COMBINED TL-ESR MgO DETECTORS FOR UV RADIATION

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INTRODUCTION

The ever-increasing demand for the control of radiation field parameters, including ultraviolet (UV) radiation, produces a set of problems among which is enhancement of reliability and validity of measurements over a wide dose range including emergency dose control. Real efficiency of the most popular materials used, for example, for thermoluminescence dosimetry, is restricted by the upper level of the measured doses, 10^2 to 10^4 Gy. However, the desired upper level of the dose interval can reach 10^8 Gy at ambient temperatures of up to 500 K (1,2). To solve this kind of problem by thermoluminescence dosimetry only is apparently not possible.

One of the most promising trends in this field is development of new working solid detector substances allowing one to obtain dosimetric information when measuring the parameters of several physical phenomena accompanying the interaction of the radiation with the detector's material. An example of such an aproach in the search for new materials has been given elsewhere (3). The basic physical phenomena used were thermoluminescence (TL) and electron spin resonance (ESR).

The purpose of this presentation is to study the dosimetric properties and operational characteristics of combined TL-ESR detectors for UV radiation on the basis of MgO:Mn, Fe crystals that have been subjected to a special thermochemical treatment (STT).

EXPERIMENTAL

MgO:Mn, Fe single crystals grown by the arc-fusion method contained 0.02 wt.% of Fe impurity. The samples were subjected to thermoreducing treatment in a vacuum oven with a graphite heating unit at 1000 to 2000 K for 1 to 10 h.

The detectors were irradiated using an deuterium lamp ultraviolet light using an interference filter with λ=250 nm or with X-rays from a Mo target tube operating at 55 kV and 15 mA.

After UV or X-ray irradiation the line with g=2.0037 appears in the sample ESR spectra (Fig.1). Lines g_1 to g_6 belong to Mn^{2+} impurity and line A corresponds to Fe^{3+} impurity ions. With thermally treated samples, line A is not observed before irradiation. After irradiation this line appears again and its amplitude increases with the increase of absorbed dose.

In MgO: Mn, Fe the ESR signal with g=2.0037 is known to correspond to the Fe^{3+} impurity ions (4). The TL maximum in the temperature range of 300 to 500 K is brought about by the recombination of thermo-ionizing electrons with Fe^{3+} impurity ions (5). At the same time, thermoreducing treatment of MgO crystals results in the emergence of Fe^{2+} ions and high concentration of electron trapping centers in the samples. During irradiation, electrons liberated from Fe^{2+} ions are captured by centers created as a result of the treatment, which leads to higher concentration of Fe^{3+} ions and, accordingly, higher ESR signals. When annealing thermo-ionizing electrons recombine with Fe^{3+} ions, this results in the ESR signal drop in the temperature range 350 to 450 K and appearance of the TL maximum. When the anneal temperature increases to 950 K, the ESR signal drops rapidly in the temperature range 350 to 450 K and more slowly in the temperature range 450 to 950 K, until the signal disappears completely at 950 K.

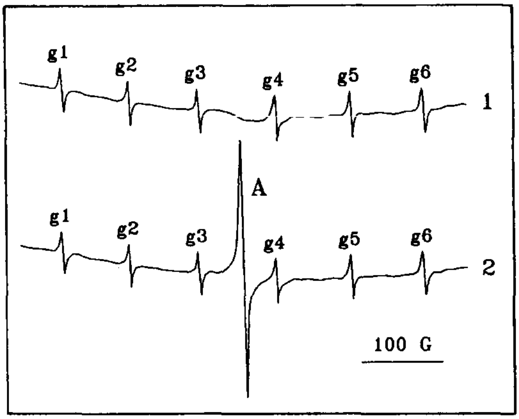

Figure 1. ESR spectra from virgin MgO:Mn, Fe single crystals (1) and crystals subjected to special thermochemical treatment (1) after (2) and befor UV or X-ray irradiation.

The ESR signal of Mn^{2+} ions does not change when irradiating and annealing. The fact that the ESR signal of thermally treated MgO:Mn, Fe crystals cannot be annealed even at high temperatures allows one to use them for measuring radiation dose at high temperatures. The dose dependence of the ESR signal of crystals irradiated at 570 K is linear in the range of 3 to 3×10^2 Gy. Under UV irradiation, the TL intensity dose dependence is linear in the irradiance range 10^{-1} to 10^3 μJ· cm $^{-2}$ (Fig.2, curve 1). The ESR signal is registered starting from irradiances of 2×10^2 μJ·cm^{-2} and grows in a linear fashion with irradiance from 10^3 to 10^5 μJ·cm^{-2} (Fig.2,curve 2). During the available time, the ESR signal did not reach saturation.

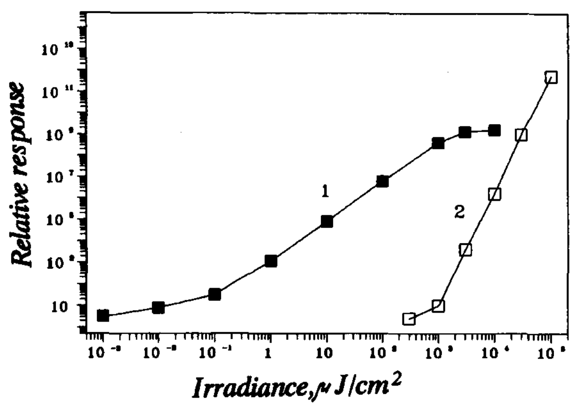

Figure 2. Irradiance dependence of the TL intensity (1) and ESR signal (2) of MgO:Mn, Fe single crystals due to UV irradiation.

Thus, MgO:Mn, Fe single crystals or ceramics can be used as combined TL-ESR detecting media after reducing thermochemical treatment.The main features of this material are the following:

1.High reliability and validity of dosimetric measurements due to readout of information from one and the same sample using two independ methods (TL and ESR).

2.Possibility of repeated reproduction of dosimetric information by the ESR signal after TL readout and influence of high temperatures ($T < 800$ K) on the sample.

3.High sensitivity and wide range of registered doses for dosimetry of UV radiation. The total range of registered irradiances using ESR and TL exceeds 8 orders of magnitude (the low level is 10^{-3} $\mu J \cdot cm^{-2}$; the upper level is greater than 10^{5} $\mu J \cdot cm^{2}$).

4.Possibly of enhancing the accuracy of dosimetric measurements for the ESR signal registration when reading out information by the ratio of the intensity of the Fe^{3+} ion line to the intensity of Mn^{2+} ion lines, whose parameters remain stable when irradiation and annealing.

5.Possibility of pre-adjustment of the TL reading devices, according to the results of ESR measurements.

6.Possibility of evaluating the current dose by the TL output and dose accumulated over a longer period of time (month, year) by the ESR output.

CONCLUSION

It can be said that the combined TL-ESR MgO:Mn, Fe detector can cover irradiance ranges of particular interest, such as erythermal dose for skin (16 $mJ \cdot cm^{-2}$) or also lower values which can be used in biological research.

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