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ARTICLE *in* NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH SECTION A ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT · SEPTEMBER 2007

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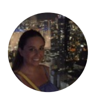
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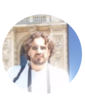
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TL/OSL properties of natural schist for archaeological dating and retrospective dosimetry

D. Afouxenidis[a,b], E.C. Stefanaki[a,b], G.S. Polymeris[a,b], A. Sakalis[a], N.C. Tsirliganis[a,*], G. Kitis[b]

[a]Archaeometry Laboratory, Cultural and Educational Technology Institute/R.C. "Athena", Tsimiski 58, Xanthi 67100, Greece
[b]Physics Department, Aristotle University of Thessaloniki, University campus, Thessaloniki GR-54124, Greece

Available online 18 May 2007

Abstract

Schist, a metamorphic rock composed largely of quartz and muscovite, has been used as a building stone through the centuries in many parts of the world. In ancient Greece, it was used in buildings and monuments (Knossos, Karthaia, etc). Basic TL and OSL properties of schist are studied in the present work to evaluate its potential use in archaeological dating and retrospective dosimetry. In particular, the optical stability, as well as the linearity of the TL and OSL signal were investigated for samples of natural schist obtained from a roofing slate. The results indicate that both signals are rapidly bleached when the sample is exposed to sunlight. An exposure of 1 min reduces the TL signal by 93%, the IRSL signal by 99% and the post-IR BSL signal by 90%. The dose response was found to be linear for a radiation dose at least up to 75 Gy for the TL and the IR OSL signal and at least up to 25 Gy for the post-IR BSL signal.

PACS: 78.60.Kn; 78.45.+h; 87.58.Sp

Keywords: Retrospective dosimetry; Luminescence; Schist; Dating; TL/OSL

1. Introduction

Luminescence has been increasingly used for dosimetric purposes that presently constitute an important part of solid-state dosimetry. Its applications cover various fields, such as medical, environmental, personnel, and retrospective dosimetry [1]. Applications of the latter fall in two major categories namely the luminescence dating and accidental dosimetry [2–4].

In nature, there are several rocks containing quartz and/or feldspar-based minerals that have certain luminescence properties that make them suitable for use as dosimeters either for environmental or retrospective dosimetry. Some of these rocks have been traditionally used as building stones, tiles, or roofing slates for the construction of many historical buildings and monuments. Such a rock is schist, a crystalline metamorphic rock that is a common geological material in the Mediterranean region. Schist was used in structures in ancient Greece, with several examples existing in the area of Knossos, Karthaia, etc. and is extensively used until now.

The objective of this study is to explore the thermally and optically stimulated luminescence (TL and OSL, respectively) properties of schist, in order to investigate the possibility of its use in environmental dosimetry and archaeological dating.

2. Materials and methods

The material used in the study was a natural schist sample obtained from a roofing slate of a house in the village Koupa, in Nothern Greece. The original sample was initially crushed and subsequently grains with dimensions of 4–11 μm were selected and deposited on aluminum discs of 1 cm^2 area. All luminescence measurements were performed using a RISO TL/OSL reader (model TL/OSL-DA-15), equipped with a high-power blue LED light source, an infrared solid-state laser and a 0.085 Gy/s

*Corresponding author. Tel.: +30 254 107 8787; fax: +30 254 106 3656.
E-mail address: tnestor@ceti.gr (N.C. Tsirliganis).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.05.142

$^{90}Sr/^{90}Y$ β-ray source. The reader is fitted with an EMI 9635QA PM Tube [5]. All OSL measurements were performed using a Hoya U-340 filter, while TL measurements were performed using a combination of a Pilkington HA-3 heat absorbing and a Corning 7–59 blue filter. A SOL-2 solar simulator (Dr. Hönle) was used for bleaching.

The power level for OSL measurements, was set, respectively, at 90% and 70% of the maximum power for the infrared and blue light-stimulated luminescence. All measurements were performed using continuous wave OSL (CW-OSL). In order to reduce the OSL contribution from the feldspars, infrared OSL measurements (IRSL) were preceding the blue-light OSL measurements (termed post-IR BSL) measurements [6,7]. Stimulation times were chosen to be 150 s for IRSL and 60 s for BSL. OSL measurements were performed at 125 °C after the sample had been preheated at the chosen temperature of 180 °C for 10 s.

Since both quartz and albite are included in schist, its glow curve shape is the sum of all overlapping peaks from these minerals. In order to distinguish between the individual glow peaks, a computerized glow curve deconvolution (CGCD) analysis was used.

All curve fittings were performed using the MINUIT computer program [8], while the goodness of fit was tested using the Figure Of Merit (FOM) [9]. Six individual glow peaks were used to fit all glow curves while the obtained FOM values were in all cases less than 1%.

3. Results and discussion

3.1. Glow and shine down curves

Fig. 1 shows the TL glow curves of schist, obtained with a heating rate of 2 °C/s to a maximum temperature of 500 °C. The natural TL signal is shown in Fig. 1A, while the glow curves obtained after bleaching for 60 s and 4 h without any other pre-treatment are shown in Fig. 1B. As can be seen from Fig. 1B, bleaching causes a significant reduction of the 270 °C peak. Glow curves corresponding to doses of 25 Gy as well as 150 Gy obtained after extensive bleaching for 4 h are shown in Figs. 1C and 1D,

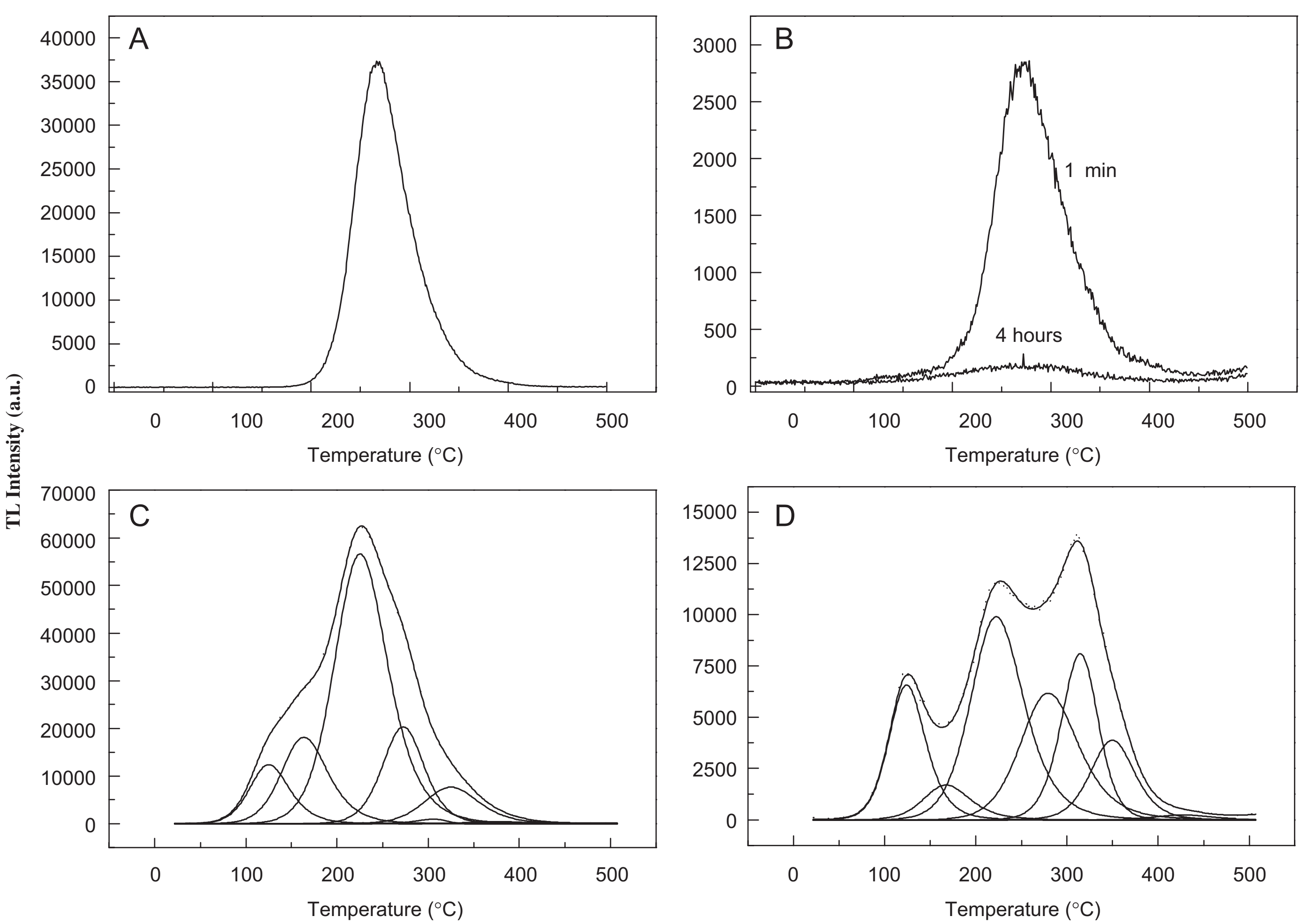

Fig. 1. TL glow curves of schist, measured up to 500 °C, using a heating rate of 2 °C/s. 1(A) glow curve of natural TL signal, 1(B) glow curves after bleaching for 60 s and 4 h, without any other pre-treatment, 1(C) and 1(D) glow curves corresponding to doses of 25 as well as 150 Gy, deconvoluted into their six individual glow peaks.

respectively. The shape of the glow curve changes dramatically as the administered doses increase above 75 Gy. For lower doses the shape of the glow curve approaches this of Fig. 1C while for higher than 75 Gy doses it is similar to the one of Fig. 1D.

The continuous wave IRSL decay curve, due mainly to feldspars, is shown in the left-hand side of Fig. 2 while the respective post-IR BSL decay curve, due mainly to quartz, is shown in the right-hand side of the same figure. Both curves were obtained at room temperature. As can be seen from Fig. 2, the OSL signal from feldspars is more intense than the one from quartz, however, both signals are easily bleached as indicated by the rapid decay of the curve in the initial few seconds of stimulation.

3.2. Bleaching properties

The bleaching properties of schist were studied on 50 aliquots, divided into groups of two aliquots each. Bleaching times ranging up to 300 s were used on 10 groups for OSL measurements, while for TL measurements were used 15 groups and bleaching times up to 4 h. Each

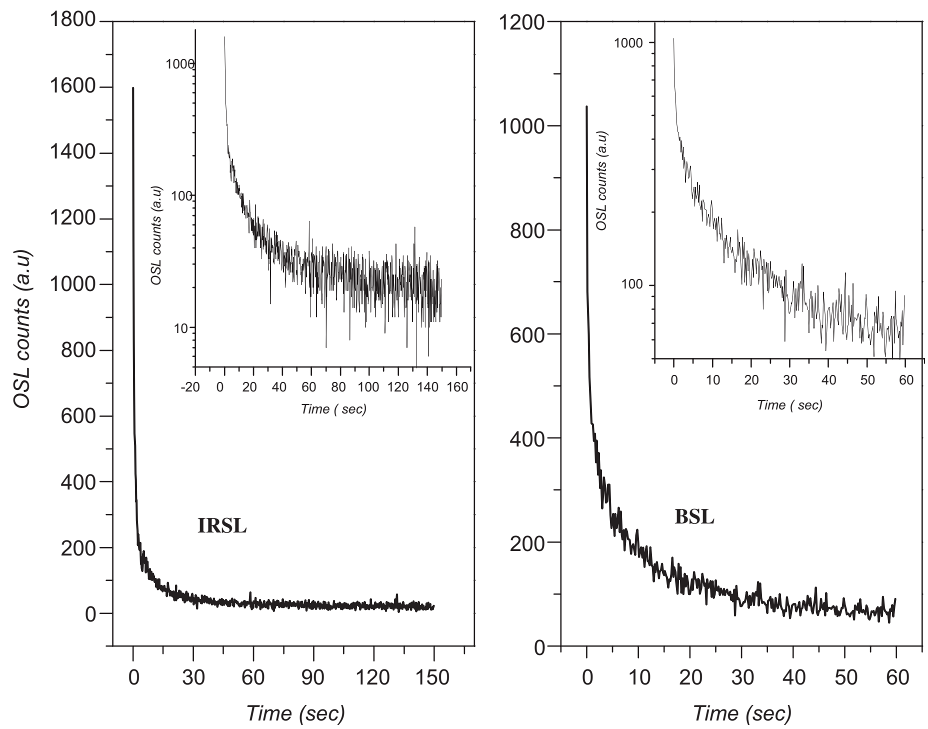

Fig. 2. IRSL decay curve (left) and the respective post-IR BSL decay curve (right). Both curves were obtained at room temperature. Insets show the respective curves in a logarithmic scale.

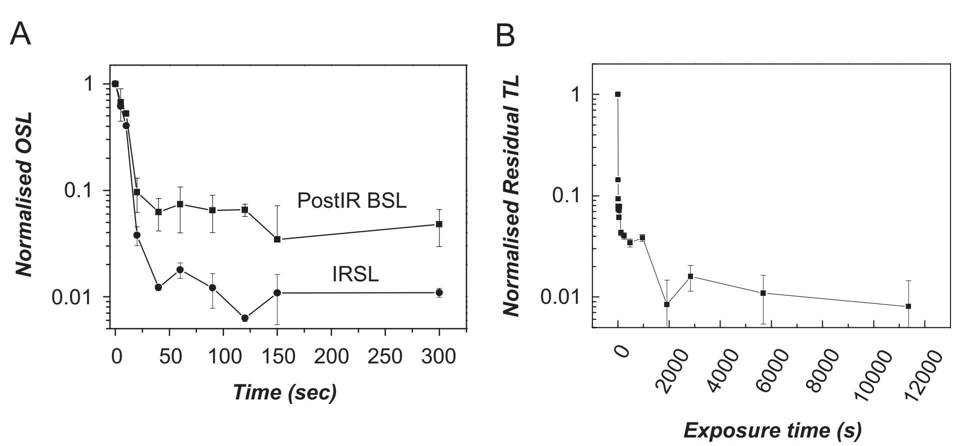

Fig. 3. (A) Residual signal of both IRSL and post-IR BSL as a function of the time of exposure to sunlight. (B) Residual TL signal of the 270 °C glow peak, as a function of the time of exposure to sunlight. The first measurement point represents the natural OSL/TL signal. Each experimental point corresponds to the mean value of the two measurements carried out in two different aliquots.

aliquot of a group was bleached for the same time and subsequently its residual luminescence signal was measured in order to obtain the mean value.

The results show that all luminescence signals are rapidly bleached when a sample is exposed to sunlight. An exposure of 60 s reduces the TL signal by 93%, the IRSL signal by 99% and the post-IR BSL signal by 91%. Furthermore, the residual signals for both OSL measurements level off after 150 s of exposure (Fig. 3A), while in the case of TL measurements (Fig. 3B), the residual signal levels off after approximately 1 h.

3.3. Sensitization

Sensitization was studied for both TL and OSL. Fig. 4 presents the normalized TL sensitivity concerning glow peaks of 110, 225, 275 and 350 °C (figures A, B, C and D, respectively) for 11 successive irradiations–TL measurements in a single sample. The dose delivered was 25 Gy. Only the glow peak at 275 °C seems to be highly sensitized by a factor of 3 between the first and the last cycle. The other three glow peaks are proven to be quite stable.

For the OSL sensitivity, a similar procedure was used with an administered dose of 17 Gy, and nine successive irradiation–measurement cycles. The results are shown in Fig. 5. Both IRSL (lower Fig. 5) and post-IR BSL signals (upper Fig. 5) show no sensitization. The same measurements were carried out using two additional test doses, namely 4.25 and 8.5 Gy, yielding similar results.

3.4. Dose response

The TL dose response was studied in the range of 0.5–150 Gy. The response curves for the 110, 225, 275 and 350 °C glow peaks are shown in Figs. 6A–D respectively. The 110 °C glow peak of quartz, responds linearly in the dose region between 1 and 50 Gy. The remaining three glow peaks exhibit a linear response in the dose region between 1 and 100 Gy.

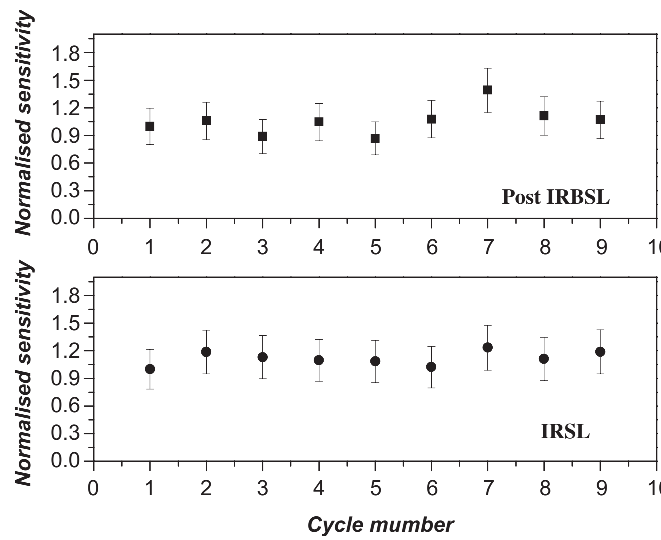

Fig. 5. Normalized OSL sensitivity for IRSL signal (lower figure) and post-IR BSL signal (upper figure), for successive cycles of irradiation–OSL measurement. The irradiation dose for each cycle was 17 Gy.

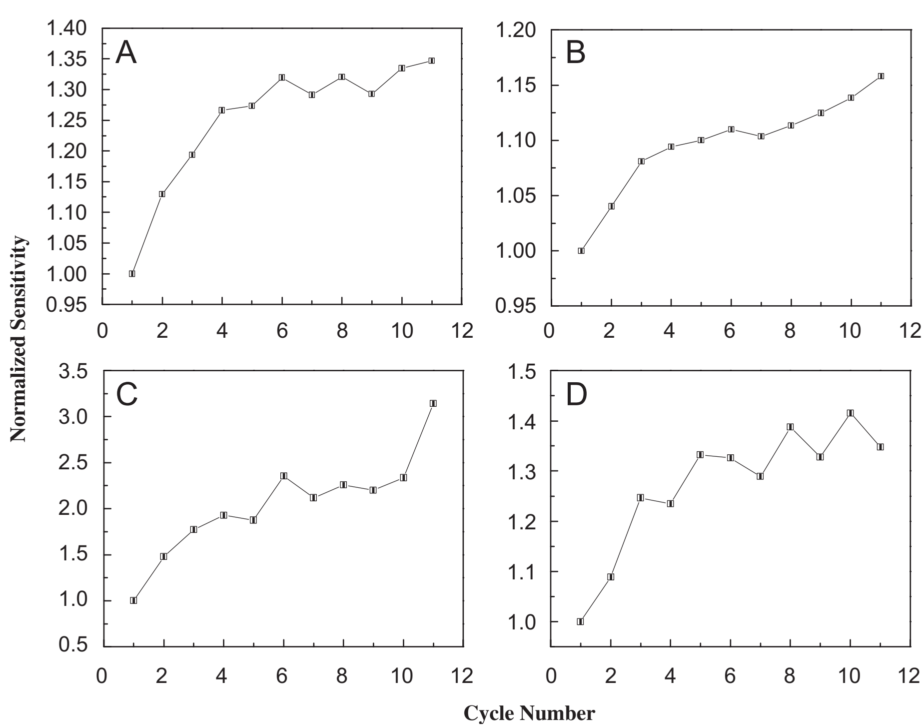

Fig. 4. Normalized TL sensitivity for the deconvoluted glow peaks of 110, 225, 275 and 350 °C (figures A, B, C and D, respectively), as a function of the successive cycles of irradiation-TL readout. The irradiation dose for each cycle was 25 Gy.

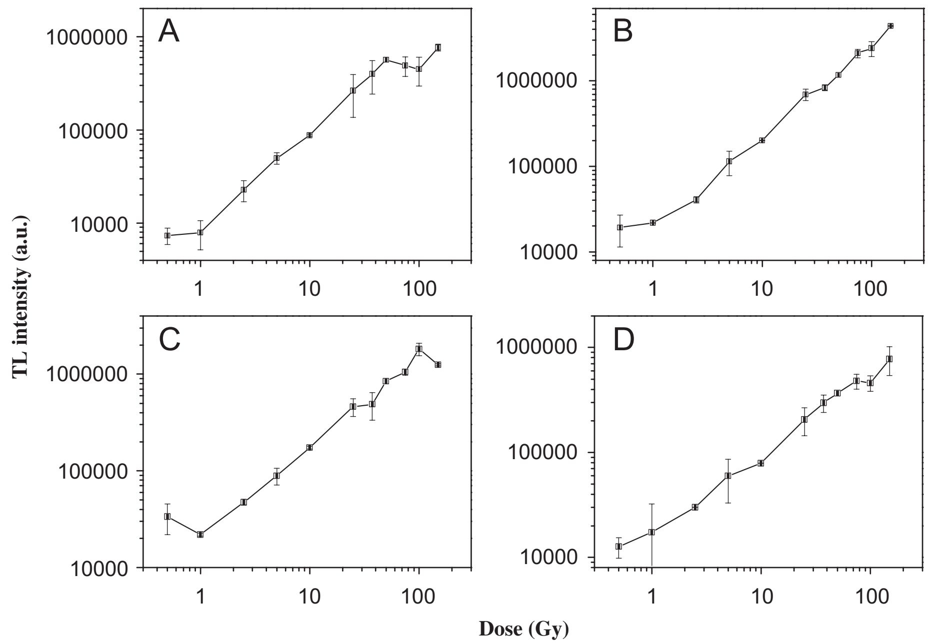

Fig. 6. TL dose response curves for the four main glow peaks of schist at 110, 225, 275, 350 °C (figures A, B, C, D).

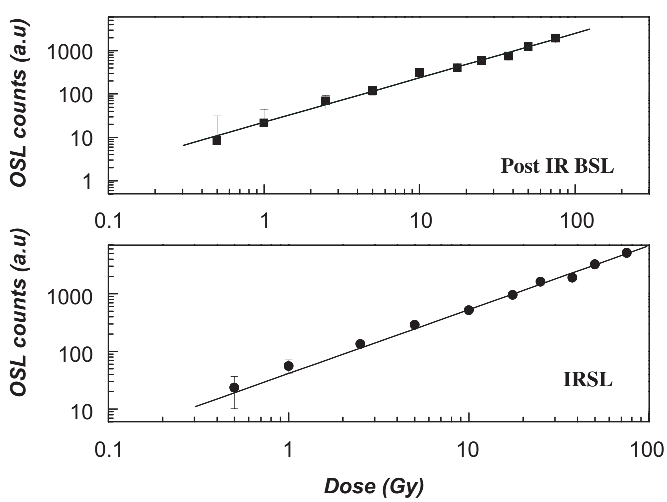

Fig. 7. Dose response curves for the IRSL (lower figure) and post-IR BSL (upper figure) signal. The solid lines represent a linear fit.

On the contrary, dose response curves of both IRSL (quartz) and post-IR BSL (feldspar) signals (Fig. 7) demonstrate satisfactory linearity over the entire dose region studied.

4. Conclusion

The optical stability and linearity of the TL and OSL signals of natural schist, for a sample obtained from a roofing slate, were investigated in the present work. The results indicate that the TL as well as the OSL response is linear for doses in the range of 1–100 Gy (with the exception of the 110 °C glow peak that is linear up to 50 Gy). The sensitivity of both signals is fairly stable, with the exception of the 270 °C glow peak that is highly sensitized. Both signals also are rapidly bleached when the sample is exposed to sunlight. These preliminary results indicate that natural schist is a promising candidate for archaeological dating measurements and retrospective dosimetry.

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