**Characteristics of Ti-Doped Sapphire for Fluorescence Thermo-Sensor**

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**Abstract:** Fluorescence thermometer based on peak intensity of photoluminescence (PL) is evaluated using Ti doped sapphire (Al₂O₃) crystal. Broad PL peak is seen at λ=725 nm. PL peak intensity is found to be sensitive to temperature. Fluorescence thermometer based on temperature dependence of PL peak intensity is reported using Ti doped sapphire crystal.

**Keywords:** fluorescence thermometer, Ti doped sapphire, photoluminescence

**1. INTRODUCTION**

A fiber-optic fluorescence thermometer, using temperature dependence of fluorescence lifetime, is a useful technique for temperature measurement in extraordinary conditions. In the fluorescence thermometer, temperature is measured based on the temperature dependence of the lifetime of photoluminescence (PL) from the phosphorous sensor. Photoluminescence (PL) intensity from sensor materials (phosphors) also varies with temperature. Temperature coefficient of fluorescence intensity of the sensors is sometimes larger than that of fluorescence lifetime.

Fluorescence thermometer based on temperature dependence of fluorescence intensity is, therefore, useful for sensitive temperature measurement.

In this paper, fluorescence thermometer based on photoluminescence (PL) intensity from Ti doped sapphire (Al₂O₃) crystals is evaluated using Ti doped sapphire crystal with various Ti concentrations. Temperature coefficients of thermo-sensors are evaluated based on intensity of PL peaks.

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Fig. 1 Schematic illustration of PL evaluation apparatus. LED and/or laser is used as excitation beam. PL is evaluated using a fiber spectrometer at various temperatures.

Fig. 2 Experimental equipment of PL evaluation at various temperatures as shown in Fig. 1. Blue LED is used as an exciting light in the figure.
2. EXPERIMENTAL

Ti doped sapphire (Al₂O₃) crystals have been grown using floating zone (FZ) technique with various Ti concentration from 0.1 to 1.0 at%. Powders were subsequently sintered at 1150 °C in air. Specimens were prepared from 4N-Al₂O₃ and 4N-TiO₂ powders. Powders were mixed with a TiO₂ concentration from 0.1 to 1.0 at%.

Emission and excitation spectra from the grown crystals were measured. Temperature dependences of PL peak intensity and peak intensity ratio were evaluated using light emitting diode (LED) as shown in Fig. 1 and 2. Temperature of specimens is changed from RT to 200 °C.

3. RESULTS AND DISCUSSION

Emission and excitation spectrum from Ti doped sapphire crystal is shown in Fig. 3. Results from Ti doped Al₂O₃ crystals with various Ti concentrations

Fig. 3 Temperature variation of peak intensity ratio from composite sensor with Cr doped spinel crystal. Broad PL peak is seen at λ=725 nm. Excitation peak for PL at λ=725 is also seen at λ=480 nm. Blue LED peak with wavelength around λ=480 nm is suggested to be suitable for exciting PL from Ti doped Al₂O₃.

Fig. 5 Photoluminescence (PL) spectra from Ti doped Al₂O₃ crystal excited using blue LED at various temperatures. Luminescence peak from blue LED used is also shown in the figure. Peak wavelength of PL from Ti doped Al₂O₃ does not change with temperature. Peak intensity decreases with temperature.

Fig. 6 Temperature variations of PL intensity from Ti doped Al₂O₃ crystals with various Ti concentrations. PL intensities decrease with temperature.
are shown in the figure. Broad PL peak at wavelength $\lambda=725$ nm is seen from Ti doped Al$_2$O$_3$ crystal with LED excitation. PL peak intensity from the specimen varies with Ti concentration. Peak wavelength does not change with Ti concentration.

Variation of peak intensity of PL on Ti concentration of the specimens is shown in Fig. 4. Peak intensity increases with Ti concentration to 0.5 at%. It then, decreases with Ti concentration due to concentration quenching. The stronger PL is seen in the specimen with 0.5 at% Ti concentration.

Temperature variation of peak intensity from Ti doped sapphire crystal is shown in Fig. 5. PL peak intensity from the specimen decreases with the temperature from 20 to 200 °C. Peak wavelength dose not change with temperature.

Temperature variations of peak intensity from Ti doped Al$_2$O$_3$ crystals with various Ti concentrations of 0.1 and 0.5 at% are shown in Fig. 5. PL peak intensities at 725 nm decrease with temperature due to the thermal activation of excited electrons. Temperature can be measured based on the temperature dependences of PL peak intensity. Ti doped sapphire crystal is useful sensor material because Ti doped sapphire can be effectively excited using LED and PL peak intensity is sensitive to temperature.

4. CONCLUSION

Temperature dependence of photoluminescence intensity is evaluated using Ti doped Al$_2$O$_3$ crystal with various Ti concentrations. Peak intensity of broad PL peak, which is seen at $\lambda=725$ nm, is found to be sensitive to temperature. Fluorescence thermometer based on temperature dependence of PL peak intensity is potentially useful in thermo-sensor using Ti doped Al$_2$O$_3$ (sapphire) crystal.

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REFERENCES


