Energetic Charged Particle Emission from the Hydrogen Loaded Pd and Ti Cathodes and its Enhancement by a He-4 Implantation


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Introduction I

- Detection of energetic nuclear products easily distinguished from the Background/cosmic emissions would be a strong evidence for LENR existence in non-equilibrium metal deuterides.

- Charged particles from DD-reaction (3.0 MeV p and 1.0 MeV t) show very low intensity and appear at such energy range where the background counts are typically non-negligible.
Introduction II


- Spectra of alpha particles in electrolysis and GD are similar to that obtained from powerful laser irradiation of Ti hydrides/deuteride target.
Objectives

- Search of energetic charged particles (ECP) signatures using SSB and CR-39 track detectors techniques in D(H)-loaded metals with a large hydrogen solubility.
- Confirmation of LENR occurrence by comparison of ECP emissions from Pd/Ti with the detector’s background response and runs with other metals.
- Study of He-4 implantation effect on the ECP emission parameters during and after electrolysis of Pd cathode. Search for enhancement of ECP yield?
Detection technique I

- Si-surface barrier detectors (ORTEC) of various efficiency calibrated with $^{241}\text{Am}$ alpha-source operated in vacuum $10^{-3}$-$10^{-6}$ torr: SSB(1): $S=100\text{ mm}^2$, SSB(2): $S=900\text{ mm}^2$ ($d=10$-$20\text{ mm}$).

- dE-E SSB detector pair ($dE->20\text{ }\mu\text{m}$, $E->100\text{ }\mu\text{m}$, time gate $\Delta\tau = 20\text{ ns}$) in air at ambient condition: 2-dimensional spectra for particle identification
Detection technique II

- CR-39 detectors (purified: < 20 track/cm$^2$) Landauer (USA), $S = 2 \times 1 \text{ cm}^2$ attached to cathode in electrolysis;
- Various metal foils used as a shielding (11-66 $\mu$m Al, 25-50 $\mu$m Cu) allow identify charged particle accordingly to stopping range.
- Accelerator $p/\alpha$ calibration of detectors
- CR-39 Etching: 6MNaOH, $t = 70 \degree \text{C}$, $\tau = 7 \text{ hr}$: Foreground and Background detectors were etched simultaneously.
Samples

- Electrochemical loading of Ti, Pd/PdO and Au/Pd/PdO:D_x (1M-Li_2SO_4/H_2O; 1M NaOD/D_2O; j=20 mA/cm^2) heterostructure (40-60 μm thick): *in-situ* during electrolysis and/or D/H-desorption @ T=300 K (SSB measurements only after electrolysis + CR-39).

- Alumina/Pd(600nm), Glass/Pd(250 nm) thin film cathodes electrolysis: CR-39 *in-situ* measurements (1MLi_2SO_4/H_2O, j=10 mA/cm^2).

- Ti, and Pd/PdO foils implantation with He-4 ions using He-gun: total fluence Φ = 2x10^{16} ^4He/cm^2, E_{He} = 20 keV (R_{He} ~ 20-30 nm)
Typical charged particle background in vacuum (t=8 days in a row), A.G. Lipson et al., Fusion Tech, 38, 238 (2000). Au/Pd/PdO pristine sample is in front of the SSB-1 (d=15 mm)
Au/Pd/PdO: Dx after the electrolytic D-loading. Sample is in front of Detector (d=15mm). Foreground run, SSB detector efficiency 3.3%
Weak spontaneous DD-proton emission from \( \text{Au/Pd/PdO:D}_x \) in vacuum (after electrolytic D-loading) SSB-1 data

\[ \langle n_p \rangle = (4.0 \pm 1.0) \times 10^{-3} \text{ p/s in } 4\pi \text{ ster.} \]

\[ \Sigma \tau (\text{BG}) = \Sigma \tau (\text{FG}) = 40.0 \text{ hr} \]

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Large area high efficiency SSB-2 detector: $S=900 \text{ mm}^2$, $\varepsilon = 12.0 \%$. Foreground run. The counts with $E > 8.0 \text{ MeV}$ are collected for a shorter time than that with SSB-1.

Detector: SSB, $\varepsilon = 12 \%$, vacuum: $10^{-3} \text{ Torr}$

Sample: PdO/Pd/Au: $D_x 40 \mu\text{m}$; $t_{\text{exp}} = 2.4 \times 10^4 \text{s}$
dE/E Background spectra of charged particles from pristine Au/Pd/PdO sample: $\Sigma \tau = 500$ hr. The sample is in front of dE detector ($d=10$ mm).

![Graph showing dE/E Au/Pd/PdO Background run (dE/E TDC 750-920 ch, gate 20 ns)]
dE/E (SSB: dE=20μm, E=100 μm) 2-dimensional spectra of charged particles from Au/Pd/PdO:Dₓ (after electrolysis): Στ = 550 hr.; \( <N_\alpha> = (6.4\pm1.2)\times10^{-4} \text{ [s}^{-1}\text{]} \) in 4π ster.

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

Alpha calibration curves for Fukuvi and Landauer CR-39 detectors

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Tracks from 11.0 MeV $\alpha$-beam @ normal direction with respect to CR-39 (Landauer) target: image area $S= 0.12 \times 0.09$ mm
Proton Calibration with Van-DeGraaf accelerator (0.6-3.0 MeV) *calibration was sponsored by Lattice Energy LLC

Proton calibration curves for Landuer and Fukuvi CR-39 detectors

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Tracks from 2.5 MeV p-beam @ normal direction with respect to the CR-39 (Landauer) target: image area S = 0.12x0.09 mm
CR-39 data on EPC emissions ($8<E_\alpha<16$ MeV) in Au/Pd/PdO:Dx (after electrolytic D-loading): $\langle N_\alpha \rangle = (5.6 \pm 0.5) \times 10^{-4} \ [s^{-1}\cdot cm^{-2}] \ 4\pi \ ster$. Compare with $dE/E$.
Open and Cu-shielded CR-39 Background Data

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Histograms of track distributions with open CR-39 detectors: Pd/Al₂O₃ cathode in-situ electrolysis
Foreground alpha energy distributions for open and Cu-shielded CR-39 detectors: Splitting of alpha “peak” in shielded CR-39 detector:
Background Alpha energy distributions for open and 25 $\mu$m Cu shielded CR-39 detectors

![Graph showing alpha track energy distribution for Background CR-39 (Pd/Alumina electrolysis).]
Possible Alpha spectrum with Background subtracting

Rough Reconstruction of alpha spectrum from CR-39 data

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Electrolysis and posteffect with a double Pd/PdO-Pd/PdO:He cathode
Typical Background in 1M-Li$_2$SO$_4$/H$_2$O electrolyte: CR-39 (Landauer) area $S=120 \times 90 \ \mu\text{m}^2$
Comparison of ECP emissions from Pd:He and Pd sides of the cathode (with the background subtracting):
Enhancement: $k_\alpha = 3.5$, $k_p = 2.0$
Group of energetic alphas (d=7.2-7.4 μm): Pd/PdO: He electrolysis: 100x100 μm² spot (negative image)
Double Ti:He/Ti cathode data (with the Background subtracting), Enhancement: $k_\alpha = 3.0$, $k_\rho = 8.0$
Comparison of ECP from Pd/PdO:He and Pd/PdO sides during exothermic H-desorption, t=5.0 hr.
Conclusions I

- Statistically significant number of energetic alphas in the range of 9-16 MeV was detected both with SSB and CR-39 track detectors techniques.

- Energetic alpha-particles accompanied by 1.7/2.8 MeV protons/deuterons are detected only in hydrogen/deuterium loaded metallic targets with a large “affinity” to hydrogen (Ti and Pd).
Conclusions II

- No ECP emissions were found either in the “cosmic” Background or from the materials with a low hydrogen solubility: Cu, Al, St. steel, Al₂O₃ (electrolysis), Ta(GD).

- ECP is a surface phenomenon, independent of sample thickness. (proof that it is not induced by Background “cosmic” rays).

- ECP emissions in Pd and Ti could be enhanced by He-4 ion implantation into a near-surface layer.
Possible mechanism speculations

- Applied energy focusing/concentration in some specific lattice sites near surface (the sites of a high internal strain?).
- Coherent energy transfer from DD-reaction sites to the light nuclei (P.L. Hagelstein).
- Effective acceleration of these nuclei (p, d and \(^4\text{He}\)) by intratomelectric electric fields.
- ECP emissions suggest anomalous energy release via the “active” lattice sites of non-equilibrium metal deuterides/hydrides.
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