BR8921735
INIS-BR--1635

CHARACTERISTICS OF SOME TRACK DETECTORS APPLIED FOR NEUTRON RADIOGRAPHY

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BR8921735
INIS-BR--163

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Abstract

The track etching method has been employed for neutron radiography purposes,by making use of a cold neutron beam obtained at the IEA-R1 Nuclear Research Reactor.

The films used were the Solid State Nuclear Track Detectors CN-85,CR-39,MAKROFOL-E and LR-115,with a natural Boron converter screen.

In order to obtain mean track diameter about 3μ with a minimum overlapping between them,adequate conditions for etching and exposure times about 30 minutes and 3 hours respectively were evaluated.For such conditions exposures of 10^9 n/cm^2 that corresponds to 10^7 track/cm^2 are achieved.

Neutron radiographs of several materials were performed and the best results in terms of optical contrast,were obtained for the films CN-85 and CR-39.

I-INTRODUCTION

The neutron radiography is a relatively recent non-destructive testing technique.Its applications vary enormously but chief among them are:ceramic capacitors,aircraft turbine blades , highly radioactive materials , hidrogen-rich substances such as oils,adhesives,water,explosives,rubbers etc.Basically it is very similar to the conventional X and Gamma-ray radiography techniques.A collimated neutron beam impinges the sample which modulates its intensity and a combination between a film and a converter screen is used as image detector(Berger 1965;Matfield 1971;Domanus et al 1981;Domanus 1986).

The track etching registration is a very important method employed in neutron radiography technique.Charged particles coming from a converter screen will give rise to latent tracks in plastic films -SOLID STATE NUCLEAR TRACK DETECTORS-SSNTD which after chemical etching become easily visible,forming a neutronic bidimensional image of the sample.The film insensibility to visible light,Gamma and Beta radiations and the small track dimensions that can be achieved by chemical etching,provide versatility and applicability to the method with potencial to obtain high resolution radiographs (Khaddury 1976;Durrani et al 1975;Fantini 1986;Pugliesi et al 1987).Although low optical contrast is obtained in these films,several techniques have been developed to improve it (Hawkesworth 1977;Lferde 1984).

The objective of this work is to give continuity to the neutron radiography program developed in the Nuclear

Physics Department of the IPEN-CNEN/SP and to determine adequate etching and exposure times for the SSNTD:CN-85,CR-39,MAKROFOL-E and LR-115.

II-EXPERIMENTAL PROCEDURES

The experimental arrangement is in the beam-hole 3 of the IEA-R1 Nuclear Research Reactor,in which a Berillium Filter Time of Flight Neutron Spectrometer is installed(Pugliesi et al 1988).A cold neutron beam emerges from this beam-hole and its main characteristics are shown in table I.

Table I

The radiography chamber is an aluminium sheet in a "L"format in which the converter screen and the film are in close contact maintained by another aluminium sheet with 1mm thickness.The sample is attached in this chamber and the assembly positioned in the neutron beam as shown in figure 1.The converter used is a natural Boron screen manufactured by KODAK PATHE FRENCH.The isotope Boron-10 has a high absorption neutron cross section and a natural abundance 19.6%.The films,chemical reagents as well as etching temperatures presently employed(Fleischer et al 1985) are shown in table II.

Table II

The first step of this work was to determine adequate etching times,for which the mean track diameter is about 3μ,the same mean silver grain sizes existing in some standard X-ray emulsions,to obtain nearly the same film resolution(Matsumuto et al 1986).

For this purpose ,the radiography chamber was positioned,without sample,in the neutron beam with each respective film converter screen assembly and exposures during 1 hour were carried out.This time was chosen in a such way to assure a low track density to prevent any overlapping between them.After exposure the films were chemically etched for different time intervals and the tracks diameter evaluated by using an optical microscope.The experimental data were fitted by straight lines,as shown in figure 2,using the least square method,and the evaluated etching times are shown in table III.

The second step was to determine adequate exposure times for the same film converter screen assemblies.These times are those for which track overlapping are minimum,otherwise the method's resolution would be worse.By making use of the SSNTD-MAKROFOL-E,the track overlapping behaviour was analysed ,in a 370μ^2 arbitrary area ,in the microscope .Photographs of the track image in the microscope screen are shown in figure 3.The adequate exposure time is achieved for track density of about 0,08/μ^2 that correspond to 30 tracks in the read area.Exposures from 2 to 4 hours for each film converter screen assembly were carried out.After chemical etching the track yield was determined by using the microscope .The experimental data as well as the straight lines obtained by the same fitting method are shown in figure 4.The evaluated exposure times are shown in table III, and correspond to exposures (neutron per square centimeter) of about 10^9 n/cm^2

Table III

It is necessary to consider, for sample analysis, its neutronic transmission, which will increase the exposure time to obtain the same track density. With these informations several radiographs were obtained and the results are shown in the figure 5. These photographs were obtained without contrast improvements.

III-CONCLUSIONS

Good contrast of the images, the smallest holes of the Cadmium test piece, the internal structures of the objects as well as the powder graininess in the projectiles can clearly be seen in figure 5.

The good optical contrast is attributed to the low energy of the cold neutron beam ($E \leq 5$ meV), the film insensibility for Gamma and Beta radiations and its low track background.

The best results were obtained with the films CN-85 and CR-39 due to their transparent background to visible light. A comparison between their values for etching and exposure times demonstrates maximum variations of about 30 minutes, which is not so high to compromise their employement, although these exposure times are intrinsically high for technological goals. However, by cooling the Berillium filter or alternatively by using two converter screens lower exposure times can be promptly achieved.

By taking into account the track yield as a function of the exposure time, the ratio "track per neutron" can be easily calculated and values of about 6×10^{-3}, 7×10^{-3}, 9×10^{-3}, were obtained for Makrofol-E and LR-115, CN-85 and CR-39 respectively. From these values is clear that CR-39 presents the greater sensitivity for the 1,47 Mev alpha-particle emitted from ^{10}B reaction with neutrons and this can be attributed to the fact that its bondings are stronger than those to the others films (Matsumoto et al 1986).

The present track per neutron values are smaller than that obtained by Matsumoto for CA80-15 (similar to CN-85), 6.16×10^{-2}. This can be explained considering the greater effectiveness of the $^{10}B_4C$ converter screen used by the author, in comparison with natural Boron used in this work.

The method's resolution for thin samples (2mm thickness) is about 70μ mainly provided by the beam geometrical unsharpness, since the film converter screen's intrinsic resolution is about 3μ. This low intrinsic resolution is very important if an intense neutron beam is available, for which geometrical unsharpness as high as 250 is possible.

FIGURE CAPTIONS

Figure 1-Schematic diagram of the experimental arrangement

Figure 2-Track diameter growth evaluation

Figure 3-Track overlapping behaviour to different exposure times
a)good exposure time b)bad exposure time

Figure 4-Tracks yield evaluation as a function of the exposure time

Figure 5-Neutron radiographs of some materials for CR-39 (a,b,c,d) and CN-85(e,f)
a)brass padlock thickness-10mm
b)rifle projectiles-powder visualization
c)Cadmium test piece-smallest holes:diameter 0.45mm and spacing 0.09mm
d)gas lighter-fuel visualization
e)revolver projectile-powder visualization
f)iron screw with a 2mm hole in its upper part;copper wire with a cadmium sheet

TABLE CAPTIONS

Table I -Neutron beam characteristics

Table II -Etching conditions

Table III-Adequate conditions

Table I

Neutron Flux $n/cm^2 \times s$	Cadmium Ratio	Beam Geometrical Unsharpness	n/γ-ratio $n/cm^2 \times mRem$
10^5	200	30	2×10^5

Table II

	CN-85	CR-39	MAKROFOL-E	LR-115
Chemical Reagents	NaOH-10%	KOH-30%	*PEW	NaOH 10%
Etching Temperatures (°C)	60	70	70	60

*PEW:45g water;40g ethanol;15g KOH

Table III

	CN-85	CR-39	MAKROFOL-E	LR-115
Etching times (min.)	19	40	9	19
Exposure times (hour)	3.1	2.4	3.5	3.6

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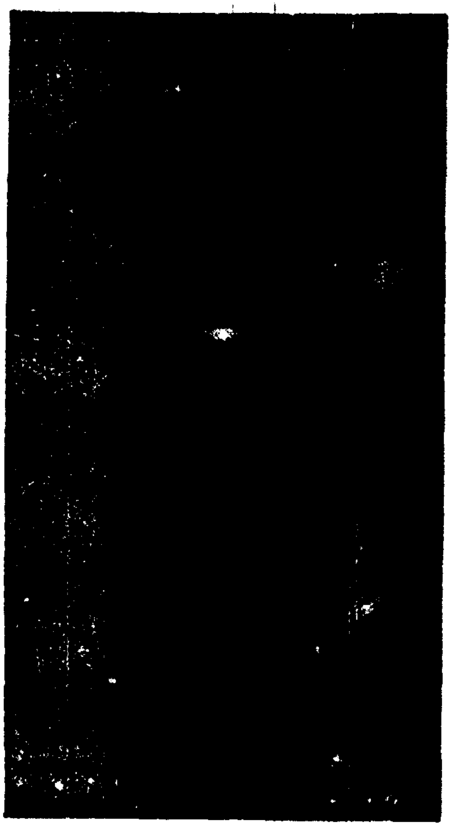
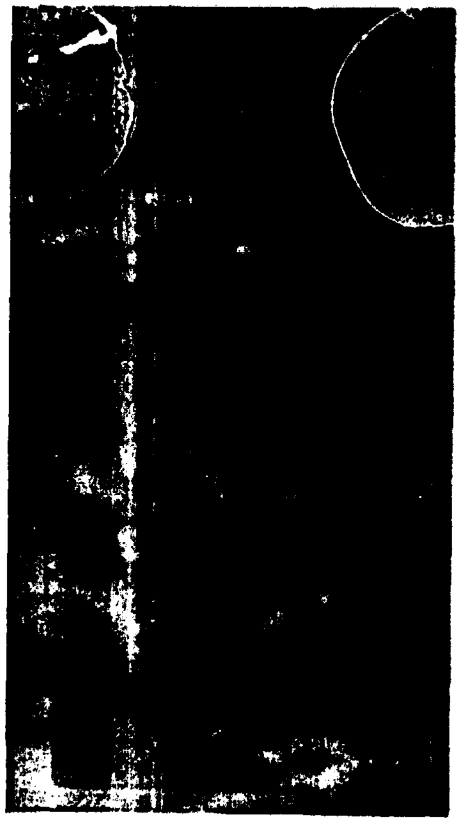
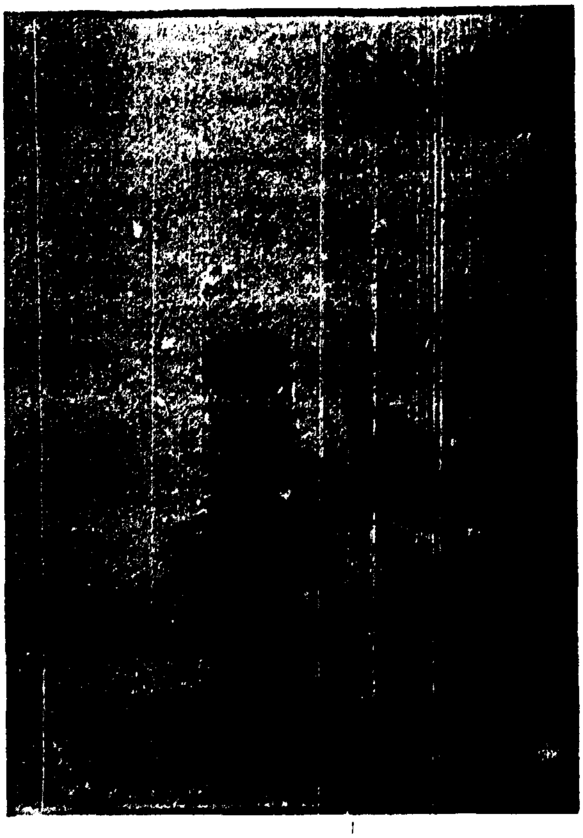
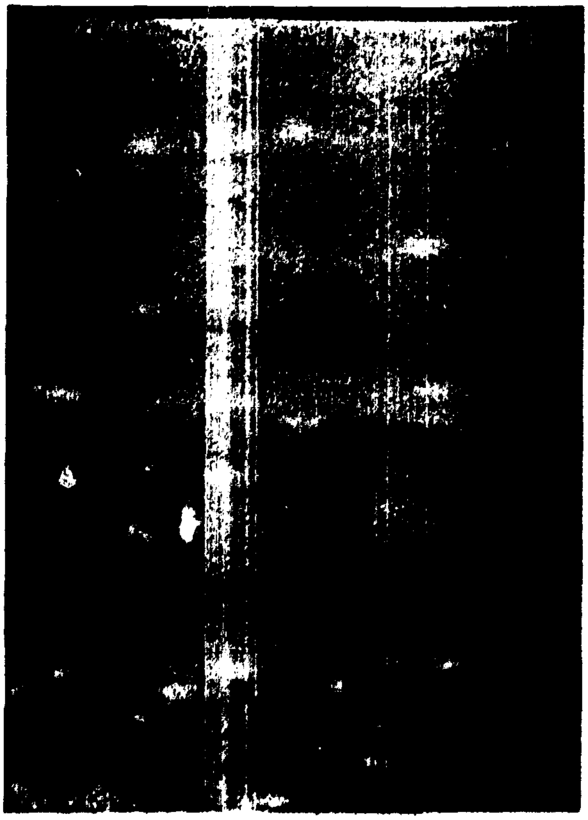

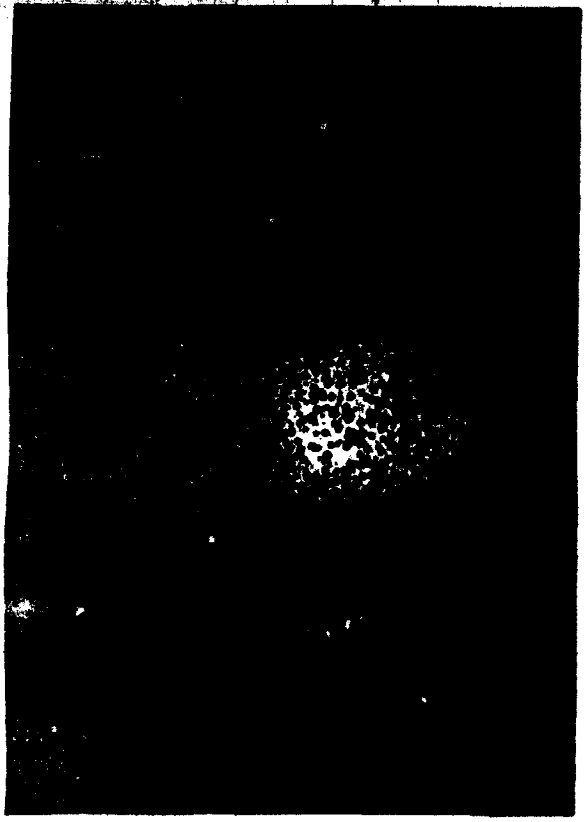

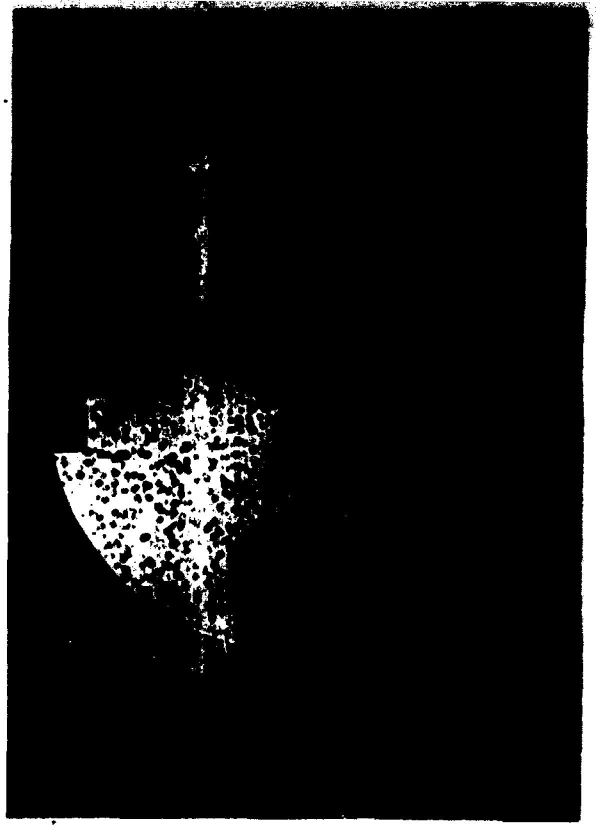

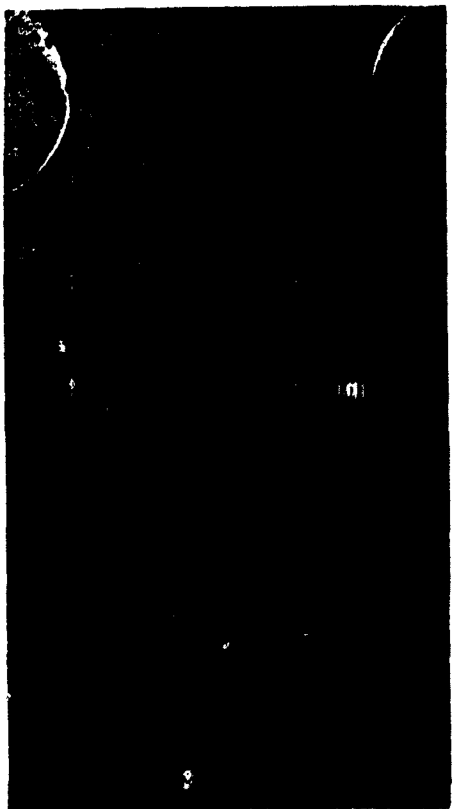

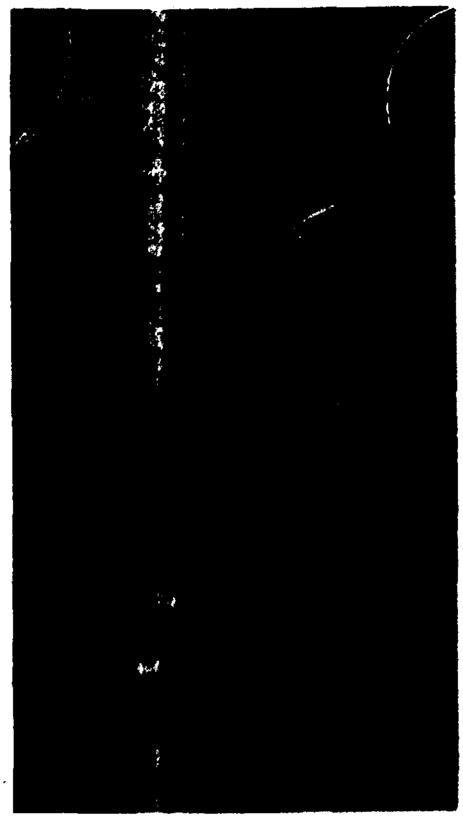

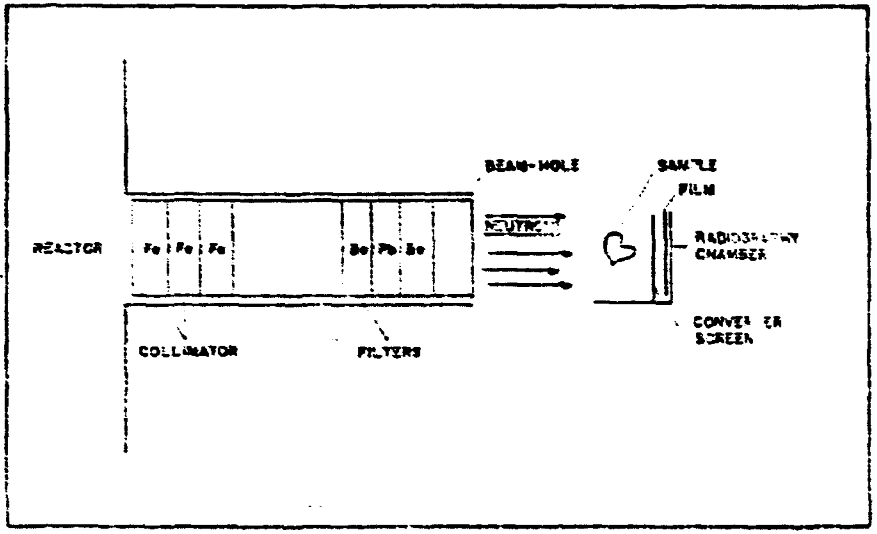
REACTOR
Fe
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Be
Pb
Be
COLLIMATOR
FILTERS
BEAM-HOLE
SAMPLE
FILM
CHAMBER
SCREEN

FIGURE-2

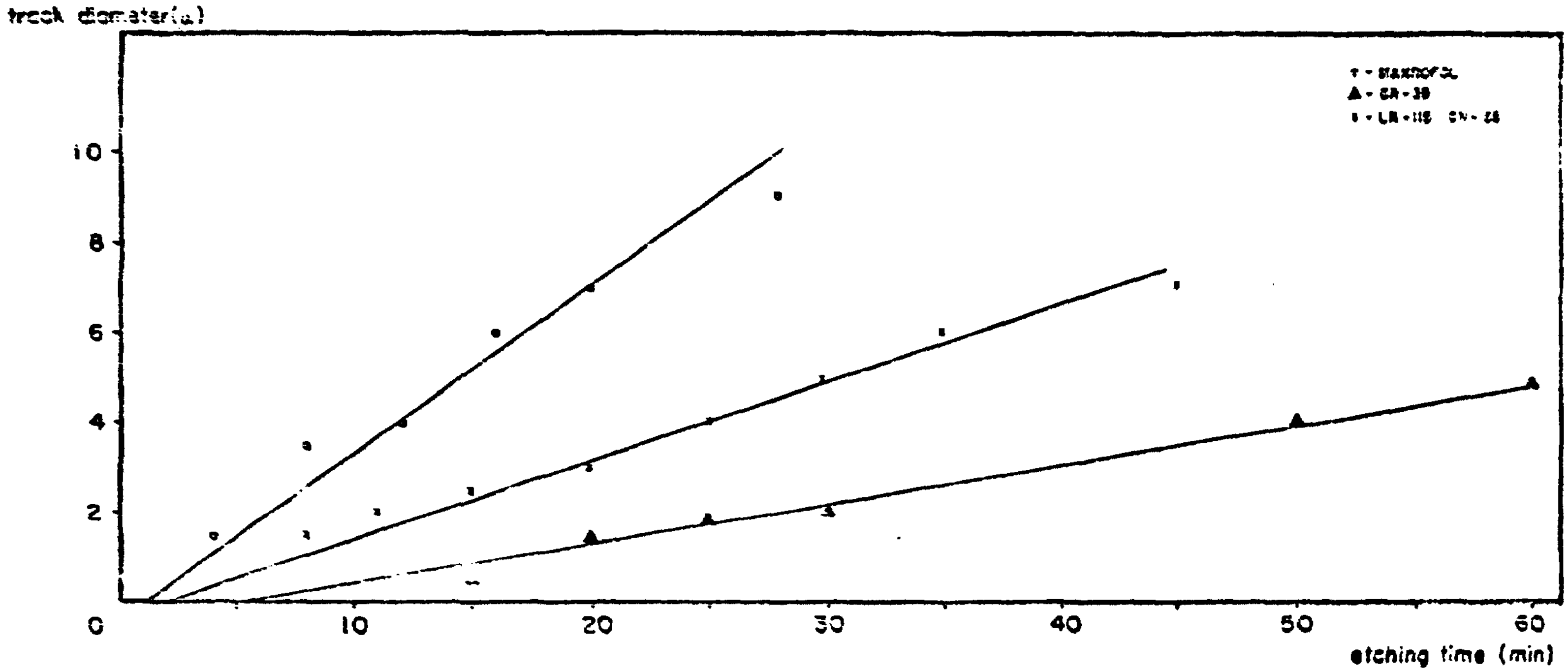

FIGURE 3 &
Figure 4