A SUMMARY OF PROGRESS IN SOLID STATE DOSIMETRY

Progress Report

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A SUMMARY OF PROGRESS IN
PASSIVE SOLID STATE DOSIMETRY:

1973-1974

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In the past contract year, research progress was documented in USAEC Technical Reports COO-1105-203 through COO-1105-214. This report summary outlines the chief features of the work discussed in those separate reports, beginning with more recent projects and including on-going projects initiated at earlier dates. A final section gives a summary of non-technical information relevant to the work pursued under AT-(11-1)-1105.

Radiation Induced Thermally Activated Currents. The RITAC effect was first described in last year's report. We had discovered that it was an extremely sensitive radiation dosimetry technique, but we knew little about the important physical origins of the sensitivity, minimum detectible doses, nor materials suitable for a device actually stable for application at room temperatures and above. In the past year we developed a RITAC radiation dosimeter based upon ultra high purity Al_2O_3 ; this largely fulfills one of the important goals specified in our 1973 contract proposal. The details are given in reports COO-1105-207 and COO-1105-208. The sapphire RITAC dosimeter, even at its present early stage:

- 1) measures doses below the millirad level.
- 2) is linear in response up to about 100 rad, and is useable up to 10^4 rad before saturating.
- 3) appears stable against fading at room temperature, at least up to time scales of months, the duration we actually have studied the system.
- 4) employs extremely simple and reliable readout instrumentation for direct measurement of electrical charge flow.
- 5) has been studied primarily in crystalline sapphire optical window blanks and unpolished discs, but also works in high purity ceramic alumina.
- 6) uses starting materials which are very inexpensive and readily available in good quality control since their primary market is one of much larger demand for electronic circuit substrates and for u.v. transmitting optical windows.

For routine field use, of course, much work remains to be done in clearing up the technical details. The potential of these results, however, is difficult to overstate. We already knew, for example, from earlier work on low-temperature materials, that RITAC sensitivity corresponded to a conductivity or polarizability phenomena. As such, the sensitivity to radiation theoretically should be independent of dosimeter thickness or form of the material. These expectations were experimentally confirmed; thin dosimeters are as sensitive as thick dosimeters and powders of active materials can be suspended in an inert matrix without operational loss. Consequently, for example, we now have a suitable medium to use with proton radiator foils or powder suspension matrices. The result should yield fast neutron dosimeter which will be tissue equivalent, sensitive into the personnel range, both reliable and stable, and simple to read-out.

The physical mechanisms providing the high sensitivity of the RITAC effect (or, more properly, those which suppress RITAC in materials of improper selective purification) are beginning to emerge. The first important quantity is the initial charge trapping efficiency, and the second is the mobility-lifetime product upon thermal remobilization. The controlling factors for these were studied and reported in COO-1105-203, an electron spin resonance project carried out by Dr. Gene Fuller as his Ph.D. thesis project supported partially by this contract. The applications of those findings to the successful development of the sapphire RITAC dosimeter is given in COO-1107-207; the sapphire-based system research was carried out primarily by Gary D. Fullerton and will be the topic of his Ph.D. dissertation.

There have been interesting spin-offs from this materials-mechanisms oriented work. For example, preliminary indications were that thermoluminescence (TL) response should be very good in selectively purified materials, and that many of the problems inherent to sensitivity enhancement by additional doping of materials avoided. These findings were submitted as a patent disclosure report, COO-1105-206 which has now become a USAEC patent case. Another potentially important phenomena, applicable in nuclear explosion, e-beam pulse, or reactor situations for cheap and simple high level radiation dosimetry for metallic and non-metallic components of various types, is the Compton-effect-induced TAP readout. This also was disclosed (COO-1105-204) for patent purposes, and is being pursued as an active case.

Specific Neutron Dosimetry. This problem has been, at least implicitly, the major final focus for the past four years' work under this contract. Several passive solid state methods evolved, but none reliably sensitive into the personnel dose range. As mentioned in the previous section, combining a practical RITAC material with a suitable proton radiator now looks like only a matter of time and resources for future success. In addition, we have followed through on the sensitivity limits, neutron spectroscopy possibilities and practical applications details of neutron dosimetry by activation of TL phosphors. This formed the research material for the Ph.D. thesis work (dissertation in progress) of David Pearson. Relevant full reports on this topic are COO-1105-211 and 213. The activation method study is on-going work whose early results had already been the basis of a USAEC patent application in the 1972-73 contract year and the work documented in the previous year's annual progress report.

COO-1105-215

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We are presently setting-up to evaluate the RITAC effect in high temperature plastics. These may provide a neutron dosimetry system in which the RITAC sensitive material and the hydrogen-rich proton-recoil substance are the same.

Thermoluminescence and Environmental Dosimetry. Several projects involve continued TL developments and studies. Many of the results are specially applicable to problems in environmental and area radiation dosimetry. Some background information is helpful at this point; starting in the summer of 1972 we initiated preliminary collaboration with a program in the Institute for Environmental Studies of the University of Wisconsin. IES was studying thermal plume studies in Lake Michigan offshore from the Point Beach nuclear reactor power installation. We provided and packaged TL dosimetry devices to attach piggy-back to the thermal-probe poles. These experiments, over the past two years and continuing this summer, have not been funded by any agency, but were carried out with donated manpower. Consequently, they have been neither systematic nor extensive; nevertheless, we have learned a great deal about the technical problems of radiation monitoring (or, in fact, any passive integrating monitoring system) which must operate in environmentally hostile surroundings.

It was from these first collaborative environmental monitoring experiments that we discovered the LiF TL glow curve shape change effect, which we presumed sensitive specifically to low energy electron doses. This was reported in a 1972-73 progress report. Our project over the past year has verified that the LiF shape-change phenomenon is indeed selective to

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electron irradiations. We have examined the electron energy dependence and total exposure dependence; the details of these preliminary results are given in COO-1105-212. Thus we have confirmed that the glow-curve shape change effect is applicable, for example, to tritium monitoring either in body-water or ground-water reservoirs. Using TL powders in a water-slurry we estimate a detectability of about one nanocurie of tritium per cm^3 of water. This work will constitute part of the Ph.D. thesis research project of Mr. Jerry Lasky.

Under the supervision of Professor Mayhugh, in collaboration with Mr. Fullerton, (as reported in COO-1105-209 and COO-1105-214) studies of TL mechanisms, optical bleaching properties, and thermal treatment of TL phosphors have been pursued. Among the chief important outputs has been a useful sensitization procedure for LiF-TL dosimeters. The enhanced sensitivity, combined with the desirable energy response, make, for example, the sensitized LiF devices very suitable for the radiation levels and qualities encountered in environmental monitoring situations.

Other Information. Events of non-technical nature also reflect on the progress of work in the Radiation Dosimetry program partially supported by this contract. Among these, and an important output of University-based research programs, are the completion of student training goals. At the end of last contract year Dr. Ervin B. Podgorsak received his Ph.D. based upon discovery of and in the RITAC effect and, shortly thereafter, Dr. Gene E. Fuller received his Ph.D. Dr. Fuller's dissertation was submitted as a USAEC Report, COO-1105-203. Before the end of the present contract period, Mr. Gary D. Fullerton and Mr. David Pearson, will present their thesis defenses based upon research completed in this group.

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The principal investigator, P. R. Moran, is presently serving as Program Committee Chairman for the Fourth International Conference on Luminescence Dosimetry, Krakow, Poland (August), and our recent series of publications on the discovery and dosimetry applications of the RITAC effect has been requested by the American Institute of Physics for news release purposes. This same topic was also invited and presented as the Scientific Lecture at the annual meeting of the North Central Chapter of the AAPM.

The following bibliography gives articles and short talks from this group during the past contract year.

1. Fields and Moran; Analytic and Experimental Check of Correlated TL and TAC, *Phy. Rev. B*, **9**, 1836 (1974).
2. Fuller, Podgorsak, and Moran; TL Supralinearity as an Optical Emission Efficiency Effect in CaF_2 , *Radiation Research*, June-August 1974.
3. Podgorsak and Moran; Radiation Induced Polarization Transfers in CaF_2 , *J.A.P.*, June 15, 1974.
4. Fullerton and Moran, Single Crystal Sapphire; a TSC Radiation Dosimeter, *Med. Physics*, June 1974.
5. Fullerton and Moran, Sensitive Radiation Dosimetry by the RITAC Effect, Scientific Lecture: Annual Meeting of North Central Chapter of AAPM; also Proc. of AAPM meetings, Kansas City, Mo., July 1974.
6. Moran, Podgorsak, Fuller, Fullerton, New Developments in Passive Solid State Dosimetry: The RITAC Effect, Accepted for publication in *Med. Phys.*
7. Fields and Moran, Thermally Activated Polarization/Depolarization in LiF, *J.A.P.*, July 1974.

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8. Mayhugh and Fullerton, Thermoluminescence in LiF: Sensitization Useful at Low Exposures. Submitted to *Health Physics*.
9. Mayhugh and Fullerton, Altering the Energy Dependence of LiF TLDs by Pre-Irradiation. Submitted to *Medical Physics*.
10. Mayhugh and Watanabe, Fast Neutron Detection by Phosphor Activation, *Health Phys.* (in press).
11. U. W. Radiation Dosimetry Group, Progress in Passive Solid State Dosimetry, 4th Int. Conf. on Luminescence Dosimetry; Krakow, Poland (1974).