CR-39 TRACK DETECTORS IN COLD FUSION EXPERIMENTS: REVIEW AND PERSPECTIVES

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Introduction

Last few years it is popular to use CR-39 track detector for measurement of charged particle emission in CF-experiments. Using of CR-39 is quite simple and cheap, but this technique demand the observance of some necessary special conditions. It will be shown below, that the observance of these conditions allows not only detect charged particles but also identify their types and estimate their energy spectrum. On the other hand, it is necessary to note, that non fulfillment of these conditions may result in fails results, connected with detection of radioactive nuclides contained in surrounding materials (electrolyte, air, cathode etc.) or mechanical defects, developed after etching.

CR-39 TRACK DETECTOR

- **CR-39 is polymer ($C_{12}H_{18}O_7$) with density ~ 1.3 g/cm^3**
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Etching conditions: 6N NaOH solution at 70°C during 7 h.

- **$V = V_T/V_B = f\,(dE/dx)$ – etch rate ratio (V_T and V_B – track and bulk etch rates)**
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- **$\theta_c = \arc\sin(V_B/V_T)$ – critical angle of registration**
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- **$\eta = 0.5*(1 - \sin\theta_c)$ - detection efficiency**
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- **Fukuvi Chemical Industry Co and Landauer CR-39 with low background ($N_b < 20$ cm^{-2}) were used**

Necessary conditions for correct CR-39 measurement:

1. Purification of CR-39 detector surface;

2. Low density of background tracks before measurements (Landauer CR-39 – $N_b < 20\ cm^2$) and protection of CR-39 from external radioactive contamination

3. Correct calibration procedure;

4. Control of background in each measurement and using of “clean” materials (without radioactive nuclides);

5. Protection of detector surface from mechanical and thermo influences, high intensity UV irradiation;

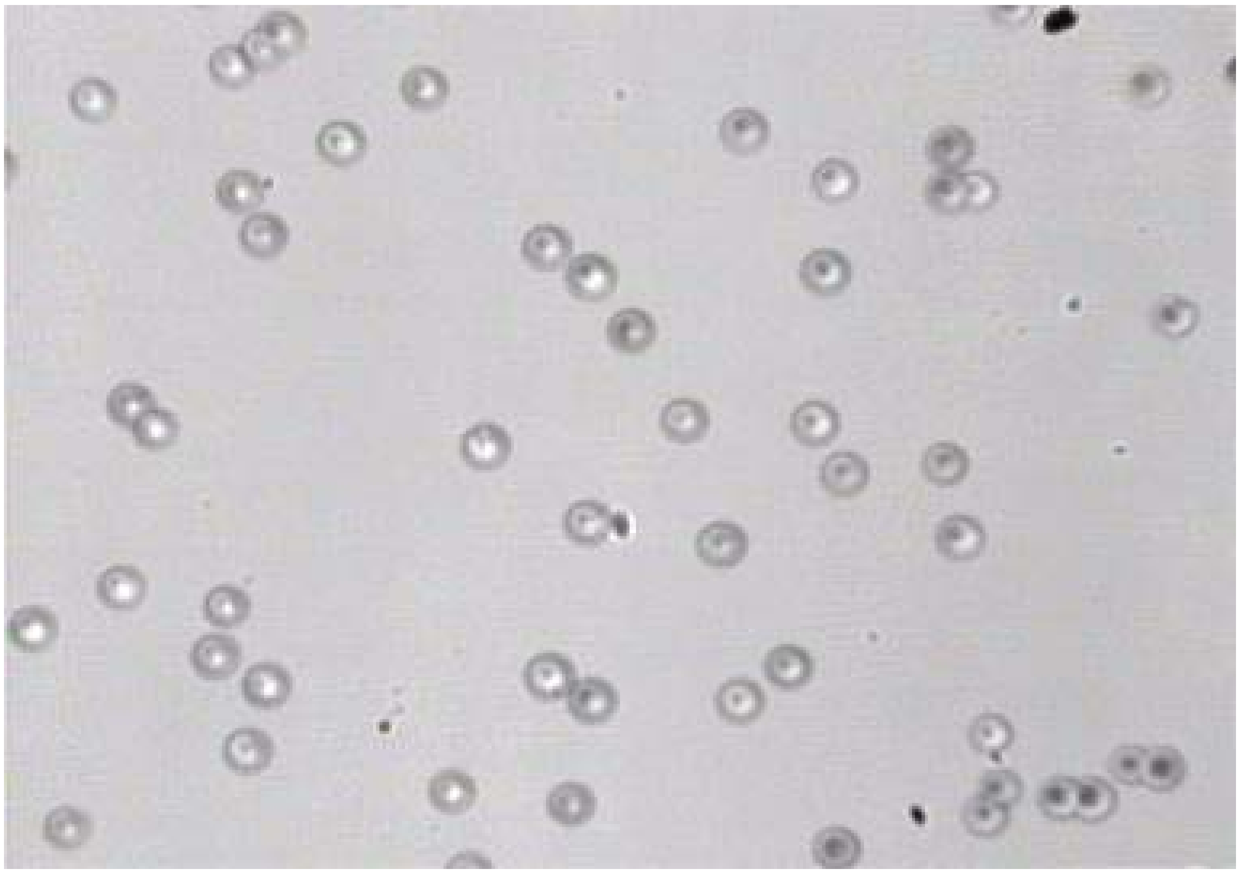
6. In special runs to use shielding foils with known stopping ranges to identify type of particles

7. Correct etching conditions in each measurement

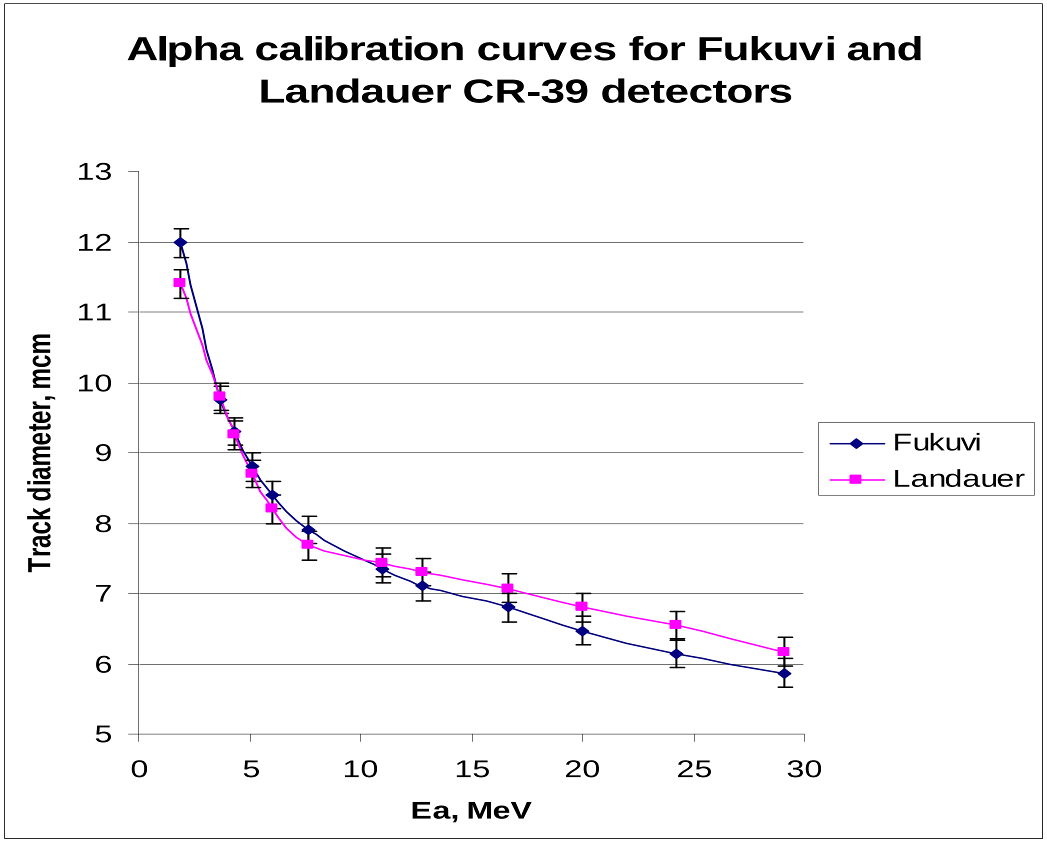
PAVICOM – completely automated device for track detector processing

Tracks from α-particle cyclotron beam (E_α = 11 MeV) normally incident on CR-39 detector.

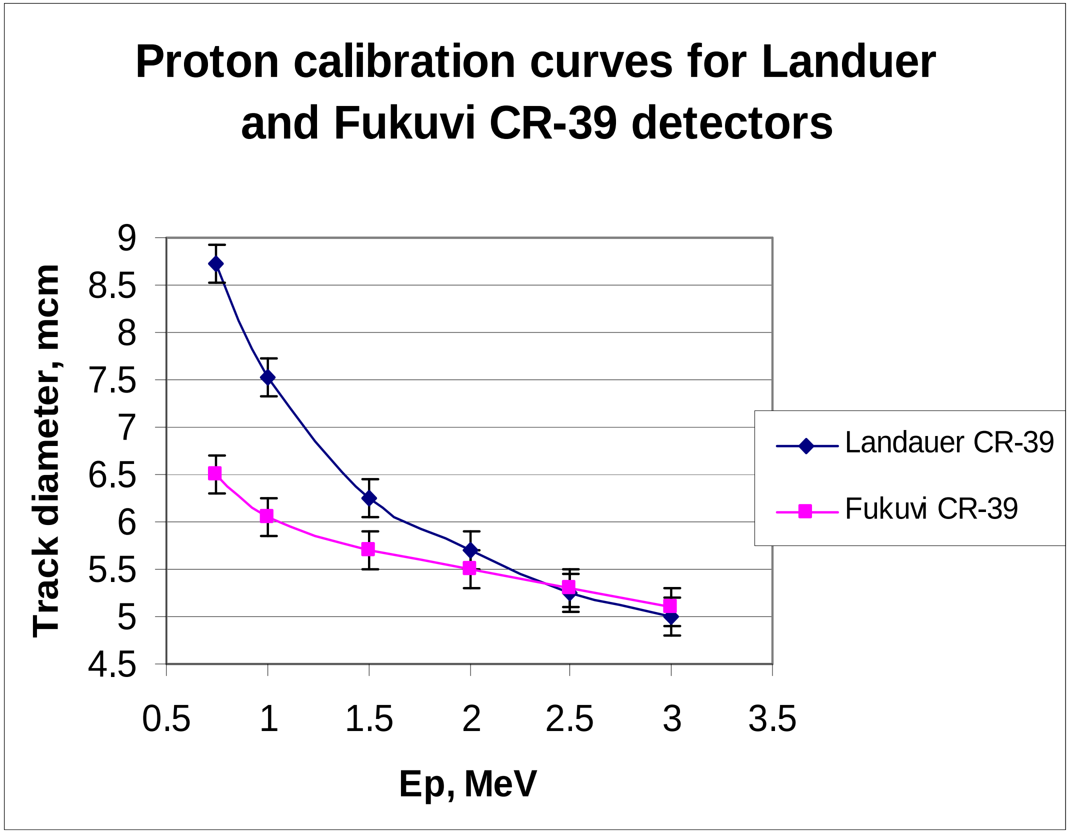
Image size – 120 x 90 μm



Alpha-sources and Cyclotron alpha beam calibration (2-30 MeV) of CR-39

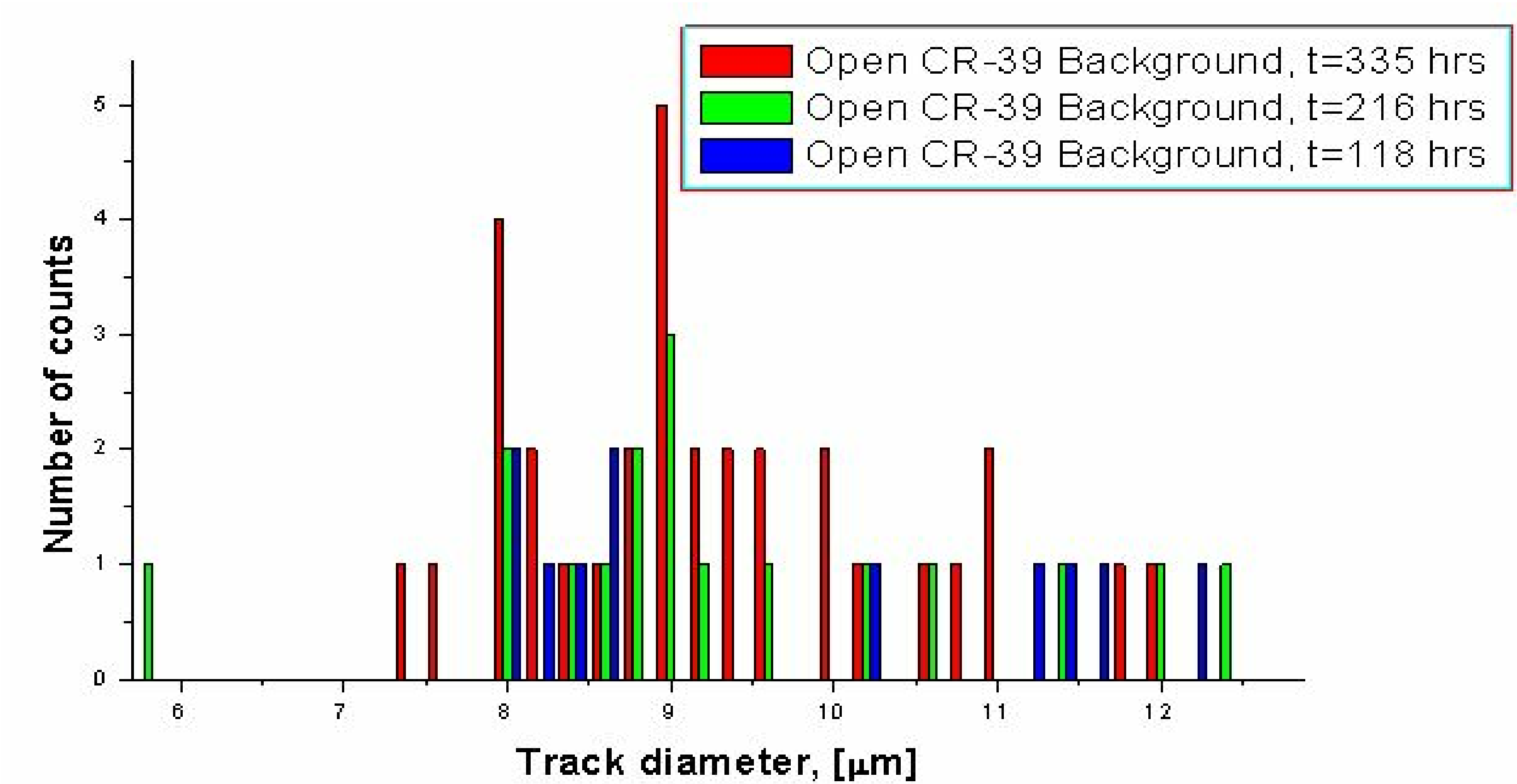


Proton Calibration with Van-DeGraaf accelerator (0.6-3.0 MeV)



Example of background during electrolysis in 0.1 M Li_2SO_4

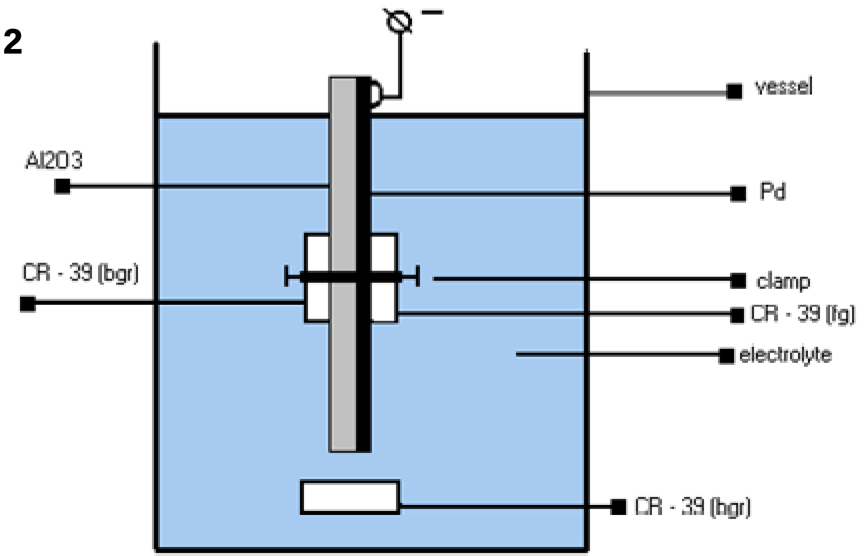
$\langle n_b \rangle = 2.7 \times 10^{-4}\ s^{-1}cm^{-2}$

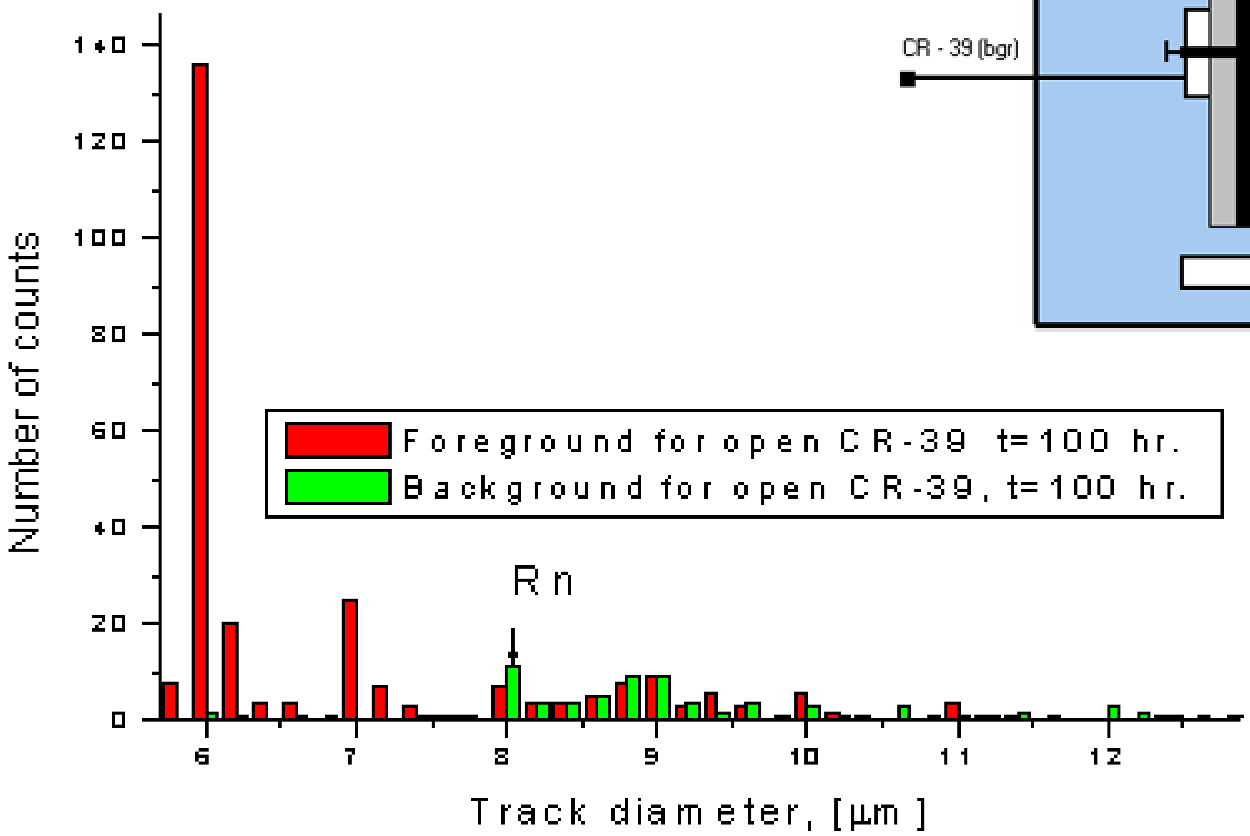


Histograms of track distributions with open CR-39 detectors: Pd/Al_2O_3 cathode in-situ electrolysis

$<n_p> = (1.15 \pm 0.10) \times 10^{-3}\ s^{-1}cm^{-2}$

$<n_\alpha> = (2.5 \pm 0.3) \times 10^{-4}\ s^{-1}cm^{-2}$.





Samples

- 1. Electrochemically loaded Au/Pd/PdO:D_x (1M NaOD/D_2O;
- j=20 mA/cm^2) heterostructure (40-60 μm thick): D-desorption
- (CR-39 measurements only after electrolysis).

- 2. Ti(30 μm), Pd(30 μm) cold worked foils
- and Pd/PdO (50 and 100 μm thick)
- CR-39 *in-situ* measurements (1MLi_2SO_4/H_2O, j=10 mA/cm^2).

- 3. Pd(30 μm) and Pd/PdO (50 μm thick) with He implanted
- $2*10^{17}$ and $2*10^{16}$ atoms/cm^2, respectively.
- CR-39 *in-situ* measurements (1MLi_2SO_4/H_2O, j=10 mA/cm^2).

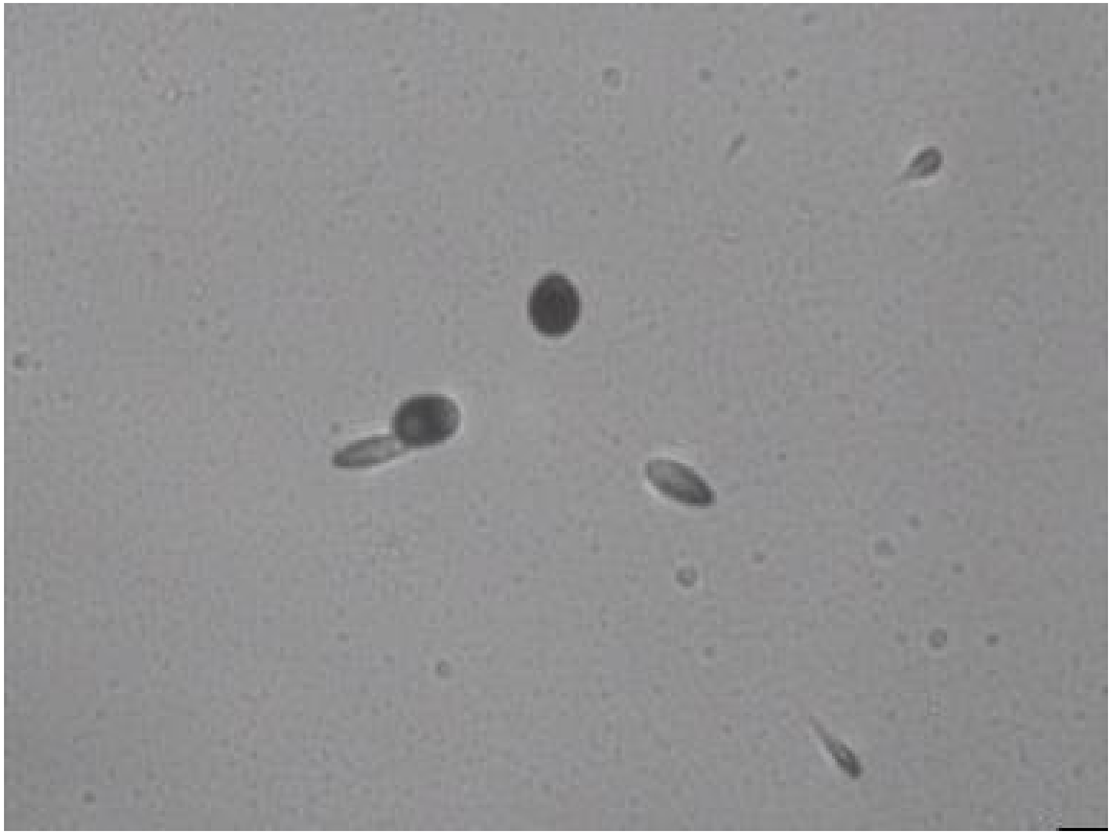
CR-39 measurements after electrolysis of Au/Pd/PdO:D_x.
Shielding of CR-39 – 50 μm of PE
Image size – 240 x 180 μm
7 α-particle emission from one point on the sample surface
Estimation of α-particle ranges in PE gives the energies:

$E_1 = E_2 = 11.2$ MeV;

$E_3 = E_4 = 9$ MeV;

$E_5 = E_6 = 8.3$ MeV;

$E_7 = 10$ MeV



CR-39 measurements during electrolysis of Pd (30 μm) in 1M Li_2SO_4 (j = 4-40 mA/cm^2); t_{exp} = 97.5 h
Shielding of CR-39 – 60 μm of PE
Image size – 120 x 90 μm
3 α-particle emission from one point on the sample surface

E_1 = 9.2 MeV;

E_2 = 9.1 MeV;

E_3 = 9 MeV

CR-39 measurements during electrolysis of PdHe (30 μm thick, $2x10^{17}$ He/cm^2) in 1M Li_2SO_4 (j = 4-40 mA/cm^2)
Shielding of CR-39 – 60 μm of PE
Image size – 120 x 90 μm
6 α-particle emission from one point on the sample surface

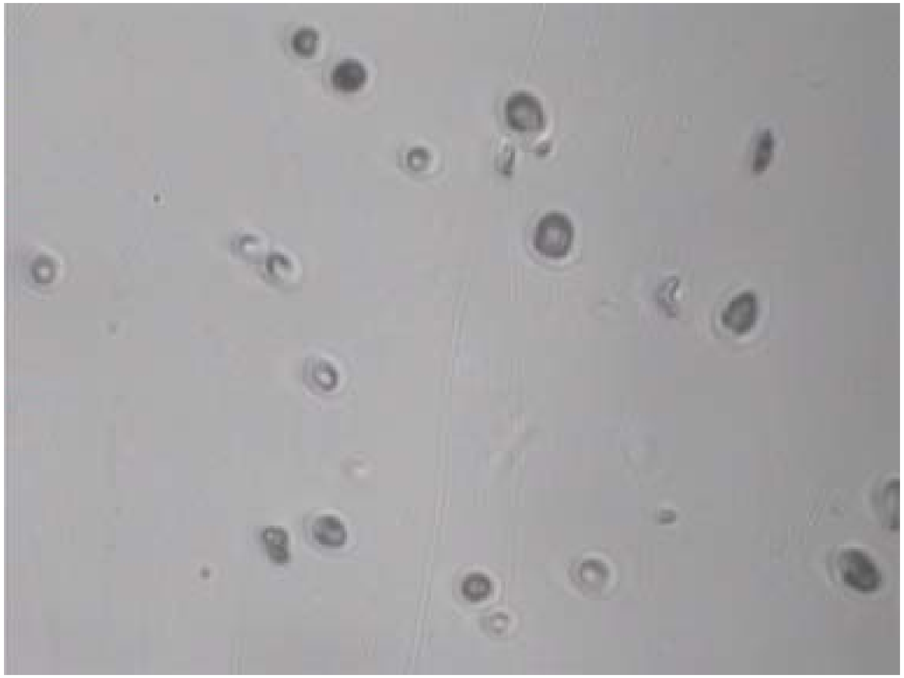
E_1 = 9.2 MeV;

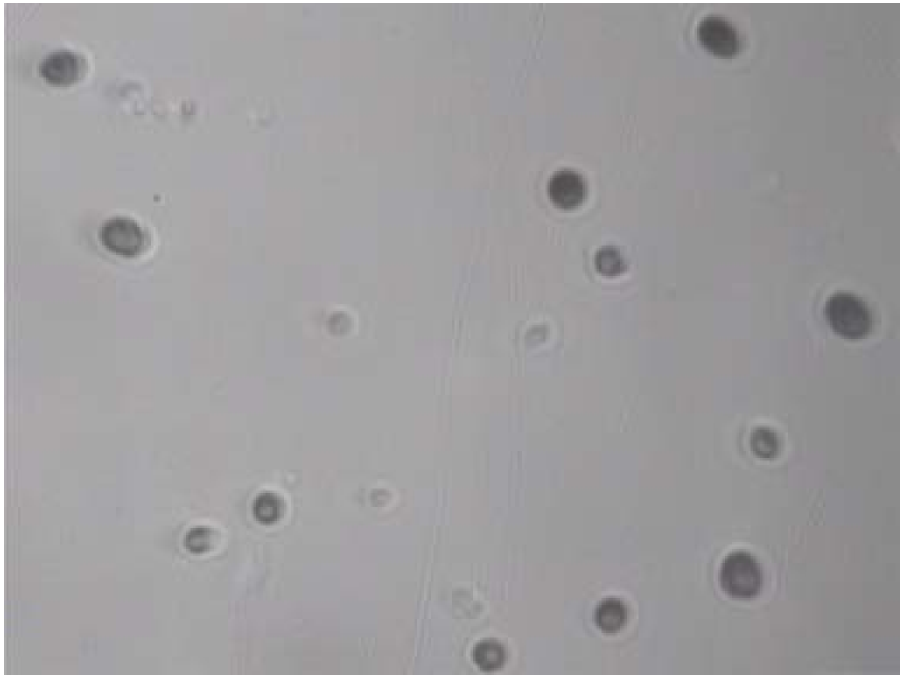
E_2 = 8.6 MeV

E_3 = 9 MeV;

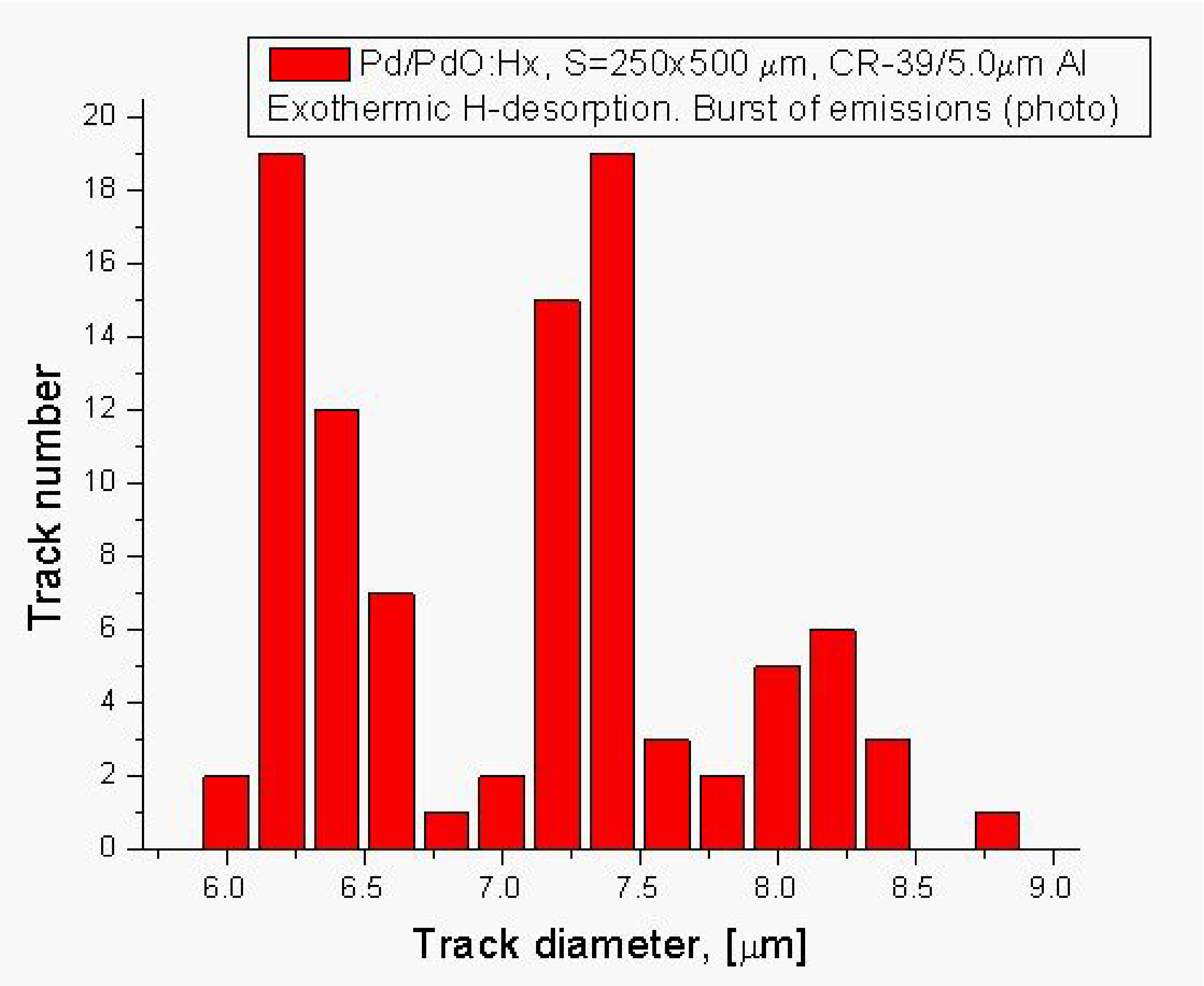
$E_4 = E_5 = E_6$ = 8.4 MeV

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 μm^2) with tracks of α-particles and protons
Image size – 120 x 90 μm

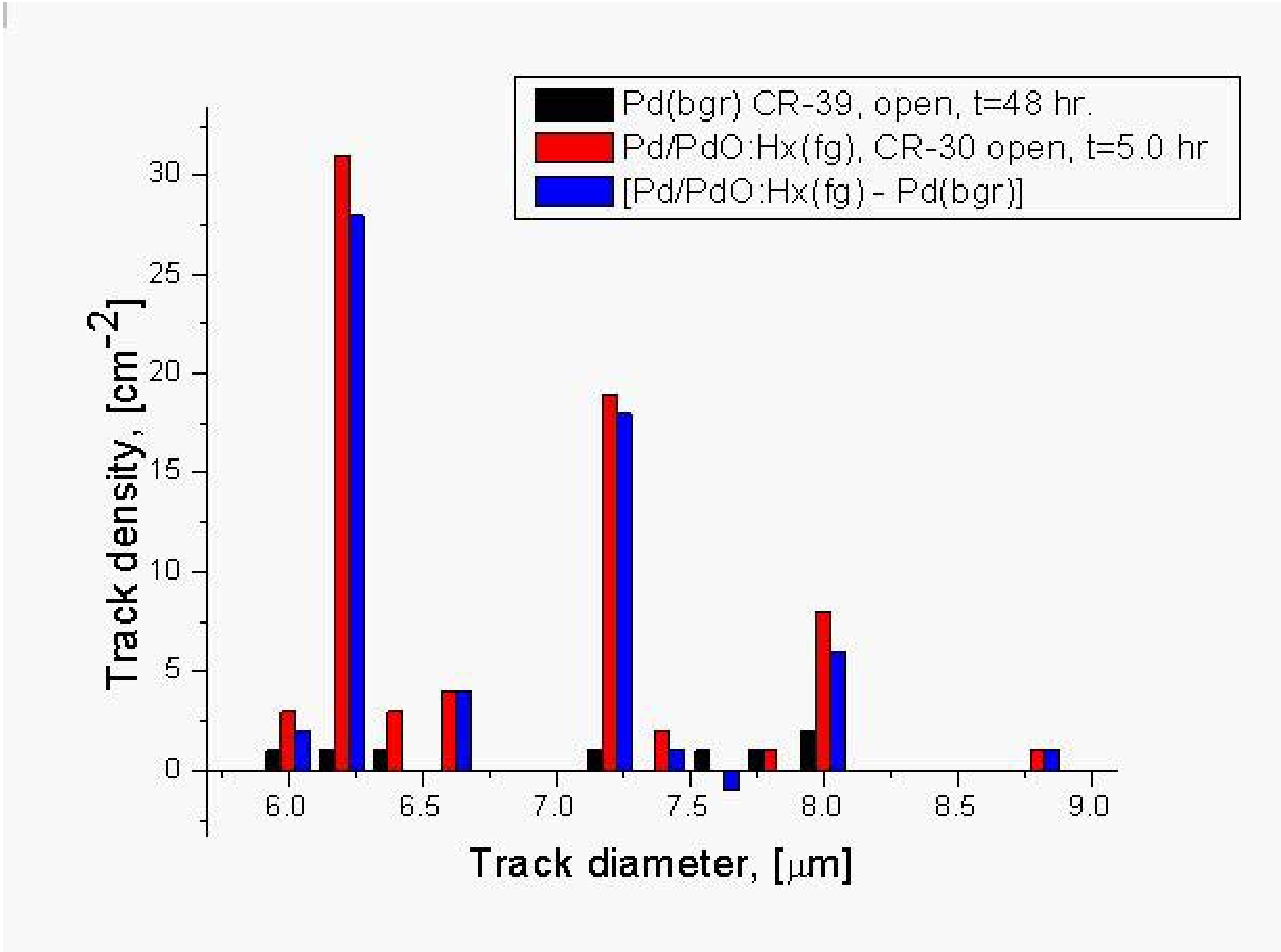




Distribution of track diameters in “hot zone” (250 x 500 μm²)



Distribution of track diameters on CR-39 surface without "hot zone"



Track diameters and energy ranges

∅ 6.0 – 6.5 → E_p = 1.4 – 1.7 MeV
∅ 7.0 – 7.6 → E_α = 9.2 – 14.0 MeV
∅ 7.8 – 8.5 → E_α = 5.6 – 7.8 MeV

Intensity of emission

$N_{flash} \sim 10^3$ particles (α's and p's) per 10^{-3} cm^2 ("hot zone" area)

<n> = 6×10^{-2} $s^{-1}cm^{-2}$ mean intensity of emission during 5h (without "hot zone")

Conclusion

1. We formulated necessary conditions for successful using of CR-39 detector in typical CF-experiments, including electrolysis, H/D desorption, glow discharge.
2. It was shown that using of CR-39 allows to measure the intensity of emitted charged particles, to determine their type and to estimate their energies.
3. We found active zones ("hot zones") on the sample surface that could be considered as areas with a high density of charged particle tracks.
4. We have observed the emission of three or more alpha-particles from one point on the sample surface, suggesting of space and possible time correlation between those events. These events assume the concentration of high energy (20 - 40 MeV) within a small areas of sample surface comparable with lattice parameter. In this case a mean power density is ~ 10^{18} - 10^{20} W/cm^2 (that comparable with power density of intensive picosecond laser emission).