Phototransferred thermoluminescence and thermally-assisted optically stimulated luminescence dosimetry using α-Al_2O_3:C,Mg

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Introduction

Aluminum oxide doped with carbon and co-doped with magnesium (α-Al_2O_3:C,Mg) is a high-sensitivity luminescence material used as a fluorescent nuclear track detector in the dosimetry of neutrons as well as energetic protons[1]. Recent studies using thermoluminescence (TL) and optically stimulated luminescence (OSL) showed that the material could also be used as a TL and OSL dosimeter. However, a major drawback of using α-Al_2O_3:C,Mg in TL/OSL dosimetry is that its luminescence signal fades faster than the rate desired for a dosimeter. It happens due to release of the radiation-induced trapped electrons from shallow and main traps.

Phototransferred TL (PTTL) and thermally-assisted OSL (TA-OSL) are two useful methods to study luminescence from deep traps where the electrons are stable at ambient condition. PTTL is technically the TL measured from a phosphor after illumination of light of specific wavelength. On the other hand, TA-OSL is the luminescence measured from a sample under simultaneous thermal and optical stimulation. Using these methods, luminescence can be obtained from deep electron traps. The previous studies of PTTL and TA-OSL in an un-annealed α-Al_2O_3:C,Mg showed that the concentration of deep traps in the sample is not very high[2,3]. Therefore, the PTTL and TA-OSL signals are weak to use in dosimetry. However, a recent study showed that the trap-distribution of the sample drastically affected by annealing at 1200 ^{o}C. Therefore, we studied the PTTL and TA-OSL features of the sample after annealed at 1200 ^{o}C to explore its application in luminescence dosimetry.

Materials and Methods

α-Al_2O_3:C,Mg chips of size 5×2.5×1 mm (Landauer, Inc; Oklahoma, USA) were used. The samples were annealed at 1200 ^{o}C for 15 min before use. Luminescence was measured using a RISØ TL/OSL DA-20 Luminescence Reader from a sample irradiated at ambient temperature using a ^{90}Sr/^{90}Y beta source at a nominal dose rate of 0.1028 Gy/s. For PTTL and TA-OSL measurements, the samples were illuminated by 470 nm blue LED with 72 mW/cm^2 power density.

Results and Discussion

A common TL glow curve measured at 1 ^{o}C/s from a sample annealed at 1200 ^{o}C shows glow peaks at 54, 80, 102, 174, 239, 290, 330 and 389 ^{o}C. The peaks at 54, 80, 102 and 174 ^{o}C can be reproduced as PTTL peaks when the irradiated sample is illuminated by 470 nm light after preheated to 230 ^{o}C. Pulse annealing experiments, intended to study the dependence of PTTL peak intensity on preheating temperature, show that the electron traps corresponding to peaks at 239, 290, 330 and 389 ^{o}C act as donor traps whereas the traps corresponding to peaks at 54, 80, 102 and 174 ^{o}C act as acceptor traps in the phototransfer process. The intensity of PTTL peaks increases with illumination time to a maximum within 200 s for measurements corresponding to doses between 1 and 10 Gy. The dose response of the PTTL peaks at 80, 102 and 174 ^{o}C is linear within 1 to 15 Gy. The peak at 80 ^{o}C, fades to background level within 18000 s whereas in the same time, the peaks at 102 and 174 ^{o}C fades only 25 and 5 % of its initial intensity. The peaks are also well reproducible.

Regarding the TA-OSL analyses, the sample show the maximum TA-OSL intensity at 200 ^{o}C under simultaneous optical stimulation. The dose response is sublinear between 10 and 300 Gy and saturates above 300 Gy.

Conclusion

The analyses show that the material can be used for radiation dose reassessment in extreme conditions such as accidental exposure to light as well as temperatures.

Bibliography

[1] M.S. Akselrod, A.E. Akselrod, S.S. Orlov, S. Sanyal, T.H. Underwood, J. Fluores., 2003, 13, 503–511.
[2] J.M. Kalita, M.L. Chithambo, J. Limin., 2017, 188, 371–377.
[3] J.M. Kalita, M.L. Chithambo, Nucl. Inst. Meth. Phys. Res. B, 2017, 403, 28–32.