Analysis of Winthrop Williams's CR-39 detector after SPAWAR/Galileo type electrolysis experiment #2

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Objectives

- To search for reality of nuclear tracks in SPAWAR/Galileo type experiment described by W. Williams in his APS March 2007 Meeting presentation: “Search for Charged Particle Tracks Using CR-39 Detectors to Replicate the SPAWAR Pd/D External Field Co-Deposition Protocol”
- To analyze high density pits at the CR-39 surface over the contact area between the detector and cathode wire.

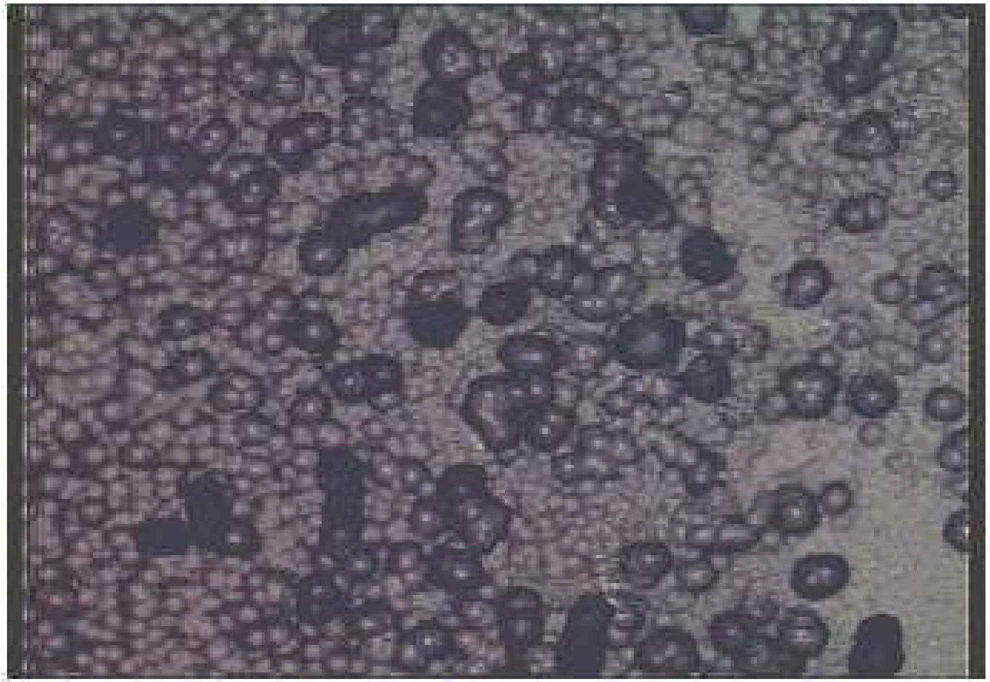
Winthrop Williams's conditions of SPAWAR type experiment with CR-39 attached to the cathode wire (taken from W. Williams presentation at APS March 2007 Meeting)

- Two cells (with & without magnets) – plastic **butyrate** rectangular cells, inch square
- Magnetic fields – approximately **2500 gauss** and **1 gauss** (+/- 40%) respectively at the cathodes
- Electrolyte – **0.03 M PdCl2 + 0.3 M LiCl in D2O**, 22ml per cell
- Anode – **Pt wire** 0.25 mm diameter and immersed length several cm
- Cathode – **Ag wire** of 0.25 mm diameter and immersed length several cm
- Detector – **CR-39** (1 cm x 2 cm **Landauer/Fukuvi**)
- **Additional CR-39 detectors** (from **TASL**) were added outside the cells during the last 24 hours of electrolysis (at 100mA). Neutron detectors from **Landauer** (designed for dosimetry badges) were also added during the last days of the "loading" electrolysis phase.
- Before etch, electrolyzed CR-39 showed SMALL amounts of apparent Pd deposition on the CR-39 plastic track detector. CR-39 was rinsed to remove electrolyte but NOT wiped to remove the deposition. All CR-39 except the neutron detectors have been **etched 3 hours at about 68 deg C in 6.5 molar NaOH**.

Cell 2 (without magnet) electrodeposition: cathode wire is attached to the CR-39 chip (right side of the cell) - (taken from W. Williams presentation at APS March 2007 Meeting)

Cell 2

Pit images after CR-39 etch at t = 68°C in 6.5 M NaOH during 3 hr, (taken from W. Williams presentation at APS March 2007 Meeting)



Cathode side of Cell 2

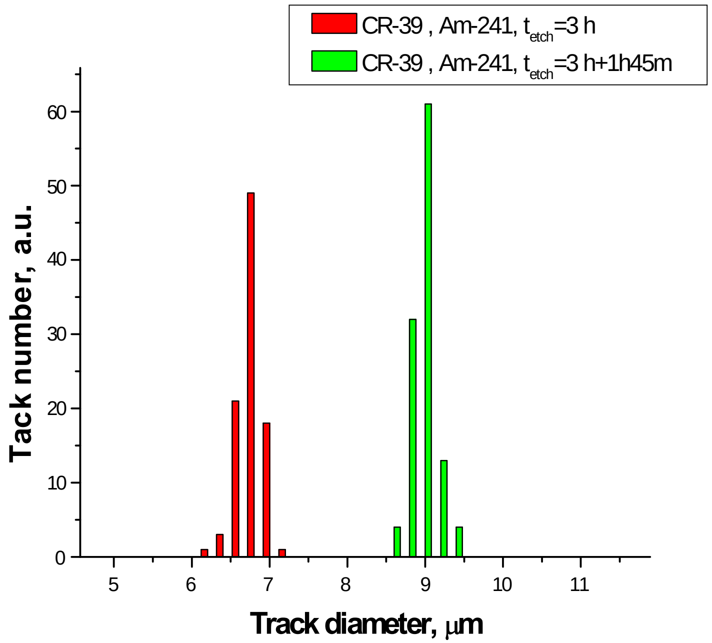
CbottomGrWh.jpg

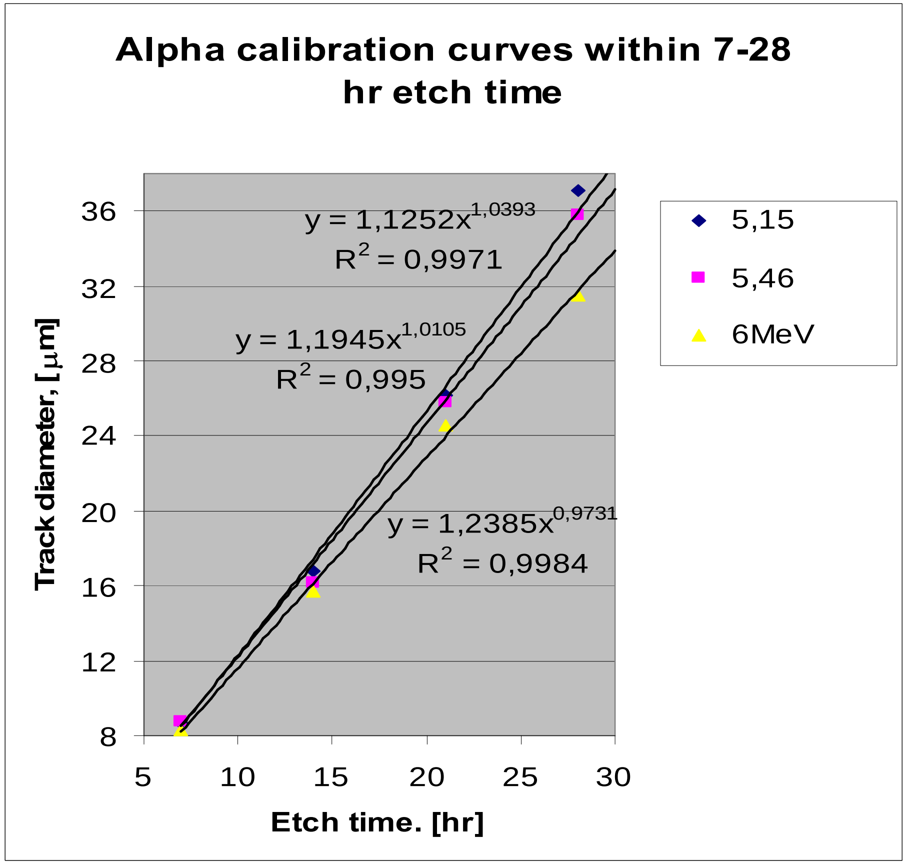
I. Preparation to track analysis

- In order to estimate the etching conditions in UCB we have been supplied also by Winthrop's calibration detector irradiated by with Am-241 alpha source (E_α = 5.45 MeV) and etched in the same condition as the #2 detector.
- At the first step we determined track diameter of Whinthrop's calibration detector and found that it is underetched compared with our standard conditions of minimal required etch (6N NaOH at T=70 C, t = 7 hr) which is a starting point for our calibration curves
- To this goal we performed additional etch in our condition during 1 h 45 min and then compared obtained track diameters with our

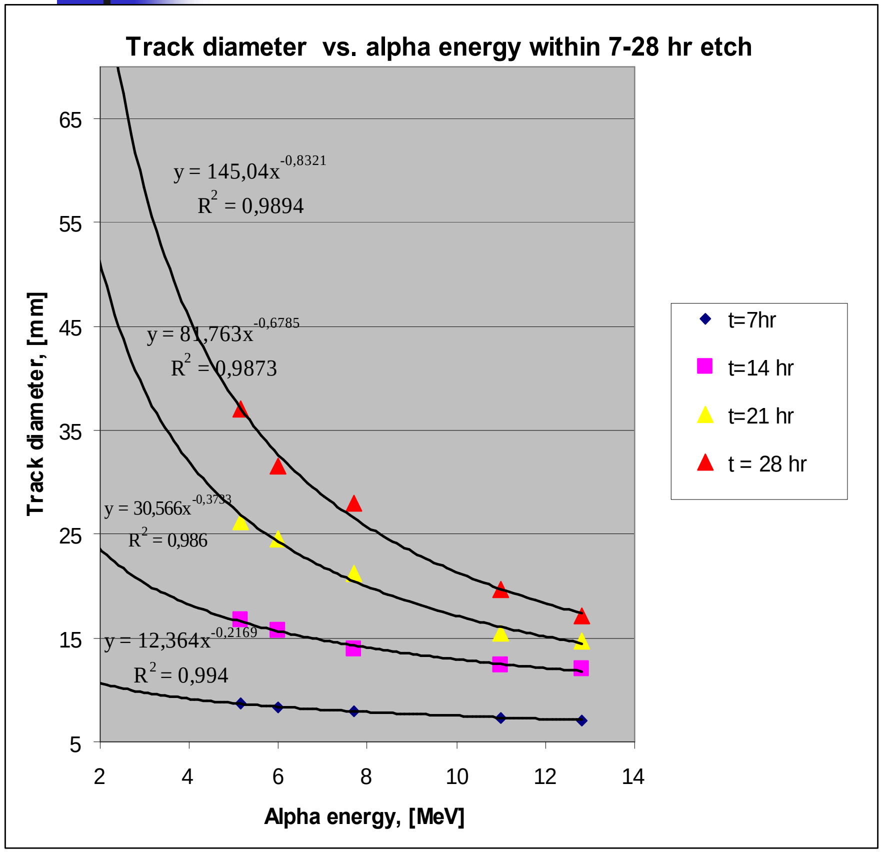
  calibrations

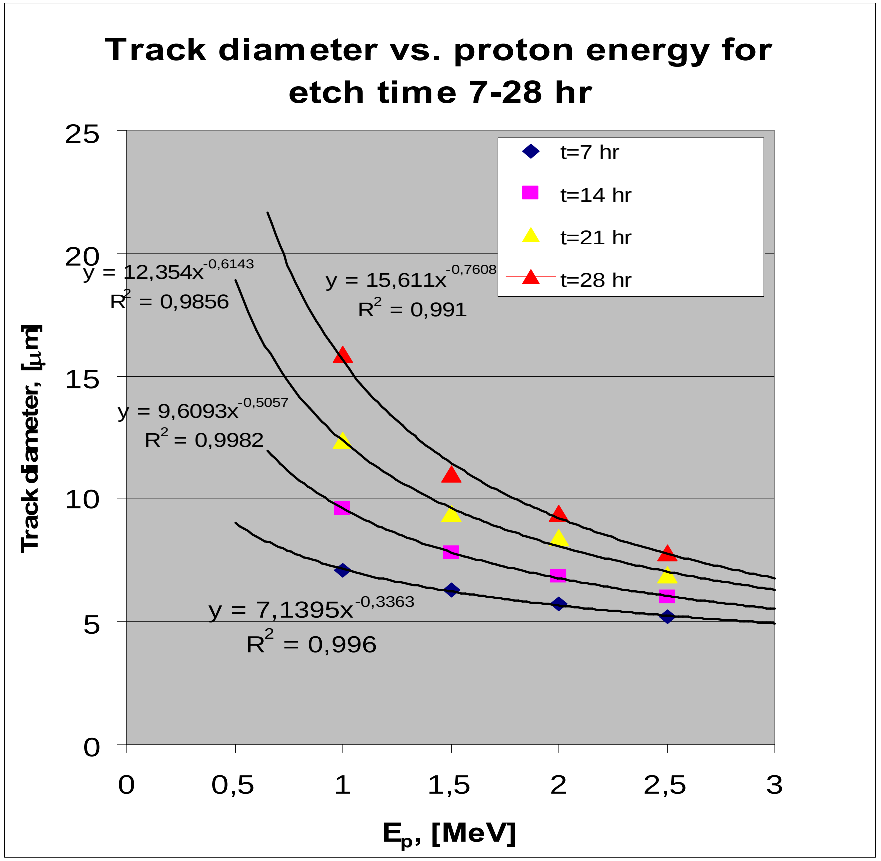
Estimation of etching condition of Winthrop's calibration detector irradiated with Am-241 alpha source (Eα = 5.45 MeV). To move to our standard condition an additional etch of this detector during 1 hr 45 min has been done



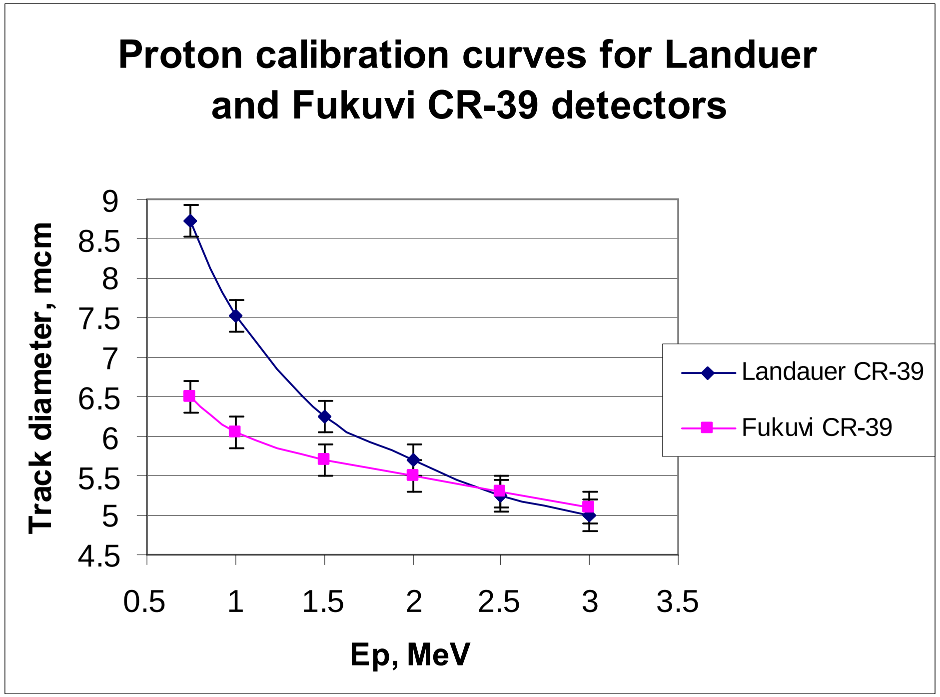


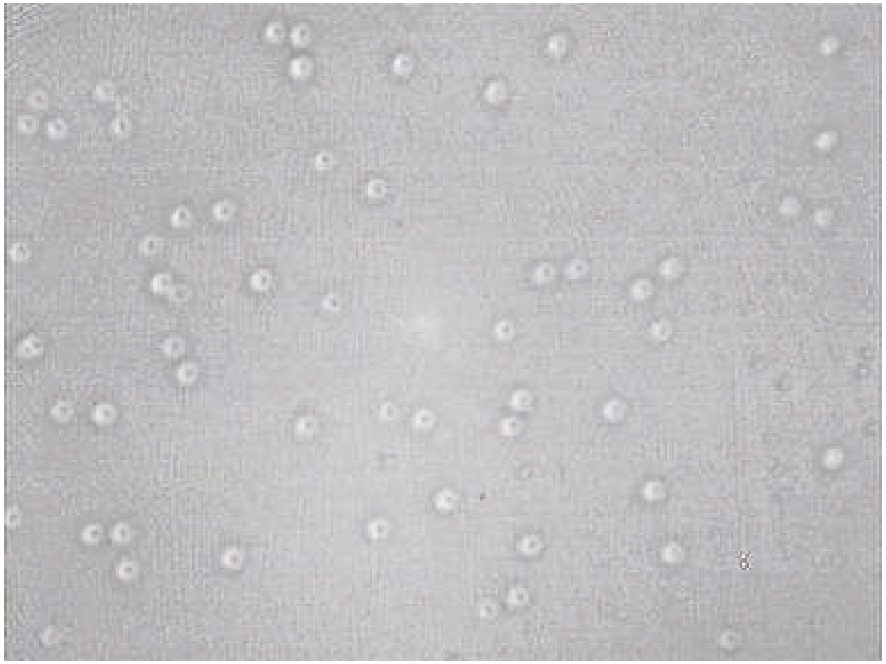
Calibration curves of D vs. alpha and proton energies for etch time within 7-28 hr in 6N NaOH at t = 70 C (bulk etch rate v_b = 1.32 μm/hr) for alphas in the range of 2-12.8 MeV and protons of 0.5-3.0 MeV



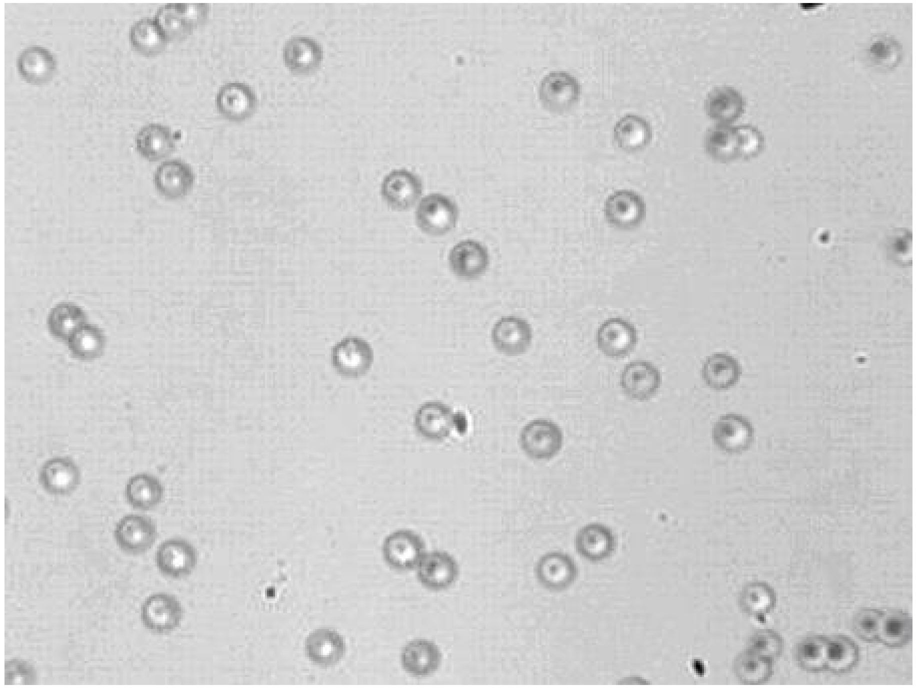


How the real nuclear tracks look: Proton calibration with Van De Graf accelerator E_p = 2.5 MeV

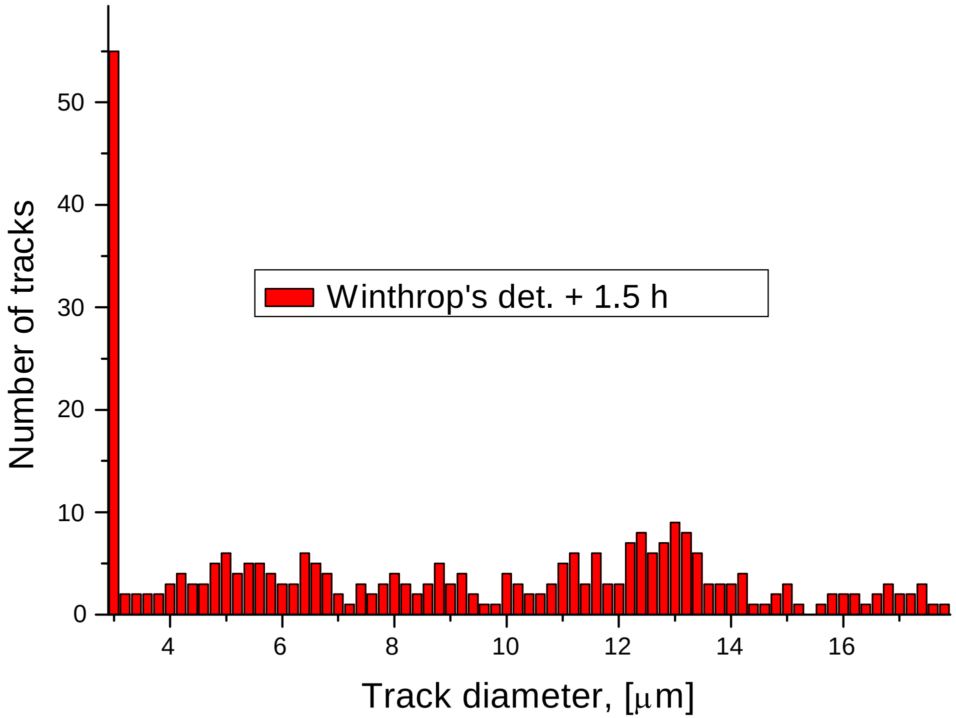




Tracks from 11.0 MeV α-beam @ normal incidence with respect to CR-39 (Landauer) target: image area S= 0.12x 0.09 mm^2, (X 600). The track density is about 10^6 track/cm^2.

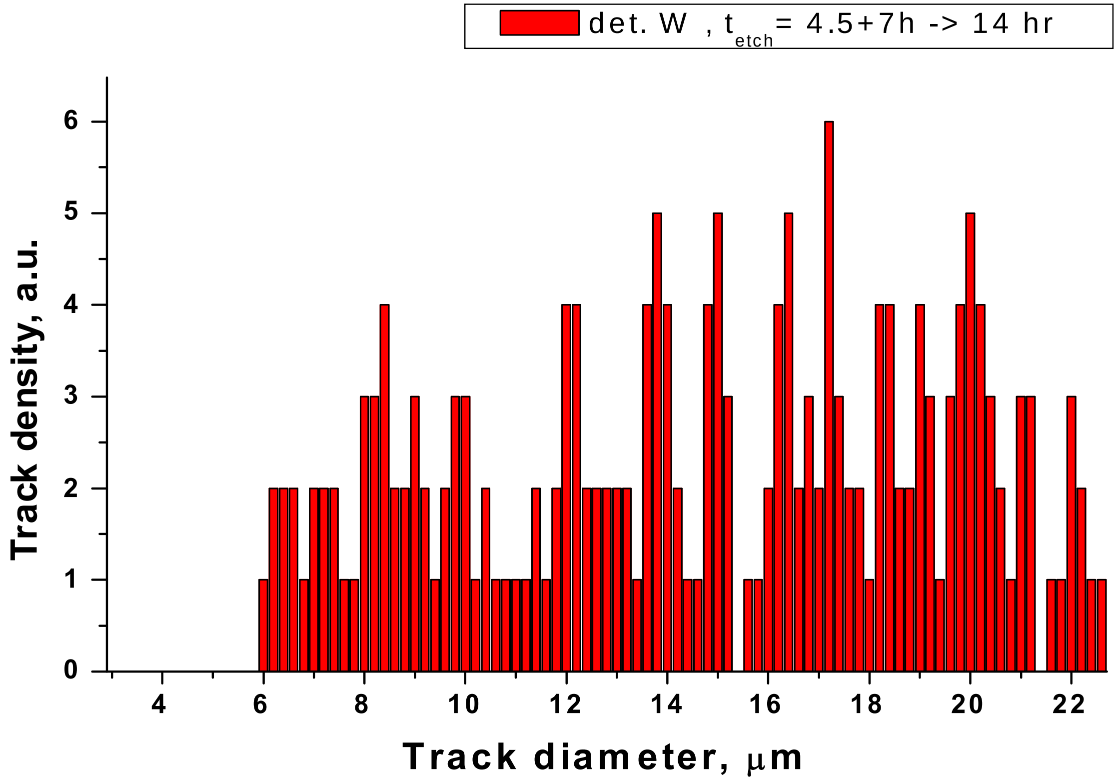


Individual track diameter distribution for Winthrop's #2 detector after additional 1.5 hr etching in 6N NaOH solution at t =70 C (equivalent to our t = 7 hr). No significant pit density was found at the back side of #2

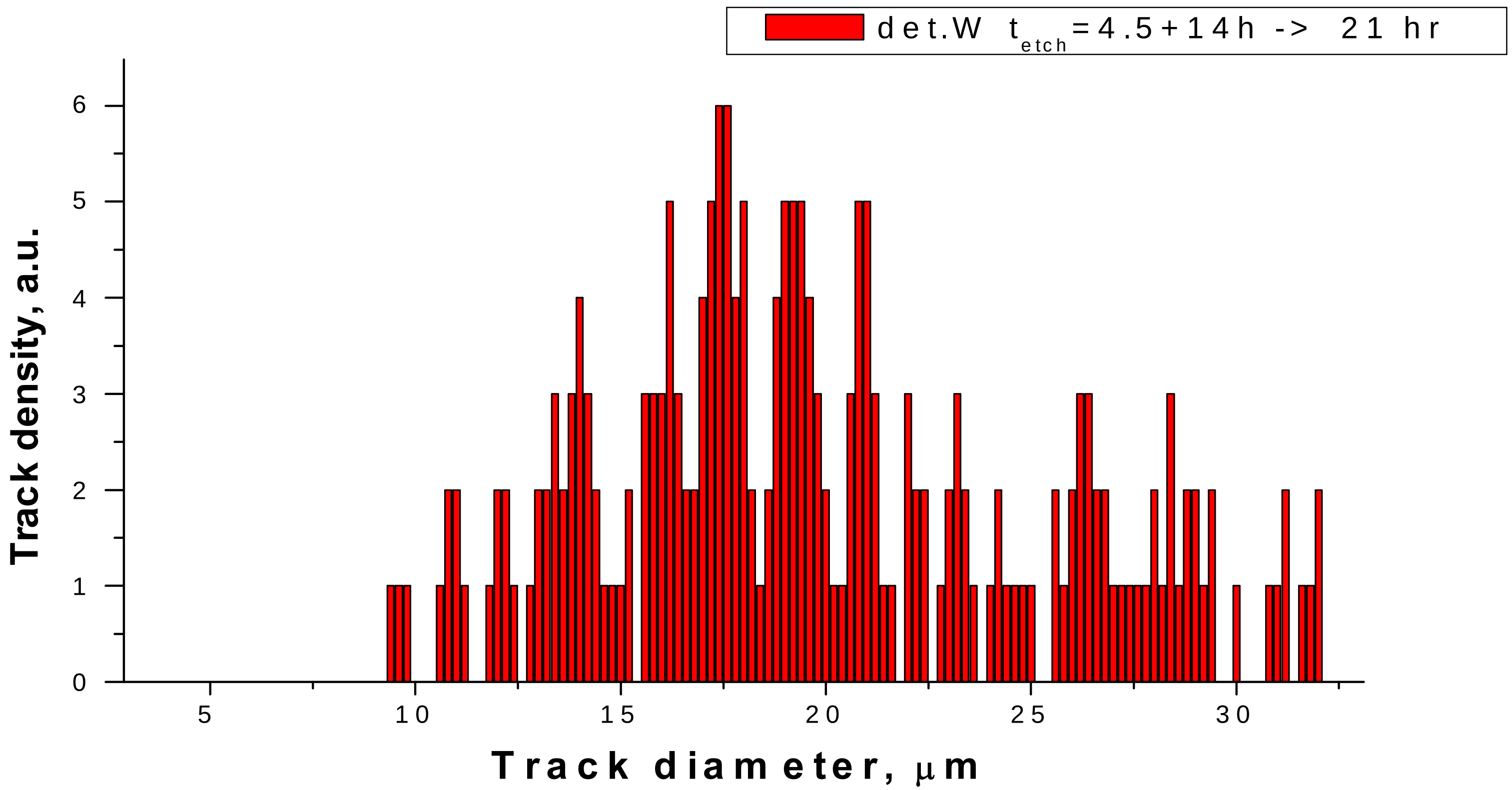


Individual track diameter distribution for Winthrop's Foreground detector #2 after additional 7 hr (4.5 hr + 7 hr -> 14 hr) etch in 6N NaOH solution at t =70 C

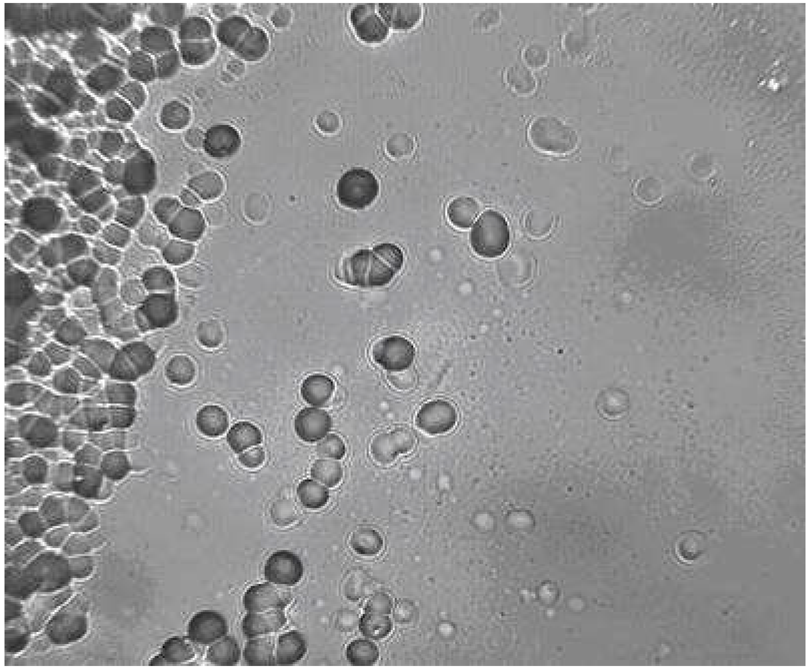
(equivalent to our etch time t = 14 hr)

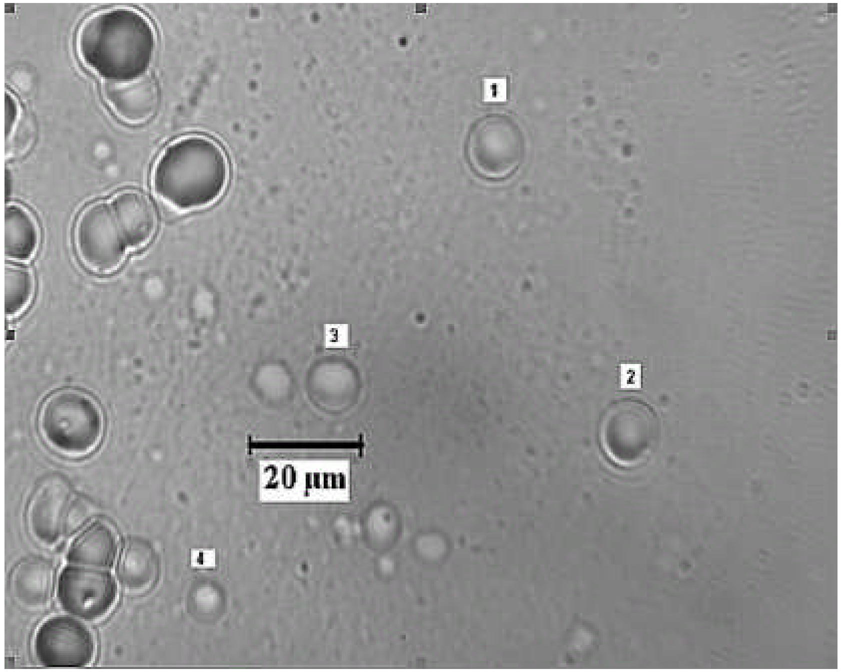


Individual track diameter distribution for Winthrop's Foreground detector #2 after additional 14 hr (4.5 hr + 14 hr -> 21 hr) etch in 6N NaOH solution at t =70 C (equivalent to our etch time t = 21 hr).

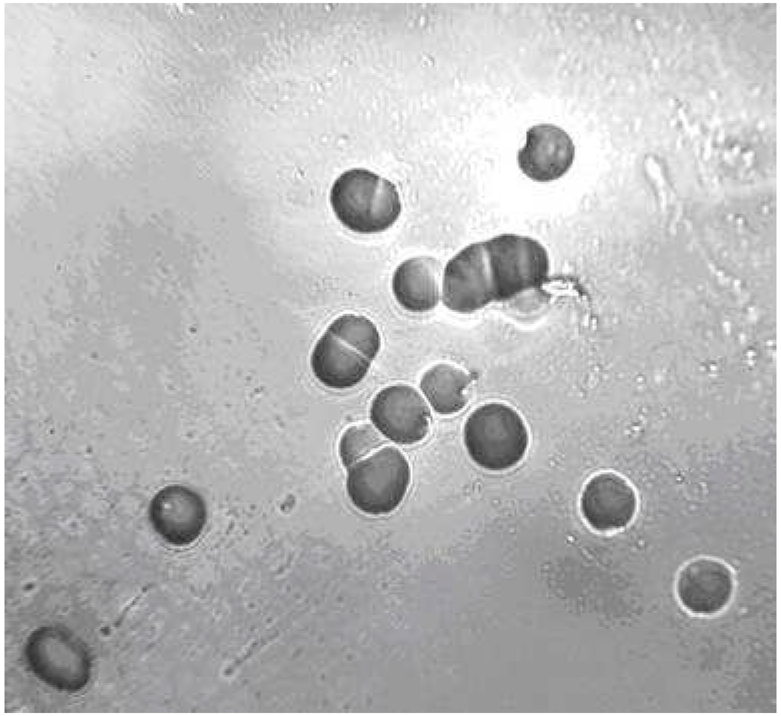


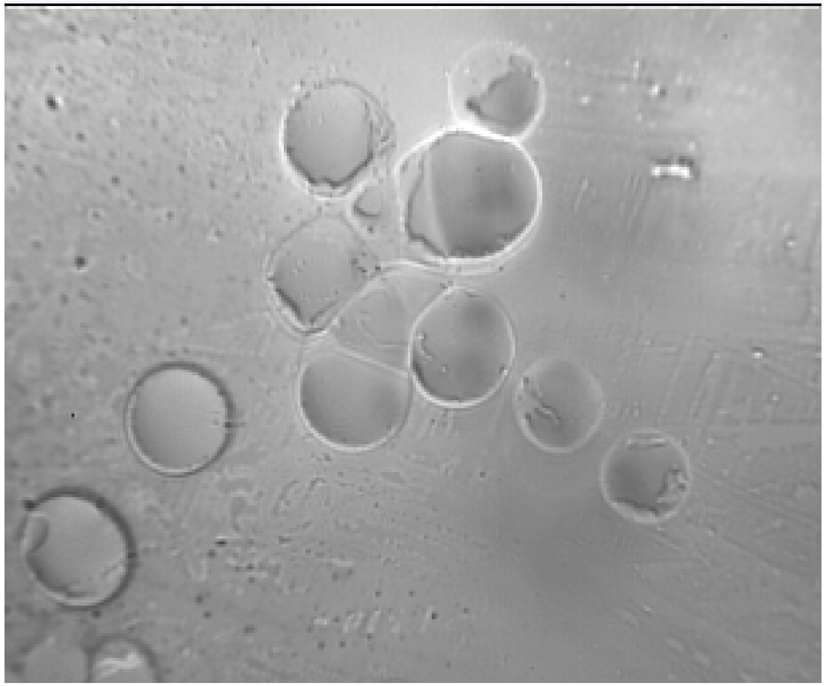
The image of the front side of the #2 detector with the fixed coordinates [x,y] = [1028, 1075]; etch time is t =7 hr (a). The same area with the higher magnification (x3) ; the individual selected pits 1-4 of the right (in terms of smoothness) shape with the size ranging of 5-12 micron are indicated (b).





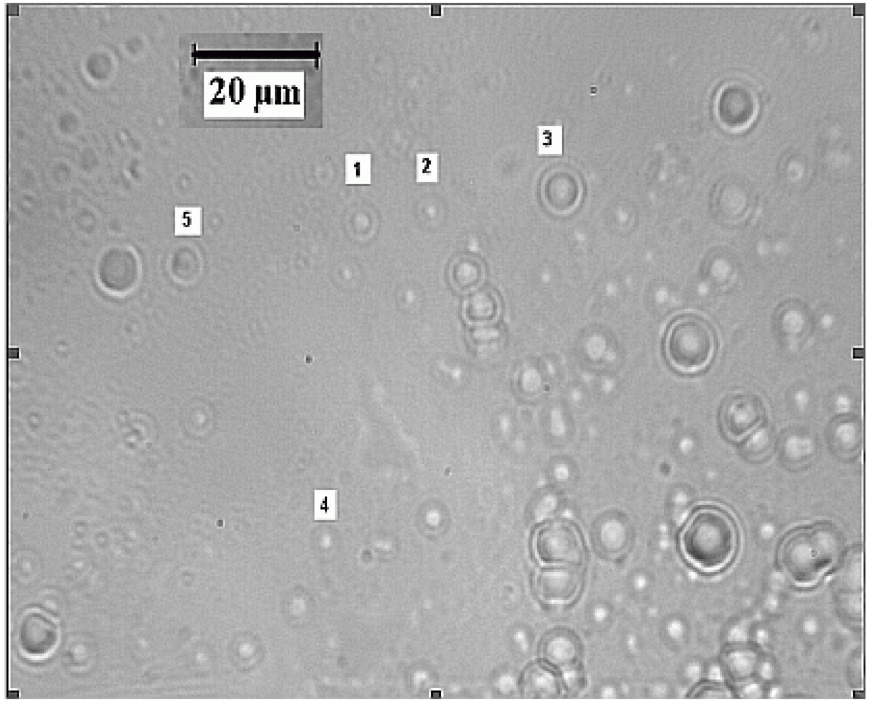
The images of the [1270,160] spot after 7 hr (a) and 28 hr (b) etch. Large diameter pits (d ≥ 20 μm at t= 7hr)) cannot be considered as alpha particles because this requires d ≤ 12 μm. It is well seen that the pits have low etch rate. Indeed, their diameters increase only by factor 1.5-2 during etching

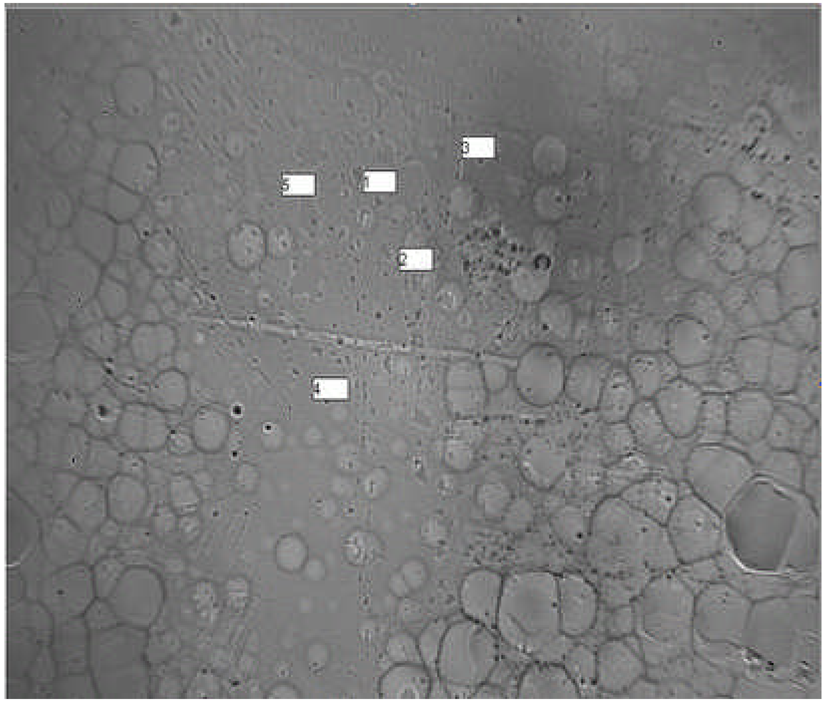




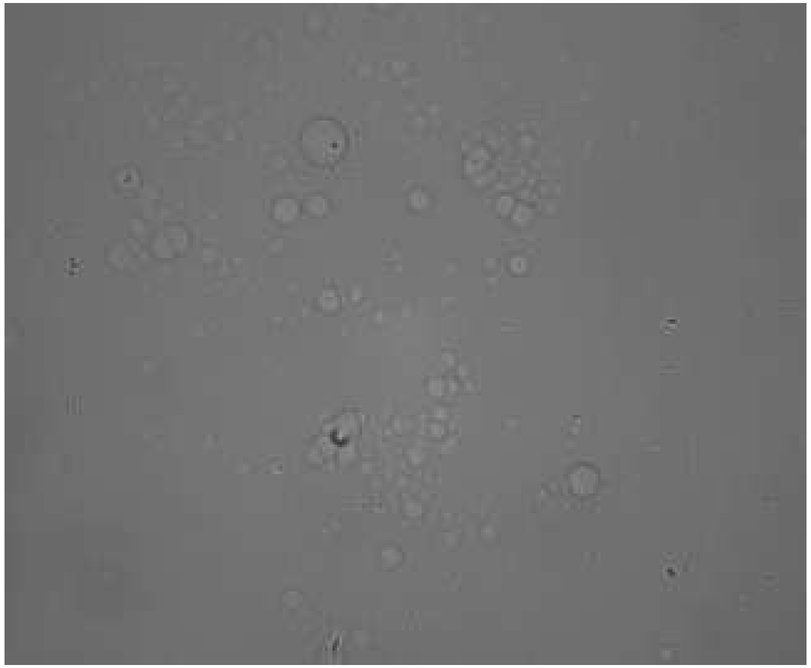
The images of the [663,435] spot at etch time t = 7(left), and 28 (right) hr; the individual selected circular pits 1-5 of the right (in terms of smoothness) shape with the size ranging of 5-12 micron are indicated. With increase of removed depth, majority of pits

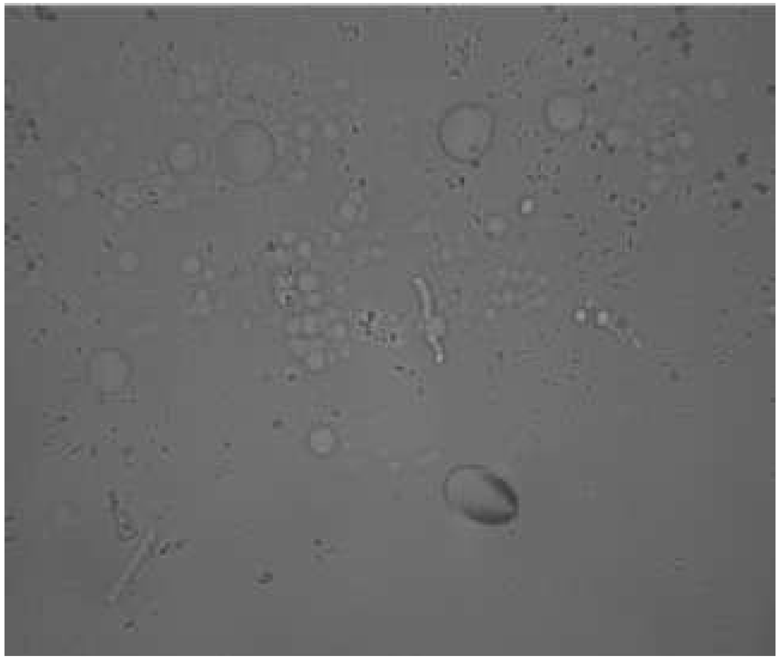
lose contrast and become of the sharp angle (noncircular) shape.



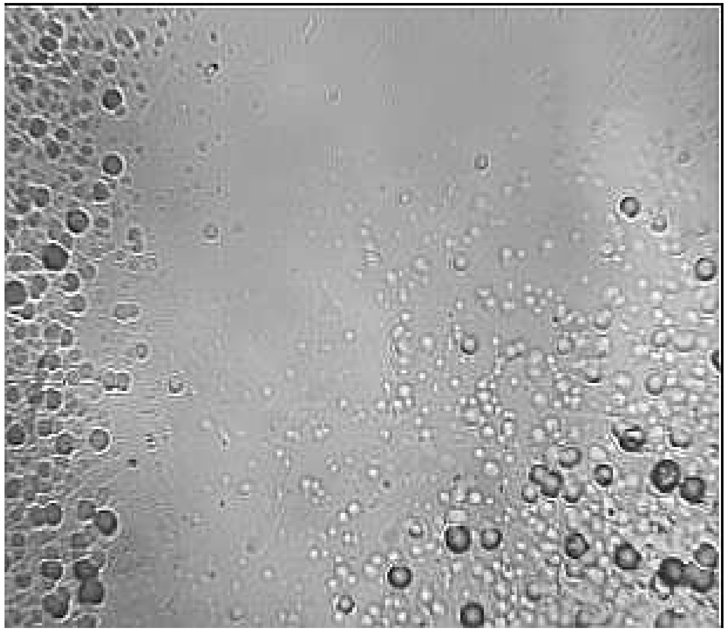


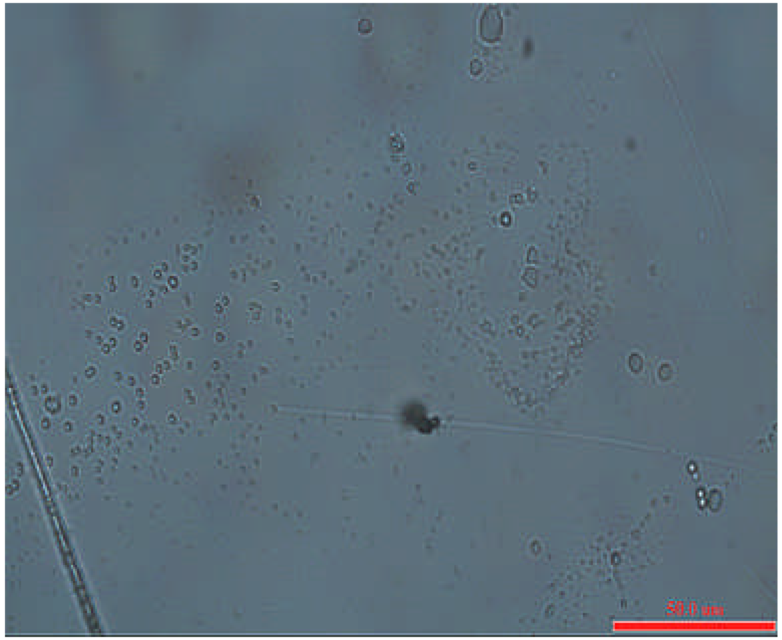
The images (a) and (b) show track simulation with the corona-discharge. The used Landauer CR-39 detector was irradiated during 5 min in corona-discharge in air atmosphere and then etched during t = 7 hr. The pits (including overlapping) absolutely similar to the pits at #2 detector (with diameters in the range 2-20 micron)





#2 detector image containing a lot of small pits (d < 4 μm)-left:; Track simulation with mechanical stress –right: the 200 μm Pt wire is attached tightly to the surface of the Landauer CR-39 detector (scratch in the left corner of the image) for 2 days before etching. Etch time is t=7 hr.





Quantitative information on the origin of the pits (of the right shape and size) selected in the spots [1028, 1075] and [663,435]

- The dynamics of etching reflecting the track etch rate allows to unambiguously identify the type and energy of nuclear particle.
- The etch rate in the track is determined by function $v_t = \partial L/\partial t$ (where L – is the track length). Noting that L = D/2 tg δ, where δ = const (at vt = const) is the local developing angle of the track (see the Figure above), we obtain that $v_t = A\,(\partial D/\partial t)$, where A – is the const.
- Thus, the slope of track diameter function vs. etch time t would effectively reflect the etch rate of the pit.
- similar procedure of track identification, involving the comparison of selected track dynamics with that of alphas and protons with appropriate track diameter, was already demonstrated in our previous works (see A.S. Roussetski et al, Proc. ICCF-12, Japan, 2005).

Illustration of development for normal incidence track

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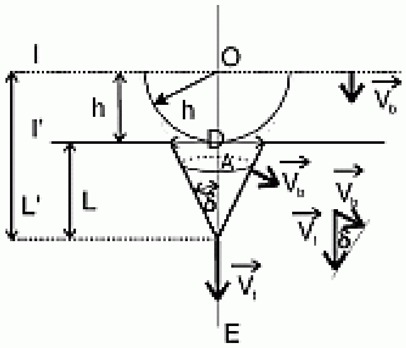
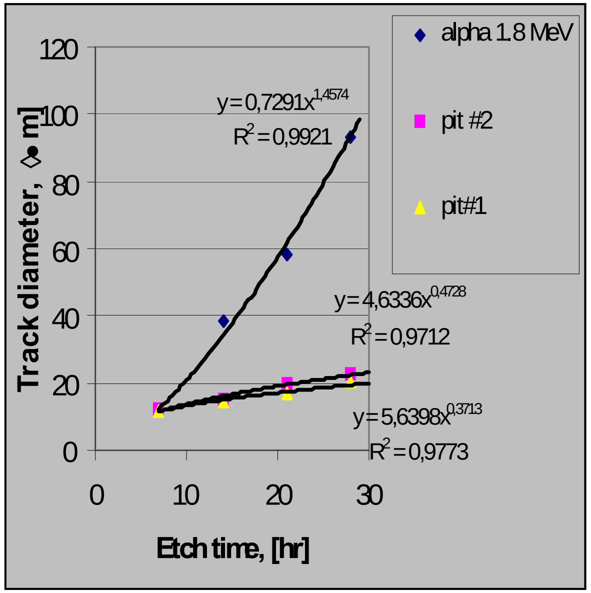
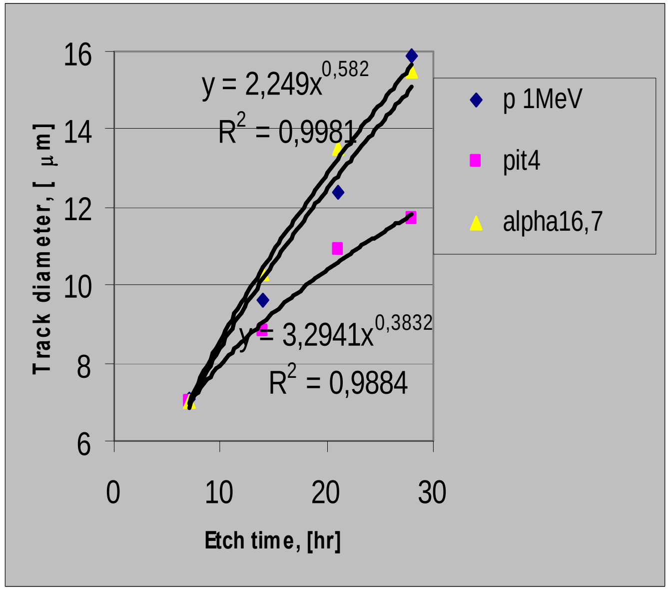
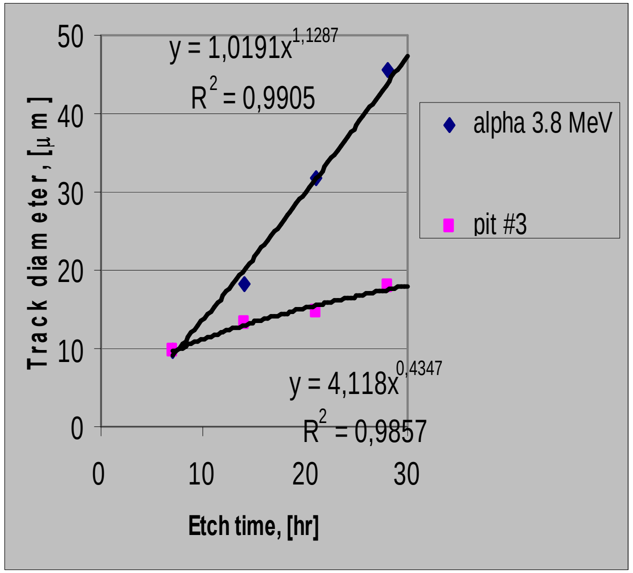


Fig. 1. Geometry of the track development. The incident angle is normal with respect to the detector surface, and V_t is constant.

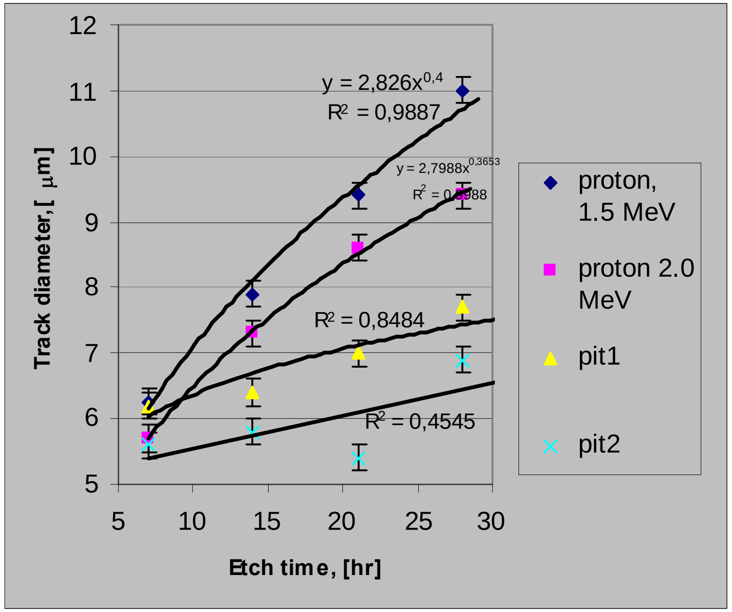
Graphs of the etching dynamics for each selected pit 1-4 from the [1028,1075] spot and for appropriate nuclear particles (with the same initial diameter); the slope of the pits 1-4 is about factor of 2 - 6 less than that for appropriate nuclear particles.

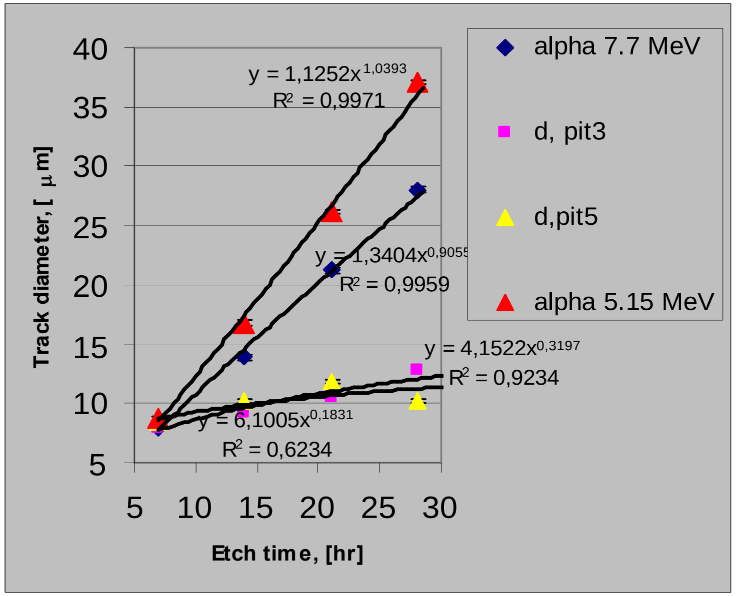






Etch dynamics for pits 1-5 from the spot [663,435] as well as for appropriate nuclear particles (p-protons, a – alphas) of the same initial diameter. As seen, the slope of the pits 1-5 is about factor of 2 - 10 smaller than that for appropriate nuclear particles





Etch dynamics analysis results

- All analyzed pits from both spots show the effective slope of dD/dt function the factor 2-10 smaller than corresponding alpha/proton tracks having the same initial diameter as the selected pits. Moreover, the dD/dt function of the pits cannot be satisfactorily fitted by power function (in most cases $R^2 < 0.98$) that normally describe charged particle diameter growth during etching in-depth.
- These findings unambiguously suggest that those selected pits has lower etch rate (inside the "track") than the nuclear particles producing the tracks of the same initial diameter at t = 7 hr.
- Thus, these selected pits of the right shape and size consistent with the nuclear particle tracks cannot be ascribed to the tracks of nuclear particles.

Conclusions I

- High density overlapping pits near the scratch from the cathode wire. During the etch in depth these pits loose their smooth circular shape (which is a signature of nuclear particles) and a contrast. The last factor indicates that these pits are shallow.
- No significant pit concentration has been found at the back side of #2 detector, indicating absence of neutron emission from the cathode.
- The individual analyzed pits show three groups of diameters: $D < 5$ μm, $D > 12$ μm and 5 μm $< D < 12$ μm at etch time equivalent to $t = 7$ hr. The first two groups, according to our calibrations, cannot be ascribed to proton and alpha particles. The group with $D < 5$ μm is totally disappeared after 14 hr etch, indicating shallow surface defects. The group of pits with $D > 12$ μm also cannot be ascribed to heavy nuclear particles (Li^6 or heavier ions) because contrary to heavy ions these pits demonstrate very slow dynamics of their diameter growth.

Conclusions II

- Almost no elliptic shape pits were found among the both overlapping and individual tracks , suggesting absence of the projectile particles with oblique incidence. This is not really possible in case of the source of these particles is placed at the cathode wire attached to the CR-39 surface.
- The group of pits with appropriate minimal diameter (5 μm < D < 12 μm) consistent with protons and alpha tracks at etch time t = 7 hr do not demonstrate track etch rate required for those nuclear particles. The etch rate for these pits is 2-10 times lower indicating that radiation destruction of CR-39 material inside the pits is significantly less than that from the nuclear particles.
- The similar high density pits of various diameter range can be successfully simulated by corona discharge and mechanical stress indicating massive defect generation at the surface of the CR-39 detector with attached wire. Application of magnetic/electric field would only enhance the pit formation due to enhancing mobility of charged defects.

Acknowledgements

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