A NEW TECHNIQUE FOR IMPROVED TRACK RECOGNITION IN NUCLEAR EMULSION FILM DOSIMETRY USING SOFT X-RAYS

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The property of grain size and granularity variation with X and gamma radiation of different energy is used to improve the recognition of proton tracks in nuclear emulsion. Suitable x-ray qualities and exposure level have been investigated for this purpose. It is found that using x-ray of 10 kV and pre-exposure of 30 mR, the sensitivity of the neutron film could be increased by 15%. This study is based on exposures made using a Pu:Be neutron source.

This enhancement relieves considerable eye strain of the scanner and in addition, one is able to pick out easily shorter tracks in neutron monitoring films.

Introduction

In the Radiation Protection Bureau (RPB) film dosimeters have been used for many years for monitoring neutrons. In the course of regular scanning of these films, very often films are found with slight exposure to gamma radiation. It is thought that this gamma radiation comes from standard neutron sources containing a small percentage of gamma contamination (2-4%) or from a reactor environment where mixed neutron gamma radiation fields exist. Further, this effect is also noticed in film dosimeters that are accidentally exposed to extremely small amounts of light. The operators noticed a very pronounced "Contrast Effect" when scanning such film dosimeters through a microscope or a TV video set up. Films of this sort were found to require shorter scanning time and there was less strain on the eye. It was observed that especially the shorter tracks were picked out easily.

It is this latter observation that suggested the application of the "Contrast Effect" into practical dosimetry. This paper studies the results of the visual and quantitative effect on contrast as a function of x-ray exposures and varying qualities of soft x-rays.

Neutron Dosimeter

As for dosimetry of fast neutrons, a conventional neutron monitoring film from Kodak called NTA Type "A" is used. Neutron films were exposed to 22°C at a relative humidity of 45%. To avoid fading problems, they were then processed promptly after exposure; the processing time in a standard fresh Kodak liquid x-ray developer was 12 minutes and the corresponding time for fixing was 24 minutes.

Radiation Sources

A Pu:Be neutron source in free air was used for all neutron exposures, which were made perpendicular to the film plane. The films were not in their normal holders and the accuracy of neutron exposure were within ±10%.

For the x-ray exposures, two different x-ray machines were used. The one used at RPB for 25 kV measurements is a Philips tube with kV selection from 25 to 100 having 1 mm Be window. The x-ray exposures were determined with an accuracy of ±5% using a calibrated EIL chamber. The 10 and 15 kV measurements were made with an x-ray machine available at the National Research Council (NRC). This machine is also a Philips special tube for precise x-ray output calibration type 150 kV with 1 mm Be window. The x-ray exposure measurements at NRC were made to an accuracy of less than 1% using a special nylon chamber.

High energy x-rays were obtained from a 250 kV Philips therapy tube with 2 mm Al inherent filtration. A Ra-226 source enabled gamma exposures to be made.

Microscopy

The fast neutron dose was related by calibration to the proton recoils density per unit area. A metallurgical research microscope Model Cooke 40487 with a TV monitor was used for this purpose. One field of view corresponded to 4.3×10^{-4} tracks cm^2 with a dry objective x 20. The tracks were counted in an area covering 150 mm^2 in three different films for each exposure and then averaged out.

The optical quality of a recoil proton track in a neutron film is generally influenced interdependently by the following factors. (1) Transparency of the film, (2) Lack of uniformity of development with depth and area, (3) Poor discrimination for desired tracks in the presence of unwanted details, (4) Distortion of track trajectories, (5) Fogging of the emulsion due to gamma or electron radiations, (6) Illumination of the field of view.

Technique

The technique is based on a well known physical property of radiation interaction with photographic emulsion. In the case of x-ray interaction with nuclear emulsion, depending on the incident quantum energy, electrons of different energies are produced; these lead to a variable distribution of silver centres. This in turn leads to the formation of different sizes of silver aggregates depending on the developing conditions. Further, the granularity of the film will be very different depending upon the incident energy. For example, extremely low energy electrons develop only a few silver grains per unit area, whereas, a high energy electron develops a relatively larger number of grains. Usually total absorption of a quantum leads to island like clusters of grains due to the short curved paths of electrons in the emulsion. Eggert and Schopper (1938) showed that this leads to increase in granularity and grain size of the photographic emulsion.

By exposing conventional nuclear emulsion film dosimeters to soft x-rays of a few mR, a distribution of developed silver grains are artificially produced. When the film is further exposed promptly to fast neutrons, the proton recoil tracks are produced additionally. The x-ray developed grains and those forming the proton track are of different sizes, different mean diameters and granularity. It therefore became clear that the optical quality of the track and hence contrast, may be controlled by the application of a suitable exposure using a defined quality of x-rays.

Experimental Procedures

After the films were exposed to x-ray, there was a gap of about four days before they were exposed to neutrons and then they were promptly processed. For films exposed to neutrons first, the delay period was two days for x-ray exposures and then processing was carried out after a maximum storage time of one day.

Generally both categories of x-rayed films, before or after neutron exposure, were processed simultaneously for convenience and to maintain processing conditions constant.

Generally, there appeared to be a critical dose and quality of x-rays at which the distribution of developed grains due to x-rays did not interfere with the recognition of normal proton tracks, consistent with providing a good contrast as seen through the microscope. If the x-ray exposure was increased beyond a certain value, the well known effect of train distribution, due to fogging, interfers with proton track recognition, whether the proton track was short or long. In order to investigate these aspects, the following experiments were conducted using x-rays of 10, 15 and 25 kV. The 10 kV was chosen due to its ready availability for providing a source of low energy electrons in the emulsion; 25 kV was chosen for comparison. The following experiments were conducted. (1) Determination of optimum time/temperature combination for development and visual recognition (quality) of developed grain distribution, (2) the effect of pre or post x-ray exposure on sensitivity and quality of tracks for 10 kV x-ray beam, (3) The effect of pre or post x-ray exposure on sensitivity and quality of tracks for 25 kV x-ray beam, (4) Distribution of tracks at 10 kV for different post x-ray exposures, (5) Distribution of tracks at 15 kV for different post x-ray exposures (6) Distribution of tracks at 25 kV for different post x-ray exposures, (7) Track distribution as a function of optical density and quality of radiation, (8) Optical density at 10 kV as a function of x-ray exposures, (9) Calibration of NTA Type "A" film with and without pre x-ray exposures using 10 kV x-ray beam, (10) Photomicrographs of the "Contrast Effect".

Results and Discussion

Experiment one showed that background grain counts in unexposed neutron films developed for 12 minutes at 64°F provided clear and good contrast of developed grains in 150 mm^2 area. The other temperature and time combinations gave rise to haziness and lack of sharpness of grain distribution. Hence in further experiments films were developed at 64°F for 12 minutes and fixed for 24 minutes.

It is observed that the "Contrast Effect" is seen in neutron film dosimeters that are exposed to x-rays either before or after neutron exposure. The visual effects are slightly different in each case. Therefore, in order to investigate this aspect, a set of three films were given 250 mRem of neutron exposure from a Pu:Be source and then subjected to different post x-ray exposures of 10 kV x-ray quality. Another set was also exposed to x-rays of the same quality using the same geometry and then to the same magnitude of neutron exposure. The results of the actual number of proton tracks mm^{-2} in these sets of films as a function of x-ray exposures for a constant neutron exposure of 250 mRem are shown in Figure 1. A 15% enhancement of sensitivity is quite clearly seen from the curve of pre x-ray exposures. It should be pointed out that both sets of films were processed simultaneously. The differences in trend arise mainly due to varying degrees of fading of proton tracks in post and pre x-rayed neutron films. It should be recalled that after neutron exposure films wait for about four days before processing in the case of post x-ray exposure and in the other case films were processed promptly after the neutron exposure. The optical quality of tracks in post x-rayed neutron films were found to be good for exposures up to about 50 mR and in pre x-ray films to about 75 mR.

The results of experiment 3, 4, 5,6 & 7 showed that the optical quality of tracks were not comparable to that based on 10 kV x-ray exposures although the enhancement effect (approx. 15%) was of the same magnitude. Figure 2 shows the result of 10 kV x-ray measurements. It is well known that increased addition of gamma or x radiation on neutron film reduces the number of observable tracks, Becker (1963), Carallini and Busholi (1967). The present measurements revealed that for 50% reduction of track density 5 R of gamma (Ra-226) and 550 mR of 250 kV (HVT 2.8 mm cu) at 1400 mRem of fast neutron dose from Pu Be source, are required.

The results from experiment 8 showed that the optical density of 10 kV x-ray exposed films did not vary up to about 150 mR. It was noticed however the microscopic distribution of grains superimposed on recoil proton tracks is found to be completely different. This results in different visual effects in a microscope ranging from clear recognition to blurring of tracks.

Figure 3 referring to experiment 9, shows the results of track density measurements for the purposes of calibration with and without pre x-ray exposure. As experimentally determined earlier, one set of neutron films were pre x-rayed using 10 kV and 30 mR exposure with an accuracy of better than 1%. These films were promptly calibrated to neutron exposures from a Pu:Be source and the proton track density distribution was compared with those neutron films of another set normally calibrated without any pre or post x-ray exposure. These observations were made by scanner A and confirmed by B. It is quite clear from this figure that the sensitivity of neutron films increases by about 15% over the useful range from 50 mRem to 5 Rem.

Experiment 10 revealed the variation in the size of grains due to pre x-ray exposure and proton tracks as seen in the photomicrographs.

Conclusions

Experimental measurement of quality and density of tracks with varying x-ray qualities of 10, 15 and 25 kV and pre or post x-ray exposures from about 5 to 100 mR on Kodak Type "A" neutron monitoring film promptly exposed and processed showed clearly identifiable contrast effect in the quality of tracks as seen in a microscope and also marked improvement in detection sensitivity (15%). Soft x-rays from a 10 kV spectrum and an exposure of 30 mR are found to be suitable to realize this effect in practice. The extension of this technique, with reference to other low energy neutron sources producing short proton tracks, employing film dosimeters for monitoring purposes appears thus feasible.

References

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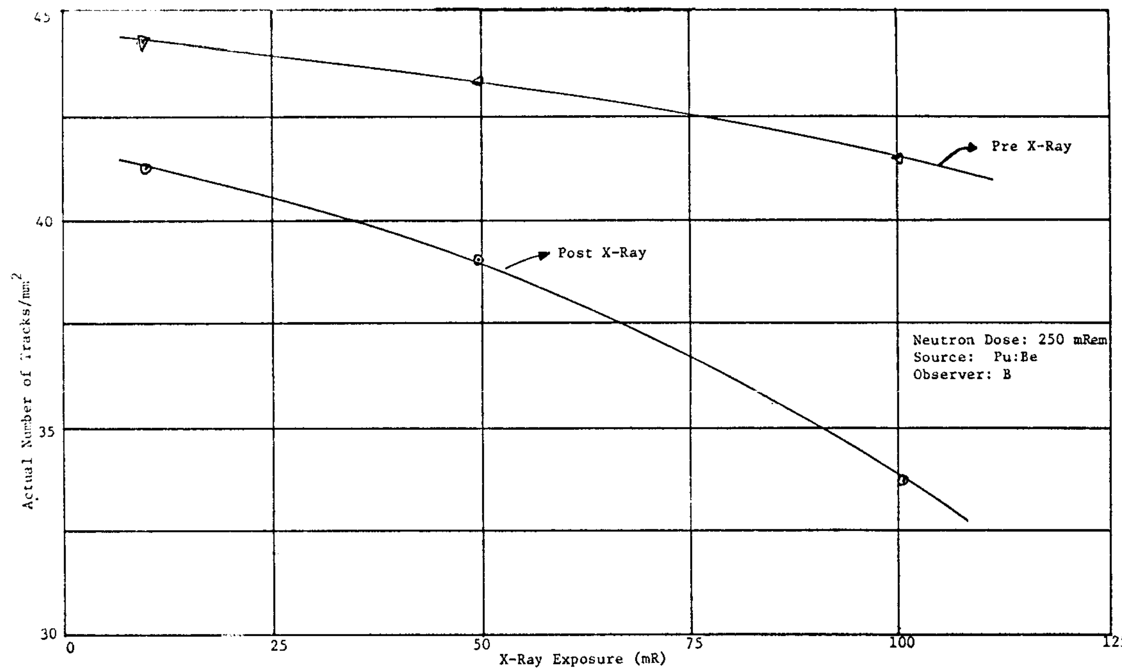

FIG 1 Effect of 10 KV X-Ray on Track Density in [illegible] Film Due to Pre or Post X-Raying

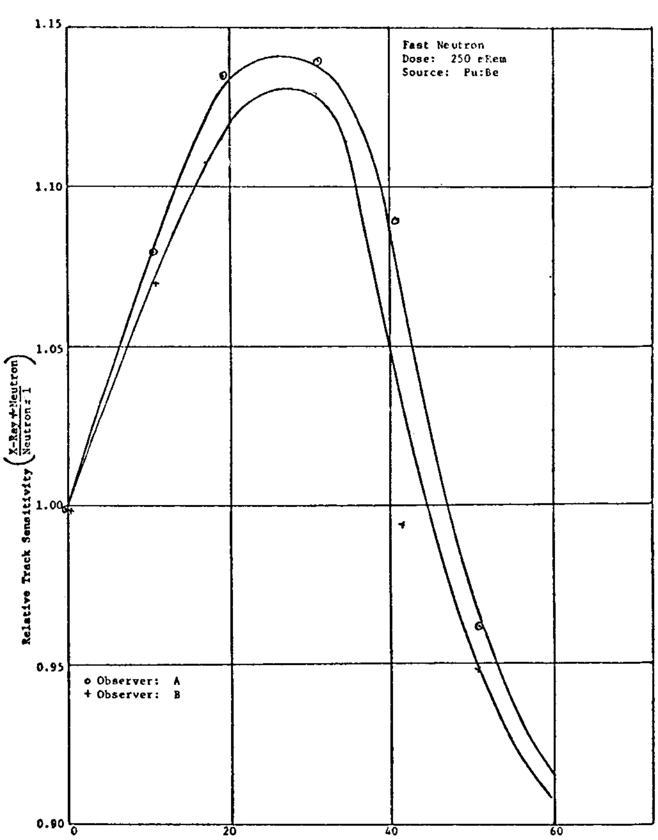

FIG 2 Track Distribution as a function of 10 kV pre x-ray exposure

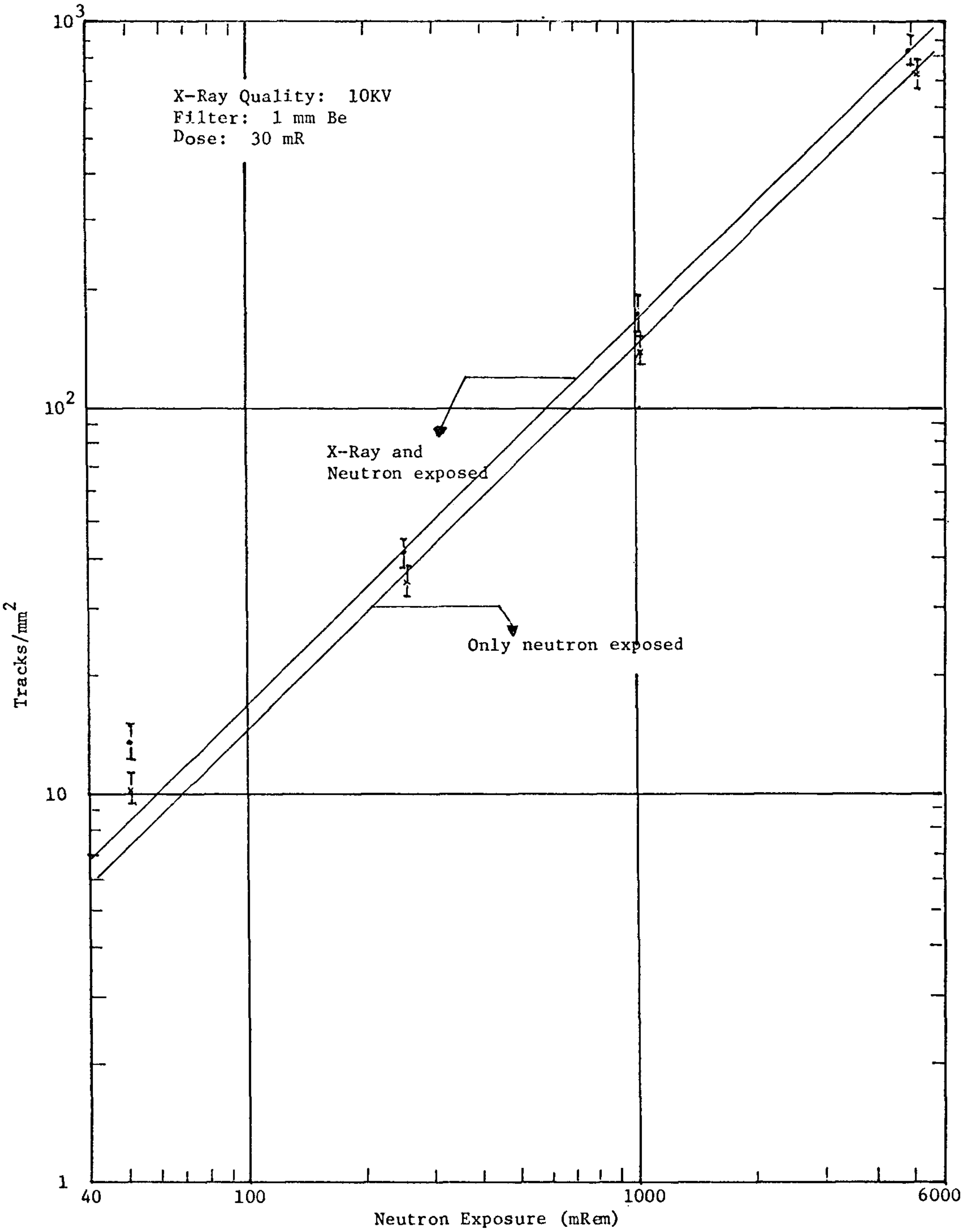

Fig. 3 Pu-Be Calibration Curve of NTA Type "A" Film with and without pre ·exposure of 10 KV Soft X Radiation