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TRACK PROFILE DETERMINATION BY DIRECT DIGITAL PROCESSING OF SEM IMAGES

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ABSTRACT

This paper is concerned with the quantitative evaluation of nuclear track profiles in solid detectors by means of digital processing of scanning electron microscope (SEM) images.

The technique utilizes Y-modulated SEM images, as opposed to the usual intensity-modulated, in order to enhance geometrical details. With a proper calibration, it is possible to determine diameter, shape, and depth of tracks in plastic detectors.

Measurements are effectuated by a specifically developed computer program that obtains its data from pre-stored digitized images. Scaling is achieved relating discrete picture elements, to the magnification indicators common to some SEM images.

Working examples from various tracks produced by different kinds of ions, as well as a detailed description of the method, are presented.

KEYWORDS

Scanning electron microscopy; digital image processing; nuclear tracks; SSNTD; computerized microscopy; SEM.

INTRODUCTION

Most tracks left by fission fragments or heavy ions in plastic detectors are readily observable by means of a scanning electron microscope (SEM). The preparation techniques have been made simple enough and take only several minutes per sample. From SEM images one may distinguish track diameter, density per unit area, angle of incidence, etc...

However, measuring and counting over the screen of the SEM or over photographs becomes repetitive and tedious in some applications. To overcome this limitation, several recent developments have been incorporated, to render automatic the information extraction process (Abmayr, 1976; Di-Liberto, 1978). SEM image analysis has been applied for some time in the solution of similar evaluations (Peralta-Fabi, 1983). Some of the main advantages of the automated approach, are related to time savings, high data volume for statistical treatment of information, and precision.

There are several methods to quantify features of nuclear tracks; one of the most recent is, for example, the application of optoelectronic methods for counting tracks i.e. Flores (1983) Other methods combine optical microscopy with image digitation and processing to acquire quantitative results (Heinrich, 1981).

In the present study an SEM linked to a microcomputer equipped for image processing is utilized to evaluate, not only the previously mentioned features, but also to quantify the track profiles left by several particles at different angles of incidence.

Following is a description of the experimental system involved, and a discussion of the results presented, to end with several short conclusions.

EXPERIMENTAL SETUP AND PROCEDURE

The experimental system consists of a scanning electron microscope, an interface circuit and a microcomputer. The computer controls some of the basic functions of the microscope, whilst it monitors the video signal, that produces images in a common TV fashion. For convenience, the scanning of the electron beam is matched in frequency to a commercial television standard known as NTSC, therefore allowing for a wide range of equipment to be used in the handling, storing and processing of signals, that contain images of nuclear track data.

Figure 1 shows a general block diagram of the system. On the upper right corner the beam deflection coils that effect the raster scan are being fed by computer controlled frequencies via the interface circuit. In turn, the electron detector that discerns topographic contrast to form an image, is connected to digitation circuitry in the computer. Digitated images may be stored in flexible or hard magnetic discs or in a high-capacity video-bank, based on a commercial video cassette recorder modified to accept digital data.

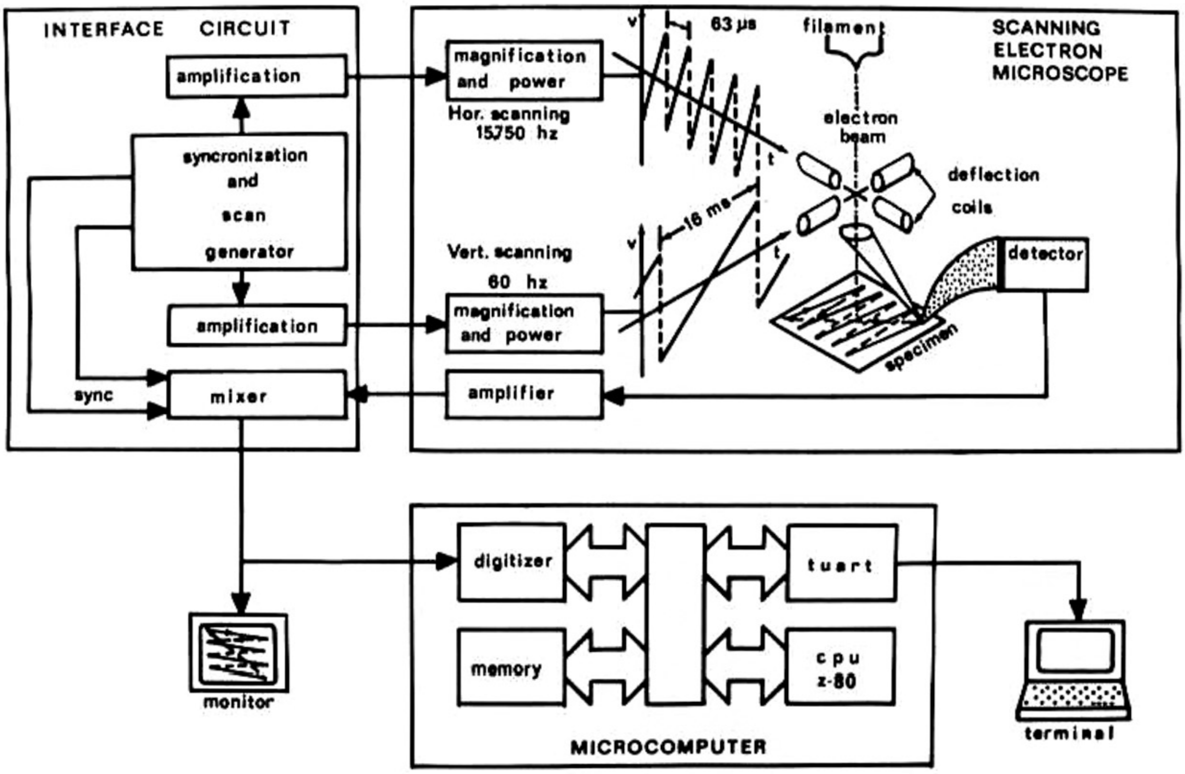

Fig. 1. General block diagram of computerized SEM.

The microcomputer is a general purpose 8 bit micropocessor based system, equipped with digitation boards and a series of I/O ports for analog or digital signal handling. The image processing operations are displayed on an RGB monitor, also a modified version of standard equipment.

The basic design criteria behind the system is to allow for the acquisition of microscopic data in various forms such as secondary electron, backscattered electron or X-ray images, all of which may be submitted to several operations to enhance their informative aspects, or to measure characteristic features of a given set of tracks.

Nuclear tracks of sizes down to tenths of micrometers may be observed with the SEM. To achieve this, the procedure for data extraction begins with a proper sample preparation, consisting of: adhering the detector to an SEM sample holder, then evaporating a conductive film over the sample under high vacuum conditions, in order to avoid the accumulation of electrons from the scanning beam. For a series of samples, the procedure consumes a few minutes per specimen. Normally, carbon and gold are used as the conductive media, because this plastic detectors are easily damaged by electron incidence; another necessity is to conduct the observations with a low energy beam, preferably between 3 and 10 KV.

Under the conditions described, it is routinary to obtain adequate quality in the image for analysis. Before digitating, it is important to carry out as much analog processing as possible to reduce background noise and enhance details; this is achieved by the optimal setting of the condenser lens, brightness and contrast control and gamma filtering, aside from the conventional focusing and astigmatism correction. Fig. 2 is an example of an analog preprocessed image; the background has been averaged to enhance the track signature.

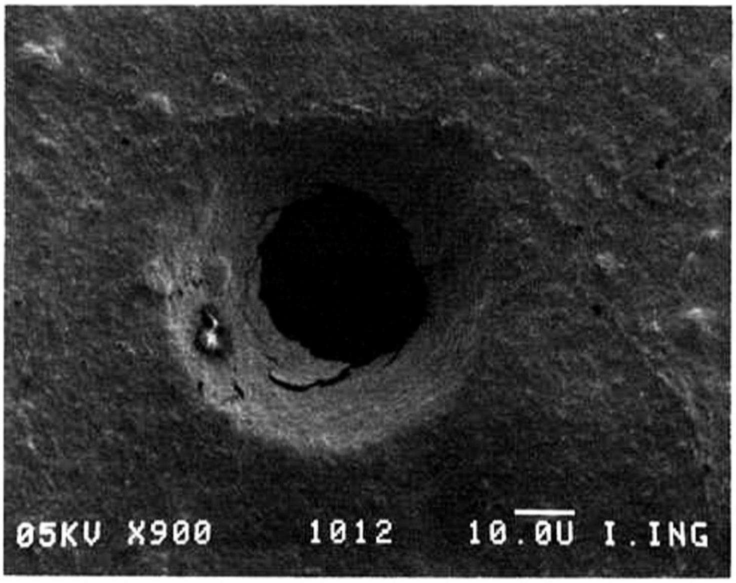

Fig. 2. Preprocessed image of nuclear track calibration line is 10.0 micrometers.

Y-MODULATION IMAGING

Quantitative methods in scanning electron microscopy are being developed now for various applications in research. Among the possible approaches, y-modulation can yield useful measurements when properly calibrated. Usually, an electron micrograph is a set of scanning lines each composed by a linear array of a bidimensional image. However, if each line is taken separately, it may be expressed in terms of a variation of gray levels, the abscissa coinciding with a horizontal scanning line and the ordinate indicating the analog values of gray. In Fig. 3 a set of y-modulated scans of a track is shown. Apparent from the figure is that this type of scan is somewhat a function of topography, therefore liable to yield quantitative information. Nevertheless, the height of the signal is also dependent on the contrast setting, which can have values entirely unrelated to topography. To solve this contradiction, the height of the y-signal is calibrated with a body of known dimensions and similar shape. In this case a carbon fibre of 6 μm in diameter is used. The fibre is localized near a track and without changing the operation conditions of the SEM a y-modulated scan is performed over the fibre. The height of the signal is computed digitally and used as a measuring scale. The resolution of this measure lies in the range of ± 0.1 μm.

On the other hand, any feature that must be quantified is compared to the calibration line present in most micrographs. Fig. 4 is an example of the calibration line when amplified to show the picture elements (pixels) that compose the line; by knowing the relation of length to pixel size, any characteristic of an image may be quantified. In this same figure, the measurement of a track is shown.

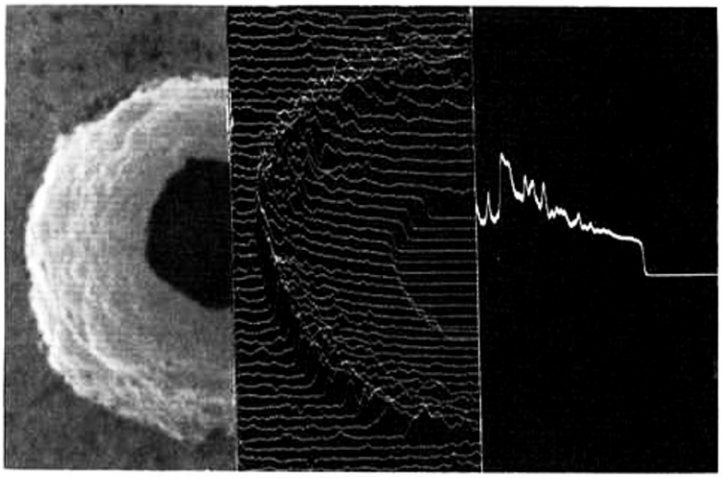

Fig. 3. Set of Y-modulated scans of heavy ion tracks. a) micrograph of track, b) sequential scans, c) single scan profile.

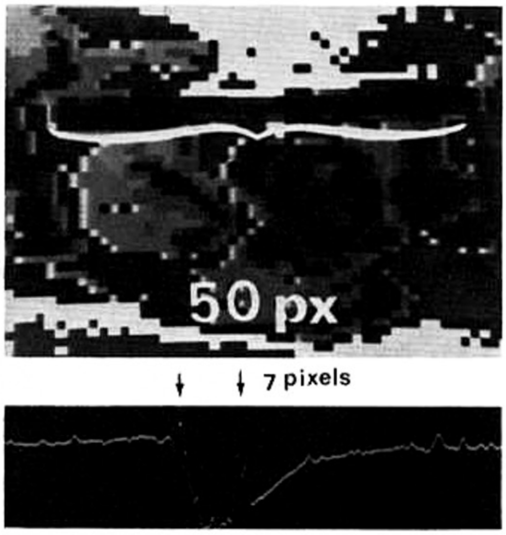

Fig. 4. Calibration line showing 1μm. length and track.

RESULTS AND CONCLUSIONS

The application of computerized electron microscopy to the evaluation of geometrical details of nuclear tracks, has been found to be of use as a quantitative tool. Y-modulation promises direct measurements of track parameters in an automated mode; in this work, it is shown that the basic procedure is correct, however, more extensive tests are necessary to convert this technique from a research tool into a practical solution.

With regards to track shape differentiation, the equipment obtains a signature of a given track. The signature is in essence the contrast variation of a scanning line that crosses the track with a given orientation, and since most tracks of similar angle of entrance present a characteristic contrast distribution in neighboring pixels, all scanning lines crossing a track will coincide in general shape. Fig. 5 compares various cases to illustrate the differentiation possibilities (Peralta-Fabi and co-workers, 1983).

The y-modulated signals, inasmuch as they result from contrast values, can thus inform about boundaries, since nuclear tracks observed with the SEM, show in most cases a bright edge. By measuring the distance from peak to peak in the trace, the diameter is readily evaluated. By estimating the entrance diameter and the exit diameter, the general profile can be quantified. However, the shape of the trace can also be obtained by calculating the slope variation down the profile from the y-modulated trace.

In conclusion, it can be stated that: a multipurpose microcomputer can extract quantitative information directly from SEM images; this information may serve as a means to differentiate tracks with respect to diameter, angle of incidence, and shape of trace profile. With the continuation of this work it is possible to interpret the results in a statistical manner to obtain parameters as: diameter distribution, track density, differentiation, and track profile shape.

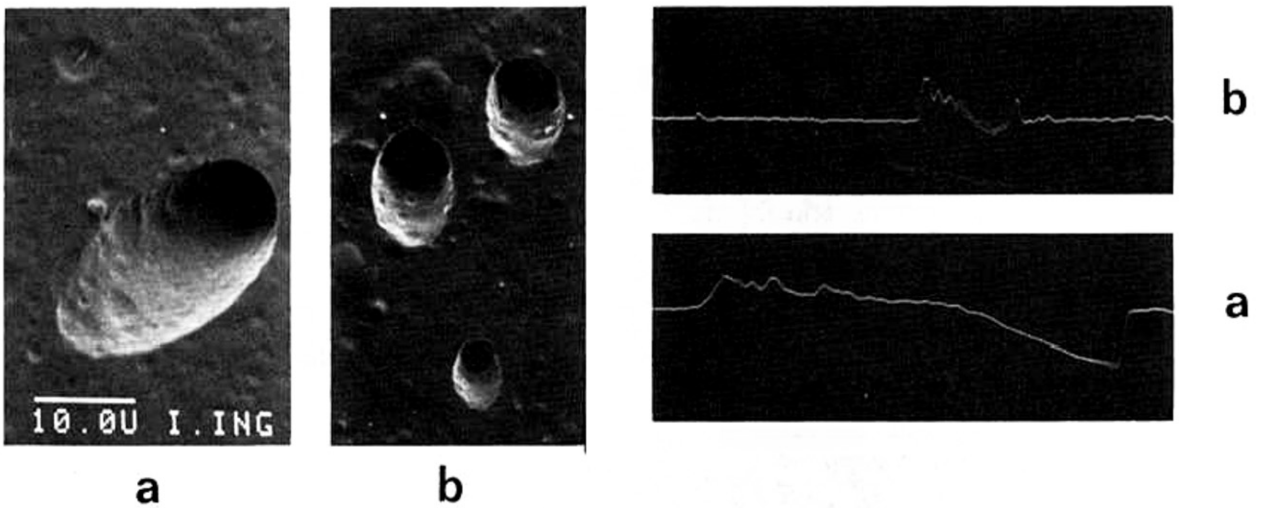

Fig. 5. Micrographs of ^{252}Cf and ^{4}He traces at angles of δ=45° and 30° respectively, on the right the track signatures.

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