PHOTO-TL IN $\text{CaSO}_4:\text{Dy}$ -- HIGH EXPOSURE DOSIMETRY

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ABSTRACT

$\text{CaSO}_4:\text{Dy}$ exposed to $10^3 - 10^8\text{R}$ then annealed in the range $280-400^\circ\text{C}$ displays little TL in the major dosimetry peak near 200°C . Subsequent illumination with 250nm light reinduces the 200°C TL. This radiation-enabled photo-TL is roughly proportional to the square root of the enabling exposure at least to 10^8R .

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C00--1105-228

High exposures ($>10^5\text{R}$) can be measured through the color centers produced in ionic crystals, for example, by measuring optical absorption¹ in single crystals, or photo-luminescence^{2,3}, reflectivity³ or thermoluminescence^{4,5} (TL) in either single crystals or powders. In TL, high temperature glow peaks are read because the more commonly used low temperature ones saturate near 10^5R . We demonstrate that high exposures can be measured by detecting color centers through photo-stimulated TL (photo-TL) rather than absorption, reflectivity or high-temperature TL. The procedure is similar to one suggested⁶ for rereading LiF dosimeters; only germicidal lamps and a conventional TL reader are needed, and powder can be used. High exposure dosimetry with this method could be useful in geological dating where saturation is one limitation.

Virgin TL phosphors are usually insensitive to ultraviolet light ($<6.5\text{eV}$) because their band gaps are large ($>7\text{eV}$). Exposure to ionizing radiation fills deep and shallow traps in the gap the shallow traps can be emptied by annealing at a temperature selected to leave some deep centers intact. In this situation illumination may empty deep traps to refill shallow ones, then heating results in photo-TL from these repopulated shallow centers. The combination of exposure and annealing renders the TL material sensitive to ultraviolet light. This type of photo-TL is also referred to as optical repopulation or transfer-TL. If the illumination is not too long and the sample is not too dense optically, then the photo-TL is a measure of the deep centers' population. Note that the deep centers' population is sampled without reading to high temperature; thermal quenching of luminescence and the reader's incandescence are not problems. Also, under proper conditions the photo-TL can be induced and read many times after a single high-exposure.

In particular we have investigated photo-TL in $\text{CaSO}_4:\text{Dy}$ (Harshaw). The main dosimetry peak near 200°C saturates with increasing exposure at about 10^5R . Figure 1 shows that photo-TL does not saturate to at least 10^8R . The figure actually reports the results of separate experiments, as follows. The circles

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represent TL obtained after the indicated exposures to 50 kV peak x-rays, followed by annealing 15 min at 280°C, after which the powder was illuminated with 250 nm light from a Bausch & Lomb SP-200 lamp passed through a monochromator. The crosses show the results of exposure to ^{60}Co at Brookhaven National Lab followed by annealing for 30 min at 400°C after which the powder was exposed to unfiltered germicidal lamps. Both experiments show that the photo-TL grows as $R^{0.55}$ up to at least 10^8 rads. (The two experiments used different lamps and readers, and the samples were purchased two years apart; the magnitude of the response in one experiment cannot be compared to the other.) The results do not demonstrate a precise dosimetry system, but they do demonstrate the principle. Preliminary experiments with 100R at various effective energies indicate that the photo-TL follows the dose delivered by the enabling exposure⁷.

The experiments with ^{60}Co were examined in somewhat more detail. The glow curves are shown in Figs. 2 & 3. Actually two peaks are observed, the usual one near 200°C, and another around 275°C. The TL in the first peak (height) grows as $R^{0.55}$, as does the total area under the two peaks.

Above 300°C a high temperature tail is seen which is not due to incandescence. This seems to be TL which remains from the original irradiation and gives a peak near 500°C. This peak was not explored further, however, since it occurs near the end of the reading cycle and the apparent position may be artifact.

As an aside we note that a growing deep population of optically active centers does not guarantee success of the technique. In LiF (TLD-100) deep centers give TL above 200°C and cause photo-TL in the main dosimetry peak near 200°C (peak 5). Even though the deep traps' population grows beyond 10^5R , the photo-TL in peak 5 saturates near 10^5R just as the direct response does. (The samples were determined not to be opaque to the illumination used to induce the photo-TL.)

ACKNOWLEDGMENTS

We are grateful for support from Comissao Nacional de Energia Nuclear (CNEN); Fundacao Amparo de Pesquisas do Estado de Sao Paulo (FAPESP); Graduate School, University of Wisconsin; and the National Science Foundation.

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FIGURE CAPTIONS

- Fig. 1 Photostimulated TL as a function of previous exposure. The circles and crosses show results of completely independent experiments; the units of response are arbitrary.
- Fig. 2 Glow curves for photostimulated TL following the indicated previous exposures.
- Fig. 3 Glow curves for photostimulated TL following the indicated previous exposures.

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- COO-1105-210 A Simple Approach to Analyzing Basic Optical Instruments . . . B. Durand and P.R. Moran
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D.W. Pearson and P.R. Moran

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G. Ph.D. Thesis Supervision

1. Lang, David Vern (August 1969) "Rotating Frame Double Resonance and Nuclear Cross Relaxation in Lithium Fluoride".
2. Wagner, Jerome (November 1969) "Spin-Lattice Relaxation and Atomic Motions in LiF".
3. Row, Kasturi Sitapati (Dec. 1971) "Pulsed NMR Study of Antiferroelectric ADP".
4. Leach, Robertson, K. (May 1972) "ESR Study of Free Radicals Produced in Cryogenic Solids and Liquids by Electron Bombardments."
5. Fields, D.E. (December 1972) - "Influence of Irradiation and Doping on Thermally Activated Polarization and Luminescence in LiF".
6. Podgorsak, E.B. (May 1973) - "Impurity and Irradiation Induced Thermally Activated Charge Transport in CaF_2 ".
7. Fuller, G.E. (Oct. 1973) - "ESR Study of Transport Dynamics of the Self-Trapped Hole in CaF_2 ".
8. Barroilhet, Luis E. (Dec. 1973) - "NMR Relaxation Study of Atomic Transport Properties in Solid and Liquid Xenon".
9. Fullerton, G.D. (Dec. 1974-J.R. Cameron, Radiological Sciences Supervisor) Thermocurrent Dosimetry with High Purity Aluminum Oxide.

H. Patents

Issued or Pending with Claims Allowed

1. Method of Measuring Fast Neutron Flux Using Thermoluminescence Dosimeters (P.R. Moran, D.W. Pearson) issued September 10, 1974, U.S. Pat. #3,835,329
2. Charge Storage Device (P.R. Moran, E.B. Podgorsak) issued Dec. 17, 1974 U.S. Pat. #3,854,337.
3. Radiation Dosimetry by Measurement of Depolarization Currents (Moran, Podgorsak). Filed Sept. 1972.
4. Radiation Dosimetry by Measurement of Polarization Currents (Moran, Podgorsak, Fields) Filed April 1973.
- 4.5 The two above applications were combined into a single case, U.S. Pat. #346,720 and claims allowed May 1974.
5. Dielectric Material for Dosimeters and Preparation (Moran, Podgorsak, Fuller, Fullerton) pend. all claims allowed. Filed U.S. Pat. #497,874, Aug. 1974.

Applications in Process

1. Tritium Dosimetry by TL Techniques (Moran, Lasky)
2. Compton Effect TAP/TAD Dosimeter
3. Thin Film "Tritium" Dosimeter

Disclosures Being Reviewed

1. Solid State Image Intensifier Screens (Moran, Siedband, Podgorsak)
2. Materials and Devices for High Sensitivity Solid State Ionization Chambers and Radiographic Imaging (Moran, Mayhugh).
3. Processing CaSO_4 : Mn TL Phosphors for Use in Thermal Dose Measurements.
4. Measuring Cell Wall Integrity by NMR and Applications to Tissue Viability, Organ Storage, and Transplant (Moran, Barroilhet).