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AUTOMATIC IMAGE ANALYSIS SYSTEM TRACOS

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ABSTRACT: An automatic image analysis system called TRACOS is introduced and its applications to evaluation of tracks in track etch detectors and crystal grains measurement are described.

Avtomatski sistem za analizo slike TRACOS

KLJUČNE BESEDE: sledi jedrske, detektorji sledi, zrna kristalna, mikroskopi, skanerji, analiza slik, analiza avtomatska, vrednotenje sledi, meritve, aplikacije, oprema programska

POVZETEK: Opisan je sistem za avtomatsko analizo slike, imenovan TRACOS, in njegova uporaba pri izvrednotenju sledi v trdnih detektorjih jedrskih sledi in pri meritvah kristalnih zrn.

Introduction

Nuclear tracks group of the Reactor physics division of the J. Stefan Institute started with development and application of track etch detectors twenty years ago. These detectors are able to detect heavy ions with energy range from 100 keV up to relativistic energies. They are made mostly of polymer materials and are known under different commercial names, such as LR-115, CN-85, CR-39 and so forth. Other heavy ion detecting materials are minerals, like mica and glasses. Detectors are usually shaped in foils with thickness from few microns up to 1 mm. Tracks, made by the incoming ions, are enlarged by chemical etching, so they are visible under an optical microscope. The transformation of a latent track to a visible track is possible because the etching velocity along the path of the ion is greater than the etching velocity of the bulk material. For the constant etching velocity along the path of an ion, the track has a shape of cone, which gives an elliptical intersection with the surface of the detector. Tracks are visible under an optical microscope due to steep track walls which refract light because the refractive index of the detector is higher than refractive index of the air. As a consequence tracks appear as dark spots. Typical track size, used for observation and measurement, is from 1 μm to 30 μm. From the size and optical density of the tracks the energy and the charge of the incoming ion can be derived while from the track shape the impact angle can be calculated. A micrograph of tracks is shown in Fig. 1.

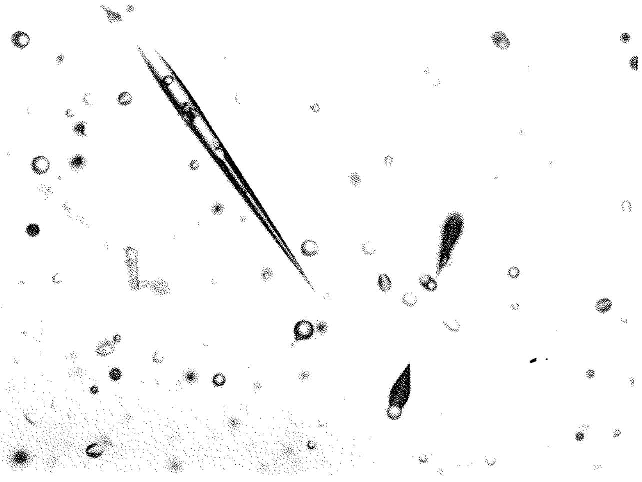

Fig. 1: *The micrograph of nuclear tracks in CR-39 detector which was 5 month in Mir space station. Tracks, marked by arrows, are induced by cosmic rays. Smaller tracks are mostly due to α particles emitted by decay of radon and its decay products.*

Measurements of large areas of the detector foils induced the need for automatic track evaluation. Manual measurement is usually limited to counting the number of tracks in a given area, while there is often need for finding the size or some other distribution of tracks. For this purpose an automatic track analysis system, called TRACOS (Track Counting System), was developed. It consists of an optical microscope, a computer controlled microscope stage, an autofocusing system, a video camera, a video digitizer and a personal computer. Additionally, an optical scanner output can be also processed. Technical characteristics of the individual components are summarized in the Table 1. Software for the measurement control and image analysis was completely developed in our laboratory. In the following capabilities of the system will be presented and some selected examples of measurements will be described.

Table: technical characteristics

Microscope:	Olympus Vanox magnification: 8-times to 250-times illumination: Hg or ordinary light bulb
Camera:	EEV with CCD sensor
Digitizer:	Data Translation 2853 SQ resolution:: 512*512 pixels, 256 grey levels memory: 512 kB (two images)
Moving stage:	Märzhäuser Wetzlar MAC 4000/2 scanning area: 100 mm * 100 mm step: 0.025 µm
Autofocus:	Elbek
Computer:	PC compatible processor: 80486/50MHz memory: 8 MB ram, 256 cache hard disk: 450 MB

Measurement

Before the measurement some of the settings are made by an operator. It is necessary to adjust the light intensity of the microscope, to set the minimum size of the objects which will be analyzed and to determine the grey level threshold which separates object from the background. An important tool for the light and the threshold setting is the grey level histogram which usually shows two peaks; one corresponding to dark objects and the second corresponding to bright background (Fig. 2).

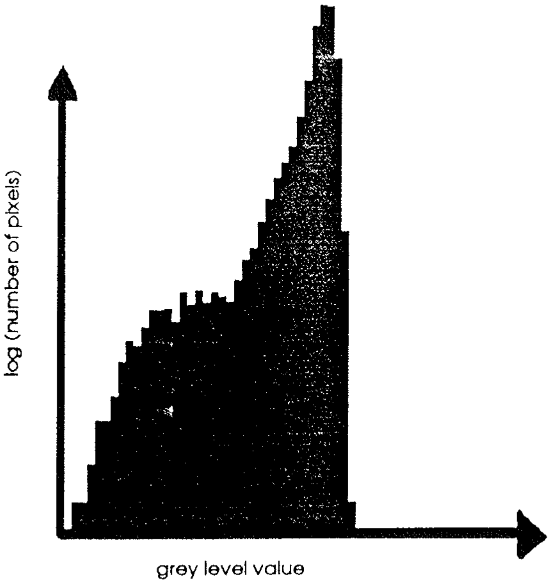

Fig. 2: Grey level distribution histogram. To achieve better visibility of the peak belonging to dark objects with relatively small total area, a logarithm scaling is used.

The concept of the analyzing program is to write measured parameters of all objects (except those smaller than the selected minimum size) in a file, which is later processed by other programs, depending on the type of application. By this approach the universality of the program is preserved what makes it more flexible and easier for adaptation to other purposes. Every record corresponding to a single object contains measured quantities, such as the object coordinates, the size of the minor and the major axis, the size of the perimeter, the area and the average grey level within a object. For the nuclear track analysis, the outer edge of the objects is fitted by an ellipse. The program is capable to fit the ellipse even when the objects overlap (Fig. 3).

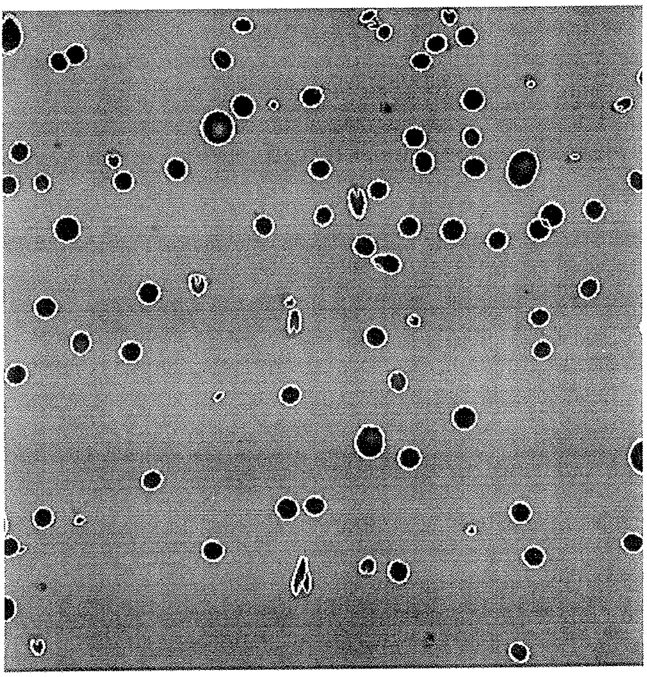

Fig. 3: Ellipse fitting to the tracks. Program is capable to fit correctly even the overlapping tracks.

Discrimination among tracks and background and/or different tracks is performed after the measurement with a help of utility programs developed for this purpose. The program for the track selection represents tracks as pixels on a computer screen for every plane that can be defined with an arbitrary pair of parameters measured by the TRACOS. Fig. 4 shows an example where track distribution is presented in a plane with the *x* coordinate corresponding to the major axis and the *y* coordinate corresponding to the minor axis of the track. The circular tracks therefore lie on the *x=y* curve. By the selection of the region of interest only tracks, relevant for further examination, are transferred to the next stage of processing. For the example given in Fig. 4 we could decide to select only tracks with minor/major axis ratio in the wanted range.

Representation in a two-dimensional sub-space of the parameter space is especially useful in cases when the properties of the objects are not known in advance. By

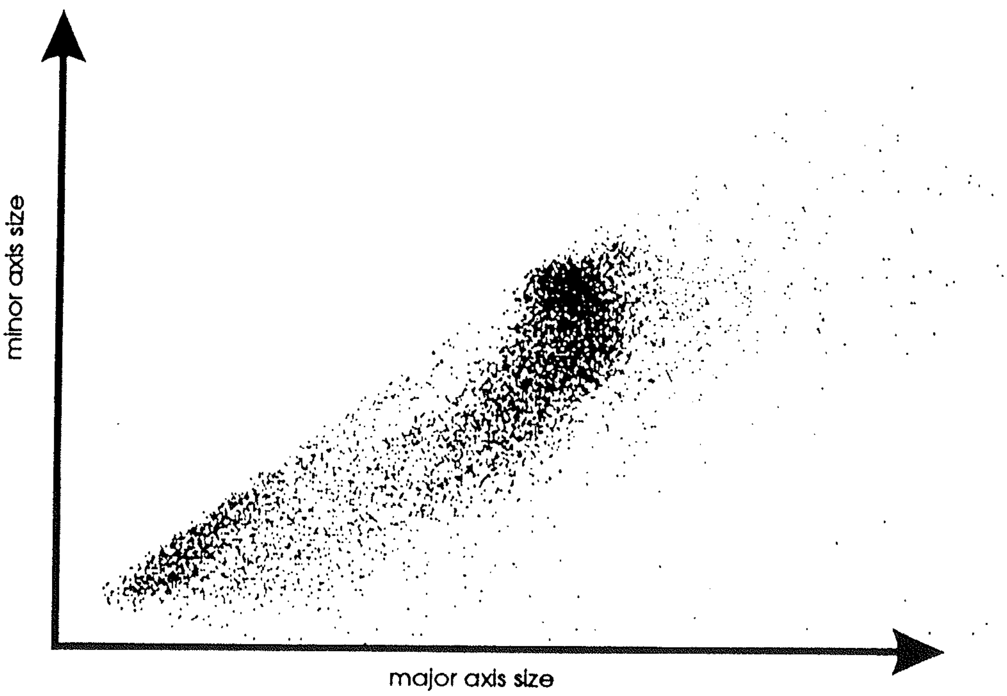

Fig. 4: *Every pixel on a diagram represents an individual track. The x coordinate corresponds to the major axis of an ellipse and the y coordinate corresponds to the minor axis.*

observing planes for different pairs of parameters it is easy to determine if the objects group together and to select them for the further processing. In more complicated cases of recognition it might be necessary to use more-dimensional cross sections in the parameter space. Here problems appear because it is difficult to present structures of more than two dimensions on the computer screen. Fortunately, in the most cases the two-dimensional selection is enough for the most of applications with track etch detectors.

After the selection of the region of interest, it is possible to process further the output of the measurement. Typically, distribution over some of the measured parameters is displayed as a final result. Advantages of the automatic track evaluation over the manual counting are mainly:

a) discrimination criteria are less prone to subjective judgment, b) exhaustion of the operator is less likely to influence the quality of measurement, c) the speed of the evaluation is much greater; at the optimal track density the system is capable to evaluate from $5*10^4$ up to 10^5 tracks/hour.

Examples of applications

The system was used for several types of tasks, some of which are presented here.

Discrimination of the ^{6}Li(n, α) reaction product tracks

Products of the ^{6}Li(n, α) reaction are ^{3}H and ^{4}He with an energy of 2.7 MeV and 2.1 MeV, respectively. Both nuclei are detectable with CR-39 track etch detectors.

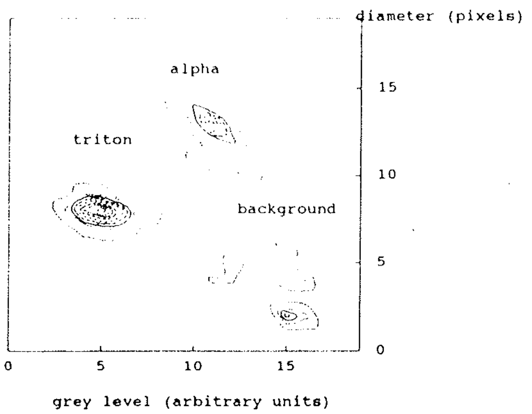

Fig. 5: *Bright areas on the diagram correspond to large number of tracks with given size (y coordinate) and average grey level (x coordinate).*

Due to different energy and charge of the reaction products their tracks are different. Smaller and darker tracks correspond to ^{3}H, while larger and brighter belong to ^{4}He. Fig. 5 shows a diagram where horizontal axis represents the average grey level within individual tracks, while the vertical axis represents the track diameter. Two groups of tracks are clearly visible and discerned from the background. More detailed description of this experiment can be found in (1).

Measurement of the track density as a function of the coordinate and application in radiography.

One of the application areas of track etch detectors are radiographic and autoradiographic methods. By this methods it is possible to measure spatial distribution of charged particle emitters as well as position dependence of transmissivity of the material for heavy ion or neutron beams. Due to the high spatial resolution and the possibility of individual track identification it is possible to make radiographic images at very low emitter concentrations or low beam fluxes. Using an autoradiographic technique we measured the adsorption of radon decay products on metal surfaces. In the radon decay chain there are two short-lived α-emitters: ^{218}Po and ^{214}Po. Contrary to radon, Po atoms stick to metal surfaces. Adsorption on Cu and Al when they were held in contact and separated was measured and compared. With the use of the automatic system it was found that density of Po atoms adsorbed on Cu is higher in comparison that of adsorbed on Al when the metals were held in contact while the densities did not differ when the metals were separated (Fig. 6).

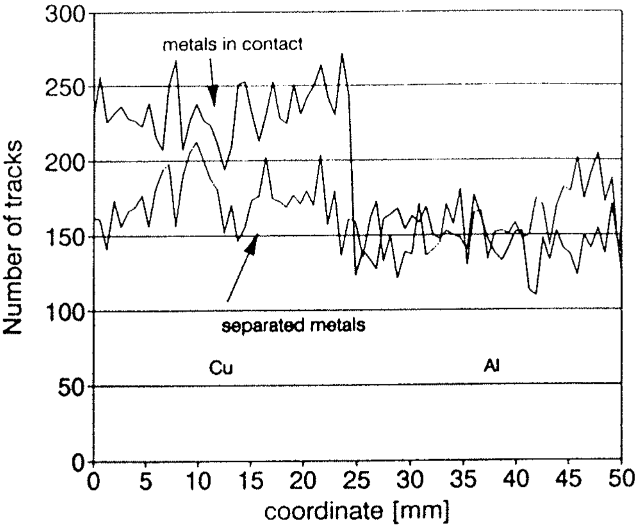

Fig. 6: Number of tracks, produced by the decay of Po, adsorbed on Cu (left) and Al (right) as function of coordinate. Curve with a step in the middle belongs to the measurement with metals in contact.

Application in metallography - Measurement of the number of sides and the number of neighbouring crystal grains

For this task the program was slightly modified. Instead of the digitized picture it accepted a scanned image. Additionally, a module for grain neighbour determination was added to the program. Before the counting, defects in picture were corrected using a drawing program. The crystal grain image, shown in its digitized form in Fig. 7 a), was taken from (2). In Fig 7 b) a number of neighbouring grains of every crystal grain is written. More of this and some other applications of the program in material science is described in (3).

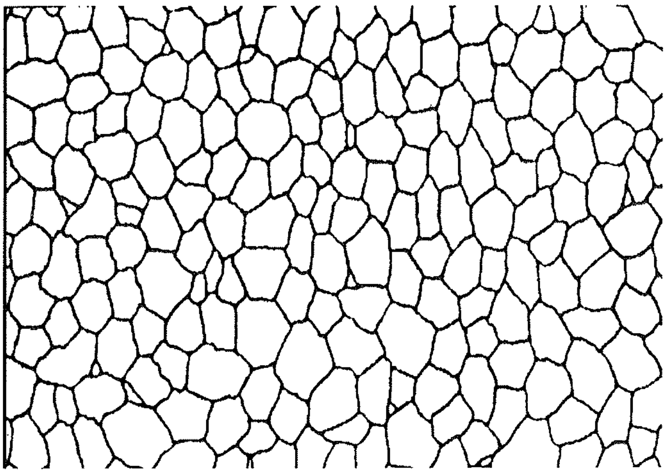

Fig. 7 a): Digitized optical micrograph of crystal grains.

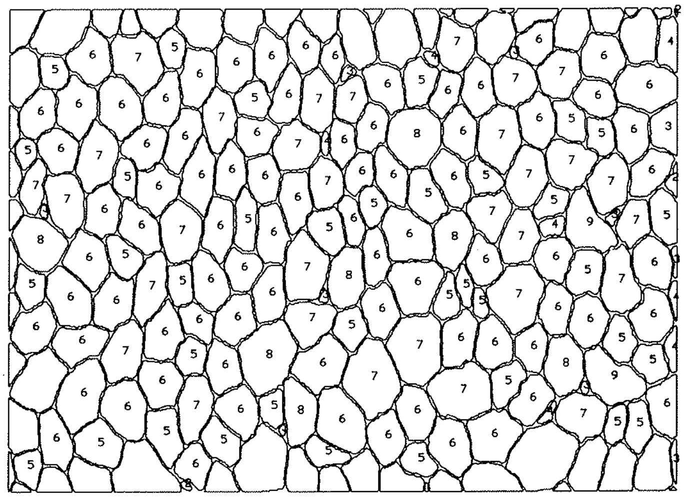

Fig. 7 b): Number of neighbours of the individual crystal grains as determined by a computer.

Conclusion

An automatic system for nuclear track measurement in track etch detectors was built and image analysis software was developed for the research and applications. The system was successfully tested in several types of experiments and in routine use. The achieved speed and the accuracy of the measurement is better in comparison to the manual evaluation. Due to a flexible design of the image analysis program it is possible to quickly adapt it to various other tasks in materials and biological applications.

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