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Radiation Dose Effect of Thermo luminescence on γ-Al_2O_3: C

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Abstract: *This study aims to investigate the effects of radiation dose on the TL of γ-Al_2O_3:C.The material was exposed to beta radiation using the Risø TL/OSL-DA-15 Reader equipped with a $^{90}Sr/^{90}Y$ beta irradiator. The luminescence signals were measured by initially heating the samples at a heating rate of 5°C/s from room temperature (RT) to 500°C following β-irradiation and the glow curves, dose response determined respectively. The sample, doped with 1.0g of carbon graphite showed clear TL peaks at 256, 254, 242, and 244°C at 0.5Gy, 1.0Gy, 5.0Gy and 10.0Gy respectively. Dose response curve analysis showed a linear response in the dose range from 0.5Gy to 10Gy. With the results obtained, it can be concluded that the TL of γ-Al_2O_3:C increases with increase in radiation dose and this indicates that this material is suitable for personnel dosimetric applications.*

Keywords: *γ-Al_2O_3:C, Thermo luminescence, radiation dose, heating rate, glow curves, personnel*

I. Introduction

Thermo luminescence (TL) is the stimulated emission of light from a dosimetric material following the previous absorption of energy from radiation when it is heated. The emitted light has a longer wavelength than the incident radiation. Materials that exhibit luminescence properties and have the specific property of having proportionality between the amount of light emitted and the dose they were exposed to, can be used as a dosimeter [1]. The application of thermo luminescence to radiation dosimetry is possible because, in principle, the luminescence intensity is proportional to the concentration of sites as well as to the absorbed radiation dose. Research has shown that exposure to ionizing radiation above certain levels can cause adverse health effects, including cancer and hereditary effects (effects that can be passed on to offspring's) [2]. Therefore, exposure to ionizing radiation is monitored and controlled using dosimeters in order to keep the doses as low as reasonably achievable (ALARA) with social and economic factors taken into consideration.

In solids, electrons populate bands of allowed energy states separated by "forbidden" band which is also called the band gap. In the band gap the allowed energy states are the valence band which is the lower band of allowed energy states and is usually filled with electrons. The conduction band which is the higher band of allowed energy states where conduction takes place [3]. Electrons lose their excitation energy in this band and can either fall back to the valence band immediately and recombine with a hole or are trapped at defects within the material structure. The property of storing energy in materials is due to the presence of defects such as vacancies and impurities incorporated in the material. Thermo luminescence (TL) process have been often used for the characterisation of Al_2O_3 for use in dosimetry by several researchers [4]-[8]. The alpha aluminium oxide (α-Al_2O_3) was one of the earlier materials studied for its possible application as a radiation dosimeter, owing to its thermal, chemical stability and low effective number [9]. Since then efforts have been directed towards the improvement of its sensitivity through introduction of various dopants by researchers such as [10]-[14]. Also, owing to the importance of glow peaks, the thermo luminescence characteristics of two subsidiary glow peaks, one below 100°C and the other above 300°C of α-Al_2O_3:C were studied by [15].

The thermo luminescence of aluminium oxide usually consists of a high-intensity near 200°C (referred to as the dosimetry peak), and a number of weaker intensity secondary peaks below and above 200°C, whose relative intensity depends on the dosimeters' treatment such as irradiation or exposure to light [16]. These peaks are usually obtained from the characteristic glow curve of the material. A glow curve is a plot of the TL intensity versus temperature, measured as the material is heated. The TL signal is usually characterised by a so-called "glow curve", with distinct peaks occurring at different temperatures; which relates to the electron traps present in the sample. An ideal dosimetric material should have a linear dose response over a wide range of doses. Dose response is defined, as the functional dependence of the intensity of the measured luminescence signal upon the absorbed dose [17]. The aim of this study was to investigate the effect of beta radiation on the thermo luminescence of gamma aluminium oxide doped with carbon (γ-Al_2O_3:C) and to observe the TL response by heating the irradiated samples at a constant heating rate and recording the luminescence emitted as a function of temperature. In this paper, the glow curves, dosimetric peaks and the dose response of γ-Al_2O_3:C prepared by synthesis are reported.

II. Experimental Procedure

The study was performed using 20g of 99% pure γ-Al_2O_3 doped with 1.0g of carbon graphite. The TL measurements were performed using an automated Risø TL/OSL reader system (Risø TL/OSL DA-15) manufactured by Risø, Danish National Laboratory and installed at the Centre for Energy Research and Training (CERT) Ahmadu Bello University, Zaria. The reader is equipped with an internal beta source ($^{90}Sr/^{90}Y$) of 1.48 GBq, which is used to irradiate the samples at an absorbed dose rate of 0.083Gy/s at the sample position. To detect the light from the stimulated sample, the reader contains a light detection system, which includes a PM tube and light filters. The PM-tube is an EMI 9235QA PMT that has a maximum detection with bialkali photocathode (Thorn-EMI 9235QA). The samples were placed in a sample disc and loaded into the automated Risø TL/OSL reader system and irradiated with the beta ($^{90}Sr/^{90}Y$) source. The sample was exposed to 0.5Gy, 1.0Gy, 5.0Gy and 10.0Gy of beta irradiation at room temperature using a $^{90}Sr/ ^{90}Y$ source at the dose rate of 0.083Gy/s. The TL glow curves were obtained by initially heating the sample at a heating rate of 5^{o}C/s from room temperature (RT) to 500^{o}C following β-irradiation. Blue filters in combination with heat absorbing filters were used to separate the thermal background signal arising from the heating element and sample during heating to high temperatures. This luminescence was detected using a bialkali PM tube. The radiation dose response of the TL signal from γ-Al_2O_3:C was obtained by irradiating the sample with radiation doses ranging from 0.5Gy to 10Gy and preheating to 500^{o}C at a heating rate of 5^{o}C/s. The sequence was repeated 6 times at successive doses. The TL signal intensity was then plotted against the radiation dose and the dose responses for the sample obtained.

III. Results And Discussion

TL glow curve

Fig. 1 to 4 show the thermo luminescence glow curves for γ-Al_2O_3:C irradiated with ($^{90}Sr/^{90}Y$) beta dose from 0.5Gy to 10Gy and measured at 5^{o}C/s. The sample shows simple glow curves with few peaks. The TL glow curves of the material irradiated at 0.5Gy and 1.0Gy presents peaks at 256^{o}C and 254^{o}C each (Fig. 1 and 2) while those irradiated with 5.0Gy and 10.0Gy present two dosimetric peaks at 242^{o}C and 244^{o}C and one subsidiary peak at 331^{o}C and 335^{o}C respectively as shown in Fig. 3 and 4. The peaks at low temperature are due to shallow traps, which require only a small amount of energy to release their trapped electrons; those at high temperature are due to deep traps [18]. The result shows that the main dosimetric peak appears at about 200^{o}C and application of the material in personnel dosimetry is based on the dosimetry peak only.

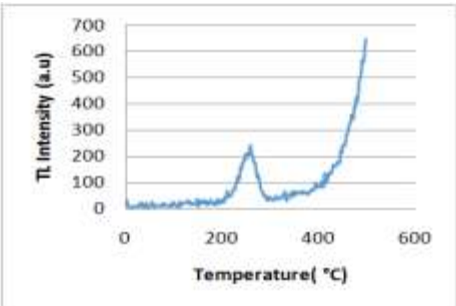

Figure. 1. Thermo luminescence glow curve measured from γ-Al_2O_3:C at 5^{o}C/s from room temperature to 500^{o}C following β-irradiation of 0.5Gy

Normally, traps which give rise to glow peaks lower than 200^{o}C are not useful for dosimetry as electrons can be drained from this traps over a prolonged time even at environmental temperatures. The sample exhibited curves at 256, 254, 242, and 244^{o}C at 0.5Gy, 1.0Gy, 5.0Gy and 10.0Gy respectively (Fig.1-4).

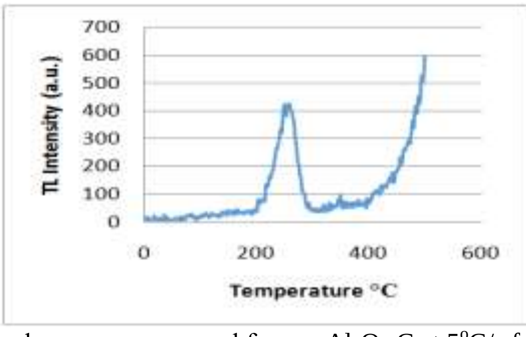

Figure.2. Thermoluminescence glow curve measured from γ-Al_2O_3:C at 5^{o}C/s from room temperature to 500^{o}C following β-irradiation of 1.0Gy.

According to our findings, the sample irradiated with the highest dose value of 10.0Gy had the highest intensity. The shapes of the glow curves obtained are similar to that presented in other research works [19]. The TL of the material increased with increase in dose.

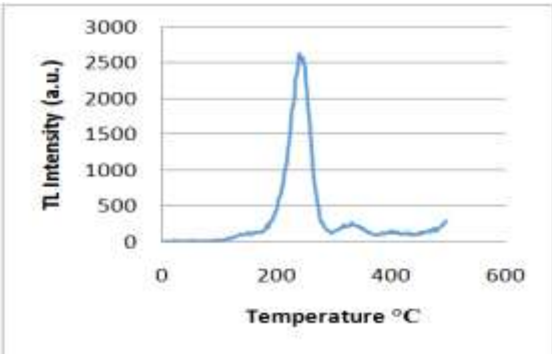

Figure 3. Thermo luminescence glow curve measured from γ-Al_2O_3:C at $5^oC/s$ from room temperature to 500^oC following β-irradiation of 5Gy.

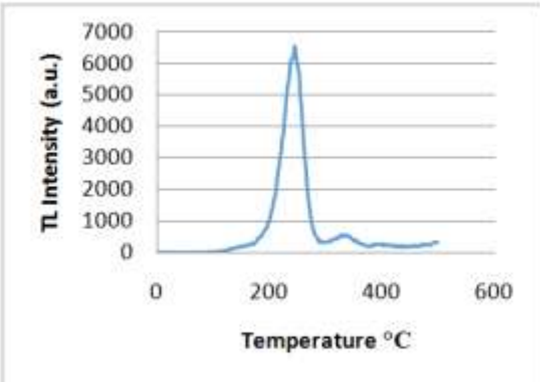

Figure 4. A thermo luminescence glow curve measured from γ-Al_2O_3:C at $5^oC/s$ from room temperature to 500^oC following β-irradiation of 10Gy.

Dose response

The TL dose response was obtained by plotting the TL intensity versus dose and the data was fit to a straight line using a standard linear regression. The dose response curves present a linear response with the equation

$$y = a + bx$$

Where y is the total photon counts and x is the delivered radiation dose (Gy), a is the intercept and b is the slope.

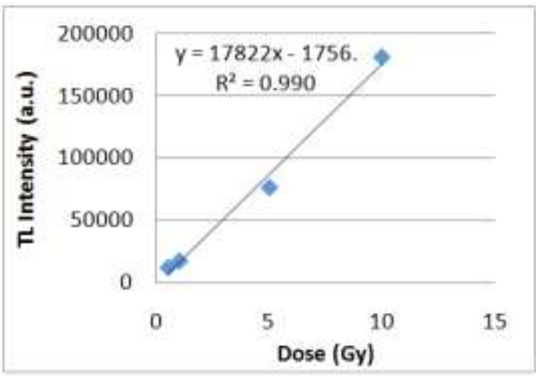

Figure5. Dose Response curve for the TL signal of γ-Al_2O_3:C irradiated from 0.5Gy to 10Gy

Fig.5. shows the change in luminescence intensity with irradiation (the dose response), for γ-Al_2O_3, doped with 1.0g of carbon graphite. A correlation coefficient (R) of 0.9950 and a coefficient of determination (R^2) of 0.9900 was obtained from the investigation. This indicates that the response is linear over the range of doses investigated and the data is closest to the line of best fit by 99% for the sample.

The linearity range and non linearity behaviour depend on the type of material and its physical characteristics, [20]. The linear dose response relationship is so called because the response is directly proportional to the dose. When the radiation is doubled, the response to radiation is likewise doubled. All other dose response relationships are defined as non-linear and they include; sub linear, super linear, and supra linear [21]. Thermo luminescence (TL) and Optically Stimulated Luminescence (OSL) of materials often depends linearly but sometimes non-linearly on the concentration following irradiation [22].

IV. Conclusion

The results obtained showed that the TL intensity increased with irradiation dose and the dosimetric glow peak positions obtained indicate mainly the suitability of the material for use in personnel dosimetry. Hence, TL of γ-Al_2O_3 doped with 1.0g of carbon graphite is dose dependent. The TL response for the sample presents a linear response with dose up to 10Gy which strongly indicates that this material is suitable for personnel dosimetric application.

References

[1]. C. Cosma,A.Timar, V. Bene, I. Pop, T. Jurcut, Ciorba, D. Using Natural Luminescent Materials and Highly Sensitive Sintered Dosimeters MCP-N(LiF:Mg,Cu,P) in Radiation Dosimeter. Journ. Optoelect. Advanc. Materials,10 (3), 2008, No. 3, 573-577.

[2]. E. J. Hall, and D. J. Brenner, Cancer Risks from Diagnostic Radiology. The British Journal of Radiology, 2008, 81,362-378

[3]. M. C.Aznar, Real-time In vivo Luminescence Dosimetry in Radiotherapy and Mammography using Al_2O_3:C. Published Ph. D. Thesis, Riso National Laboratory, Roskilde, Denmark.2005.

[4]. M. S. Akselrod, and V. S. Kortov, (1990). Thermoluminescent and Exoemission Properties of New High Sensitivity TLD α-Al_2O_3:C Crystals. Radiat. Prot. Dosim. 66, 105-110.

[5]. F. D.G.Rocha, and L. V.E.Caldas, Characterization of Al_2O_3 Sintered Pellets for Dosimetric Applications in Radiotherapy. Journ. Radiol. Prot. 19(1), 1999, pp51-55 UK.

[6]. F.Ferey, P.Grosseau, V. Guilhot,P. Iacconi, Benabdesselam, M., (2001). Thermoluminescence and Sintering of High-purity α-alumina doped by Zr, Th and Ca. Solid State Ionics, 141-142, 567-574.

[7]. X. B. Yang, J. Xu, H. J.Li, Q. Y. Bi, Y.Cheng, L. B. Su, Q.Tang, Thermoluminescence and Optically Stimulated Luminescence Disadvantages of α-Al_2O_3:C Crystals Grown by the Temperature Gradient Technique. Chin. Phys.B Vol. 19, No., 2010, 4047803.

[8]. V.S.M. Barros, W. M.Azevedo,H. J. Khoury, P. L.Filho, Preparation and Characterisation of thermoluminescent Aluminium Oxide Doped with Al_2O_3 Tb^{3+} and Tb^{3+}- Mg^{2+}. Journ. of Phys. ,2010, 249, 1742-6596.

[9]. J. K. Rieke, and F.Daniels,Thermoluminescence Studies of Aluminium Oxide. J. Phy. Chem., 1957, 51: 629 - 633.

[10]. C. X. Zhang, Q.Tang, L. B., Lin, D. L. Luo, Thermoluminescence Glow Curves and Optical Stimulated Luminescence of Undoped α-Al_2O_3 Crystals. Radiat. Prot. Dosim. 199(1-4), 2006, 402-407.

[11]. B. Zhang, S. Z. Lu, H. J. Zhang, Q. H. Yang, The Fluorescence and Thermoluminescence Characteristics of α-Al_2O_3:C Ceramics Chin. Phys. B19(7),2010, 077805.

[12]. N. A. Larsen,Dosimetry Based on Thermally and Optically Stimulated Luminescence. Ph.D. Thesis, Risø National Laboratory, Roskilde, Denmark. 1999.

[13]. V.S. M.Barros,H. J. Khoury, W. M. Azevedo, E. F.da Silva Jr., Characterization of Nanoporous Al_2O_3:C for Thermoluminescent Radiation Dosimetry. Nucl. Inst. And Meth. in Phys. Res., 2007, A 580, 180-182.

[14]. E. G. Yukihara, R. Gaza, S. W. S. Mckeever, C. G. Soares, Optically Stimulated Luminescence and Thermoluminescence Efficiencies for High-Energy Charged Particle Irradiation in Al_2O_3:C. Radiat. Meas., 2004, 38, 59-70.

[15]. M. L. Chithambo, Concerning Secondary Thermoluminescence Peaks in α-A_2O_3:C. SouthAfrican Journal of Science, 2004, 100, 524-527.

[16]. S. W. S. Mckeever, M. Moscovitch and P. D. Townsend. Thermoluminescence Dosimetry Materials: Properties and Uses. (Nuclear Technology, Publishing, kent, UK, 1995).

[17]. S. W. S. Mckeever, M. S. Akselrod, B. G. Markey, Pulsed Optically Stimulated Dosimetry Using α-Al_2O_3. Radiat. Prot. Dosim., 1996, 65, 267-272.

[18]. B. E. Bøtter-Jensen, G.A. T.Duller, A.S.Murray, Advances in Luminescence Instrument Systems. Radiat. Meas.,2000, 32, 523-528.

[19]. D.T. Fukumori, W. K. Yoshito, V.Ussui,D. R. R Lazar, L. L. Campos, Preliminary Results on TL and OSL of Aluminium Oxide Dosimeters developed at IPEN. International Nuclear Atlantic Conference-INAC Brazil, October 24-282011.

[20]. D. Lo, J. L. Lawless, R. Chen, Superlinear Dose Dependence of High Temperature Thermoluminescence Peaks in Al_2O_3:C. Radiat. Prot. Dosim.199,(1-4), 2006, 71-71.

[21]. R. Chen, and G.Fogel, Superlinearity in Thermoluminescence Revisited. Radiat. Prot. Dosim.,1993, 47, 1-4, 23-26.

[22]. Lawless, J. L., Chen, R., Pagonis, V. Sublinear Dose Dependence of Thermoluminescence and Optically Stimulated Luminescence Prior to the Approach to Saturation Level. Radiat.Meas.,2009, 44, 606-610.