STUDY ON THE MAKROFOL-DE MATERIAL FOR FAST NEUTRON DOSIMETRY APPLICATIONS

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ABSTRACT: The solid state nuclear track detector commercially known as Makrofol-DE was studied with the aim of verifying the possibility of using this material as a fast neutron dosimeter. This policarbonate is made by Bayer (Italy). The low and reproducible background and the high sensitivity comparing to others policarbonates make this material very attractive for dosimetric applications. The so-called electrochemical etching(ECE) was carried out to obtain the best response of the material. The following topics were verified: optimisation of etching parameters, determination of dose detector range of utilisation, determination of detector sensitivity for energy range > 144 keV, the possibility of using the own material as a neutron radiator, the angular dependence of the detector response. The high threshold of detection which is one of the disadvantages of this material was studied taking into account different etching possibilities for neutron energies ranging from 144 keV to 1.2 MeV. All data were compared with those obtained using the poli allyl diglicol carbonate (CR-39), in use at ENEA/BO fast neutron dosimetry service, irradiated in the same conditions.

1.INTRODUCTION:

The material in use at the fast neutron personal dosimetry service in the ENEA/BO institute is the poli allyl diglicol carbonate(CR-39) made by the American Acrylics Inc. Although this material shows good properties to be used as a neutron personal dosimeter, its use is limited by the low reproducibility of its background. Trying to overwhelm this difficulty and to improve the dosimeter response, the policarbonate commercially called Makrofol-DE was investigated to state its behaviour when considered for fast neutron dosimetry applications.

The makrofol properties as solid state nuclear track detector are well-known since the sixties(1). This material choice took into account the better reproducibility of its background and the fact that due to its hardness and optical transparency, that are similar to the CR-39 ones, this material etching and reading can be carried out in the same systems already in use in this laboratory.

The data presented here are those obtained for the following steps: determination of the electrochemical etching parameters, energy response, angular dependence, linearity of response and dose range of utilisation. Data obtained for the CR-39, 700 µm thick, irradiated in the same conditions were also included.

2.EXPERIMENTAL PROCEDURE:

2.1.Irradiations:

To optimise the etching parameters to be used during this work the detectors were irradiated with a ^{252}Cf neutron source. The detectors that were etched to verify the other proposed items were irradiated during the 1992 Eurados Joint Neutron Irradiations.

The neutron energies, as well as, the way of production and fluence to dose equivalent conversion factors employed here are shown in table 1 by Alberts (2).

Figure 1 shows a schematic irradiation card that was sent to the different institutes. In each identified position in the figure a three-detector pile was placed so that the detector thickness influence could be verified.

2.2.Reading and etching system

The detector reading was carried out using an optical microscope(magnification 25x) connected to an image analyser system Optomax V. In this system the reading area is lighted using a guide that channels the light through one edge in the detector to be read.

The counting field area was 12 mm^2 and six fields were read in each detector. The detectors were always etched on the opposite side referring to the neutron incident beam. Etching was carried out using an ECE cell system in which 48 cells can be etched at the same time. This etching system was developed in the own institute.

3.RESULTS:

3.1.Determination of etching parameters.

The Makrofol-DE etching conditions employed in this work were experimentally determined. The studied parameters were the following: electric field strength, ethil alcohol concentration in the KOH solution,

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and etching time applied to the detectors. Figures 2, 3 e 4 show the obtained curves for these parameters, respectively. The determined etching conditions were:

etching time: 90 min,
solution: PEW40(15%, in mass, KOH, 40% ethil alcohol, and 45% distilled water),
temperature: 60 °C,
electric field strength: 32 kVcm^{-1}(r.m.s.),
frequency: 2 kHz.

The detector sensitivity was noticed to vary for the different sides of the material. For solving this problem the detectors were always etched on the same face. The sensitivity variation between the two sides of the material was experimentally evaluated to differ by a factor of 3.

The employed parameters to etch the CR-39 material were previously determined and were:

etching time: 150 min,
solution: 30%, in mass, KOH,
temperature: 60 °C,
electric field strength: 28 kVcm^{-1}(r.m.s.),
frequency: 2 kHz.

Energy(MeV)	Production[1]	Fluence to ambient dose equivalent conversion factors(H*(10)) (pSv.cm^2)
0.144	Reaction $^{7}Li(p,n)^{7}Be$ EP=1.946 MeV	100
0.565	Reaction $^{3}H(d,n)^{4}He$ ED=1.5 MeV	265
1.2	Reaction $T(p,n)^{3}He$ EP=2.08MeV	345
5.3	Reaction $D(D,n)^{3}He$ ED=2.3 MeV	416
15.1	Reaction $T(D,n)^{4}He$ ED=0.40 MeV	559
^{252}Cf	Spontaneous fission	340

Table 1: Irradiation energies, way of production of the monoenergetic beams and fluence to ambient dose equivalent conversion factors after Alberts(2).

3.2.Energy response:

The Makrofol-DE and CR-39 response for the studied energy range are shown in figure 5. The detectors used here have been placed on a 30x30x15 cm^3 PMMA phantom for irradiating.

To verify the increase of the sensitivity for the neutron energies lower than 1 MeV a five-hour-pre electrochemical etching at 100 Hz was applied to the detectors. The increase obtained for the detector response was found to be insufficient to improve the detector sensitivity. The same treatment was applied to the detectors irradiated with 1.2 MeV neutron energy. The obtained increase in the Makrofol response was found to be 25 %.

3.3.Lower and highest detectable doses, linearity of read out and dose range of utilisation:

The lower detectable dose was defined here as $2\sigma_{bg}/S(E)$ where σ_{bg} is the standard deviation of the background reading and S(E) is the detector sensitivity for the studied energies.

The determination of the highest detectable dose took into account the highest track density possible to be read using our reading system and the track diameters obtained with the etching parameters here determined.

The values of the lower and highest detectable doses for the different energies are shown in table 2.

Neutron energy (MeV)	Lower detectable dose(mSv)	Highest detectable dose(mSv)
1.2	0.592	20
^{252}Cf	0.336	13
5.3	0.313	8
15.1	0.227	14

Table 2: Lower and highest detectable doses for the investigated neutron energies .

Due to the low sensibility of the Makrofol-DE the dose range that is possible to be used with this material is larger than that obtained to the CR-39 which was found to be between 0.2 and 5 mSv for the ^{252}Cf average energy.

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[1] EP= target incident proton energy
ED= target incident deuteron energy

The read out linearity for the neutron energies: 1.2, 5.3 and 15.1 MeV were experimentally verified for the irradiation dose between 0.4 and 10 mSv. These curves are shown in figures 6, 7 and 8.

3.4.Angular response

The detector angular dependence for the energy range between 1.2 and 15.1 MeV is shown in figure 9.a. The presented values were normalised to the response for the zero degree neutron beam incidence angle.

The angular dependence obtained was found to be as highly variable as that obtained for the CR-39 material (figure9.b).

The influence of the detector thickness was found to be not significant to reduce the detector angular dependence. This can be due to the fact that the thickness range studied (500-1500µm) was not large enough to alter the detector response. In the future it seems to be interesting to investigate the influence of thicker radiators to increase sensitivity and to reduce the angular dependence.

4.CONCLUSIONS

Due to its high energy threshold the Makrofol-DE is a material that is indicated to be used just for high energy fields dosimetry, or as a passive dosimeter together with the CR-39 or other materials.

Its sensitivity is poorer than that obtained to the CR-39 material, as well as, the lower detectable dose. However, the Makrofol-DE response is less energy dependent than that obtained for the CR-39. When the etching conditions here determined are used the obtained energy threshold of this material is 1.2 MeV.

Another point to be considered is the background reproducibility that was found here to be 10%. The CR-39 background reproducibility measured by us indicated a value for about three times greater than that one.

REFERENCES:

1.E.Piesch, J.Jasiak, M. Urban "Makrofol and CR-39 Recoil Track Etch Detectors as a Suplement of a Universal Albedo Neutron Dosemeter. Nucl. Tracks 8(1-4), 323-326(1984)

2.W.G.Alberts "Investigation of Individual Neutron Monitors on the Basis of Etched-track Detectors: The 1990 Eurados-Cendos Exercise: eurados-Cendos Report 1992- 02 pag 1-7

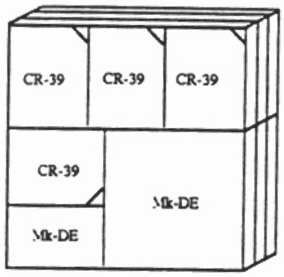

Figure 1: Schematic irradiation card.

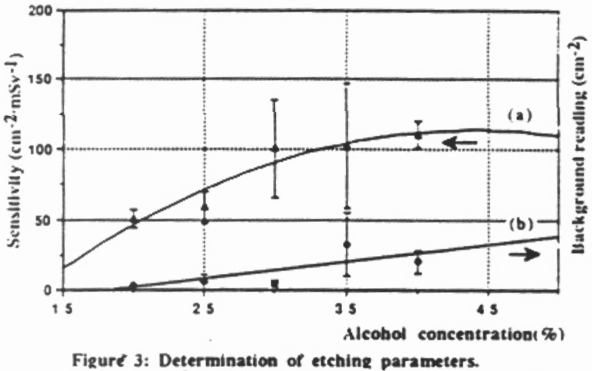

Figure 3: Determination of etching parameters.
a)Sensitivity versus ethil alcohol concentration in the KOH solution. b) Background reading versus alcohol concentration in the solution.

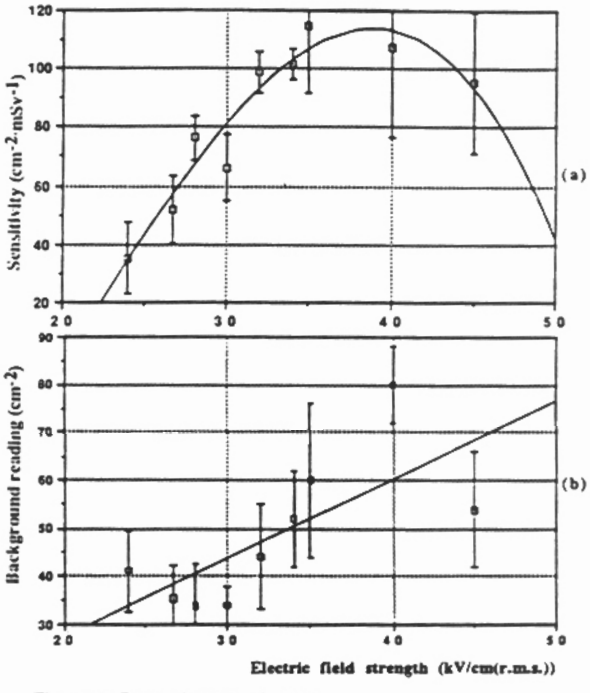

Figure 2: Determination of etching parameters.
a)Sensitivity versus electric field strength.
b)Background reading versus electric field strength.

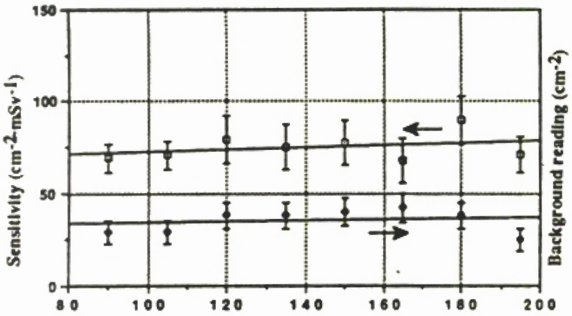

Figure 4: Determination of etching parameters.
a) Sensitivity versus etching time.
b) Background reading versus etching time.

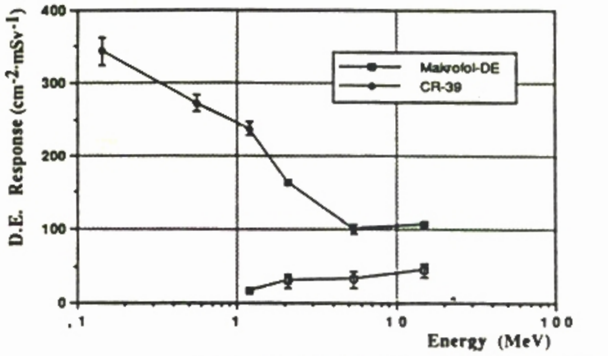

Figura 5: Energy response for Makrofol-DE and CR-39 materials.

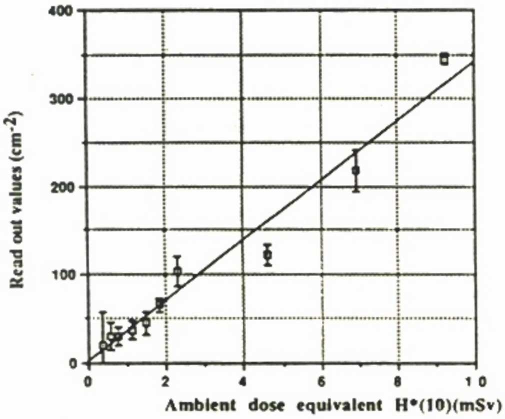

Figure 6: Read out values against the ambient dose equivalent. Energy: 1.2 MeV.

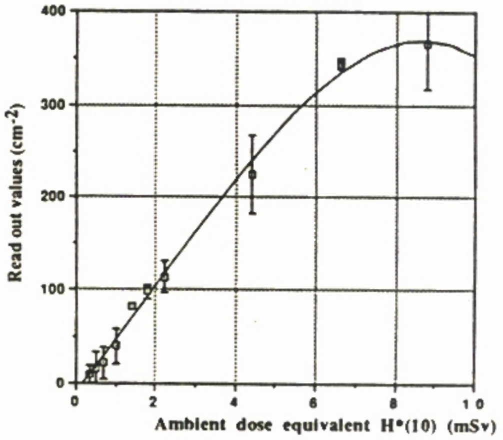

Figure 7: Read out values against the ambient dose equivalent. Energy: 5.3 MeV.

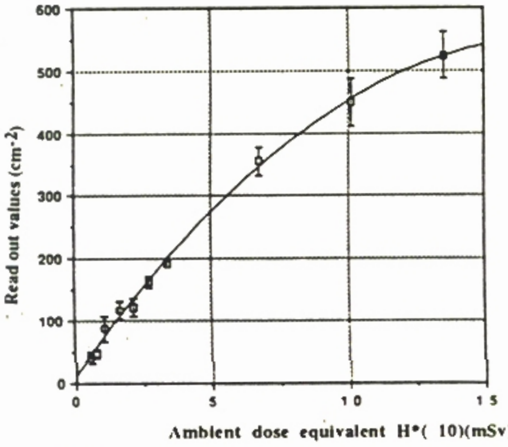

Figure 8: Read out values against the ambient dose equivalent. Energy 15,1 MeV.

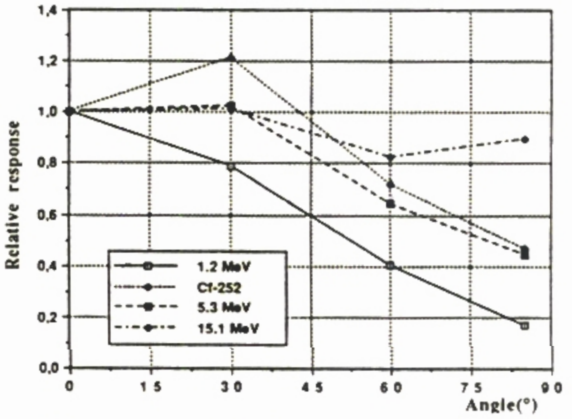

Figure 9.a: Makrofol-DE angular dependence. Values were normalised to the zero degree measured value.

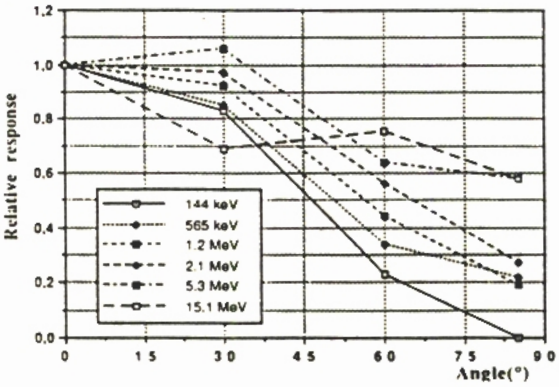

Figure 9.b: CR-39 angular dependence. Values were normalised to the zero degree measured value.