AUTOMATED SCANNING OF PLASTIC NUCLEAR TRACK DETECTORS USING THE MINNESOTA STAR SCANNER

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1. Introduction. This report describes the problems found in an attempt to adapt an automated scanner of astronomical plates, the Minnesota Automated Dual Plate Scanner (APS), Landau and Humphreys (1982), to locating and measuring the etch pits produced by ionizing particles in plastic nuclear track detectors, CR-39. A visual study of these pits was made to determine the errors introduced in determining positions and shapes, by comparing measurements made under a low power microscope with those from the APS.

2. The Apparatus. The scanner was designed to detect the boundaries of the images on astronomical photographic plates by scanning them with a swept 12 μm diameter laser beam. This beam sweeps over a 12 mm wide stripe during each scan. The location of coordinates where the intensity of the beam is abruptly changed by an image on the plate is recorded with a nominal accuracy of 3/8 μm. These coordinates are then organized into images by an online computer. The resulting data consist of images defined by a series of strips. At its maximum rate the system can scan at a rate of 1300 cm^2/hour. As a consequence it would be able to scan in a reasonable time the very large areas of plastic that might be expected to result from the exposures that have been planned to study the UH-nuclei in the cosmic radiation, such as those on LDEF I and II. Obviously, such scanning is only worthwhile if the detection efficiency is high and if the images obtained adequately represent those of the etch pits in the plastic.

In operation there are three parameters that can be selected by the user: the scan line spacing, trigger level or "gate", and the frequency cutoff of a low pass filter. The spacing between scans may be set at either 5 or 10 μm. The change in intensity needed to trigger the recording of an image, the gate level, may be selected as a percentage of the incident light, so that the higher the gate level selected the more images will be recorded. Finally, the analog stream of data from the scanner is put through a low pass filter which removes small transitions, or noise, typical of a fogged background on a photographic plate. The range of this filter can be set by the user and generally must be selected by trial and error for each exposure. The images obtained can then be examined at any desired degree of magnification by software selection. The depth of focus is sufficient that pits in nominally 600 μm CR-39 plates can be scanned with equal efficiency on both surfaces.

3. Experimental Material. Three different set of CR-39 plastics, exposed to different types of particles and etched under different conditions, were scanned in order to evaluate the capabilities of the system.

a) Plates that had been exposed at the LBL Bevalac to a beam of 1.0 Gev/n gold nuclei. These plates were deliberately overetched, in an attempt to look at the lighter charged fragments, so that the majority of the pits had etched through and produced large images some 500 μm long and 200 μm across.

b) Plates exposed to a beam of 1.7 Gev/n manganese nuclei, also from the Bevalac. These plates contained well defined etch pits of both the primary nuclei and their secondary fragments. The data from these plates has been reported elsewhere by Atwater et al. (1984) and shown to be capable of yielding a charge resolution characterized by a standard deviation of 0.14 charge units.

c) Plates exposed to the cosmic radiation during a balloon flight from South Dakota and made available to us by B. Price. These plates show widely scattered pits of all sizes below about 100 μm due to the isotropically distributed cosmic ray particles. Furthermore, due to the incidence of both slow and fast particles, the shapes of the pits vary considerably. These plates represent the most severe test of the system, since the additional degrees of freedom introduced by the isotropy and energy spread makes the detection of true events much more difficult.

4. Scans. As a first assay of the system capabilities the Au plates were scanned with a 10 μm scan separation using a 50 kHz filter and a 35% gate. Typical high and low magnification views are presented in Fig. 1. The low magnification view shows large images and it was found that the detection efficiency was essentially 100%. The high magnification view shows the images of two etched through pits produced by Au-nuclei, (a) and (b), and the images of a secondary fragment of lesser charge which has a separate pit on each surface, (c1) and (c2). It can be seen that the images are somewhat deformed by occasional scan lines continuing past the envelope of the optical image. We estimate that the average systematic error on the true length of an individual scan line is of the order of 10 μm. This result would appear to preclude the use of the system to make accurate measurements of individual pits, but still leaves the possibility that it would be capable of being used as a rapid scanning device.

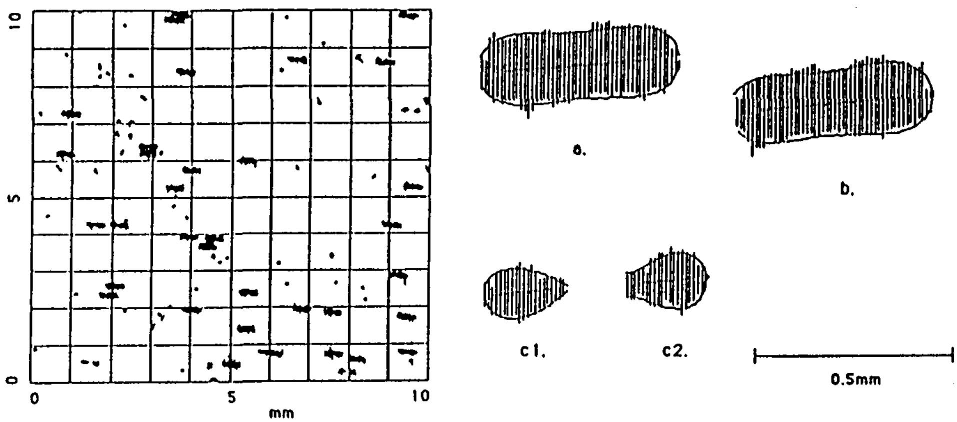

Fig. 1. Scans of Au plates. (a) Under low magnification. (b) Under high magnification. Envelopes shown are computer best fits to the images.

The two manganese plates were scanned with a 5 μm scan separation over the same area that had been visually studied by Atwater et al. (1984), using various settings on filter and gate. The Table shows, for various scans, the signal-to-noise ratio, i.e., the ratio of the number

Table

	Plate 1		Plate 2	
settings	S/N	Eff.	S/N	Eff.
90 kHz filter 50% gate	0.36±0.07	0.83±0.18	0.13±0.02	1.00±0.24
90 kHz filter 40% gate	0.33±0.09	0.44±0.12	0.27±0.07	0.49±0.14
60 kHz filter 50% gate	0.32±0.08	0.44±0.12	0.29±0.07	0.57±0.16
60 kHz filter 40% gate	0.13±0.08	0.07±0.04	0.19±0.04	0.17±0.08

of located pits to the number of recorded images; and the efficiency, the number of located pits to the number of pits identified visually as true pits. Although the statistics are poor it appears that the efficiences are sensitive to the settings chosen and that in order to obtain a high efficiency it is necessary to accept a poor signal to noise ratio. Figure 2 shows medium magnification views of scans made under two different settings. It can be seen that not only does the signal to noise ratio change, but so do the sizes of the individual images and the detection efficiency. It should also be noted that the identification of pits in this scan depends on the predetermined knowledge of the direction and angle of incidence, thus requiring a matched pair of pits. Individual pits are not uniquely distinguished from the background images.

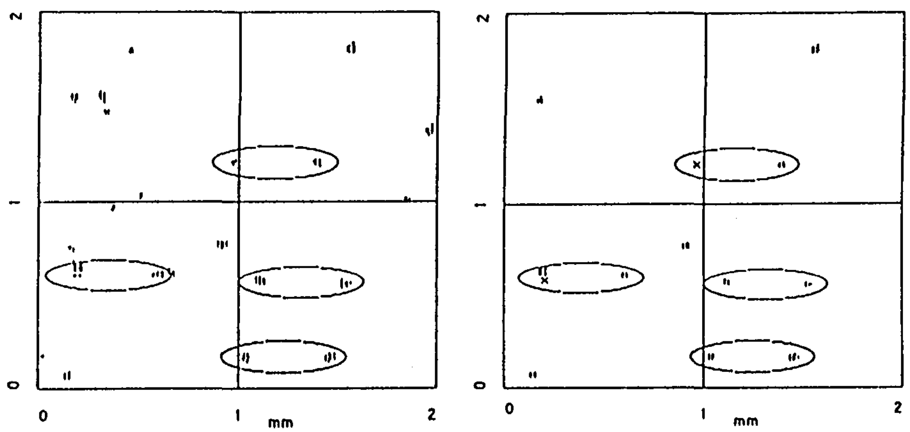

Fig. 2. Moderate magnification scans of Mn plates. (a) 90 kHz filter, 50% gates; (b) 90 kHz filter, 40% gate. Crosses denote positions of missing images of real pits.

Finally, the cosmic ray plates were scanned with a scan width of 5 μm, 90 kHz filter and gate settings of 40 and 60%. In order to distinguish genuine pits from noise it was necessary to develop a technique of "blinking" the images in two adjacent plates against each other. This greatly improved the signal-to-noise ratio but at the cost of a reduced efficiency and increased scanning time.

We conclude that this system is not suitable for the tasks described above, having neither the detection efficiency nor the spatial resolution needed for the low contrast, non-circular images involved in this application.

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References

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