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A SYSTEM OF TRANSFER DOSIMETRY IN RADIATION PROCESSING*

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Radiation processing provides accurate, reliable and standardized dosimetry and proper dose interpretation. The reasons for this are related to effectiveness, economy and - as far as e.g. food preservation is concerned - public health. Nationally or internationally centralized dose control and interplant dose standardization require a special transfer type dosimetry. Transfer dosimetry should be able fulfill particular criteria such as documentary evidence and suitability for mailing apart from requirements for wide dose and energy ranges and minor dependence on radiological and ambient parameters; the dosimeter probes should preferably be rugged and of low cost. Transfer dosimetry for high photon doses was subject of intensive investigations since IAEA initiated, supported and guided comparisons of, at present, promising dosimeters. A main purpose was to evaluate qualified dosimetry for international dose-assurance. According to the final report of an Advisory Group to IAEA, it was the GSF alanine/ESR dosimetry which showed, among other systems, most reliable results covering all dose ranges of interest with a single detector type /1/.

The alanine/ESR dosimetry is based on measurements of radiation induced free radicals in polycrystalline samples of alanine by electron spin resonance (ESR) spectroscopy. Since the stability of the radicals at normal ambient conditions is very high, the dosimeter can be stored as a document over years. The concentration of free radicals produced serves as a measure for the absorbed dose. Other methods to evaluate the radicals or subsequent products in organic materials are lyoluminescence or optical density (Fig. 1).

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Table 1 Some chemical-physical and dosimetric properties of the alanine/ESR system

Composition	Alanine CH_3-$CHNH_2$-COOH (80-90%) Paraffin H-$(CH_2)_n$-H(20-10%)
Effective atomic number	$Z_{eff} \cong 7.2$
Effective specific gravidy	$\rho \cong 1.15$ gcm^{-3} (80% Alanine + 20% Paraffin)
Range of dose D	1 Gy $\leq$ D $\leq$ 1 MGy (present state) 1 Gy $\leq$ D $\leq$ 0.01 MGy (linear range) 0.1 Gy $\leq$ D $\leq$ 10 MGy (objective)
Energy dependence	calibration factor: 1 for $E_{ph} \geq 100$ keV, 1.6 - 1 for 10 keV < E_{ph} < 100 keV
Dependence of dose rate $\dot{D}$	none for $\dot{D} \leq 10^8$ Gys^{-1} (present state of research)
Relative standard deviation s_{rel} for interspecimen scattering	3 s_{rel} $\leq$ 1 %
Time behaviour of signal S	(1 - S/So) $\leq$ 0.01 for 2 years, at 22 ^{o}C and 40 - 60 % rel. humidity
ESR stability	< $\pm$.1 % (3s)
Overall uncertainty	$\leq$ 5 % (2s), including calibration uncertainty

The dosimeter sample is a pellet about 5 mm in diameter and up to 15 mm in length consisting of 80% to 90% pure crystalline alanine and 20% to 10% pure paraffine as a binder. For mechanical protection and provision of charged particle equilibrium, the samples are encased in a polyethelene capsule with 2.5 mm wall thickness (Fig. 2). Since a transfer dosimeter has to operate under moderate and extreme climatic conditions and cannot be evaluated immediately after exposure, its response should only be moderately dependent on temperature and air humidity during irradiation, storage and transport. The chemical, physical and dosimetric properties are compiled in Table 1.

The ESR signal S depends to a minor extend on the sample temperature during irradiation, i.e. $(\Delta S/S)/\Delta T = 0.0018$ $^{o}C^{-1}$. An influence of day light or lab illumination to the ESR signal for normal probe handling was not detectable.

Concerning the long-term stability of the free radicals, no significant signal loss could be found up to several years under moderate ambient conditions. Even at 70 °C the fading is within 10% for a relative humidity of 40% - 60% after two months. For comparison, radiochromic dyes show a 30% signal loss after 10 days at 60 °C; respective data for perspex are 20% signal loss already after 3 days at only 45 °C.

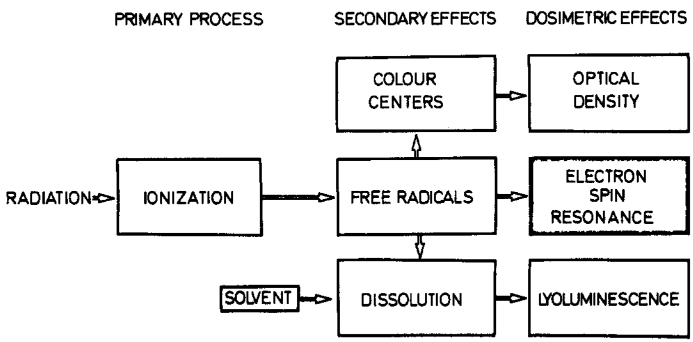

Fig. 1 Dosimetry paths in solid organic molecules

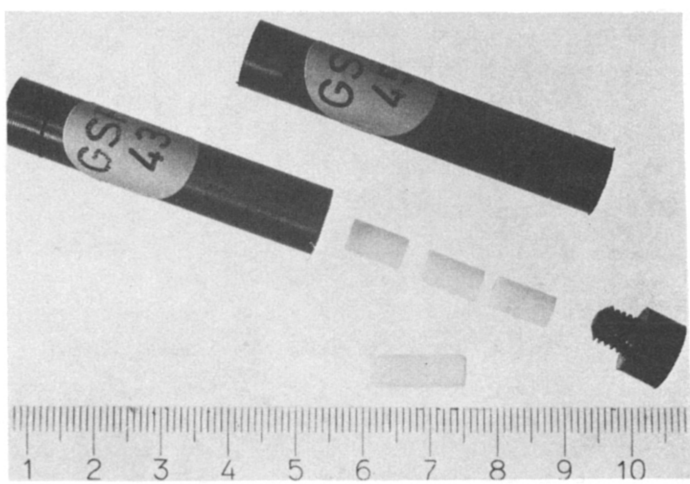

Fig. 2 Present assembly of the GSF alanine/ESR transfer dosimeter consisting of alanine probes and a polyethelene capsule

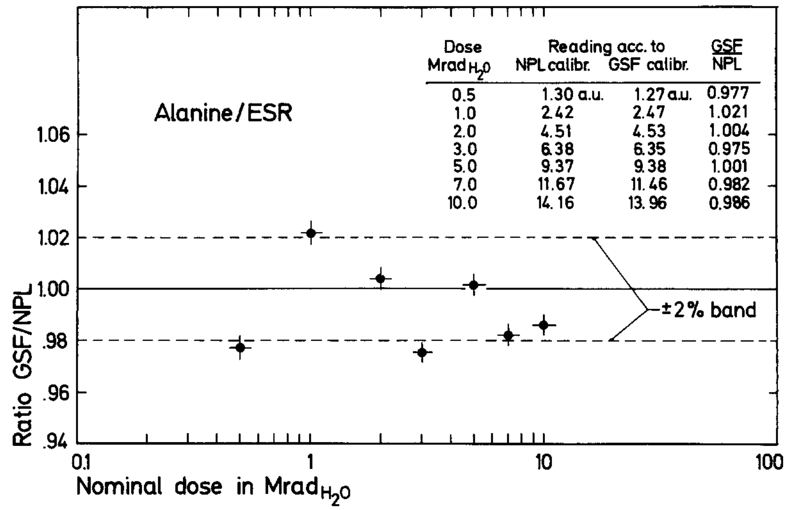

Fig. 3 Results of a Co-60 dose comparison between NPL and GSF by alanine/ESR dosimetry

The overall uncertainty of dose estimation of alanine/ESR dosimetry depends on uncertainties intrinsic to the evaluation method and uncertainties related to the calibration dosimetry. The latter uncertainties are given by national laboratories to within 1.5% on a 90% confidence level for cobalt-60 radiation. The intrinsic uncertainties consist of component incertainties from batch uniformity, effects of influence quantities, readout geometry and electronic stability of the readout equipment. The quadratic summation yields an overall uncertainty of ≦ 5% on a 95% confidence level.

Fig. 3 shows, as an example, results of a dose intercomparison between GSF and the National Physical Laboratory (NPL), Teddington, UK with the dosimeters being mailed. NPL provided the irradiations with gamma doses which were unknown to GSF. The evaluated results fitting an uncertainty band of ≦ 2.5% demonstrate the standard of the alanine/ESR dosimetry and confirm the estimations of uncertainty.

Conclusion

The alanine/ESR method is obviously suited for transfer dosimetry. The samples can repeatedly be evaluated. The detector material is rather low-priced. Surface contaminations are of minor importance for the reading value. The wide dose range and the achievable accuracy based on a long-lived signal are worth mentioning. In addition alanine/ESR dosimetry is versatile and may serve also for commissioning of radiation processes,processing plants and dosimetry as well as for quality control of radiation treatments. Among these applications may be measurements of doses at surfaces, interfaces and of depth dose profiles within heterogeneous materials. More details were recently published in /1/.

LITERATURE

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