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Three Dimensional Thermoluminescence Emission Spectra of the LiF:Mg,Cu,Na,Si Thermoluminescent Materials

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1. Introduction

A new sintered pellet-type LiF:Mg,Cu,Na,Si TL detector which has a high sensitivity and good reusability, named KLT-300 (KAERI LiF:Mg,Cu,Na,Si TL detector), was recently developed by the variation of dopant concentrations and the parameters for the preparation procedure at the Korea Atomic Energy Research Institute (KAERI)[1].

To establish a possibility for an improvement in the dosimetric properties of the LiF: Mg, Cu, Na, Si TL detectors, a study to understand the mechanism of the TL for the TL material is essential.

The simple model of the mechanism of the TL comprises of three steps[2]: (1) the trapping of the charge carriers during an irradiation with ionizing radiation, (2) the release of the charge carriers out of the traps due to thermal heating, and (3) the capture of the charge carriers in the luminescent centers under a photon emission. The TL glow curve, the emitted light as a function of the temperature, can give some information on the trapping centers of the TL material, but cannot give the information for step (3). To understand the mechanism of a TL for a TL material, the information for step (3) should be provided. A possible technique to obtain information for the step (3) in the TL mechanism is the measurement of the light emission during a heating of the sample as a function of the temperature and wavelength (three-dimensional TL spectra).

In this paper, the TL spectra for the four kinds of samples which had a different composition of the dopants: LiF:Mg,Cu,Na,Si (MCNS); LiF:Mg,Cu (MC); LiF:Mg,Na,Si (MNS) and LiF:Cu,Na,Si (CNS) were presented for the study. The detailed results of the analysis for the three-dimensional TL spectra of the LiF:Mg,Cu,Na,Si TL materials which have various concentrations of the dopants is reported as a comprehensive study to understand the TL mechanism for the material. The TL spectra were fitted by Gaussian curves to establish the components of the spectra.

2. Methods and Results

The experimental apparatus for the measurement of the three dimensional TL spectra was composed of a spectrometer, temperature control unit for the linear heating program, photon detector with photomultiplier tube and a personal computer to control the entire system. Temperature control was achieved by using the feedback to ensure a linear-rise in the sample temperature. The data was recorded over the temperature range of 30 – 300℃ and wavelength range of 300 – 800 nm under the heating rate of 0.4℃/sec.

Figure 1 - 4 show the contour maps of the typical TL emission spectra and the results of the analysis of the spectra at each peak temperature of the TL glow curves for the LiF samples. In the contour map of the spectra for MCNS, the peak wavelength is observed at around 380nm at the low temperature range (30 – 160℃) and around 370 nm at the main peak, the 210℃ peak. At the higher temperature (~ 250℃), the peak wavelength is observed at a lower wavelength, around 350 nm. For a detailed analysis of the TL spectra, the data of the luminescence intensity versus the emission wavelength at each peak temperature of the TL glow curve, 107℃, 159℃. 204℃ and 240℃, respectively, were selected. The TL spectra were fitted by Gaussian curves to establish the components of the spectra. As for the results of the analysis, the spectra were deconvoluted to three component Gaussian curves peaking at 355 nm, 385 nm and 440 nm, respectively. In the spectra, the peak wavelength is shifted to a shorter wavelength by increasing the heating temperature. The 385 nm emission is dominant at the low temperature, and the 355 nm emission is relatively intensified by increasing the temperature, which results in a shift of the peak wavelength to a shorter wavelength. At the high temperature range, the 355 nm emission is dominant. The TL characteristics of CNS sample are totally different from the others. There is one TL glow peak at around 120℃. The spectrum was selected at 120℃ and deconvoluted to two components, Gaussian curves peaking at 335 nm and 385 nm. The 385 nm emission is also observed for this sample, but the 335 nm emission is dominant. This 385 nm emission is due to the Cu dopant in this sample.

The emission characteristics of MC sample are very similar to the MCNS. The spectra were deconvoluted to three components, peaking at 355 nm, 385 nm and 441 nm, respectively. The behaviours of the each component are almost the same as that for the MCNS. No significant changes are observed in the emission characteristics of MC sample in comparison with that of the MCNS sample. There are no effects from Na and Si on the TL emission spectra, thus it can be concluded that Na and Si are not luminescent dopants.

For the MNS sample, there are significant differences in the emission peak in comparison with the samples which have Cu as a dopant. In the spectra of the sample, there is no 385 nm emission which was observed at the spectra of the other samples. The spectra were deconvoluted to three curves peaking at 355 nm, 401 nm and 441 nm, respectively. The TL intensity of this MNS sample is just 3% of that of the MCNS sample. From these results, it is concluded that the 385 nm emission in the MCNS corresponds to the Cu^{+} emission as reported by Patil and Moharil[3].

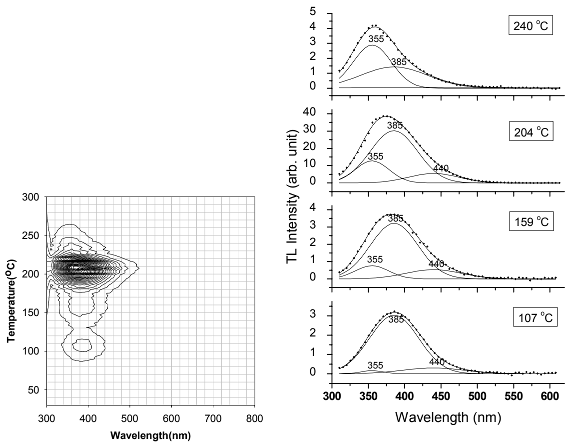

Figure 1. Contour plot of the TL spectra from the MCNS sample and analysis of the spectra at each peak temperature of the TL glow curve.

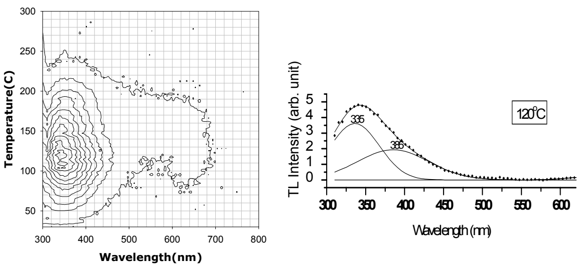

Figure 2. Contour plot of the TL spectra from the CNS sample and analysis of the spectra at peak temperature of the TL glow curve.

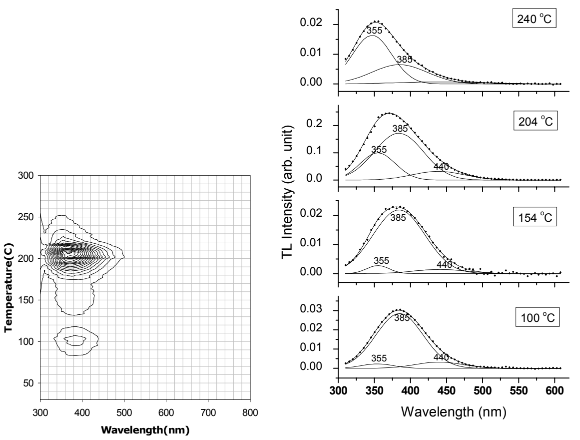

Figure 3. Contour plot of the TL spectra from the MC sample and analysis of the spectra at each peak temperature of the TL glow curve.

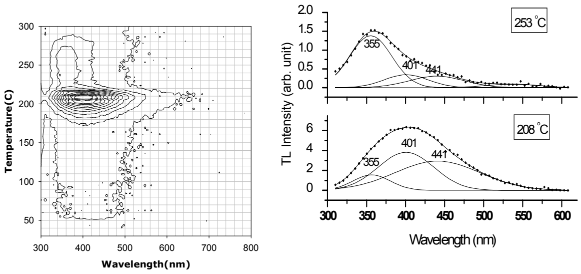

Figure 4. Contour plot of the TL spectra from the MNS sample and analysis of the spectra at each peak temperature of the TL glow curve.

3. Conclusion

The thermoluminescence emission spectra from LiF:Mg,Cu,Na,Si TL materials with various dopant concentrations are measured and analyzed. The spectra from the four types of samples with various concentrations of the dopants were deconvoluted to Gaussian curves. In the spectra from the samples having Mg and Cu as dopants, there are three components of the Gaussian curves peaking at 355 nm, 385 nm and 440 nm, respectively. The 385 nm emission is dominant at the low temperature, and the 355 nm emission is relatively intensified by increasing the temperature, which results in a shift of the peak wavelength to a shorter wavelength. At the high temperature range, the 355 nm emission is dominant. The 385 nm emission is observed in all the spectra from the samples with the Cu dopant, but in those from the samples without the Cu dopant a very weak 401 nm emission is observed. From these results, it is concluded that the main emission center of the LiF: Mg, Cu, Na, Si TL material is due to the Cu dopant.

The 355 nm emission is observed in all the TL spectra from all the samples except for the sample which has no Mg dopant. The 355 nm emission is also observed in the TL emission for LiF:Mg,Cu,P, according to a previous Mckeever's report[4] for the study on the TL emission for LiF:Mg,Cu,P TL material. These results suggest that the 355 nm emission is not due to the Cu, P, Na and Si.

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