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RESEARCH ARTICLE

Solid State Nuclear Track Detector (SSNTD) Applications in Neutron Radiography

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ABSTRACT

In recent years neutron radiography has found potential applications in nuclear technology, aerospace, ordinance items, metallurgy and biology. The films for recording neutron radiographs are conventional X-ray films. These films are sensitive to visible light and gamma radiations. Hence it is difficult to record the radiographs of radioactive materials using these films. Keeping these limitations in view various workers have tried SSNTD films for neutron radiography. These films have been preferred because of their insensitivity to visible light and gamma radiations and ability to record fast neutrons. In the present study an attempt has been made to evaluate varieties of SSNTD (CA, CN, CR-39 and indigenously developed CN) films. In addition sensitivity and resolution of these films have also been determined. Their values are 2% and less than 100 µm respectively. It is generally observed that the contrast of these films is very low. Experiments for improvement of contrast using chemical methods and image processing technique have also been performed.

Key words: *SSNTD, neutron radiography, CN and CR-39 films*

INTRODUCTION

Neutron radiography (NR) is emerging as powerful non-destructive testing technique to overcome some of the limitations of X-radiography, because of their difference in attenuation behaviour. Since X-rays interact with orbital electrons and therefore attenuation coefficient increases with the increasing therefore attenuation coefficient increases with the increasing atomic number Z (i.e. increasing number of atomic orbital electrons). The neutrons on the other hand, interact directly with the nucleus and the interactions are governed by the type of nuclei. The attenuation is therefore random. The growth of track diameter as a function of the etching time and the variation of track density with neutron exposure for five minute etching time are shown in figure 1&2. It may be noted that unlike X-rays, neutron attenuation is higher for low Z materials. For same neighboring elements and isotopes of same element neutron attenuation are widely different. These properties make neutron radiography advantageous in certain cases where conventional X-ray or gamma rays radiography technique have limitations. Use of neutron is more suited than X-rays as a probing tool in the following applications.

1. Inspection of thin samples of low Z materials or thick samples of high Z materials.
2. Inspection of low Z materials encased in high Z material.
3. Discrimination between same neighbouring elements e.g. Boron, Carbon ^{235}U – ^{238}U etc.
4. Inspection of highly radioactive materials like reactor fuel and components

Basically neutron radiography (NR) makes use of a well collimated beam of neutrons either from a reactor or from a non-reactor source for penetrating specimen under test [l and 2]. The neutron beam under goes intensity modulation due to composition and/or thickness changes in specimen These intensity modulations in neutrons beam cannot be detected by photographic emulsion efficiently and special convertor screen (having a high neutron absorption cross-section) are necessary to record the image. The convertor screen absorbs neutrons and emits suitable secondary radiations (alpha, beta, gamma or light) capable of sensitizing photographic film. The films used for recording the secondary radiations are X -ray films. These films are sensitive to light and gamma radiations. Dark room facilities are needed for processing these films. Hence in the mixed radiation field it is not possible to record the neutron radiograph of radioactive materials on these films. Keeping these limitations of X rays of films various researchers [3 and 4] have tried to use Solid State Nuclear Track Detectors for neutron radiography purpose. In this paper an attempt has been made to evaluate varieties of these films from neutron radiographic point of view.

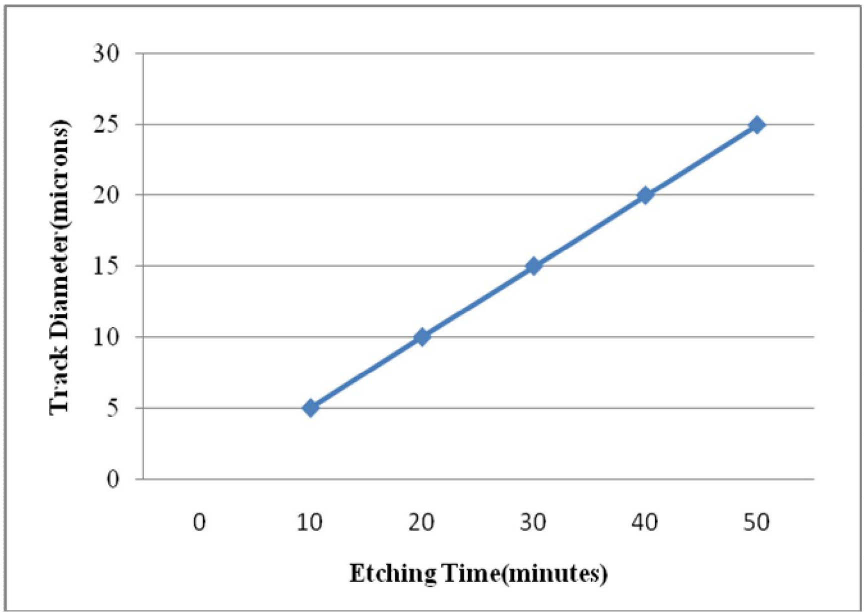

Fig. 1: Growth of track diameter as a function of the etching time

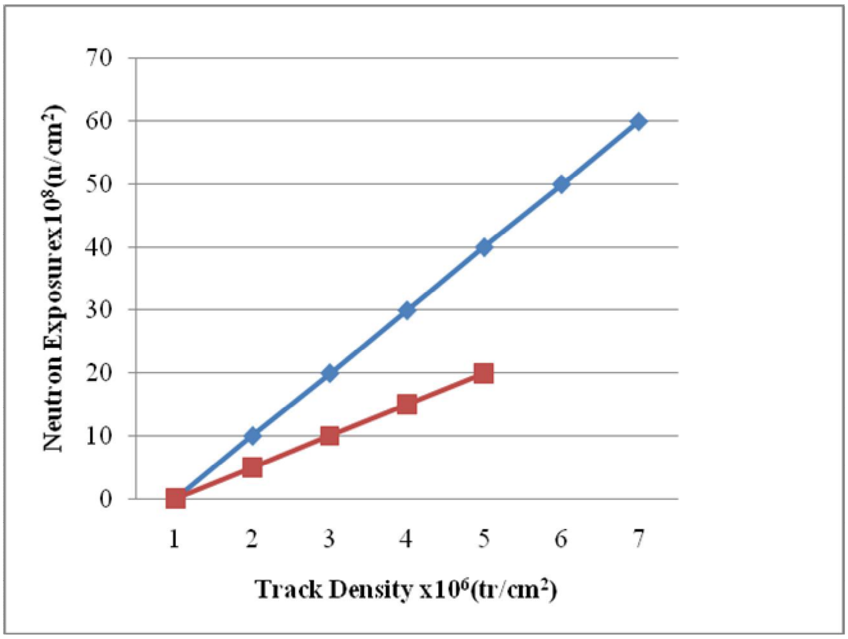

Fig. 2: Variation of track density with the neutron exposure for five minute etching time

EXPERIMENTAL TECHNIQUE

Boron coated cellulose nitrate films and Cr-39 films along with boron convertor screen were exposed to behind the object to thermal neutron fluence of 10^7 to 10^8 n /cm^2. The source used was $^{252}C_f$ of strength 166 µgm in a specially designed neutron radiography camera [5, 6, 7, 8 and 9]. After exposure cellulose nitrate films were etched in 2.5 N - NaOH at 60°C for one hour whereas CR-39 films were etched in 2.5 N - NaOH at 60°Cfor 2 hours. These films are then washed with distilled water and were cleaned using ultra sonic cleaner for a period of 15 minutes. These were then dried in a dust free chamber. Radiographs of Bullets, Anti-Air Craft Shells and other objects were recorded. These neutron radiographs recorded on SSNTD films were evaluated by determining thickness sensitivity, resolution and contrast.

RESULTS AND DISCUSSION

Sensitivity:

For the measurement of thickness sensitivity, the neutron radiograph of step-wedge having five different steps of 1 mm thickness each was recorded on the SSNTD films using the above procedure. Optical density was measured at five different steps visible in the radiographs. From the measurement, the sensitivity has been determined using the relation.

$$\text{Sensitivity} = \frac{\text{Change in optical density between the two steps}}{\text{Thickness difference between two steps}}$$

The value obtained is 2%

Resolution:

For determining the resolution of the SSNTD films from neutron radiography point of view, radiograph of two 100 µm thick Cd wires separated b a distance of less than 100 µm were also recorded on SSNTD films. It is observed that these can be resolved very clearly using these films.

For the measurement of the contrast of radiograph of objects recorded on the SSND, optical density was measured on background as well as on the image of the object, using UV spectrophotometer. It is observed that the latitude of the cure is not sharp, there by indicating that the contrast of the films is poor. Different methods have been used for improvement of contrast.

Treatment of Films with Sandal Wood Oil:

Two ml of sandal wood oil was applied to the radiograph recorded on SSNTD films for 10 min duration. These films were then washed with water and kept in boiling solution of 6N - NaOH for 5 to 10 minutes. After wards washed with distilled water and dried. By viewing these films under microscope it was observed that there is enhancement in diameter of the alpha tracks. Hence the process was repeated till the diameter of the alpha tracks increased by a factor of ten as compared to original value. The optical density was also measured using UV spectrophotometer. It was observed that the improvement in the contrast was 3%. The possible enhancement in the diameter of alpha tracks may be because of santhalol contained in the sandal wood oil which acts as sweating agent.

Image Processing Technique:

Image processing technique was applied to neutron radiographs recorded on SSNTD films using ANDREX image processor for improvement of the contrast by this method the details of the object which were not visible, could be seen with the help of this technique then transferred to high contrast photographic films.

CONCLUSION

The SSNTD films can also be used in neutron radiographic technique for quality assurance point of view. Although there is little disadvantage regarding the contrast of the films, yet this problem can be overcome by transferring it on high contrast photographic films.

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