Phase measurement of pulse modulated photoluminescence from long afterglow phosphor

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Fiber-optic thermometer using photoluminescence (PL) lifetime is one of promising technique for temperature measurement in extraordinary condition such as plasma, high temperature. In this type of thermometer, temperature has been measured based on temperature dependence of PL lifetime from phosphorescent materials. Thus, sensitivity and measurement resolution of thermometer are strongly influenced by the PL lifetime from the phosphorescent materials and the measurement accuracy of PL lifetime of thermometer.

PL lifetime has been measured commonly from decay curves of PL intensity using exponential curve fitting. However, in phosphorescence with many different decay lifetimes, curve fitting technique is complicated, and it is difficult for evaluating directly the relationship between the decay lifetime and temperature. In order to improve the fiber-optic thermometer, we have proposed the fiber-optic thermometer using a phase shift measurement technique. In this technique, phase shift of PL is greatly influenced by the PL lifetime and frequency of the excitation light pulse. Temperature is, therefore, decided directly from the phase shift from exciting light pulse with an optimum frequency.

The fiber-optic thermometer using phase shift measurement technique is consist of blue GaN LED (470 nm) with the peak power of 2.0 mW, pulse generator for modulation of excitation light, optical fiber bundle (10 mm diameter), silicon photo diode detector, and lock-in amplifier. Long afterglow phosphor (strontium aluminate co-doped with dysprosium ion and europium ion) was used as a sensor head material because its long lifetime is convenient for this technique. When sinusoidally modulated excitation light pulse is irradiated on the long afterglow phosphor sensor head, sinusoidally phosphorescence is observed with a certain delay time. This delay time between excitation pulse and detected phosphorescence is measured as the phase angle shift in degree by using the lock-in amplifier. The phase angle shift is found to dramatically change for temperature variation. Moreover, amplitude also depends on the temperature variation.

Temperature dependence of PL lifetime from long afterglow phosphor sensor head were measured using the phase shift measurement technique at the temperature from 270 K to 360 K. Modulation frequency of blue LED pulse was 10 Hz. Phase angle monotonously shift from 180 deg at 273 K to 100 deg at 360 K. Amplitude also decreases from 45 mV at 273 K to 10 mV at 360 K. The phase shift measurement technique is potentially useful for the temperature sensing using long afterglow phosphors with extremely high sensitivity at the temperature ranging from 270 to 360 K.

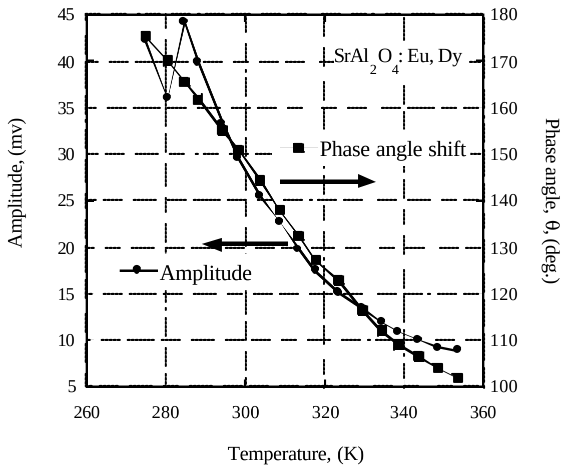

Fig. 1 Temperature dependence of phase shift angle and amplitude of PL from $SrAl_2O_4$: Eu, Dy. Phase shift angle was measured using a blue LED and modulation frequency of pulse was 10 Hz.