Thermal radiation spectrum from rare-earth doped SiO_2 for a fiber-optic thermometer

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Thermal radiation spectra from SiO_2 fibers doped with rare-earth elements were studied for the fiber-optic thermometer application in high temperature region. Thermal radiation similar to the black body radiation was observed in visible light region from the SiO_2 fibers doped with Y, La, Ce, Eu, Pr, Tb, and Lu. Thermally excited visible light radiation peaks due to f-f transitions of rare-earth ions were clearly observed in the SiO2 fibers doepd with Er, Dy, Yb, Tm, Ho and Nd. In these elements, thermally radiated visible light can be observed above about 900 K. The intensity of thermally radiated visible light increases monotonously with the temperature. Thermal radiation from rare-earth ions in SiO_2 fiber is suggested to be potentially applicable to the fiber-optic temperature measurement.

Fiber-optic thermometer based on the fluorescence decay and thermal black body radiation have been reported for the temperature measurements in the extraordinary conditions. In the fiber-optic thermometer system, thermometer based on the fluorescence decay have some advantages at lower temperature measurement against the black body radiation. However, fluorescence thermometer is not so convenient at high temperature region because of decreasing PL intensity due to thermal quenching and decreasing the PL lifetime. The upper temperature of measurement is limited up to about 1000 K in the Cr^{3+} doped sensor head. On the other hand, the fiber-optic thermometer using the thermal black body radiation requires infrared (IR) transparent Sapphire fiber. In this paper, thermal radiation from rare-earth doped SiO_2 fibers are studied for high temperature measurement.

Rare-earth doped SiO_2 fibers were prepared using 4N SiO_2, Al_2O_3 and Ln_2O_3 powders. Powders were mixed with 5% polyvinyl alcohol (PVA) solution. Quartz rod with 2 mm diameter is dipped into the solution, then, dried, sintered and melted in a flame. Sensor probe is set inside of the quartz tube with a Pt-Rh thermocouple. Thermal radiation spectra from 350 nm to 1100 nm are measured at various temperatures from RT to 1673 K.

Thermal radiation spectra similar to the black body radiation are seen in Y, La, Ce, Eu, Pr, Tb, and Lu doped specimens. Strong radiation peaks with narrow bandwidth are seen in Er, Dy, Yb, Tm, Ho and Nd doped specimens as shown in Fig. 1. These narrow peaks can be assigned with the f-f transitions of rare-earth ions in the specimens. In the specimens doped with Er, Dy, Yb, Tm, Ho and Nd, thermally excited f-f emissions are clearly observed in the visible light region. Intensities of these visible light emissions also increase with temperature. The near IR emission from Yb doped SiO_2 sensor head is found to be sensitive at the temperature region around 900 K. The temperature dependence of the thermal radiation intensity of rare-earth doped SiO_2 fiber is potentially useful for the temperature measurement in high temperature region above about 900 K. These investigations extend the temperature range and increase the temperature resolution based on the hybridization of fluorescent thermometry and thermal radiation thermometry using the same sensor head.

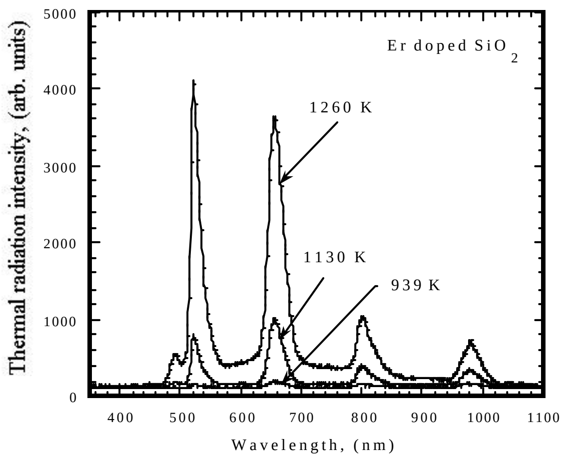

Fig. 1. Thermal radiation spectra from Er doped SiO_2 glass. Radiation peak intensities increase with temperature.