

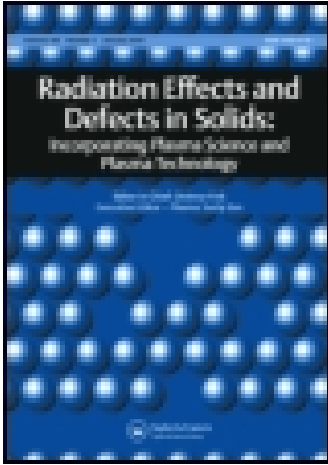
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SENSITIZATION AND DESENSITIZATION OF THE LUMINESCENCE YIELD OF $\text{Al}_2\text{O}_3:\text{C}$

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The effects of optical and thermal treatments on the luminescence and thermoluminescence efficiencies were investigated in $\alpha\text{-Al}_2\text{O}_3:\text{C}$ crystals. Emission bands appeared at 500, 410 and 330 nm with excitation maxima near 300, 200 and 260 nm respectively. These bands are ascribed to the emission of interstitial Al_i^+ ions, F and F^+ centers. Prolonged UV illumination with 200–220 nm light caused a notable increase in the luminescence yield of the 410 and 330 nm luminescence bands, while the illumination with 300 nm had a reverse effect on these bands. Wavelengths of 260 and 300 nm were most efficient for the optical bleaching of the PTTL.

Keywords: $\text{Al}_2\text{O}_3:\text{C}$; Luminescence; Sensitization; Desensitization

I. INTRODUCTION

The anion defective $\alpha\text{-Al}_2\text{O}_3:\text{C}$ crystals show a much higher thermoluminescence (TL) and phototransferred TL (PTTL) sensitivity than the pure Al_2O_3 crystals under the same conditions. The very high TL sensitivity of the C-doped crystals has been attributed to the relatively large concentrations of oxygen vacancies due to the C content and to the growth of these crystals under highly reducing conditions [1]. These C-doped crystals have recently become of interest due to their

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application as highly sensitive TL radiation detectors [2]. In recent studies also the optically stimulated luminescence (OSL) has been studied in these crystals under constant as well as under pulsed excitation and it has been shown that $\alpha\text{-Al}_2\text{O}_3:\text{C}$ crystals can also be used as a sensitive OSL dosimeter, which can detect doses as low as $1\ \mu\text{Gy}$ [3,4]. In the present work the effects of various pre-treatments on the efficiencies of the TL, PTTL, OSL, photoluminescence (PL) and X-induced luminescence (XL), as well as effects of optical bleaching were studied in $\alpha\text{-Al}_2\text{O}_3:\text{C}$ crystals.

II. EXPERIMENTAL PROCEDURE

The C-doped samples were grown at the Urals Polytechnical Institute [1], and the nominally pure synthetic $\alpha\text{-Al}_2\text{O}_3$ crystals were from Insaco Inc. The X-irradiations were performed with a W-tube (40 kV, 15 mA) and the β -irradiations with a Sr^{90} source of a $1.5\ \text{Gy}/\text{min}$ dose-rate. For the UV-illuminations a 150 W Xe-lamp and a 0.25 m grating monochromator were used. For the investigations of effects of optical bleaching of the PTTL, the β -irradiated samples were first heated to 500°C and then exposed at RT to prolonged illuminations of monochromatic UV light. The power of the incident light beam was monitored and the irradiance at 300 nm was $\sim 1.7\ \mu\text{W}/\text{cm}^2$. The PTTL, induced by a constant small dose of UV light, was recorded before and after the exposure to the prolonged UV illumination and the changes in the TL sensitivity were measured.

III. RESULTS AND DISCUSSION

The main emission band of the XL appeared at 410 nm and a weaker band at 330 nm, and they have been attributed to F and F^+ luminescence respectively [5]. This is supported by the finding that the same two bands were also recorded in the OSL and PL and had UV excitation maxima near 200 and 260 nm, which coincide with wavelengths of the F and F^+ absorption bands. Recent time resolved measurements indicated that the main 410 nm luminescence band involves electron and hole transitions via the delocalized bands and not a donor acceptor pair recombination [4]. The OSL showed also an emission band near 500 nm

with an excitation maximum near 300 nm; a weak absorption band has previously been reported at this wavelength and ascribed to an interstitial Al_i^+ ion [6]. The temperature dependencies of the emission bands are shown in Fig. 1. During cooling from 300 to 230 K the relative quantum yield of the 410 nm PL emission decreased by an order of magnitude, while only a slight decrease was recorded by further cooling to 80 K. The yield of the 500 nm emission increased slightly during cooling from 300 to 230 K but decreased markedly by further cooling between 170 and 130 K. The 330 nm emission was not affected by the cooling. The luminescence efficiency of the 410 and 330 nm emission increased after exposure of the samples to X or β radiation. Prolonged UV irradiation in the 200–220 nm region had a similar effect on the emission intensities of these bands. This increase may be due to the transfer of electrons from the valence to the conduction band, perhaps via an intermediate impurity level, and the capture of excited electrons by existing anion vacancies and formation of additional F and F^+ centers. The possibility of such a two step transfer process is supported by the finding that simultaneous illuminations with 3.5 and 6 eV photons causes a further increase of the luminescence intensity in these crystals of 9.5 eV bandgap; illumination with 3.5 eV photons only had

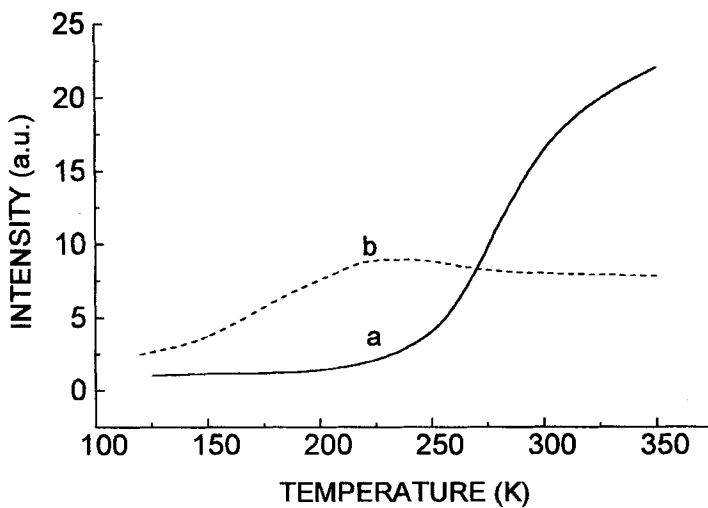


FIGURE 1 Temperature dependence of: (a) 410 nm, (b) 500 nm PL emission bands.

no effect on these emission bands. The 500 nm emission was not affected by these irradiations, but prolonged illumination into the Al_i^+ band at 300 nm had a reversed effect and caused a decrease in the PL efficiency. This is shown in Fig. 2. Step by step heating to temperatures between 500°C and 1000°C and recooling to RT caused a decrease of the PL intensities and after heating to above 1000°C the PL intensities returned to their initial low values, indicating that the F and F^+ centers become thermally unstable at this temperature. The effects of heat treatment and of pre-irradiation on the PTTL sensitivity were also studied. For these studies the crystals were first X or β -irradiated at RT, heated to 500°C, then cooled either to RT or to LNT and illuminated with monochromatic UV light. Wavelengths of 200–220, 260 and 300 nm were found to be most efficient for the stimulation of the PTTL. Heating to 1000°C for 1–2 h and slow recooling to RT caused a thermal bleaching of the PTTL similar to that observed in the PL. After such a heat treatment the PTTL could be stimulated with 200–220 nm light, but not with longer wavelengths. Investigations of optical bleaching showed that prolonged exposure of the samples to UV light in the 250–400 nm region resulted in a notable decrease of the

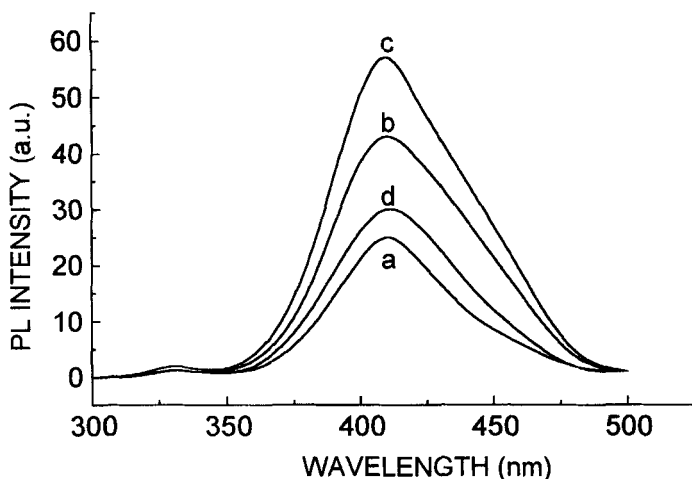


FIGURE 2 PL emission spectra, excited by 220 nm light: (a) at the beginning of the 220 nm illumination; (b,c) after 10 and 30 min exposure to 220 nm UV light; (d) PL recorded after 30 min exposure to 300 nm light.

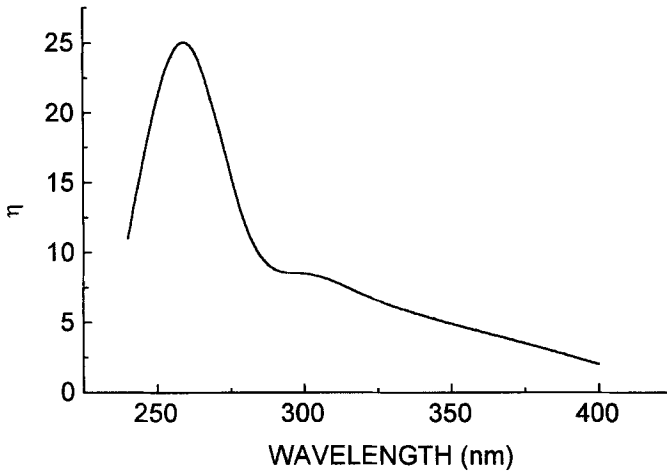


FIGURE 3 The relative bleaching efficiency (η) of the 180°C PTTL peak as a function of wavelength. The PTTL was induced at RT by a constant test dose of 370 nm light. Results are normalized for a constant photon flux of the bleaching light at various wavelengths.

PTTL intensities. In Fig. 3 the efficiency (η) of the PTTL bleaching is given as a function of the wavelength ($\eta = 1 - I/I_0$), where I_0 and I are the intensities of the 180°C peak, before and after 240 min illuminations. The wavelength of 260 nm, which was effective for the OSL and PTTL stimulation, was found to be also efficient for the optical bleaching of the PTTL. A shoulder appeared in the bleaching curve near 300 nm. It should be noted that prolonged exposure to 300 nm light, which caused the decrease of the PTTL, was also effective for the desensitization of the 410 and 330 nm PL emission. This desensitization may be due to the transition of holes from the interstitial Al ions to the F and F^+ centers and to a decrease in the concentration of these centers.

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