Long afterglow phosphoresce from $YTaO_4$ crystals

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$YTaO_4$ crystal doped with Tb is found to be a new long afterglow phosphor, which shows large temperature coefficient of fluorescence lifetime and afterglow fluorescence intensity. Fluorescence lifetime of $YTaO_4$ crystal varies linearly from 1.31 ms to 0.89 ms with the temperature from 323 K to 423 K. Long phosphorescent $YTaO_4$ crystal is potentially useful as a highly sensitive sensor material for the fluorescence thermometer.

The fiber-optic thermometer based on fluorescence lifetime is one of the most promising techniques for the temperature measurement in the extra-ordinal environments. In this thermometer system, the phosphors used in the sensor head are responsible for the accuracy and the sensitivity of the measurements. Various phosphor materials such as, ruby (Al_2O_3), spinel ($MgAl_2O_4$) and $SrAl_2O_4$ have been studied for developing sensitive and accurate thermometer systems. $YTaO_4$ crystal doped with rare-earth element is a phosphor, which shows photo-stimulated luminescence (PSL) and thermally stimulated luminescence (TSL). $YTaO_4$ crystal doped with Tb is found to be a long afterglow phosphor with long lasting phosphorescence for 120 minutes. In the tentative mechanism for long afterglow phosphorescence, carriers are excited and captured by the traps. The carriers trapped are released gradually from the traps by thermal excitation at room temperature. Highly sensitive fluorescence thermometer can be developed based on this thermal excitation process of trapped carriers in $YTaO_4$ phosphor. In this paper, fluorescence thermometer characteristics of long afterglow phosphorescent $YTaO_4$ sensor material is reported based on the thermal excitation process of trapped carriers.

$YTaO_4$ crystals doped with 1 atomic % Tb_4O_7 was grown by floating zone technique. Emission and excitation spectra, long afterglow characteristics of phosphorescence were evaluated by the excitation using Xe lump, He-Cd leaser (wavelength at 325 nm) and 4th harmonic generation of YAG laser (wavelength at 266 nm). The trap depth and the concentration of trapped carriers are estimated based on TSL measurement.

XRD patterns of grown Tb doped $YTaO_4$ crystals agreed perfectly with the reported results. In the emission spectra, phosphorescence with the peak wavelength at 492, 543, 590 and 624 nm are clearly observed. From the excitation spectra, 4th harmonic generation of YAG laser (wavelength at 266 nm) is found to excite these emissions effectively. After the excitation by He-Cd laser turn off, crystals show long afterglow phosphorescence lasting for about 120 minutes. Phosphorescence intensity from the Tb doped $YTaO_4$ crystals decreases linearly with temperature from 293 K to 423 K. Lifetime of the phosphorescence also decreases linearly from 1.31 to 0.89 ms with temperature from 323 K to 423 K. Glow peak at 330 K is observed in TSL glow curve. Trap depth, E, of 0.85 eV is estimated based on fitting of the TSL glow curve. Thermal excitation of carriers from the traps at E=0.85 eV is, therefore, considered to dominate the characteristics of fluorescence thermometer using Tb doped $YTaO_4$ sensor head. From these results, newly developed long afterglow phosphorescent Tb doped $YTaO_4$ is suggested to be a sensor head in fluorescence thermometer application.