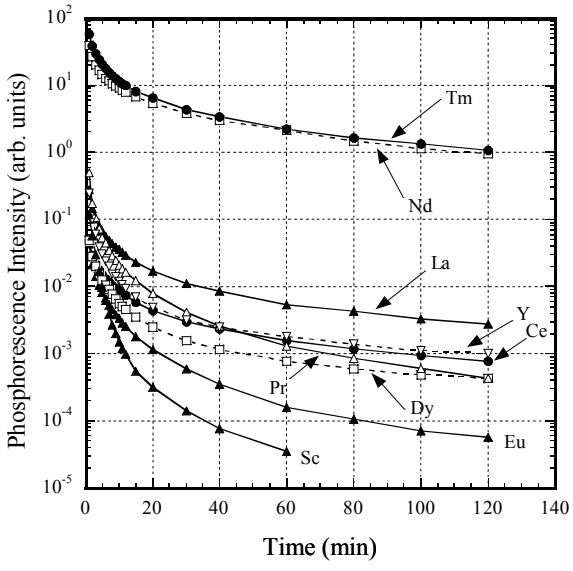

Fig. 1 Decay curve of PL intensity from $CaAl_2O_4$ co-doped with Eu and 15 rare-earth elements