Thermoluminescent and optical properties Al_2O_3:C and ZrO_2:Eu exposed to ultraviolet light

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This paper reports the experimental results of studying the thermoluminescent (TL) and optical characteristics of Al_2O_3:C and ZrO_2:Eu exposed to UV light of wavelength in the range of 200 to 400 nm. Excitation spectrum was also obtained. The photoluminescence spectrum of ZrO_2:Eu induced by 275 nm UV light exhibited four maxima at 560, 575, 612, and 650 nm with the major emission at 612 nm. The TL response as a function of wavelength showed a maximun at 230 nm for Al_2O_3:C and showed four maxima at 210, 230, 260, and 300 nm for ZrO2:Eu. The glow curve exhibited two peaks at 110°C and 220°C that of Al_2O_3:C; and 120°C, 290°C, and 390°C for ZrO2:Eu, for all the wavelengths studied. The 110°C and 120°C peaks faded completely within the first 24 hours after exposure. Meanwhile, the 220°C, the 290°C and the 390°C peaks show great stability for a long time. The TL response of Al_2O_3:C exposed to 230 nm UV light was linear from 20 to 700 $\mu J \cdot cm^{-2}$ spectral irradiance; meanwhile that of ZrO_2:Eu exposed to 260 nm UV light was linear from 2.4 to 2000 $\mu J \cdot cm^{-2}$ spectral irradiance. The results showed that Al_2O_3:C crystals as well as the ZrO_2:Eu films deposited on glass substrates have the potential to be used as UV dosimeters in personal or environmental dosimetry

Keywords: Thermoluminescence; thin films oxides

En este artículo se presentan resultados experimentales de estudiar las características termoluminiscentes (TL) y ópticas de Al_2O_3:C y ZrO_2:Eu expuestos a luz UV de longitud de onda en el intervalo de 200 a 400 nm. El espectro de excitación también fue obtenido. El espectro fotoluminiscente del ZrO_2:Eu inducido por luz UV de 275 nm exhibió cuatro máximos a 560, 575, 612 y 650 nm con la mayor emisión a 612 nm. La respuesta TL en función de la longitud de onda mostró un máximo en 230 nm para el Al_2O_3:C y mostró cuatro máximos a 210, 230, 260 y 300 nm para el ZrO_2:Eu. La curva TL del Al_2O_3:C exhibió dos picos TL, a 110 y 220°C; mientras que la del ZrO_2:Eu mostró tres, 120, 290 y 390°C para todas las longitudes de onda estudiadas. Los picos de 110°C y 120°C se desvanecen completamente en las primeras 24 horas después de la exposición. Mientras que los picos de 220, 290 y 390°C mostraron gran estabilidad durante mucho tiempo. La respuesta TL de Al_2O_3:C expuesto a luz UV de 230 nm fue lineal entre 20 y 700 $\mu J \cdot cm^{-2}$ de irradiancia espectral; mientras que, la del ZrO_2:Eu expuesto a luz UV de 260 nm fue lineal entre 2.4 y 2000 $\mu J \cdot cm^{-2}$ de irradiancia espectral.

Descriptores: Termoluminiscencia; oxidos en películas delgadas

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1. Introduction

The monitoring of UV light has become more important in recent years as people become aware of the biological effects of UV radiation either from sunlight or from artificial sources. The use of thermoluminescent (TL) dosimeters of different materials to monitor UV radiation has been reported by many authors [1–5]. Thermoluminescence induced in Al_2O_3:C and in ZrO_2 irradiated by UV light has been reported by several authors [6, 7]. TL properties has been studied by some authors for rare earths oxide impurities used as dopants in single crystals of ZrO_2 [8].

This paper reports the experimental results of studying the TL optical properties of Al_2O_3:C and of ZrO_2:Eu thin films exposed to UV light of wavelength in the range of 200 to 400 nm. Excitation spectrum was also obtained.

2. Experimental procedure

Materials were constituted by α-Al_2O_3:C discs 5 mm in diameter and 1 mm thick obtained from Victoreen Inc. Cleveland, USA and by $5 \times 5 \times 1$ mm^3 chips of quartz substrate on which a thin film 0.05 mm thickness of ZrO_2:Eu was coated in our laboratory using the ultrasonic spray technique.

Selected samples of the deposited films were investigated with an X-ray diffractometer Siemmens D-5000 with wavelength radiation of 0.15406 nm to determine their crystalline structure; and by X-ray fluorescence and neutron activation analysis to determine impurities.

Previously to the exposure of the Al_2O_3:C and ZrO_2:Eu samples to the light they were annealed at 800°C for 30 minutes and at 300°C during 10 minutes, respectively in order to erase all previous information.

To investigate the TL response of the samples, they were individually exposed to a normalized beam of UV light from a Xe lamp coupled with a monochromator to select different wavelengths between 200 and 400 nm. Samples of ZrO_2:Eu with various concentrations of the dopant, produced at different coating temperatures, were compared using the UV induced TL response to test the dependence of this response on different crystalline structures and different dopant concentrations.

The Photoluminescence spectrum induced by 275 nm UV light was measured with a Perkin-Elmer 650-10S fluorescence spectrophotometer.

Thermoluminescence readings were made in a Harshaw 4000 TL analyzer connected to a PC computer to obtain and analyze the glow curves digitizing both TL and temperature signals by means of two channels of an RS 232C interface. All TL measures were made in nitrogen atmosphere in order to reduce the thermal noise resulted from the heating planchet of the TL reader. Glow curves were registered from room temperature to 300°C for Al_2O_3:C and from room temperature to 400°C for ZrO_2:Eu at a heating rate of 10°C/s in both cases.

3. Results

Optimum concentration of Eu in ZrO_2 determined on the basis of the maximum TL response was 5%. Then, all results were reported for this concentration.

X-ray diffraction patterns of undoped and Eu-doped ZrO_2 were very similar and demonstrate tetragonal crystalline structure. These X-ray spectra obtained for different coating temperatures showed similar shapes too, and it was found that all diffraction peaks appeared with higher peak heights and narrower peak widths as the coating temperature became higher.

The results of the experimental tests on TL response of ZrO_2:Eu films coated at different temperatures showed that a close relation exists between the TL phenomenon and the coating temperature. Thus, combining the results of X-ray diffraction and TL response of ZrO_2:Eu films coated at different temperatures, it was found that the optimum temperature was 600°C.

The photoluminescence spectrum of ZrO_2:Eu induced by 275 nm UV light, shown in Fig. 1, exhibited four maxima at 560, 575, 612, and 650 nm with the major emission at 612 nm. These maxima corrrespond to $^5D_0 \rightarrow {}^7F_0$, $^5D_0 \rightarrow {}^7F_1$, $^5D_0 \rightarrow {}^7F_2$, and $^5D_0 \rightarrow {}^7F_3$ energy transitions of the Eu^{3+} ion.

The TL response of Al_2O_3:C exposed to UV light as a function of wavelength exhibited three maxima at 230 nm, 435 nm, and 600 nm meanwhile the ZrO_2:Eu showed six maxima at 210 nm, 230 nm, 260 nm, 300 nm, and 400 nm. The glow curves, shown in Figs. 2 and 3, exhibited two peaks at 110°C and 220°C that of Al_2O_3:C; and at 120°C, 290°C, and 390°C that of ZrO_2:Eu for all the wavelengths studied.

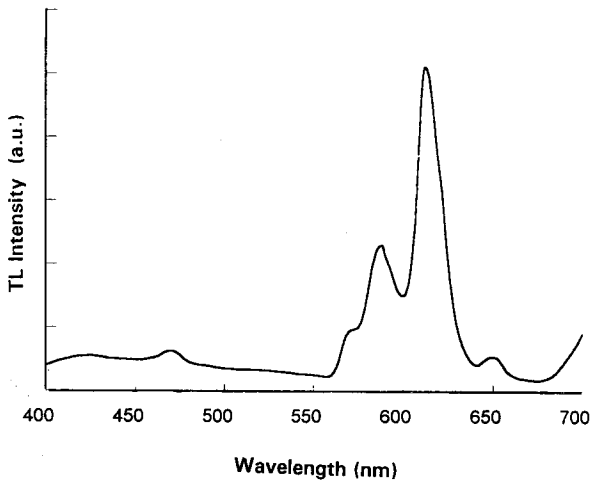

FIGURA 1. Photoluminescence spectrum of ZrO_2:Eu induced by 275 nm UV light.

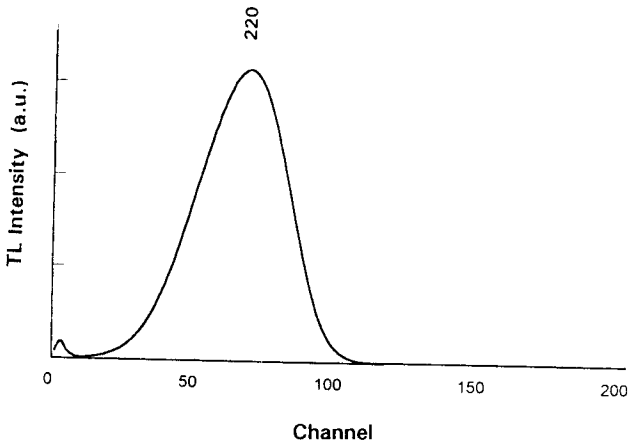

FIGURA 2. Glow curve of Al_2O_3:C exposed to 230 nm UV radiation.

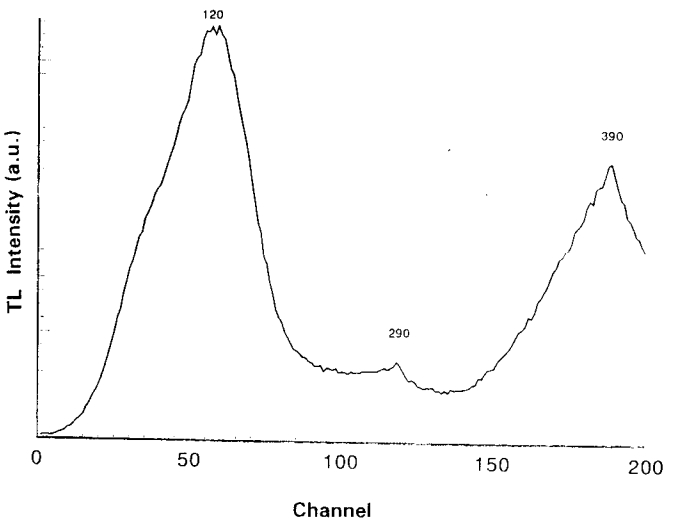

FIGURA 3. Glow curve of ZrO_2:Eu exposed to 260 nm UV radiation.

The intensity of the low temperature glow peaks faded completely within the first 24 hours after exposure. Meanwhile, the high temperature peaks showed great stability for a long time.

The TL response of Al_2O_3:C exposed to 230 nm UV light was linear from 20 to 700 $\mu J \cdot cm^{-2}$ spectral irradiance; meanwhile, that of ZrO_2: Eu exposed to 260 nm UV light was linear in range of 2.4 to 2000 $\mu J \cdot cm^{-2}$ spectral irradiance.

4. Conclusions

The coating temperature of ZrO_2 films plays an important role in the TL response. Then using the appropriate temperature during the coating process we can conclude that ZrO_2:Eu films deposited on quartz substrates as well as the Al_2O_3:C crystals have the potential to be used as UV dosimeters in personal or environmental dosimetry.

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