

Correct identification of energetic alpha and proton tracks in experiments on CR-39 charged particle detection during hydrogen desorption from Pd/PdO:Hx heterostructure

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Introduction

Earlier experiments have showed emissions of energetic charged particles (α -particles and protons) during exothermic H desorption from the Pd/PdO:Hx heterostructures. The occurrence of these emissions was confirmed by independent experiments using both Si-surface barrier and CR-39 plastic track detectors. Earlier we already showed that purified CR-39 plastic track detectors can be considered as an adequate scientific instrument, which suitable for detection of individual uniformly distributed charged particles and also for the groups of these particles being emitted from the active spots (“hot zones”) attributed to the maximum internal strain area at the surface of PdD_x and TiD_x samples. The analysis of CR-39 data showed that in some cases energetic charged particle tracks (α -particles and protons) concentrated inside the small spots of detector. The typical “hot zone” with ~200 tracks within the area with the size of 0.2x0.5 mm² were found to be appeared during the hydrogen desorption experiments with Pd/PdO:Hx samples.

- In present work we demonstrate the advance of track detection technique allowing to perform an unambiguous identification of CR-39 tracks in order to obtain full information about type and energy of detected particles as well as to distinguish them from usual background events and surface defects.

PAVICOM – completely automated device for track detector processing

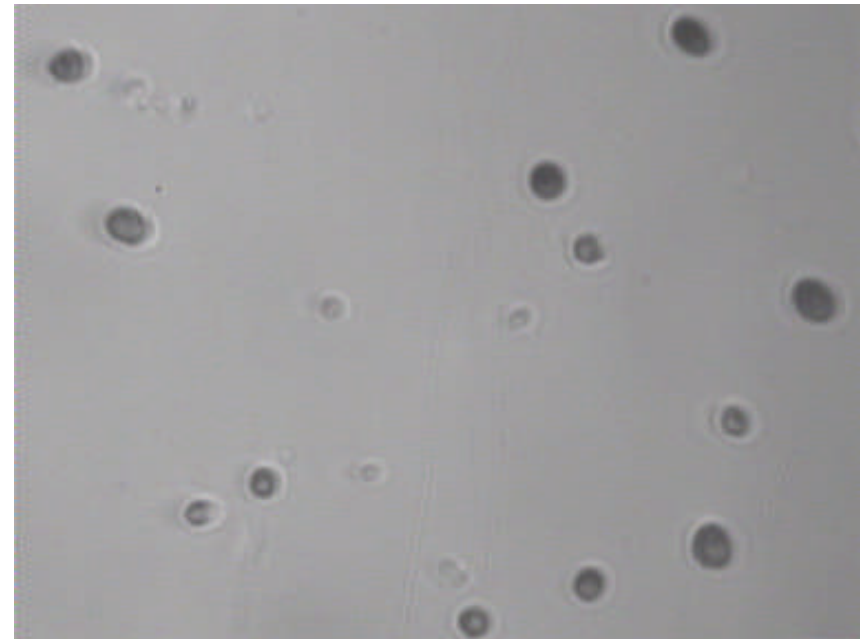
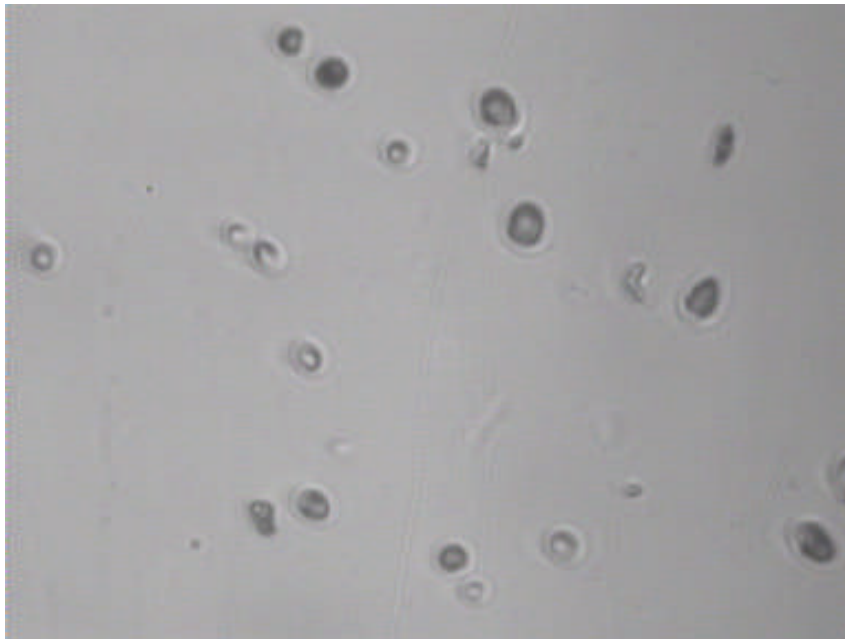


**CR-39 measurement after electrolysis of Pd/PdO:H_x
(50 μm)**

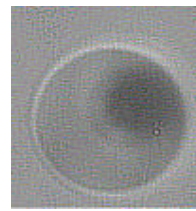
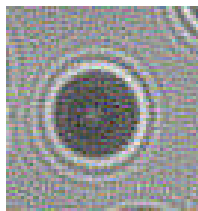
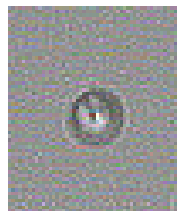
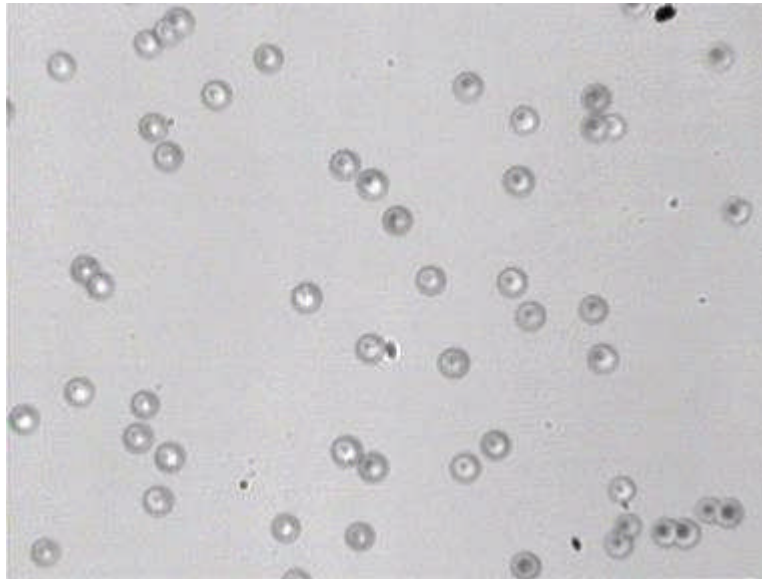
Shielding of CR-39 – 11 μm of Al

**Photomicrographs of “hot zone” (250x500 μm²) with
tracks of α-particles and protons**

Image size – 120 x 90 μm



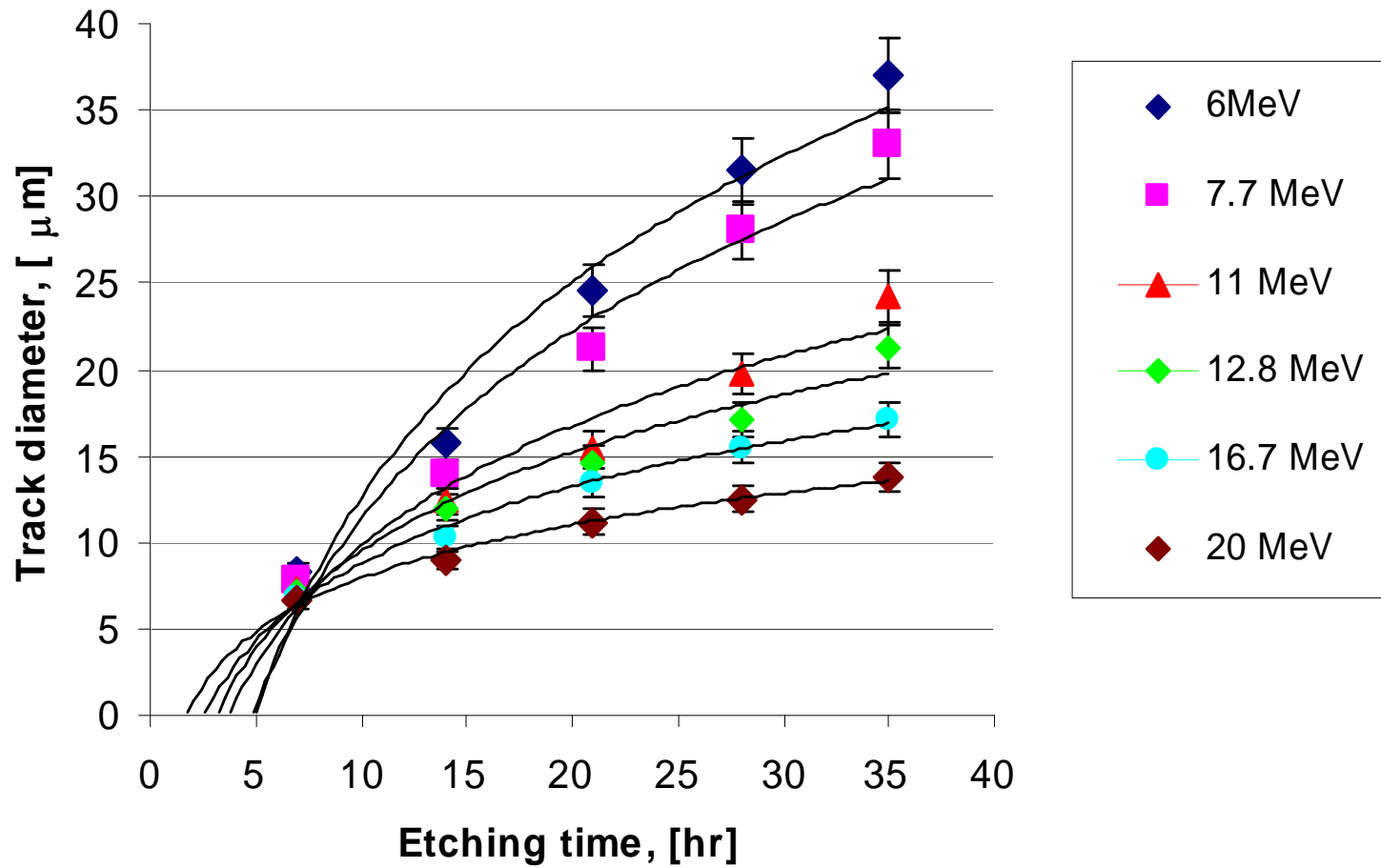
**Tracks from α -particle cyclotron beam (E_{α}
= 11 MeV) normally incident on CR-39 detector.
Image size – 120 x 90 μm**



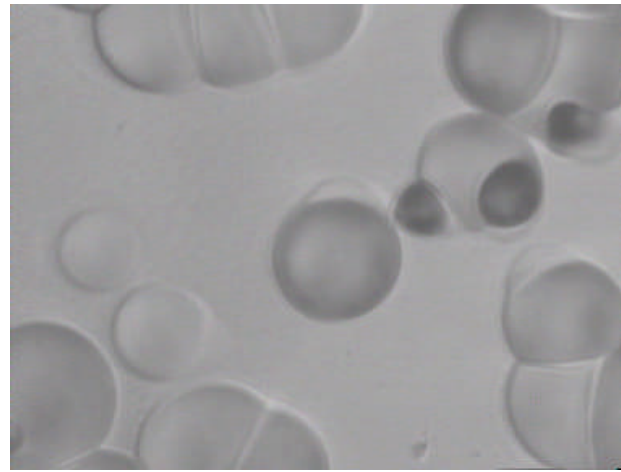
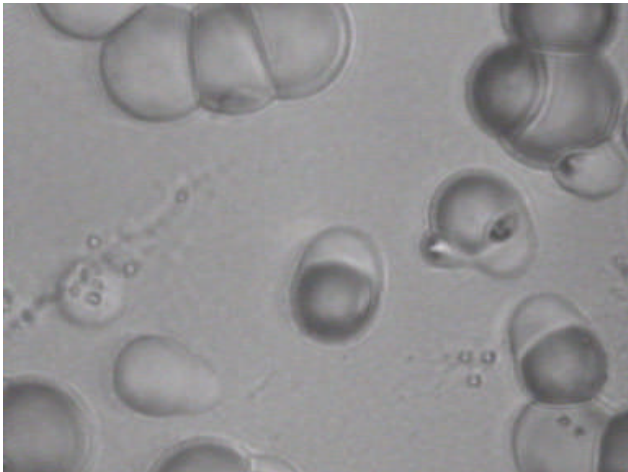
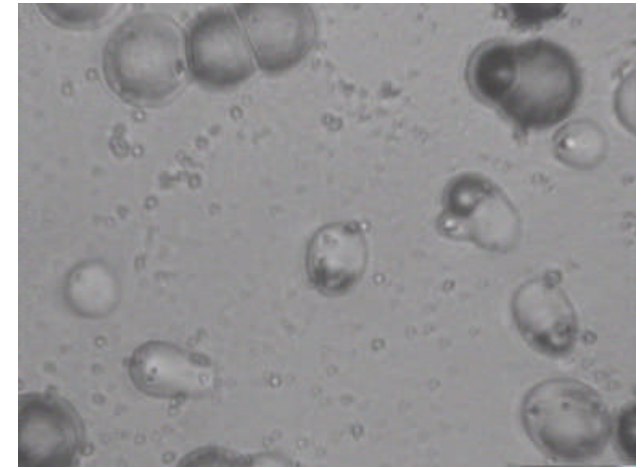
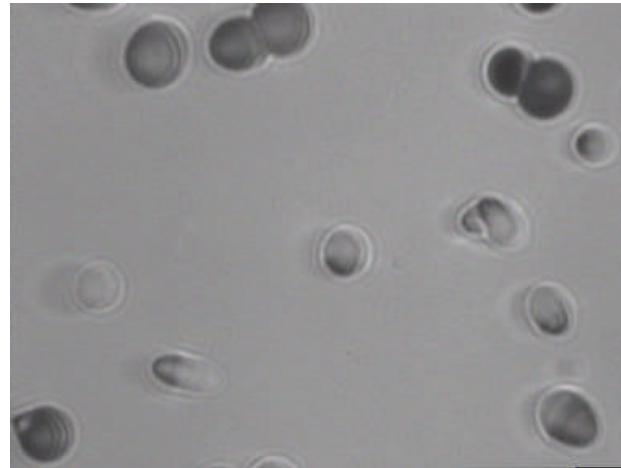
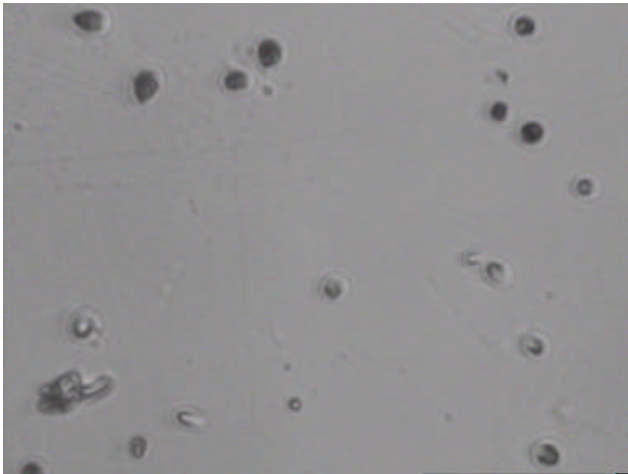
11 MeV alpha track
etch dynamic

- 1) t = 7.0 hr 2) t=14.0 hr 3) t=21 hr 4) t=28 hr 5) t = 35 hr.

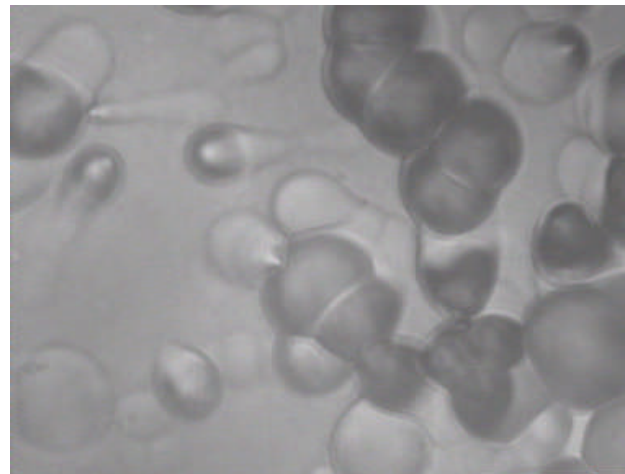
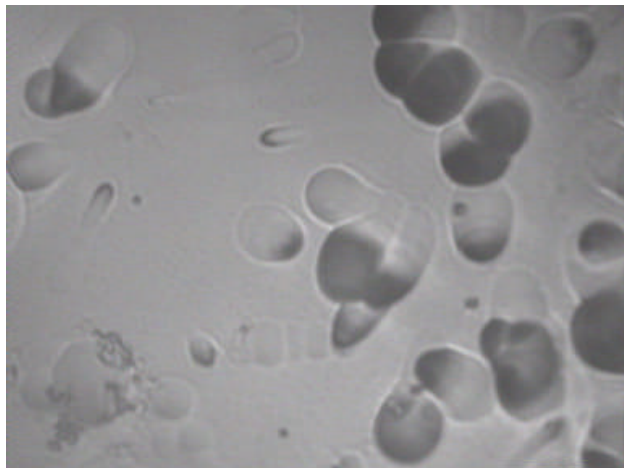
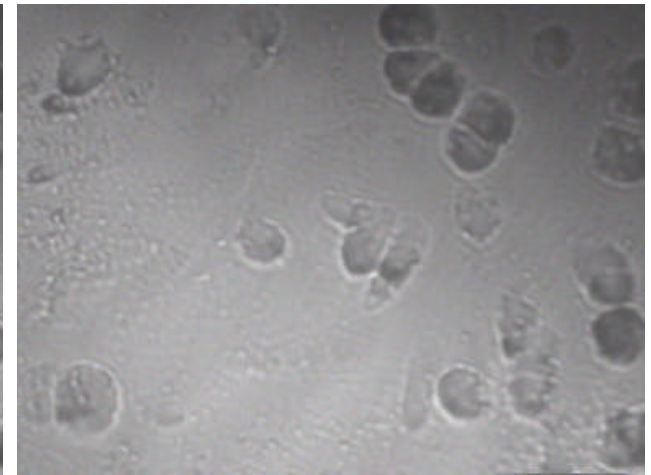
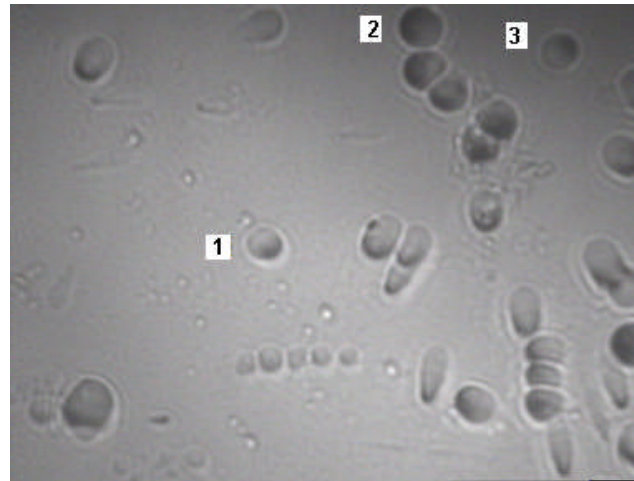
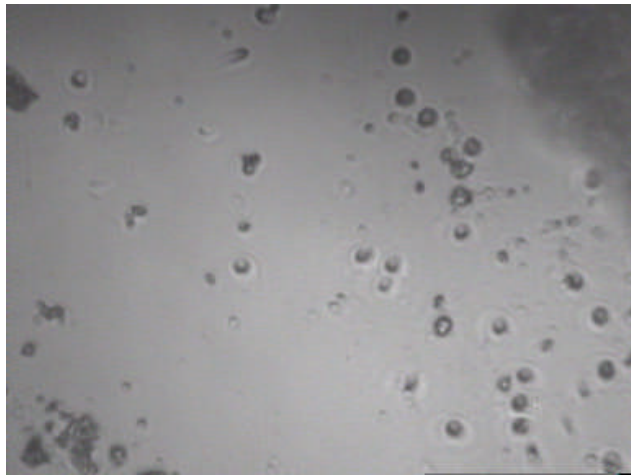
Track diameter vs. etching time for 6-20 MeV alpha calibration and their fit with logarithmic functions



Hot zone: the spot with coordinates: [-433,-2285],
track etch dynamic at etching time – 7, 14, 21, 28 and 35 h.



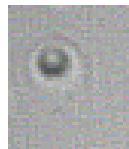
Hot zone: the spot with coordinates: [-71, -1972]
track etch dynamic at etching time – 7, 14, 21, 28
and 35 h.



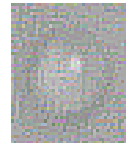
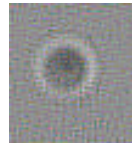
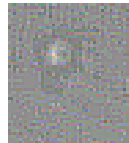
Examples of comparison proton calibration track etch dynamic with that of proton candidate



1 MeV Proton
calibration



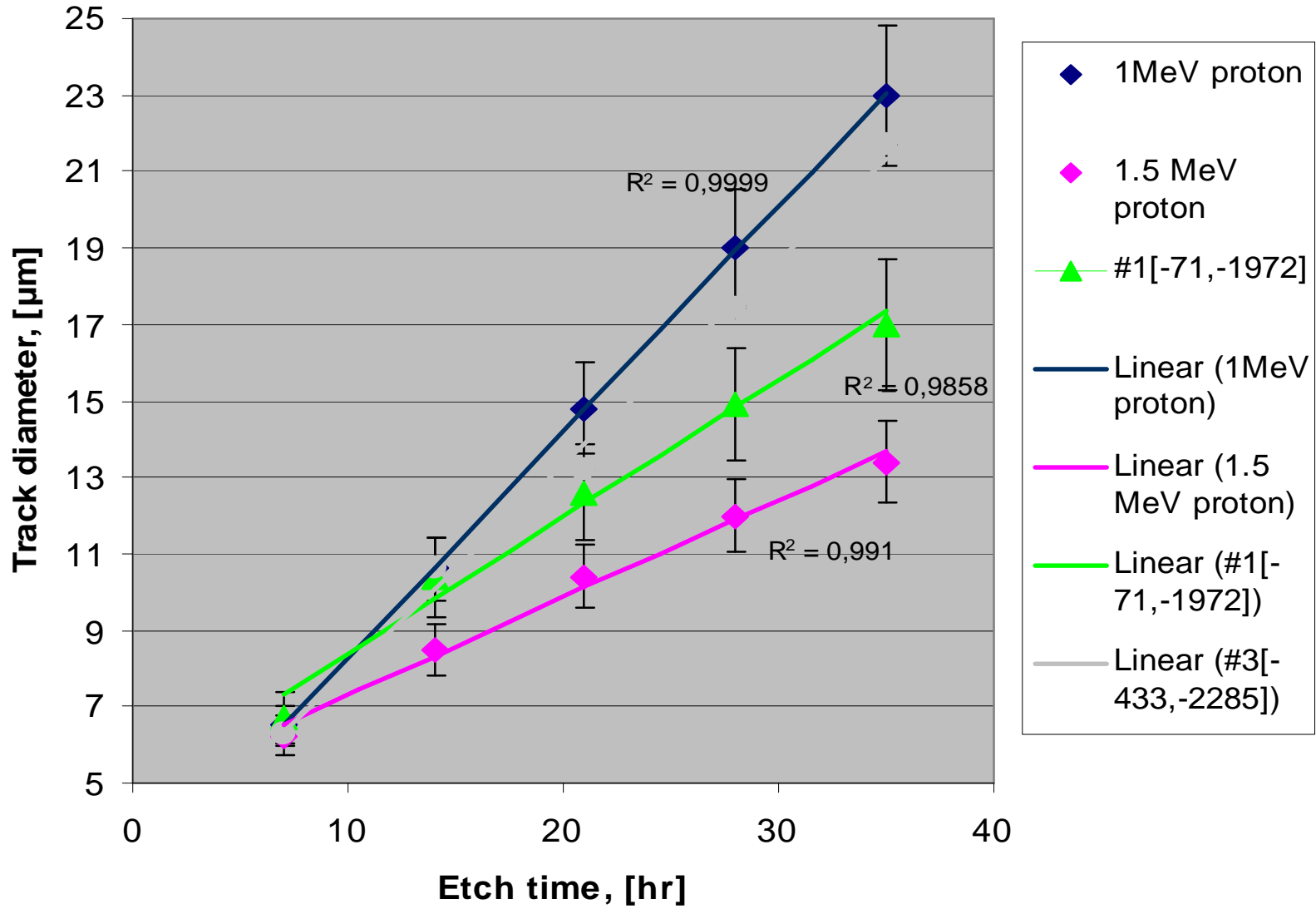
[-71;-1972], track#1
proton



1.5 MeV Proton
calibration

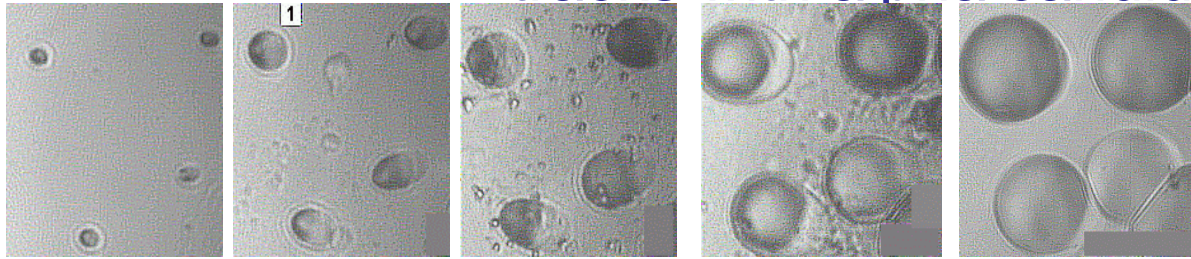
•1) t = 7.0 hr 2) t=14.0 hr 3) t=21 hr 4) t=28 hr 5) t = 35 hr.

Track diameters vs. etch time: proton-like tracks

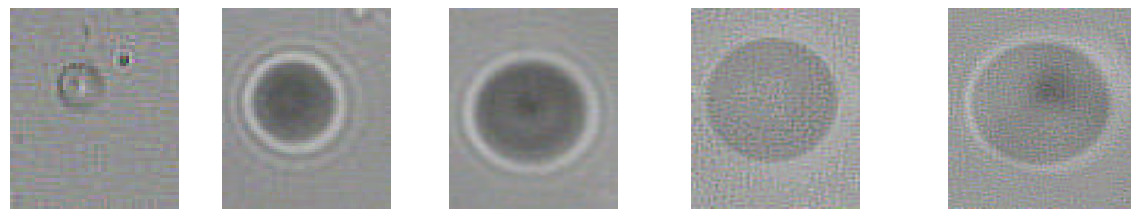


Example of comparison 11 and 12.8 MeV alpha calibration

tracks with alpha candidate



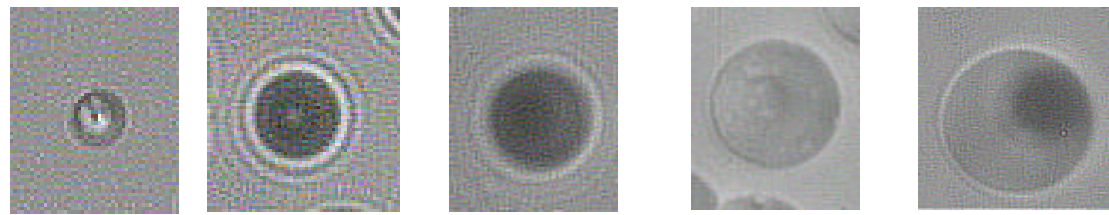
the spot [-116,-1621]
-4 track group



12.8 MeV alphas



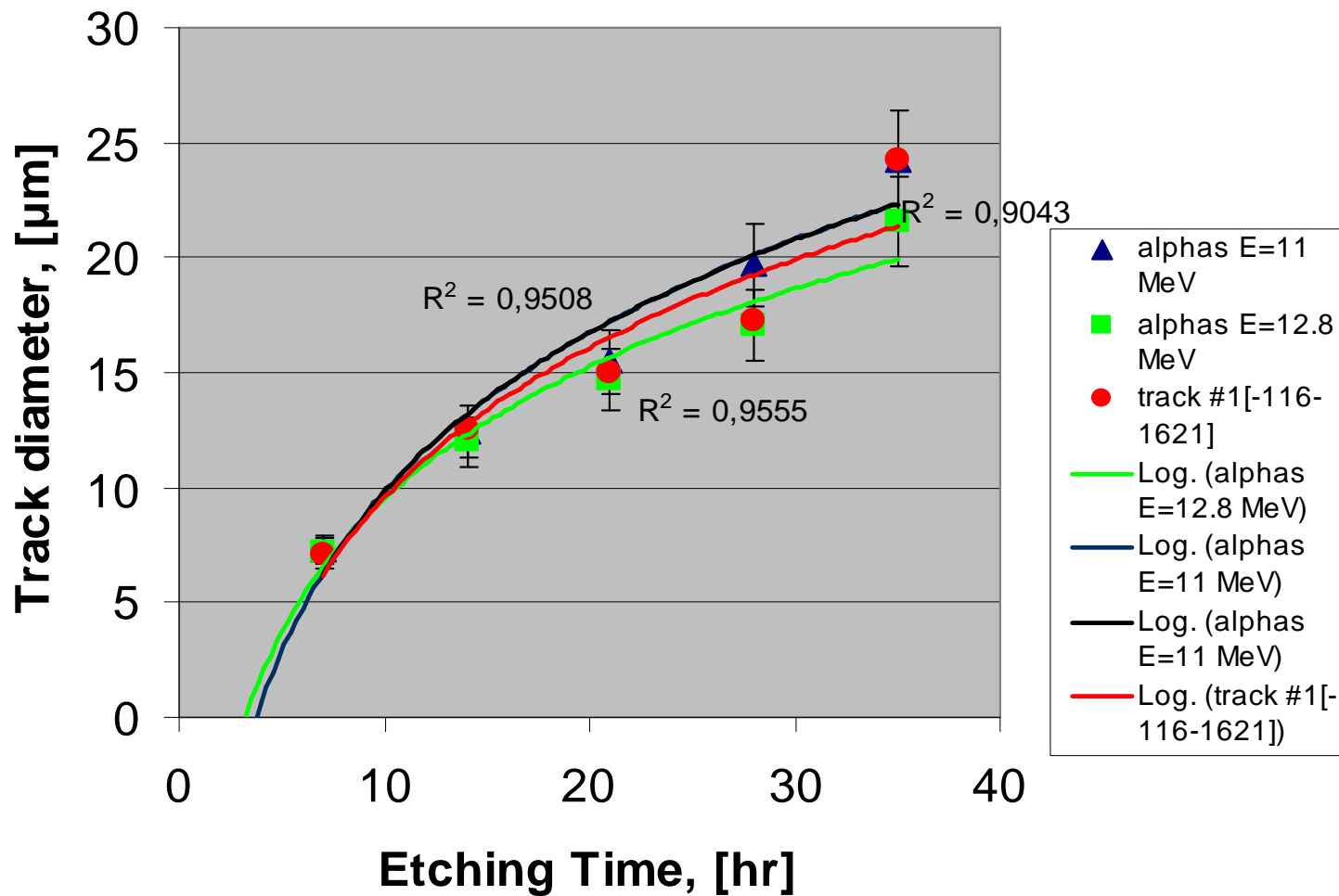
track #1 [-116,-1621]



11 MeV alphas

1) t = 7.0 hr 2) t=14.0 hr 3) t=21 hr 4) t=28 hr 5) t = 35 hr.

Comparison of track #1 [-116, -1621] etching dynamics with that for 11 and 12.8 MeV alphas



The dependence of track etch rate V_t vs. track diameter D and removable depth h for normal incidence

- In simple model of track etch dynamic

$$D = 2h [(V - 1)/(V + 1)]^{1/2}$$

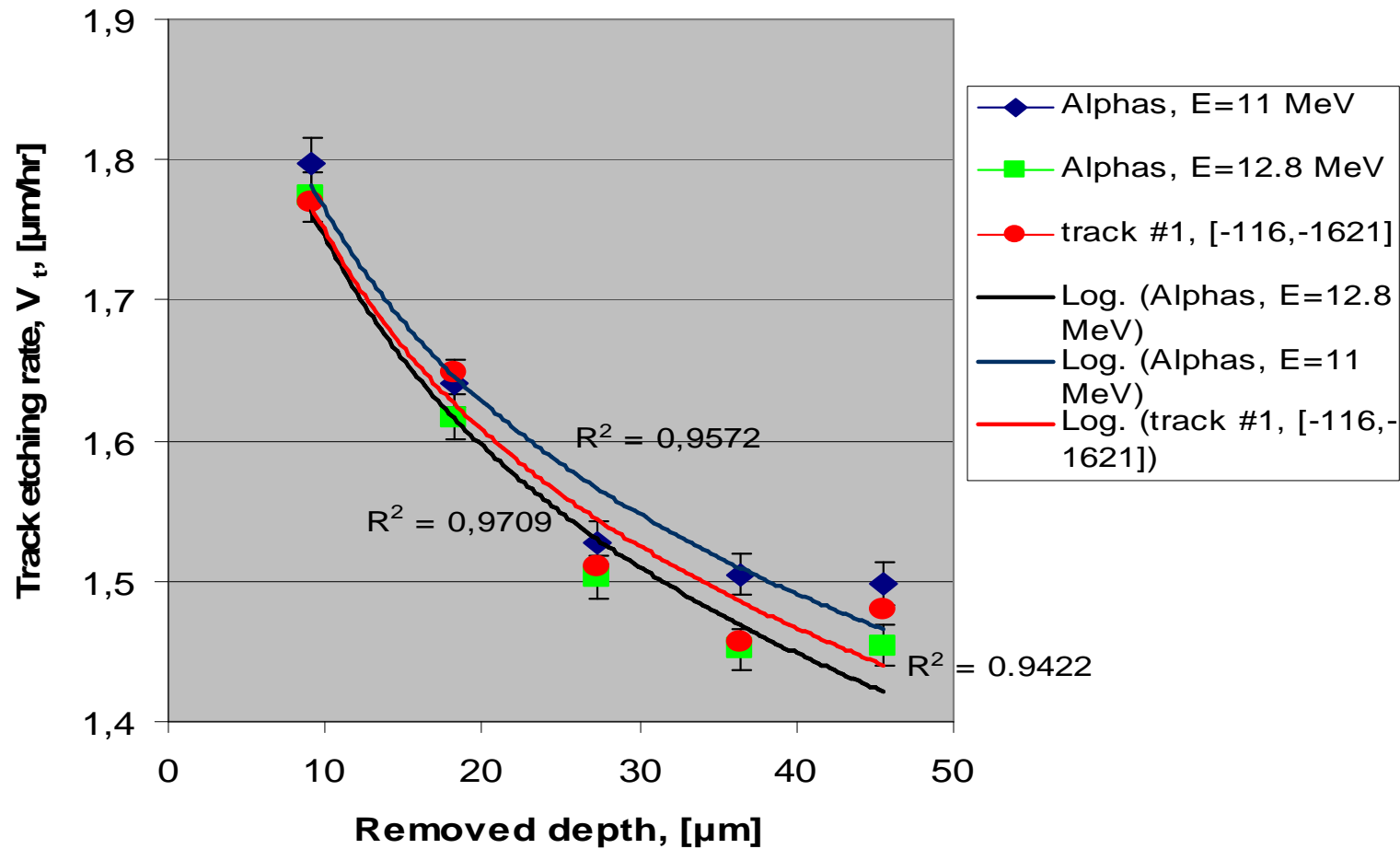
$$V = V_t / V_b - \text{track etch ratio}$$

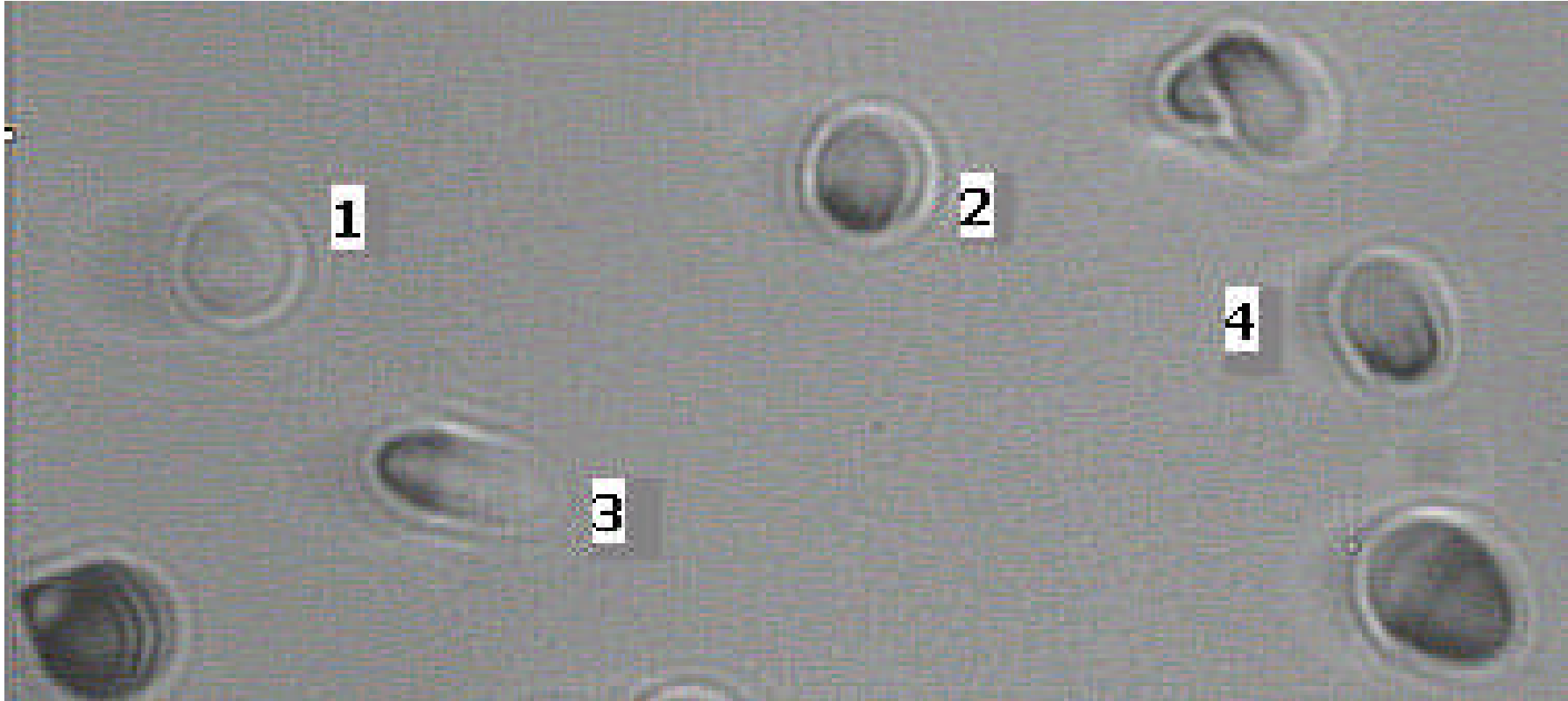
$$V_b = 1.3 \mu\text{m/h} - \text{bulk etch rate for etching in 6N NaOH at } 70^\circ\text{C}$$

$$h = V_b t - \text{removed depth}$$

$$Vt / Vb = [(2h)^2 - D^2] / [(2h)^2 + D^2]$$

Rate of track etching V_t vs. removed depth of CR-39 for 11 and 12.8 MeV alphas and track #1[-116,-1621] at $V_b = 1.3 \mu\text{m/hr}$





Hot zone: the spot with coordinates: [-433,-2285]

Example of comparison 12.8 and 16.7 MeV track etch dynamic with that of alpha candidate

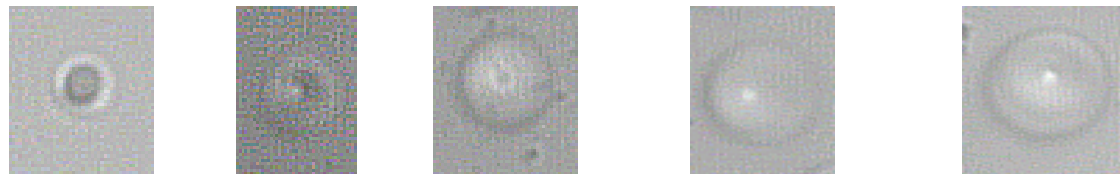
- 1) t = 7.0 hr 2) t=14.0 hr 3) t=21 hr 4) t=28 hr 5) t = 35 hr.



12.8 MeV alphas

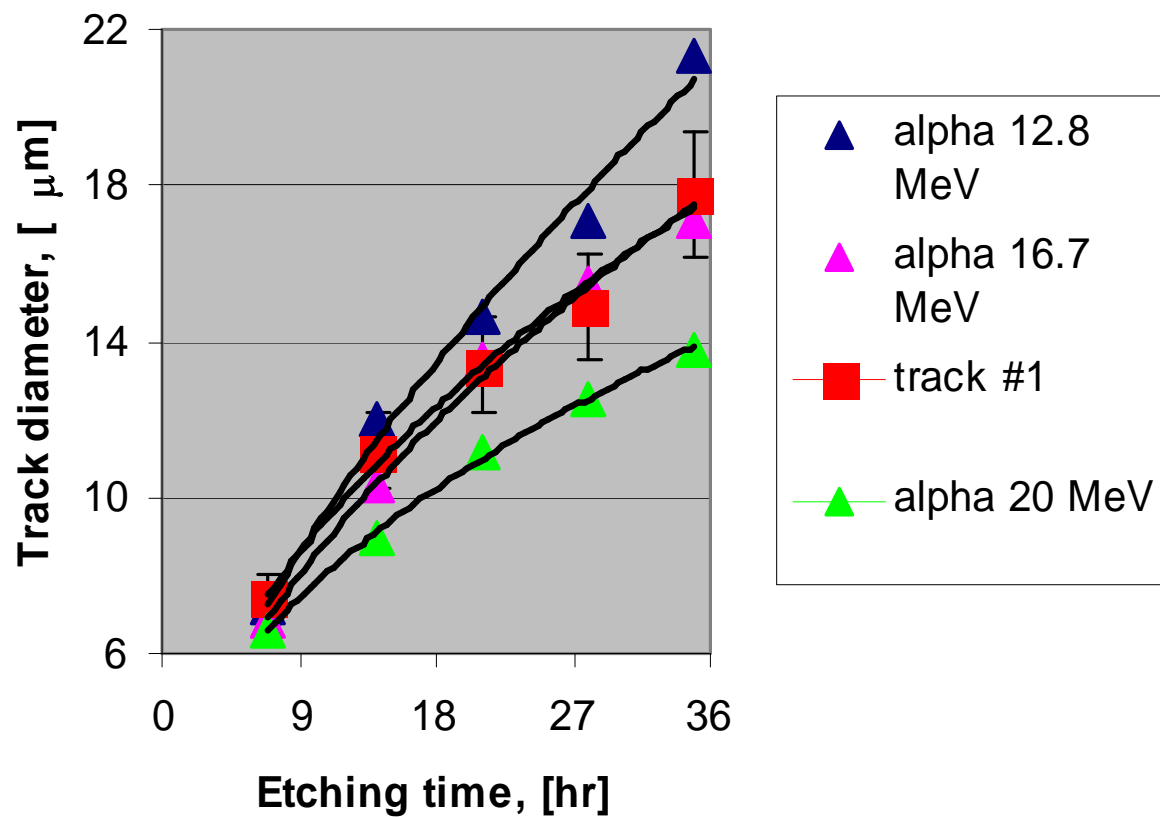


[-433;-2285], track #1

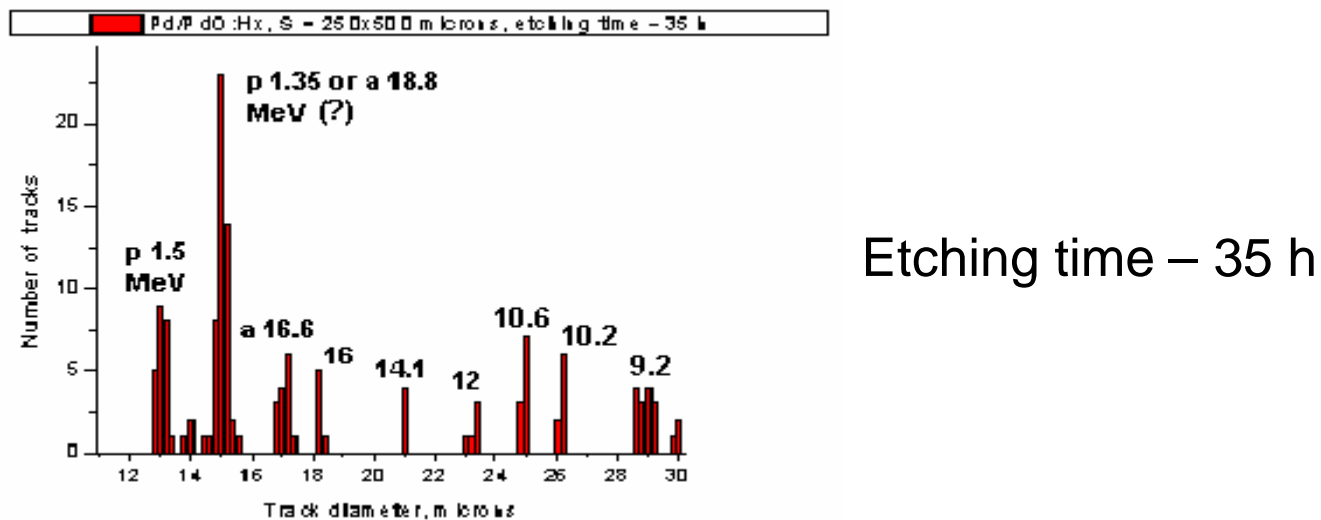
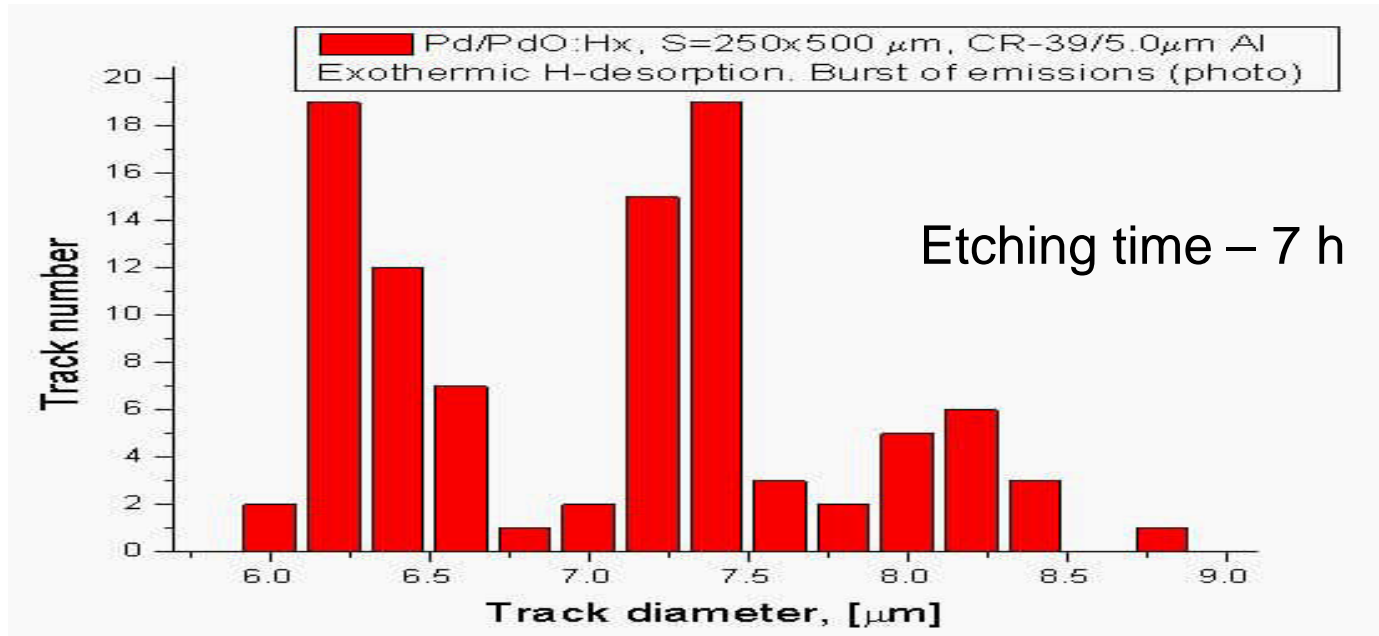


16.7 MeV alphas

**Track diameter vs. etching time: comparison
of high energy alphas and track #1[-433,]
kinetics: E(track#1) ~ 16 MeV**



Distributions of track diameters in “hot zone” (250 x 500 μm^2)



Take into account the shielding 11 μm of Al, we can to estimate the energies of primary particles:

- Alpha particles emitted with primary energies

10.4 ± 0.3 ; 11.6 ± 0.3 ; 13.0 ± 0.2 ;

15.0 ± 0.2 ; 16.7 ± 0.2 ; 17.4 ± 0.3 MeV

- Protons emitted with primary energy
~ 1.7 – 1.9 MeV

Conclusion

- We unambiguously identified tracks of as minimum 2 groups of alpha particles with energies 10 – 13 and 15 – 17.5 MeV. The emission of such alphas was previously measured by CR-39 detectors with different shielding.
- We confirmed the emission of protons with energies ~1.7 – 1.9 MeV during of exothermic hydrogen desorption from Pd/PdO:Hx samples.
- The comparison of track etch dynamic of calibration α 's and protons including functions $D = f(t)$ and $V_t = f(h)$ with that of individual tracks, unambiguously confirms the effect of energetic charged particle emission from surface of metals with high affinity to hydrogen.
- Method of track depth measurement to improve the energy resolution and separation different types of particles is on the way.