MASTER**Ca SO₄ as a TL Neutron Dosimeter**

Ervin Podgorsak, James M. Hevezi, and John R. Cameron

Department of Physics

University of Wisconsin

Madison, Wisconsin

Ca SO₄:Mn has a rapid fading of thermoluminescence (TL) to 60% of its original value in 24 hours (1). It is, nevertheless, the most sensitive TLD phosphor available at present. Doping the phosphor with rare earth elements has been shown to reduce the fading problem (2), but these are not the only activators which were found to improve the dosimetric properties of Ca SO₄. No fading was apparent when Ca SO₄:Mn:Na* was tested over a three day period. Evaluation of this phosphor as a neutron dosimeter is the subject of this report. The phosphors are excited by indirect mechanisms such as recoil protons, gamma rays from the (n,γ) reaction, alpha particles from the (n,α) reaction, or fission products.

Two batches of Ca SO₄ powder were used in the experiment. One was doped with Mn and Na, the other with Mn, Na, and depleted U (nominal concentration 0.2% by weight). The total cross section for the interaction of neutrons with fissionable material is composed of scattering (elastic and inelastic), capture, and fission cross sections. In the case of ²³⁸U, the total cross section has a resonance at a neutron energy of about 38 eV ($\sigma_{\text{tot.}} = 5000$ b), but for thermal energies this cross section is negligible (3). Hence, the response of the

*Obtained from the Harshaw Chemical Co. - Cleveland, Ohio

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

two samples is expected to be the same for exposures to thermal neutrons even though one batch was doped with ^{238}U . In addition, the TL response can be expected to be higher in the case of the Uranium doped material irradiated with fast neutrons. Collisions with neutrons of average energy 1 MeV with ^{238}U can result in elastic and inelastic scattering events. There is also a small but non-negligible probability of fast fission occurring in ^{238}U . The fission cross section of ^{238}U for neutron energies above 1 MeV increases with energy.

Both phosphors were exposed to thermal neutrons, fast neutrons, and γ photons separately. Powder samples were put into gelatine capsules and were exposed in the thermal and fast neutron columns of the 1000 kW G.E. Research Reactor at the University of Wisconsin; the irradiations with γ rays were made with the 2000 Ci ^{137}Cs unit at the University of Wisconsin Medical Center.

The crystalline powder was annealed for 1 hour at 400°C before being exposed to neutrons and γ rays. A Harshaw TL detector (Model 2000 A) was used to read the TL response. The glow curve of the doped Ca SO_4 has only one peak which was at approximately 210°C in one batch and somewhat lower in another shipment. Thermoluminescent response was obtained from the peak height. In general, the glow curves had the same shape for both γ and neutron irradiation but the response to thermal neutrons was about three times as large as the response to γ photons for the same dose in "rems". Neutron dose in "rems" was obtained by using the relation $1 \text{ rem} = 9.7 \times 10^8 \text{ neutron/cm}^2$ for soft tissue. Fast neutron exposures

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe primarily owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

were measured with a solid state neutron dosimeter*, dose rates being about 5 rads/min. at the point of irradiation. The fast neutron response on this basis was a factor of 25 less than the γ ray response. The relative response of the phosphors to neutron irradiation was obtained by taking the ratio between the neutron and gamma ray response for the same phosphor. One could then hope to observe a larger ratio for fast neutrons with the Uranium doped material than the phosphor without Uranium because of the fast fission cross section of ^{238}U . Ratios for the thermal neutron flux are expected to be the same for both types.

The results of the investigation are shown in Figs. 1-4. As expected, the thermal neutron ratios for the two phosphors are the same within experimental error. Surprisingly, the fast neutron ratios are also the same with and without Uranium doping. This result may be due to one of the following conditions: the Uranium doped phosphor may have had very little Uranium actually present in it, or the average fission neutron energy was not high enough to induce appreciable fission. Replacement of Ca for U at the lattice sites in the crystal may have been inefficient bringing about the first condition. Hence, the Uranium concentration may have been much smaller than the nominal value quoted. The latter condition may have been brought about by the fact that the fission spectrum had a maximum below 1 MeV neutron energy. An extension of this work to higher neutron energies is in progress using the T (d,n) and D (d,n) reactions as neutron sources.

*Dosimeter Reader Model SNDR-2, Phylatron Corporation

We wish to thank Mr. Richard Cashwell, Reactor Supervisor for his cooperation in this study, and Mr. Morgan Cox of Harshaw Chemical Co. for supplying the phosphors used in the investigation.

REFERENCES

- (1) J. Lippert and V. Mejdahl:
Thermoluminescence Readout Instrument for Measurement of
Small Doses
Luminescence Dosimetry 1967 (Proc. Int. Conf. Stanford 1965)
- (2) T. Yamashita, N. Nada, H. Onishi, and S. Kitamura:
Calcium Sulfate Phosphor Activated by Rare Earth
Proceedings of the Second International Conference on
Luminescence Dosimetry
- (3) D. J. Hughes, and R. B. Schwartz:
Neutron Cross Sections
Brookhaven National Laboratory Report BNL - 325, 1958

Fig. 1 Thermal neutron and γ ray response of Ca SO₄:Na:Mn as a function of dose in "rem". The dose was determined by the relation 1 rem = 9.7×10^8 n/cm² for soft tissue.

Fig. 2 Thermal neutron and γ ray response of Ca SO₄:Na:Mn:U as a function of dose in "rem". The dose was determined by the relation 1 rem = 9.7×10^8 n/cm² for soft tissue.

Fig. 3 Fast neutron and γ ray response of $\text{Ca SO}_4:\text{Mn}:\text{Na}$ as a function of absorbed dose. The neutron dose was determined with a solid state neutron dosimeter and may not represent the actual absorbed dose in the phosphor.

Fig. 4 Fast neutron and γ ray response of $\text{Ca SO}_4:\text{Mn}:\text{Na}:\text{U}$ as a function of absorbed dose. The neutron dose was determined with a solid state neutron dosimeter and may not represent the actual absorbed dose in the phosphor.