FURTHER DEVELOPMENT OF A TRACK DETECTOR AS THE SPECTROMETER OF LINEAR ENERGY TRANSFER

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Abstract: Track revealing in a track etch detector is a phenomenon related to the linear energy transfer (LET) of the particle registered. The measurements of track parameters permit to determine the LET corresponding to each revealed track, i.e. LET spectrum. We have recently developed a spectrometer of LET based on the chemically etched polyallyldiglycolcarbonate (PADC). In this contribution the results obtained with such spectrometer in some neutron fields are presented, analyzed and discussed. Several radionuclide neutron sources have been used, LET spectrometer has been also exposed in high energy neutron reference fields at CERN and JINR Dubna, and on board aircraft.

1. Introduction

There are circumstances in which the tissue equivalent proportional counters (TEPC) cannot be used to determine the microdosimetric characteristics of a radiation beam or field (too high dose rates, intense low LET radiation,). LET spectrometer based on a track etch detector can in some extent replace TEPC in such cases. The measurements of track parameters permit to determine the LET for each revealed particle track [1], i.e. establish their LET spectrum. From that, the dosimetric and microdosimetric characteristics can be calculated. We have developed such LET spectrometer based on a polyallyldiglycolcarbonate (PADC), chemically etched [2]. Further development of this spectrometer is presented and discussed. The main attention is devoted to the tests of such instrument in different neutron beams and fields.

2. Experimental

Detector used

PADC available from Pershore Moulding Ltd., curing time 32 hours, thickness 250 and/or 500 μm, has been used. The detector samples have been etched in a 5 N NaOH solution at 70°C. Before etching, each sample was irradiated in a corner with ^{252}Cf fission fragments and ^{241}Am alpha particles to check the exact conditions of etching and to determine the bulk etching rate and the thickness of the layer removed by etching. This thickness was in studies described in this contribution about 17 μm.

Determination of the etch rate ratio V

Etch rate ratio $V = V_T / V_B$; (where V_T is the track etch rate and V_B is the bulk etch rate) were established through the determination of track parameters by means of an automatic optical image analyzer LUCIA II based on a Leitz microscope [3]. The tracks with minor axes higher than 5 μm were taken into account. There are several possible procedures to establish V from track parameters [4], the choice depends also on the depth of track etching. In any case, at least two procedures are used, the final optimization is performed through the comparison of the removed layer thickness, recalculated from the V value, with that directly measured through the fission fragment tracks diameter. The obtained spectra of V are corrected for the critical angle of the registration of a particle with a given value of V.

LET spectra

Spectra of V values of the secondary particles were transformed to LET spectra on the basis of the calibration performed by means of heavy charged particles [4]. The calibration is checked using high dose electron irradiation [5]. The calibration curve used is presented in Figure 1.

Figure 1. Calibration curve of PADC used

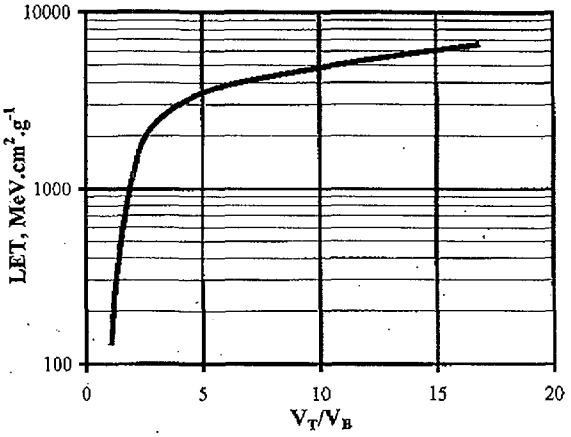
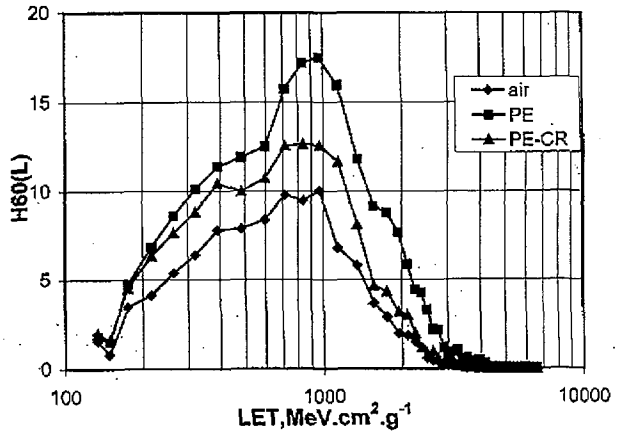


Figure 2. LET distributions; AmBe neutrons, different radiators



Detectors exposure

Samples of PADC have been irradiated in the following neutron beams and fields:
* at the radionuclide neutron sources AmLi, AmBe and ^{252}Cf, at distances from 20 to 50 cm;
* in the high energy neutron reference fields at CERN [6] and JINR Dubna [7]; and
* on board supersonic aircraft.

The exposure has been chosen in such a way that the background track density did not represent more than about 20 % of track density evaluated in the exposed samples.

Two sheets of the PADC have been always irradiated, perpendicularly to the prevailing neutrons direction. The sheet (4x4 cm^2) oriented to the neutron source have been from one half (2x4 cm^2) covered with polyethylene (PE), 2 mm thick. In such a way, there are four different radiators in each exposed set: air, PE, PADC (CR39) behind air, and CR39 behind the PE.

3. Results and discussion

General remarks

The spectra of V values have been collected from V=1.00 up to V=16.8, it corresponds to the LET in tissue values between 100 and 6560 MeV.cm^2.g^{-1}. It was found that the background track densities are generally quite comparable with densities in irradiated samples for V values lower than 1.06. Only tracks with V higher than this limit has been therefore taken into account, it corresponds to the threshold LET value equal to 120 MeV.cm^2.g^{-1}.

In our previous studies in the beams of high energy photons and protons we have observed that neither the shape of LET spectra nor their absolute values do not depend on the radiator adjacent to the surface of the PADC detector [2]. In the case of neutron irradiated samples the situation is a little different.

The shape of spectra is still practically independent of the radiator, however, the number of tracks are systematically higher immediately behind the polyethylene radiator (see Figure 2). It is understandable because an important part of etched tracks is due to the secondary protons. And , the density of these nuclei is much higher in PE than in the PADC. Of course, the effect would depend on the neutron spectrum and ,also, on the thickness of layer removed from the detector's surface by etching.

Microdosimetric spectra

Radionuclide neutron sources

Spectra established in samples exposed at radionuclide neutron sources shows similar characteristics. Qualitative agreement is demonstrated in the Figure 3, when dose and dose equivalent distributions in LET are presented for AmBe ($E_N \sim 4$ MeV) and ^{252}Cf neutron sources ($E_N \sim 2.2$ MeV). The spectra are dominated by a peak situated close to 1000 MeV.cm^2.g^{-1}, the value corresponding to the maximum of the LET due to secondary protons. The contribution of higher LET particles (alphas, recoil nuclei) is low, it represents for ^{252}Cf about 5 % of the absorbed dose, about 15 % of the dose equivalent with ICRP 60 conversion factors [8]. As far as the AmBe neutrons are concerned these contributions are a little higher: 12 % and 30 %, respectively. The microdosimetric spectra obtained are in Figure 4 compared with the spectra established by means of a tissue equivalent proportional counter NAUSICAA [9]. The agreement of both spectra is reasonably good. It should be reminded in this context that no normalization procedure has been adopted to compare the spectra established by two quite different methods.

Figure 3. Dose and dose equivalent distributions established with PADC LET spectrometer at AmBe and ^{252}Cf neutron sources

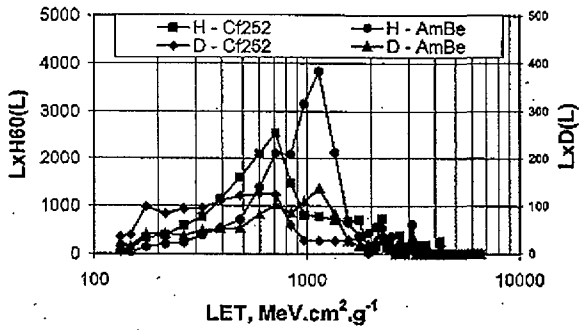
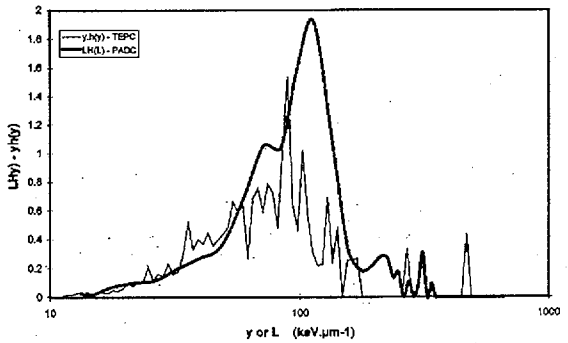


Figure 4. Comparison of microdosimetric spectra obtained with PADC spectrometer and with TEPC at AmBe neutron source



High energy neutron fields

Examples of dose and dose equivalent distributions in LET established in some high energy neutron fields are presented in Figure 5. One can see there that they differ from the spectra determined at radionuclide neutron sources. The contribution of particles with LET above 1000 MeV.cm^2.g^{-1} is more important for high energy neutron sources. For example, at JINR Dubna high energy neutron reference field this contribution to absorbed dose is about 20 %; to the dose equivalent (ICRP 60 conversion factors) almost 50 %. The comparison of microdosimetric spectra obtained with PADC spectrometer and with TEPC is shown in Figure 6. One can see again a quite reasonable agreement of both spectra obtained still without any normalization procedure.

4. Acknowledgements

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Figure 5. Dose and dose equivalent distributions established with PADC spectrometer in some high energy neutron fields (Dubna hard field [7], supersonic aircraft board)

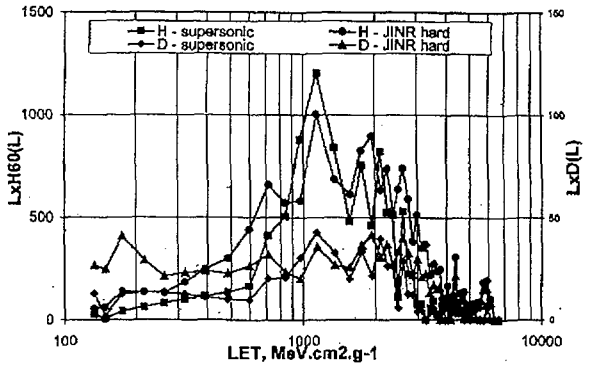
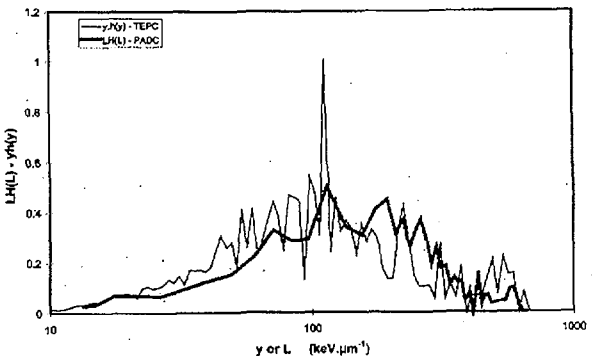


Figure 6. Comparison of microdosimetric spectra obtained with PADC spectrometer and with TEPC in CERN high energy neutron reference field [6]



5. References

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