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20 Years of LENR Research using Co-Deposition

March 22, 2009

Stan Szpak
Pam Mosier-Boss
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SSC San Diego … on Point and at the Center of C4ISR

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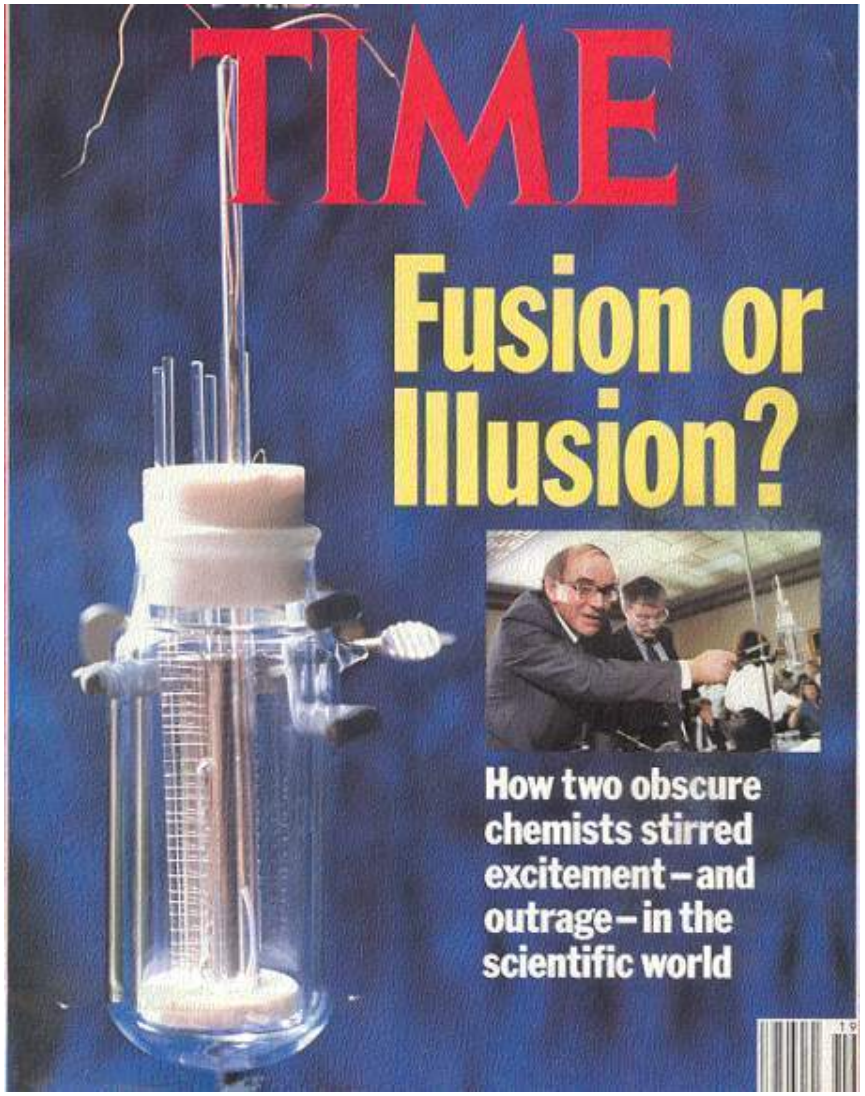
March 23, 1989

- Pons and Fleischmann announce that electrochemical cells are producing more heat than can be accounted for by chemical means and speculated that nuclear reactions must be occurring.
- Physics community notes:
  - the experiments aren't repeatable
  - there aren't any refereed papers
  - the experiments haven't been replicated
  - If it's nuclear, where are the neutrons?"
  - It doesn't match theory
- Thousands of scientists worldwide attempted experiments—most failed



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Why Nuclear?

Reaction	Energy/atom
• Nuclear Fission	200,000,000 eV (200 MeV)
• Nuclear Fusion	20,000,000 eV (20 MeV)
• Chemical	< 5 eV

Nuclear reactions are *millions of times* more energetic than chemical reactions!

Triggering nuclear events with electrochemical energies is not consistent with theory!

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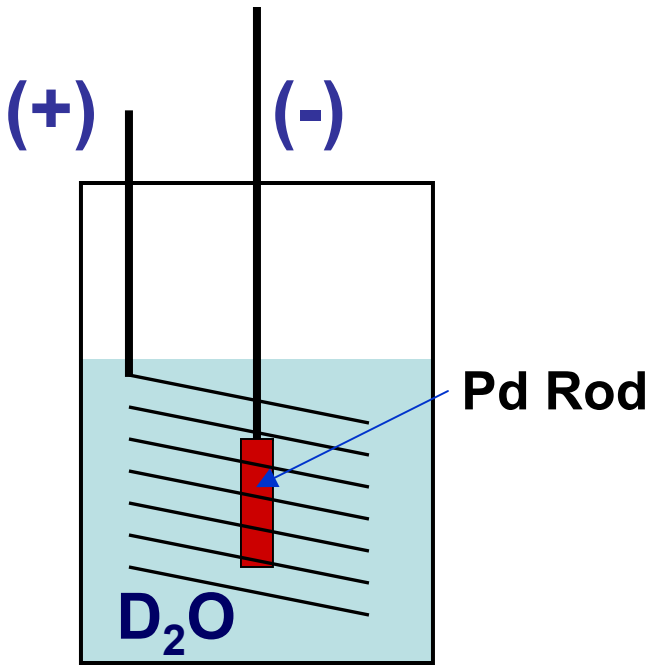
Why Many Laboratories Failed to Reproduce the Fleischmann-Pons Effect

F/P Approach



D_2 is loaded into the Pd electrode over a several day period

- Improper cell configuration
  - Cathode was not fully immersed in the heavy water
  - Asymmetrical arrangement of anode and cathode
- Unknown history of the palladium cathodes used in the experiments
- Lack of recognition that an incubation time of weeks was necessary to produce the effect

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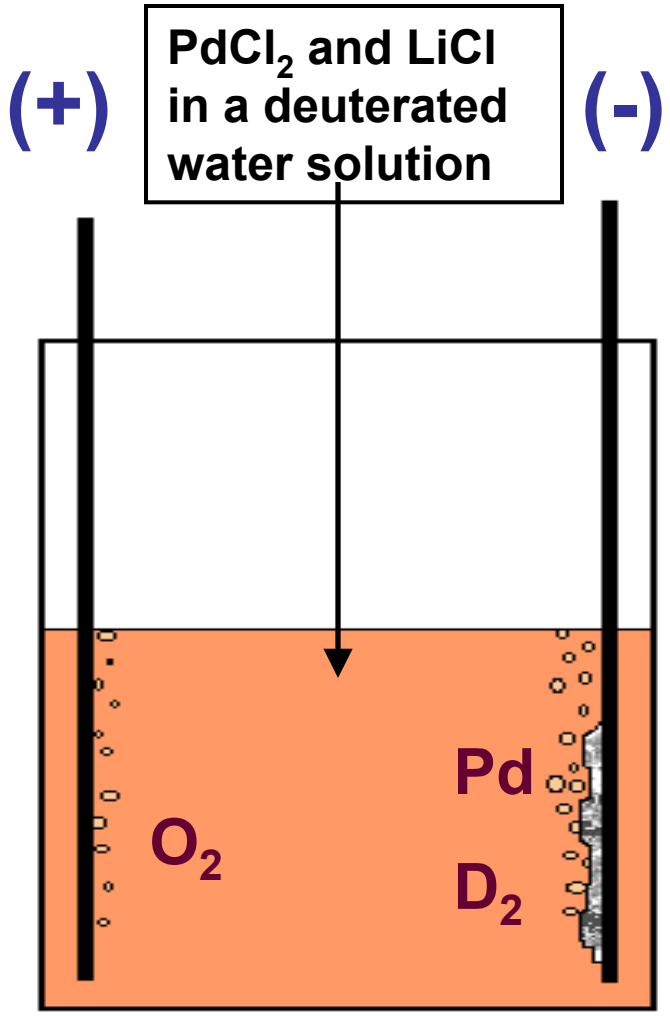
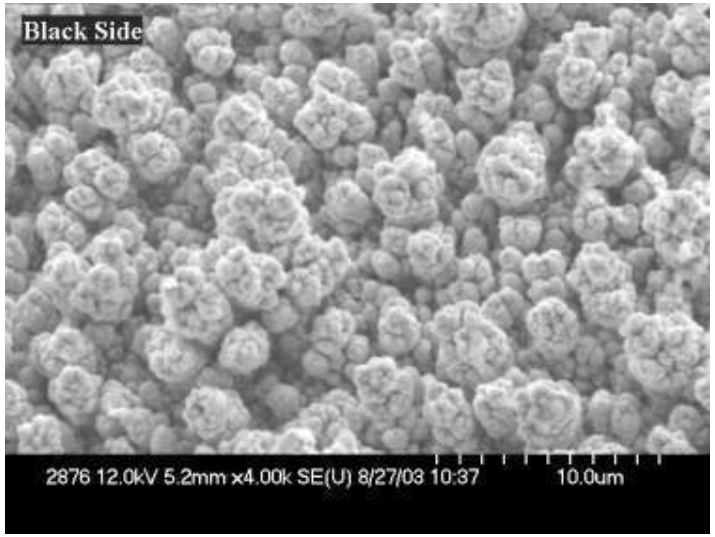
Another Way to Conduct the Experiment: Pd/D Co-deposition





As current is applied, Pd is deposited on the cathode. Electrochemical reactions occurring at the cathode:

$$Pd^{2+} + 2\ e^{-} \rightarrow Pd^{0}$$

$$D_2O + e^{-} \rightarrow D^{0} + OD^{-}$$

The result is metallic Pd is deposited in the presence of evolving D_2

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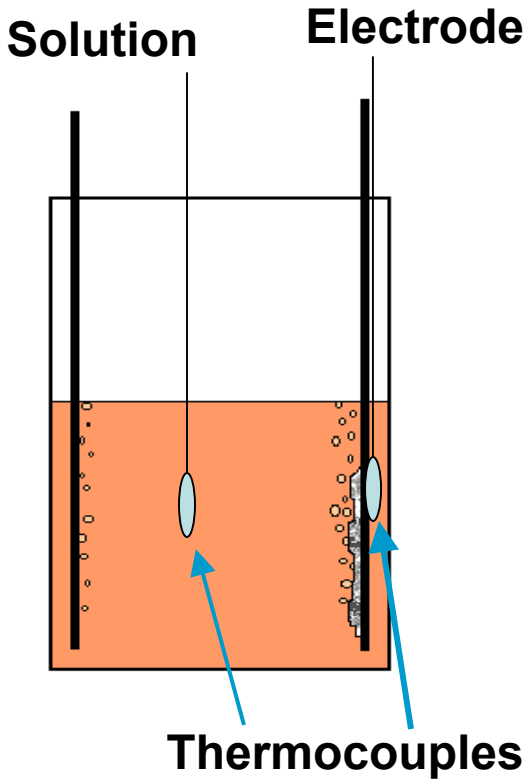
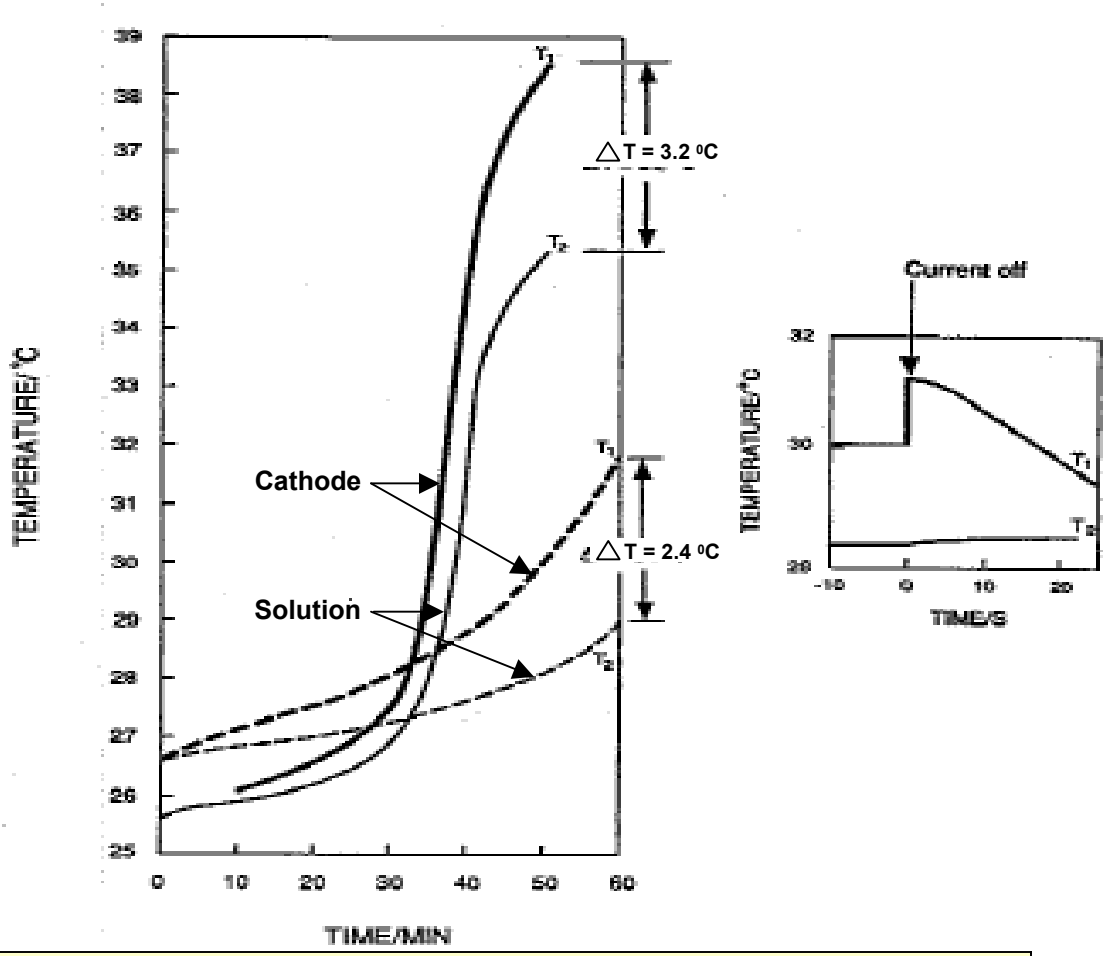
Temperature vs Time Profile

J. Electroanal. Chem., Vol.302, pp. 255-260 (1991)





The Electrode is warmer then the Solution!

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Advantages of Pd/D Co-Deposition

- Short loading times—measurable effects within minutes, no incubation time
- Extremely high repeatability
- Maximizes experimental controls
- Experimental flexibility
  - Multiple electrode surfaces possible
  - Multiple electrode geometries possible
  - Multiple cell configurations possible
- Extremely high surface area
- Defects are built into the lattice
  - J. Electroanal. Chem., Vol.337, pp. 147-163 (1992)
  - J. Electroanal. Chem., Vol.379, pp. 121-127 (1994)
  - J. Electroanal. Chem., Vol. 380, pp. 1-6 (1995)

Multiple groups have successfully used the Co-Deposition approach

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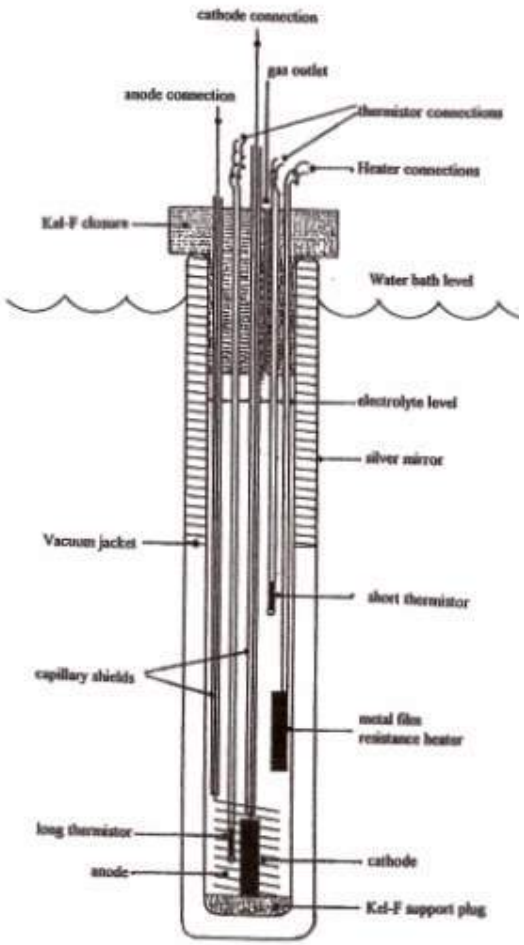
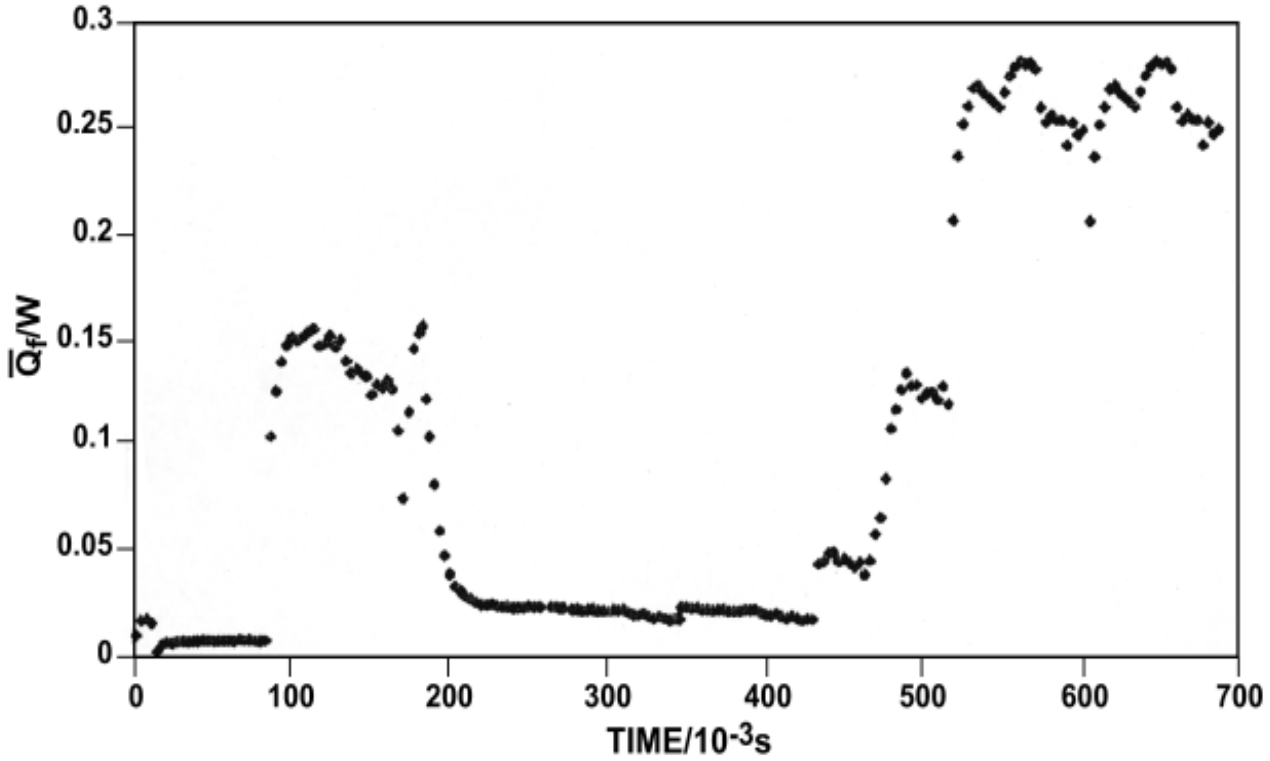
Excess Enthalpy Generation

Thermochimica Acta, Vol. 410, pp. 101-107 (2004)



Isoperibolic Dewar Calorimetry Cell



Pd-D co-deposition yields excess power comparable to conventional bulk Pd cathodes.

Experiments performed by Mel Miles at China Lake

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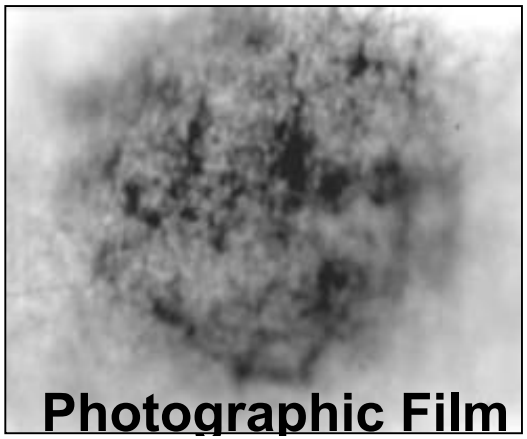
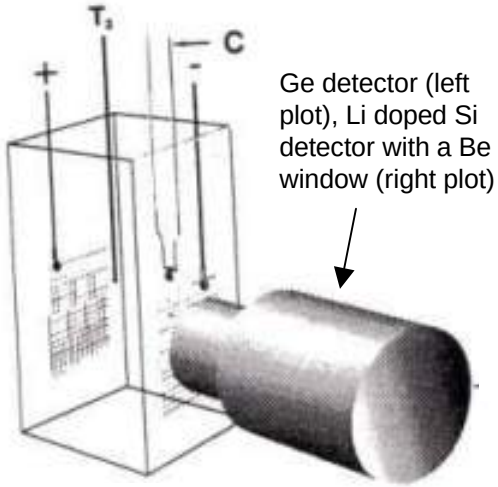
Emission of Low Intensity Radiation

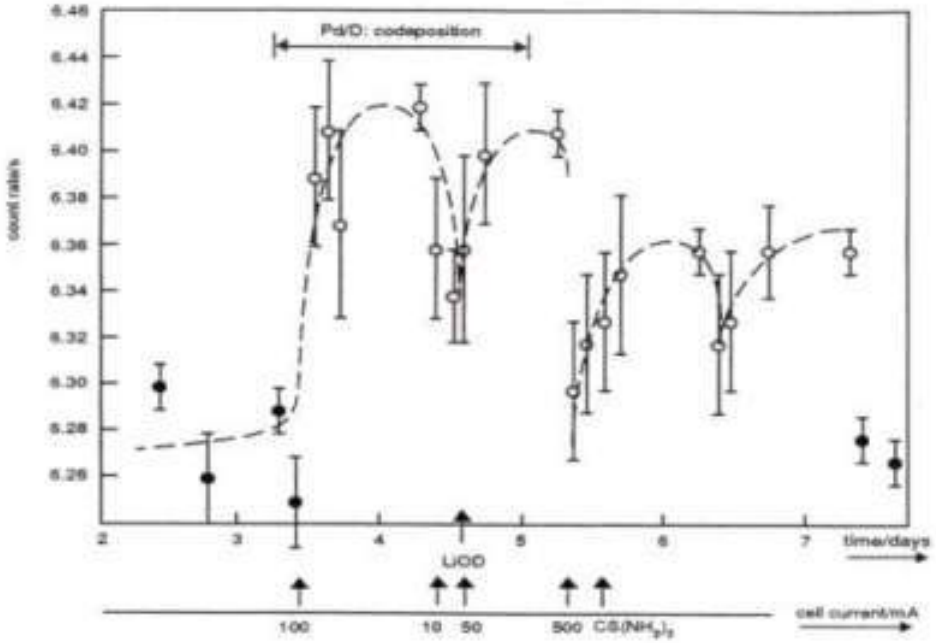
Physics Letters A, Vol. 210, pp. 382-390 (1996)



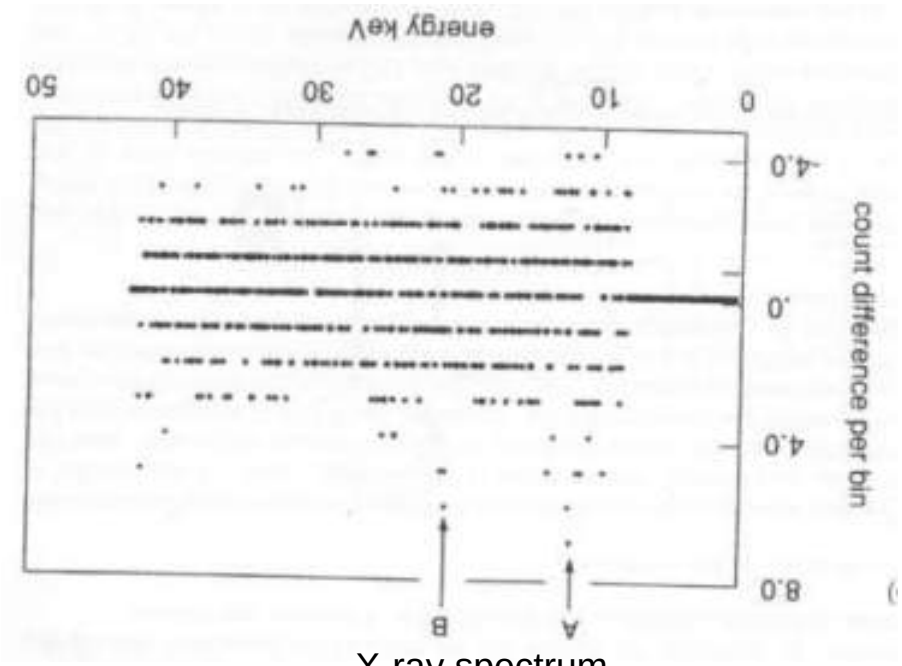


Ge detector (left plot), Li doped Si detector with a Be window (right plot)

- **X-rays with a broad energy distribution are emitted (with the occasional emergence of recognizable peaks (20 keV due to Pd Kα and 8-12 keV due to either Ni or Pt)**
- **Emission of radiation is sporadic and of limited duration**



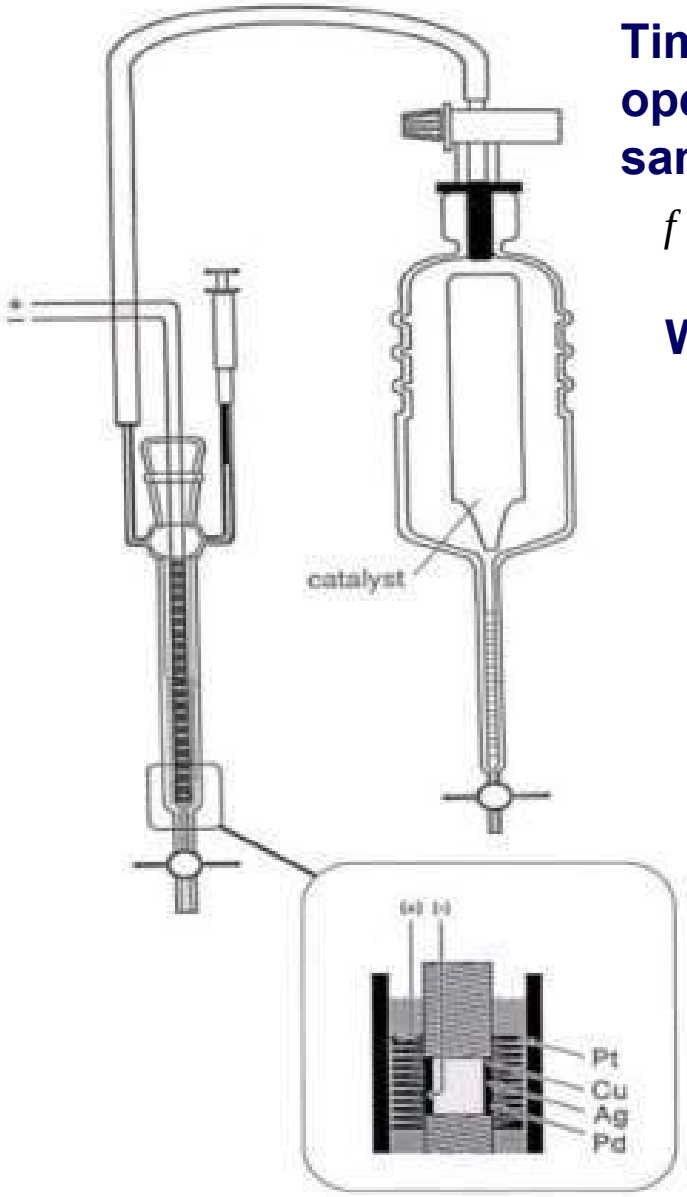
Gamma count rate



X-ray spectrum

Tritium Production

Fusion Technology, Vol. 33, pp.38-51 (1998)



Time dependence of tritium content of an open cell operating galvanostatically with intermittent sampling:

$$f(t) = f(0)\left(\frac{m(0) - r(i)t}{m(0)}\right)^{S-1} + \frac{q}{(S-1)r(i)} \bullet \left\{1 - \left[\frac{m(0) - r(i)t}{m(0)}\right]^{S-1}\right\}$$

Where:

f = tritium mass fraction

m = mass of the electrolyte phase

r(i) = $iM_w / 2F$= denotes the rate of change associated with the cell current i

q = rate at which tritium is added/removed from the solution phase

S = isotopic separation factor = $\left(\frac{C_T}{C_D}\right)_G \Big/ \left(\frac{C_T}{C_D}\right)_L$

Three of five tests gave a rate of tritium production ranging between 3000-7000 atoms sec-1 for a 24 hr period

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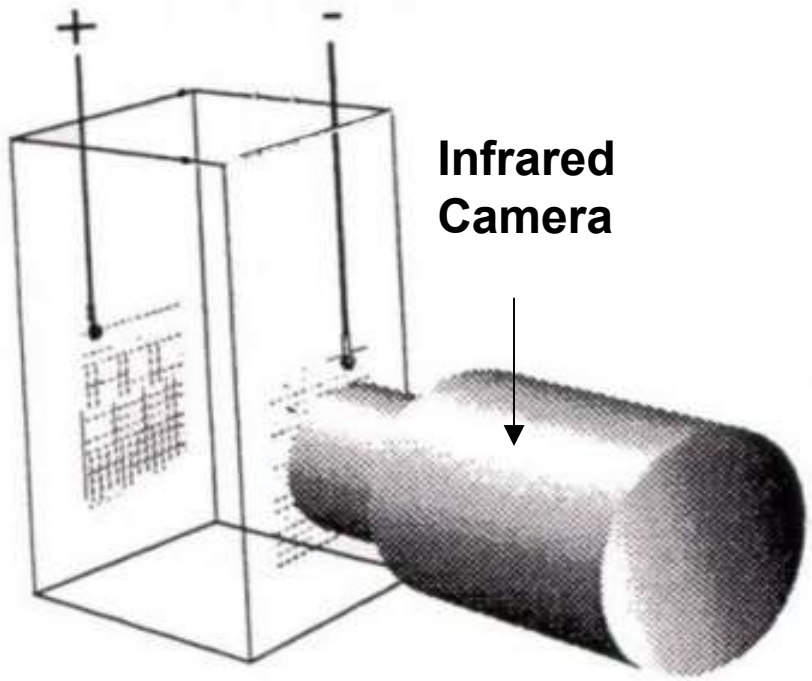
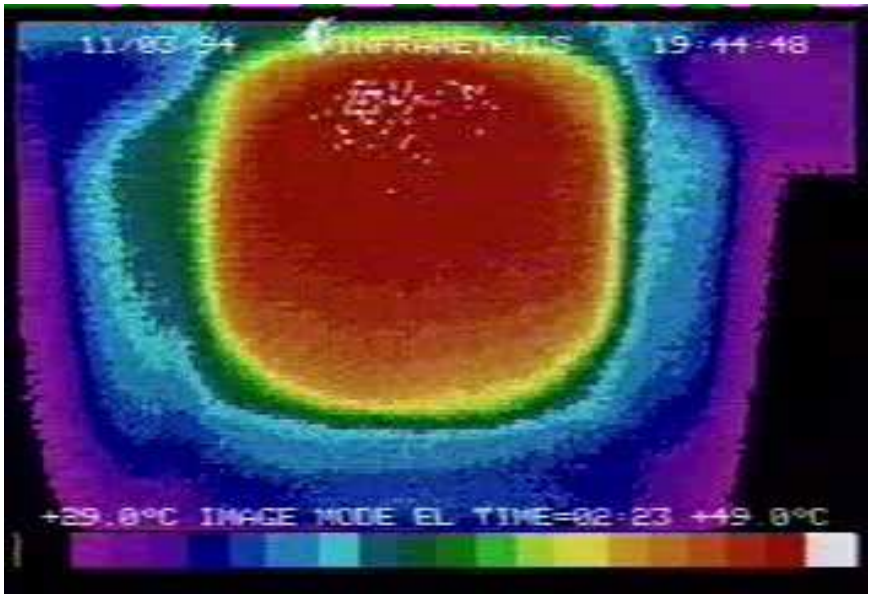
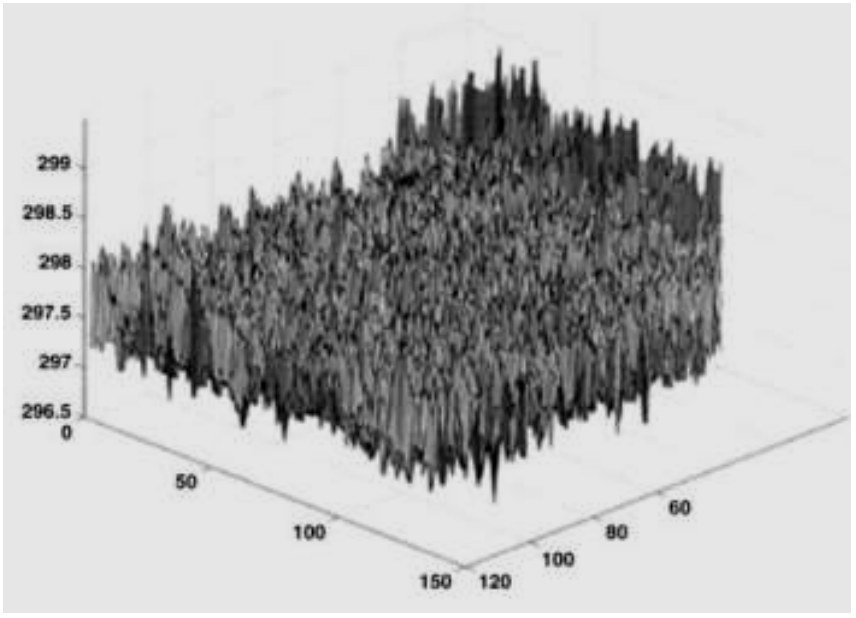
Formation of 'Hot Spots'

Il Nuovo Cimento, Vol 112A, pp. 577-585 (1999)







- View perpendicular to the electrode surface showing the distribution of hot spots. View parallel to the surface showing temperature gradients.
- Shows that the cathode is the heat source and not Joule heating.

Prof. Simnad, UCSD and Todd Evans participated in experiments

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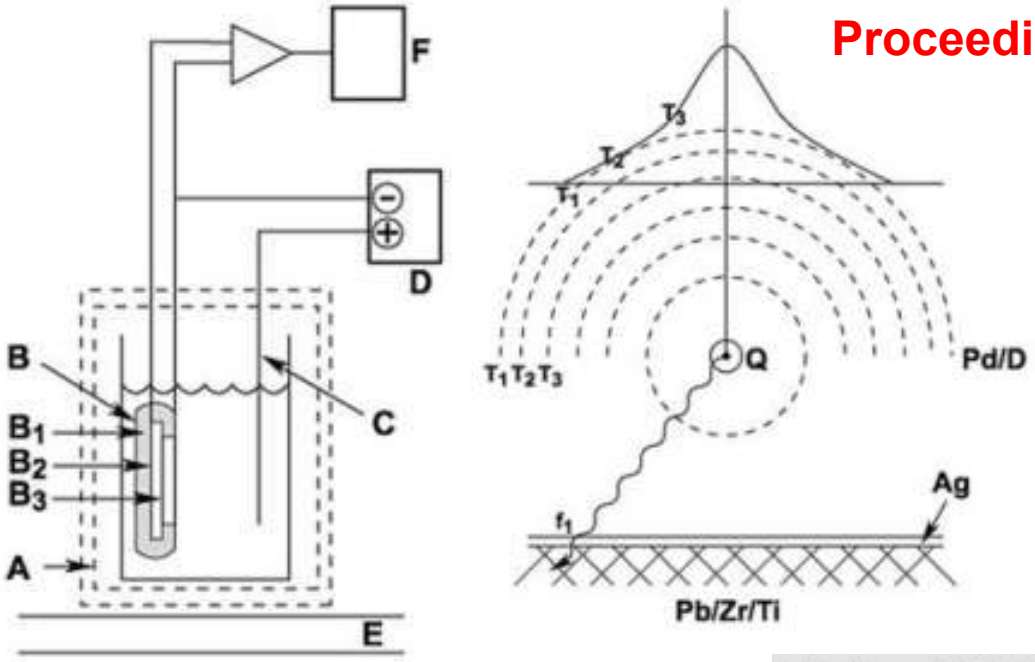
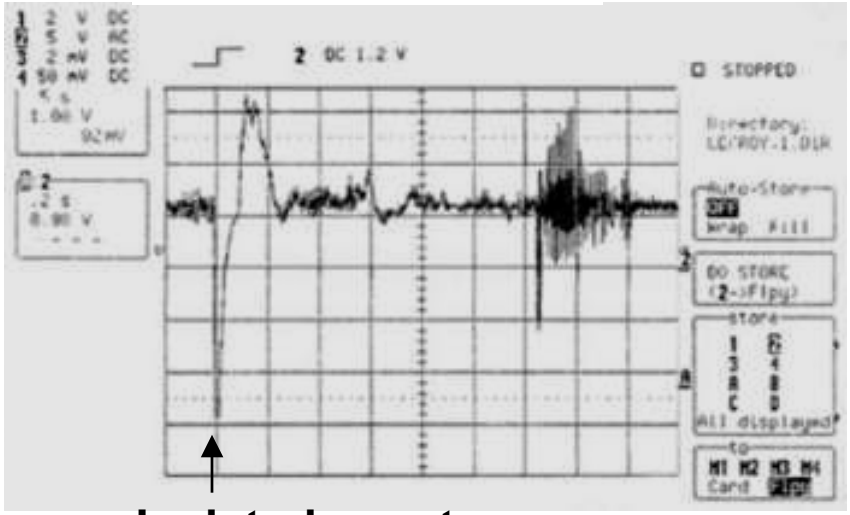
Piezoelectric Response: Evidence of Mini-Explosions and Heat Generation

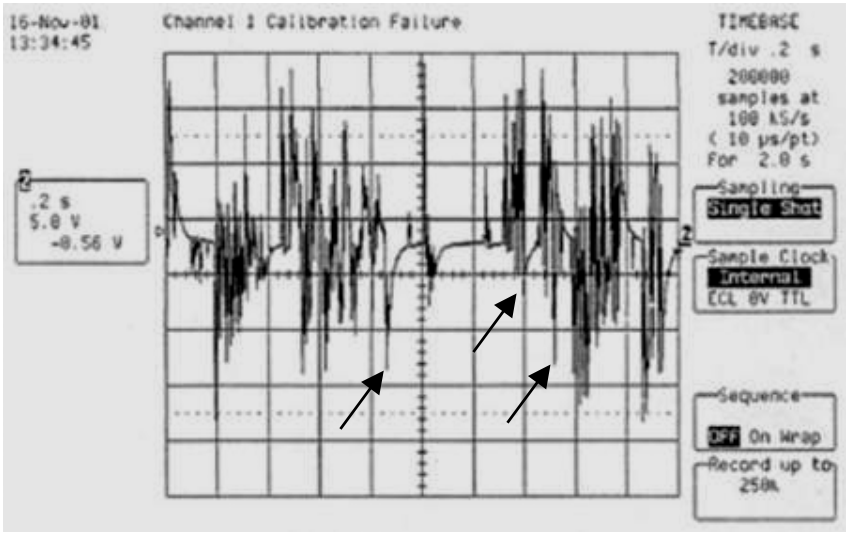
Proceedings of the ICCF-10, (2003)



Piezoelectric crystal responds to both pressure and temperature



Isolated event



Expanded series of events

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Overview of Earlier Efforts

At this point we knew the following:

Heat generation, radiation emission, and tritium production are sporadic and occur in bursts. Implies that the sources are discrete/domains

Reactions are subsurface (including several atomic layers)

There is a relationship between surface state and the bulk

QUESTIONS:

- What is the underlying physics?
- Can the effects be made more pronounced through the application of external electric and/or magnetic fields?

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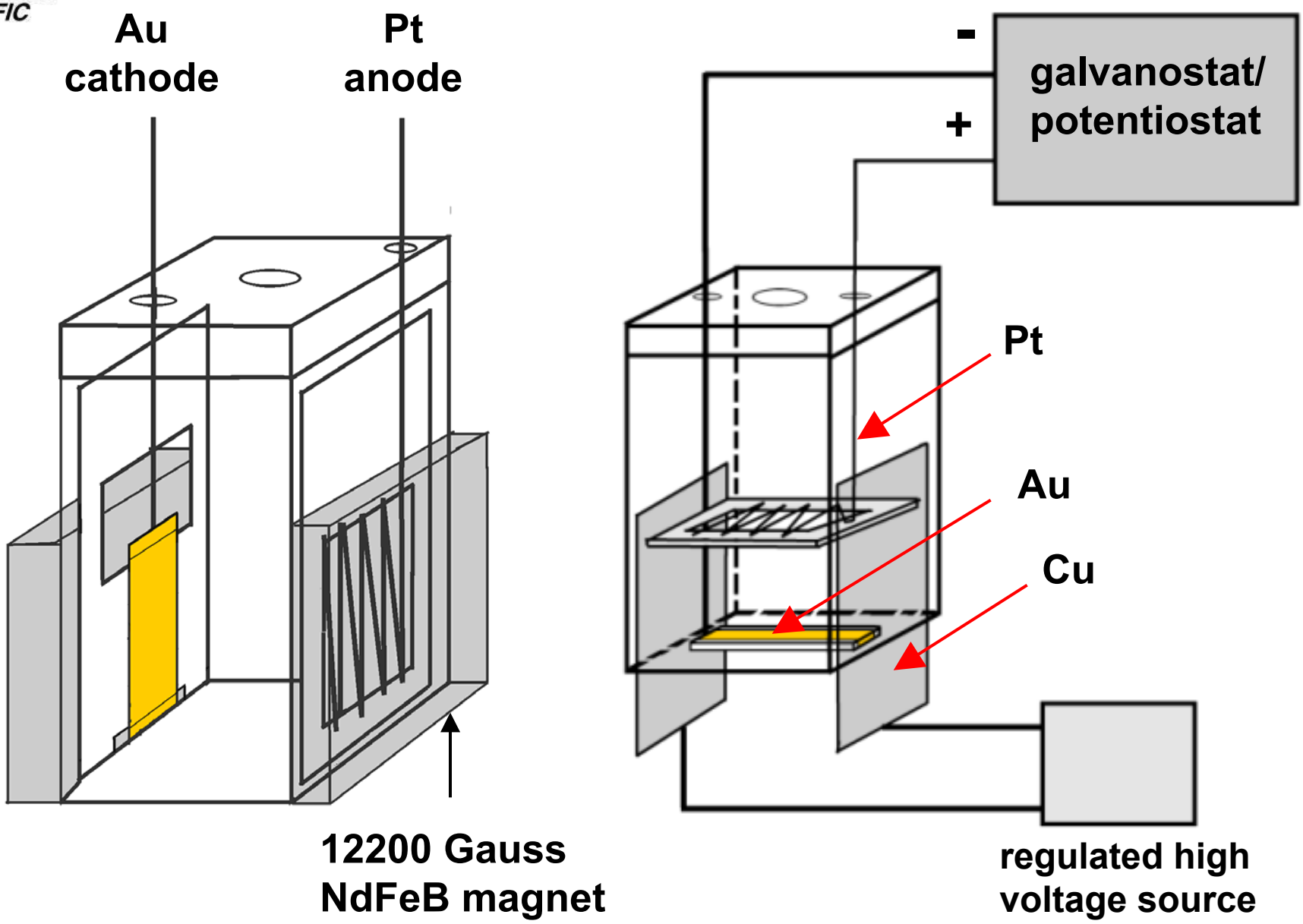
External Electric and/or Magnetic Field Experimental Configuration



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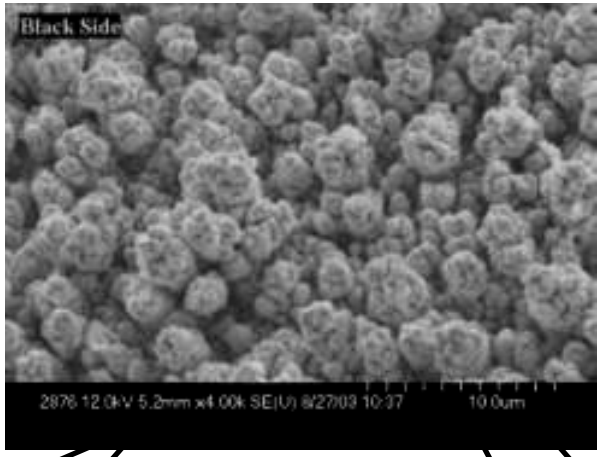
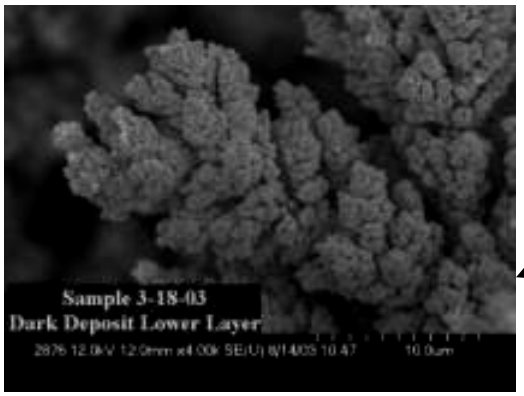
E-Field Morphology Changes

J. Electroanal. Chem., Vol. 580, pp. 284-290 (2005)

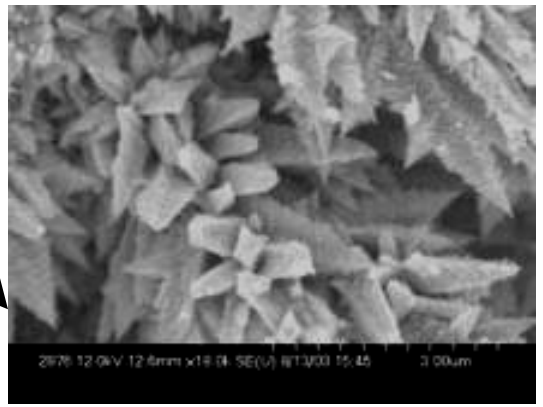


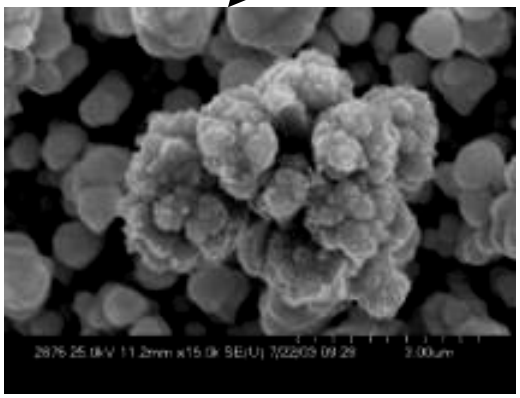
absence of field: cauliflower-like morphology

reorientation of globules without change in size

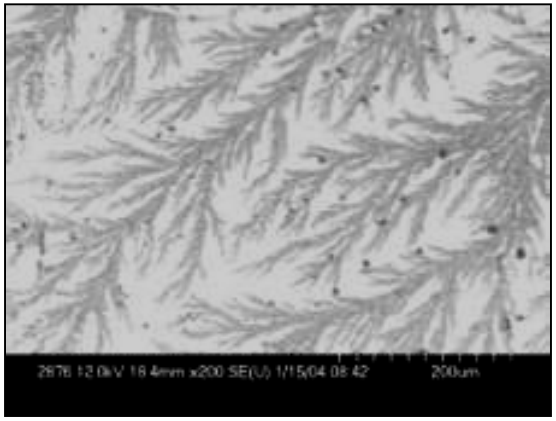


production of dendritic growth





separation of weakly connected globules



formation of fractals

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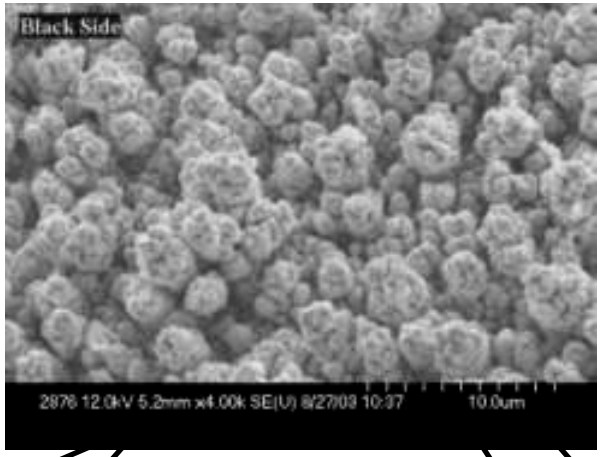
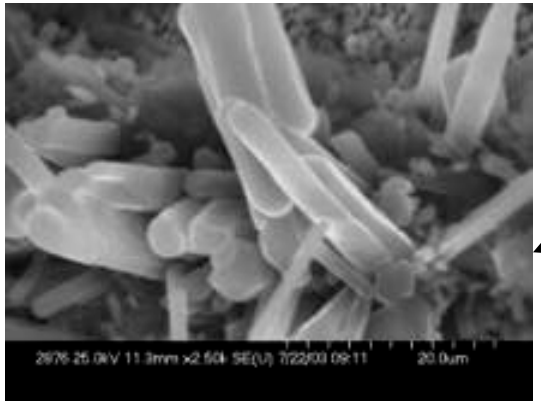
E-Field Morphology Changes – Reshaping of the Spherical Globules

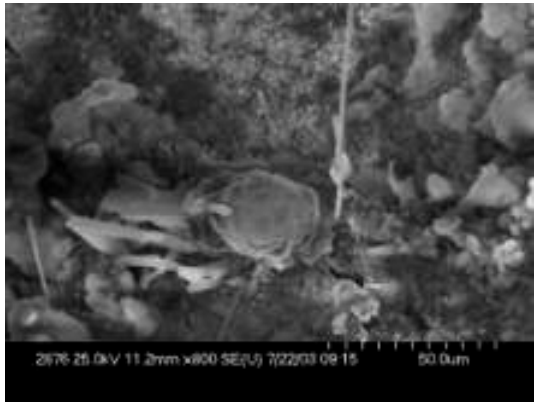


absence of field: cauliflower-like morphology

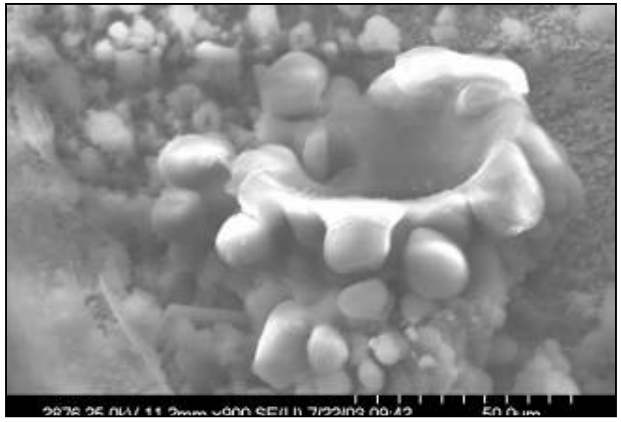
rods (circular and square)



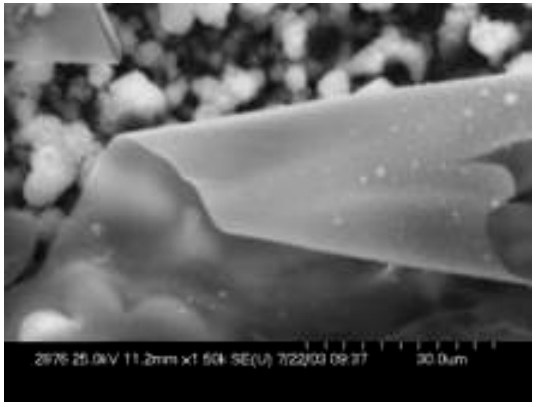
craters



long wires



solidification of molten metal



folded thin films

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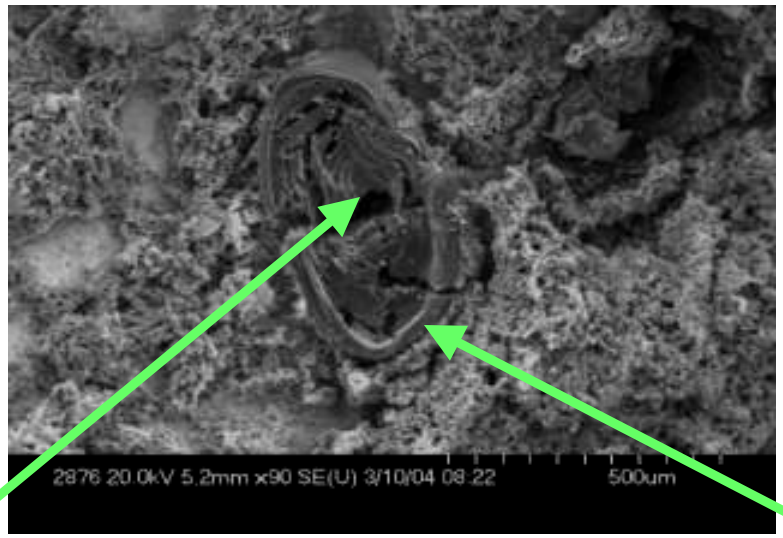
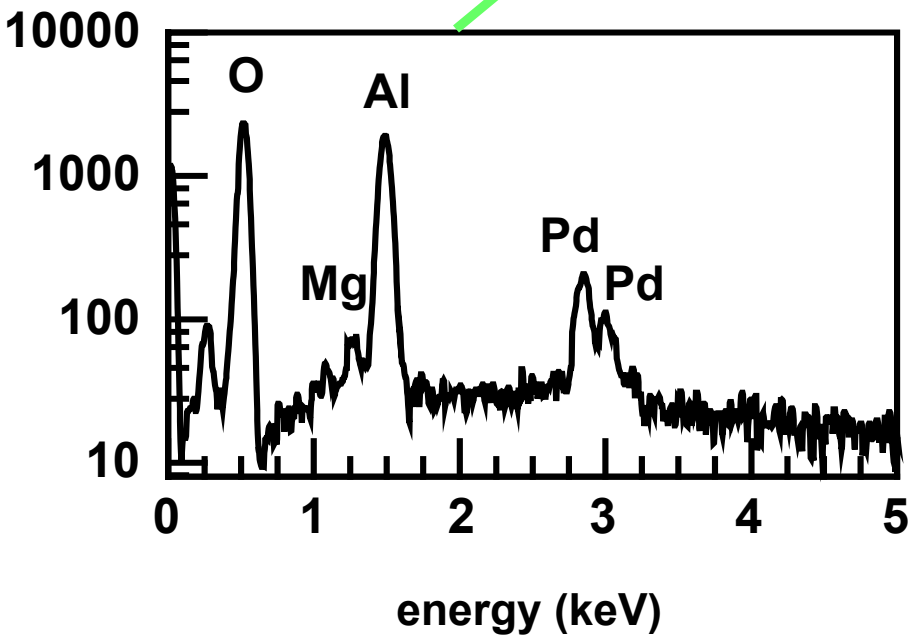
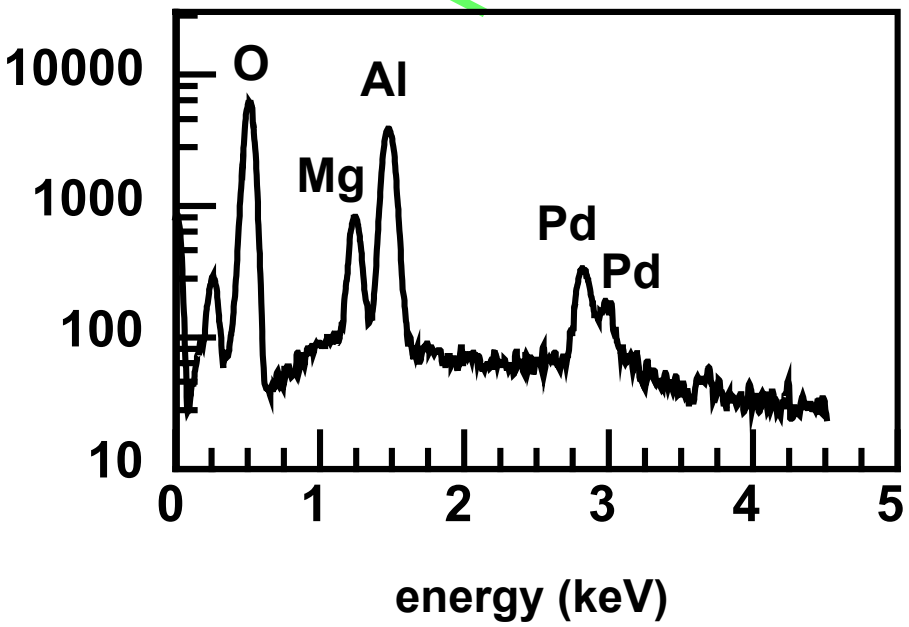
Chemical Composition of the Inside and Outside Rims of a Crater







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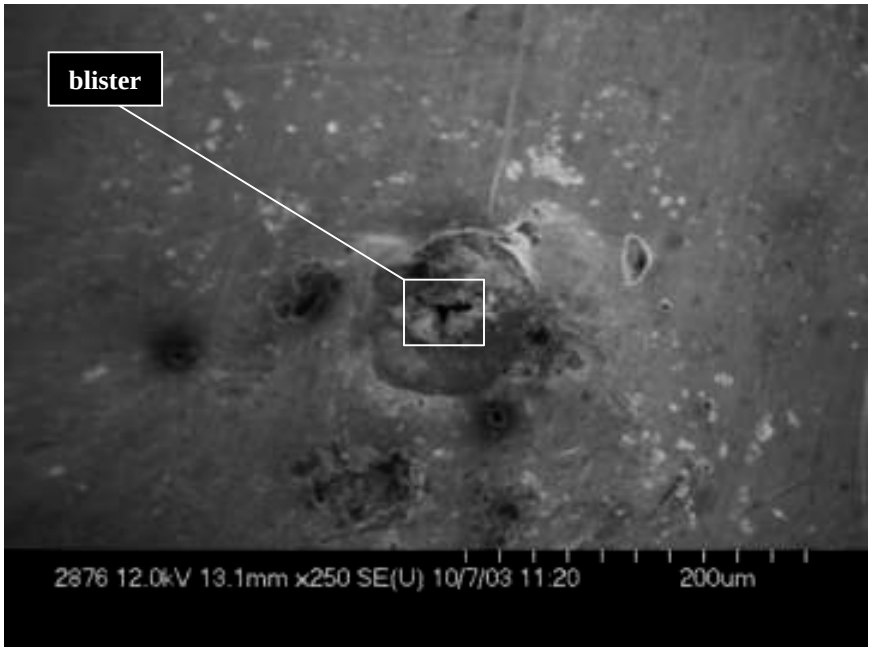
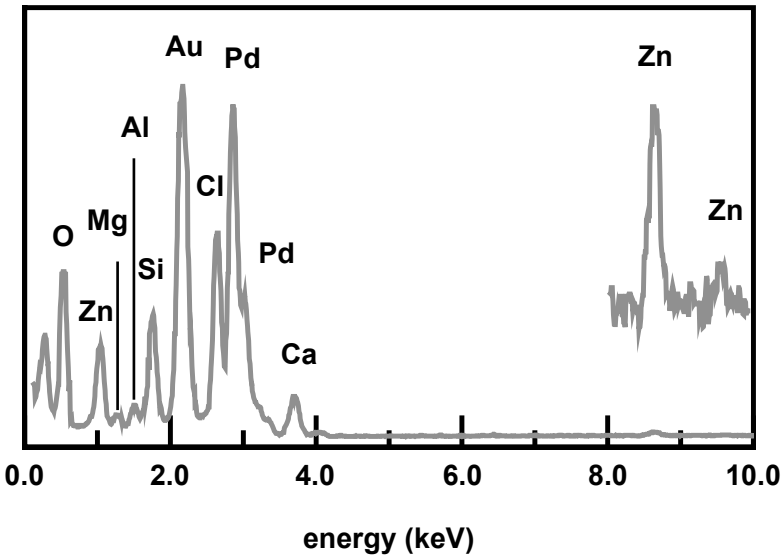
Chemical Composition of a Detached Thin Film ('Blister') Formed in an Applied Electric Field

Naturwissenshaften, Vol. 92, pp. 394-397 (2005)





- Analysis of the 'blister' shows the presence of Ca, Al, Si, Mg, Zn, Au, O, and Cl.
  - Au, O, and Cl are present in cell components and cannot be attributed to nuclear events.
- Distribution of Ca, Al, Si, Mg, and Zn is not uniform suggesting that their presence is not the result of contamination.
- Ca, Al, Mg, and Si cannot be electrochemically plated from aqueous solutions

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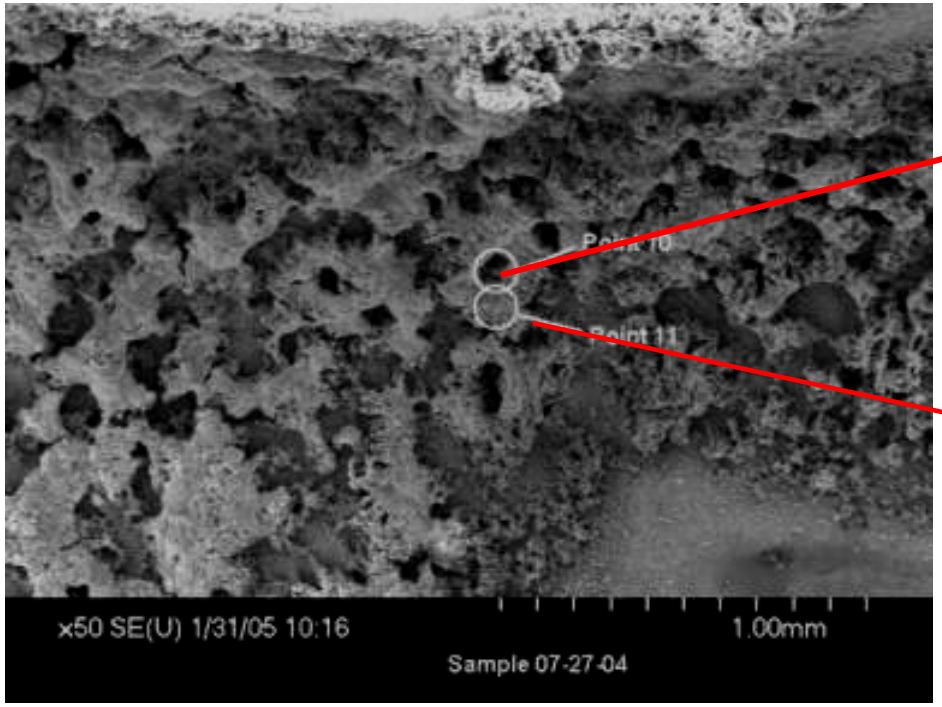
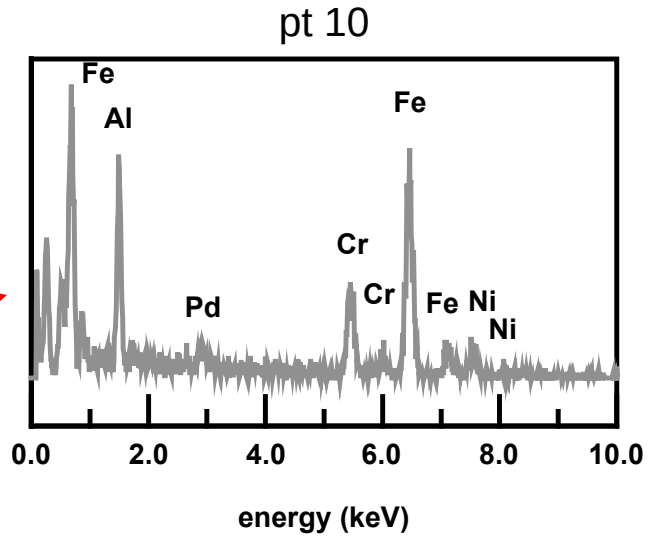
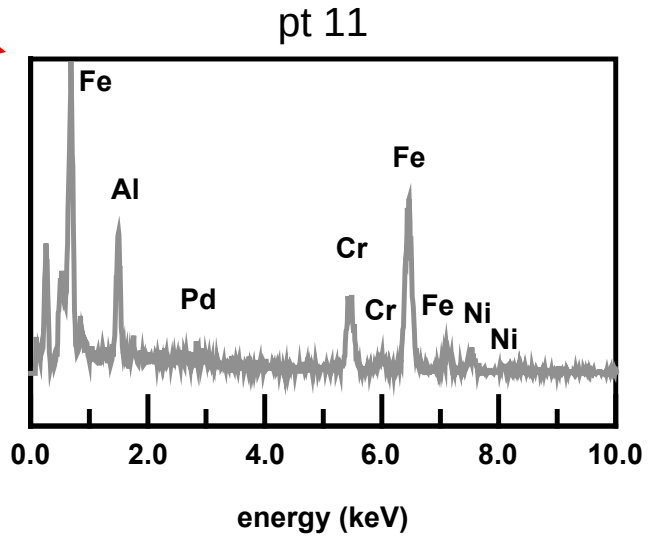
Chemical Composition of Structures Formed in an Applied Magnetic Field







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Observations of Unexpected Elements

16 Labs Reporting Transmutation Results
(Compilation by Miley, Univ of Illinois)

Hokkaido Univ., Japan - Mizuno et al.; Notoya et al.
Mitsubishi Corporation, Japan - Iwamura et al.
Osaka University, Japan - Takahashi et al; Arata et al.
University of Lecce, Italy - Vincenzo et al.
Frascati Laboratory, Italy – De Ninno et al.
SIA "LUTCH", Russia - Karabut et al; Savvatimova et al
Tomsk Polytechnical Univ., Russia - Chernov et al.
Lab. des Sciences Nucleaires, France - Dufour et al.
Beijing University, China - Jiang et al.
Tsinghua University, China - Li et al.
University of Illinois, USA - Miley et al.
Portland State University, USA – Dash et al.
Texas A&M University, USA - Bockris et al.
Schizuoka University, Japan – Kozima et al.
Iwate University, Japan – Yamada et al.

Number of Labs reporting:

11	Fe
8	Cu
7	Ca, Cr, Zn
6	Ni, K
5	Ag, Cl, Ti
4	Mg, Mn, Co, Pb
3	Al, Li, Ba, Os, C, Si

SPAWAR Systems Center, San Diego → **Al, Mg, Ca, Fe, Zn, Si, Cr, Ni**

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How Can We Verify that the Observed New Elements are Nuclear in Origin?

- **SEM-SIMS: look for changes in the isotopic ratios**
- **Measure γ and X-ray emissions**
- **Detect particle emission using CR-39 chips**
  - **Easy to do**
  - **Inexpensive**
  - **Requires minimal instrumentation**
  - **Is a 'constant integration' method**
  - **No electronics**

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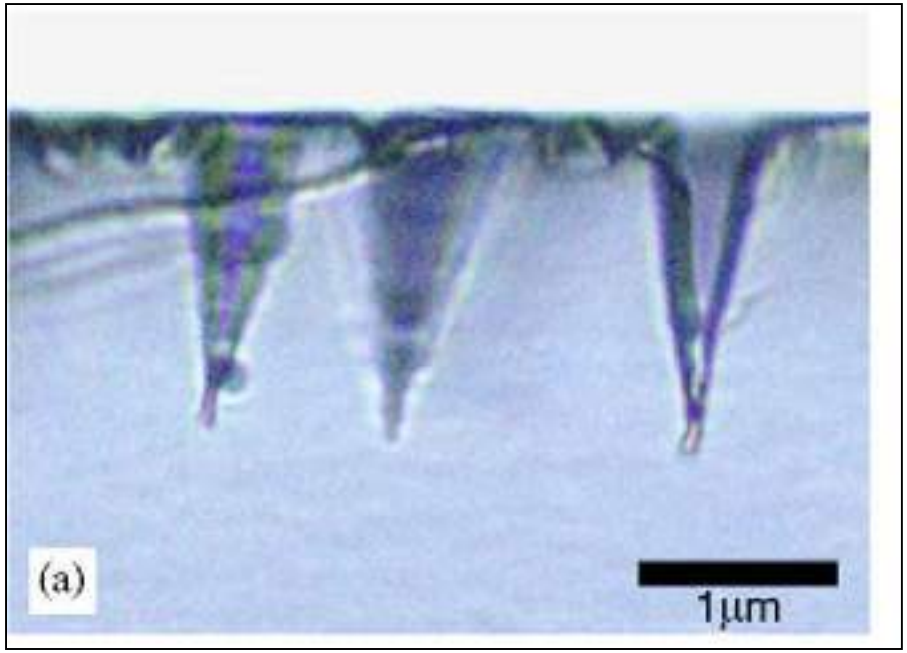
Particle Detection Using CR-39

- CR-39, polyallyldiglycol carbonate polymer, is widely used as a solid state nuclear track detector
- When traversing a plastic material, charged particles create along their ionization track a region that is more sensitive to chemical etching than the rest of the bulk
- After treatment with an etching agent, tracks remain as holes or pits and their size and shape can be measured.



Alpha track cross-sections after etching on a CR-39 detector.
T. Yoshioka, T. Tsuruta, H. Iwano, T. Danhara, Nucl. Instru. and Meth. Phys. Res. A, Vol. 555, p. 386 (2005)

Source: In collaboration with JWK International under CRADA agreement

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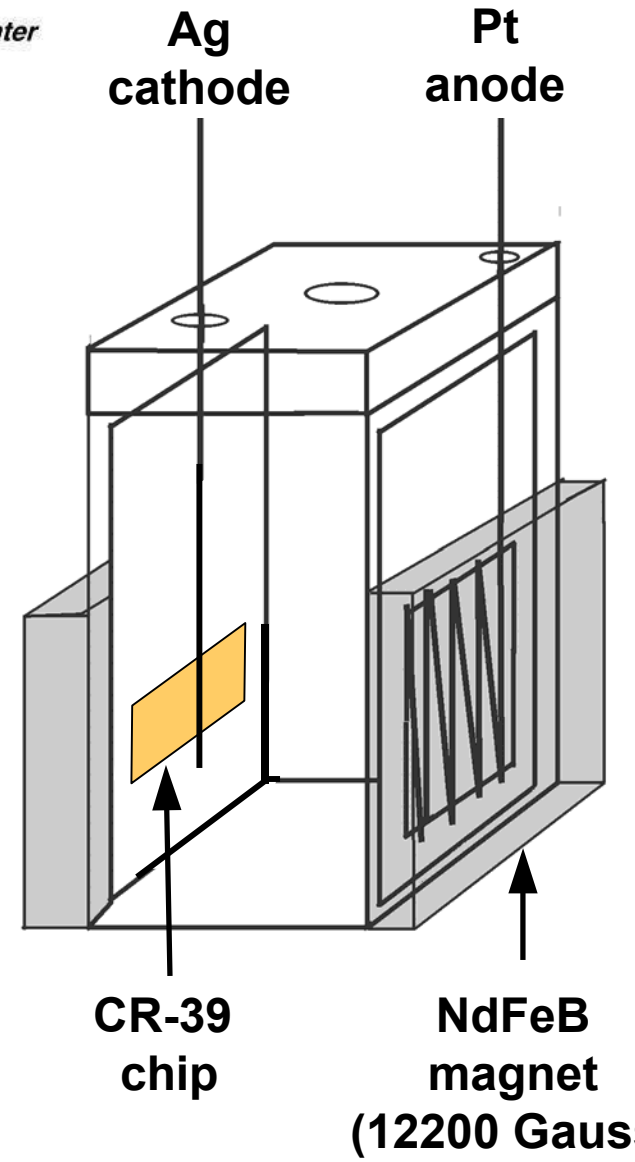
Experimental Configuration



- CR-39 in close proximity to the cathode because some high energy particles do not travel far
- Cathode substrates used: Ni screen; Ag, Au, Pt wires

Source: In collaboration with JWK International under CRADA agreement

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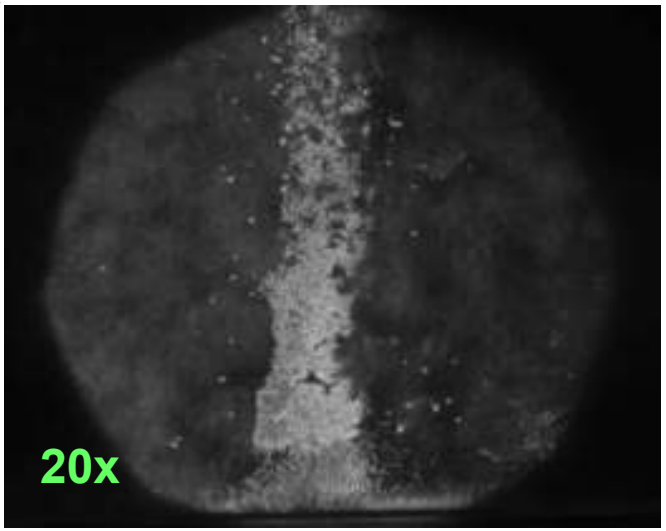
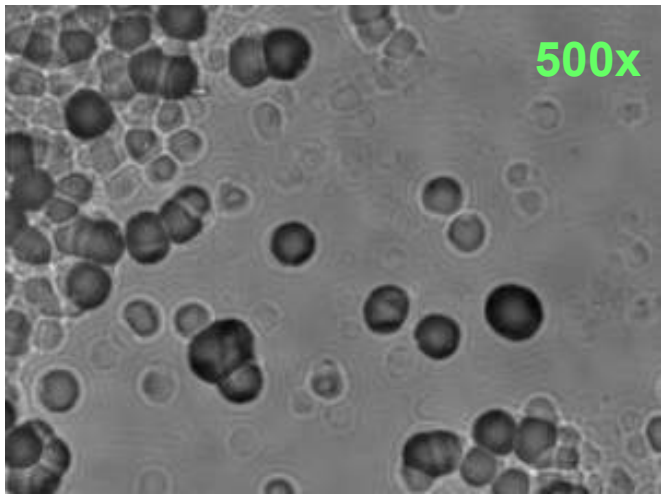
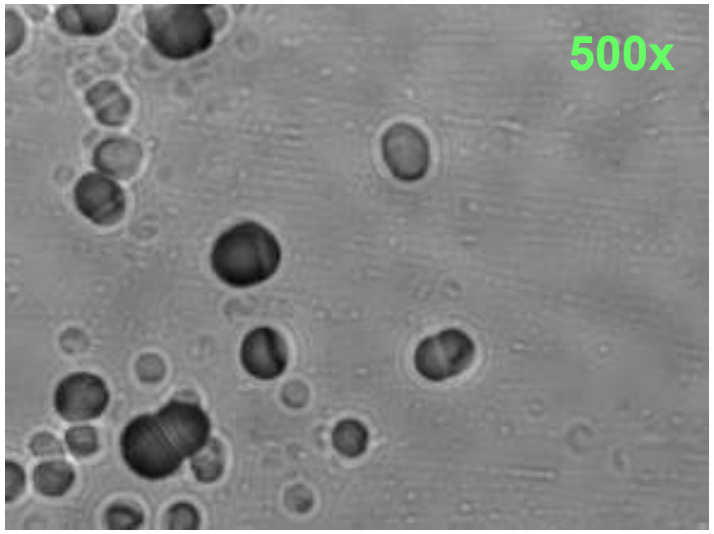
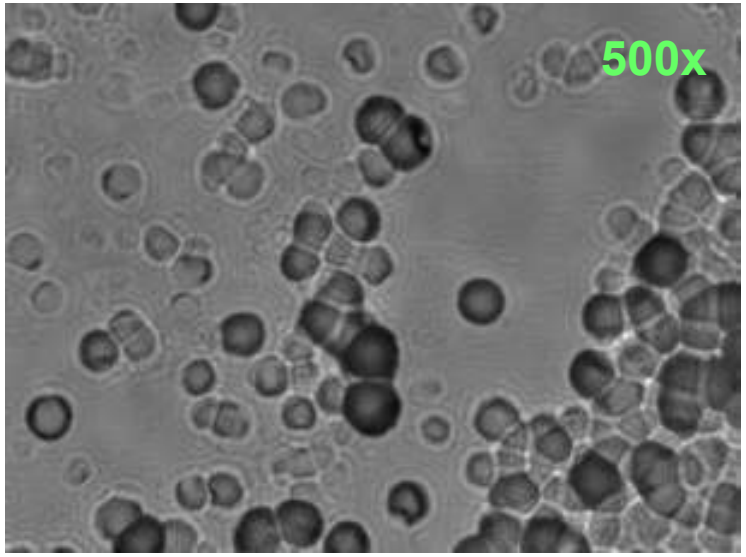
Ag wire/Pd/D in Magnetic Field

Naturwissenshaften, Vol. 94, pp. 511-514 (2007)









Source: In collaboration with JWK International under CRADA agreement

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Summary of Control Experiments

EPJAP Vol. 40, pp 293-303 (2007)

- Pits are not due to radioactive contamination of the cell components
- Pits are not due to impingement of D_2 gas on the surface of the CR-39
- Pits are not due to chemical reaction with electrochemically generated D_2, O_2, or Cl_2
- LiCl is not required to generate pits
- D_2O yields higher density of pits than H_2O
- Pd/D co-dep gave higher density of pits than Pd wire

Source: In collaboration with JWK International under CRADA agreement

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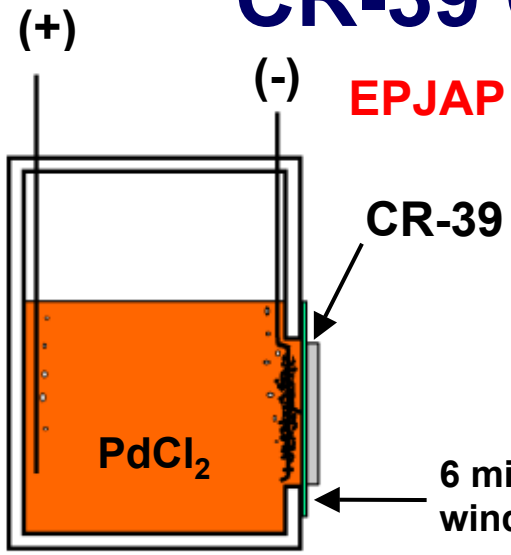
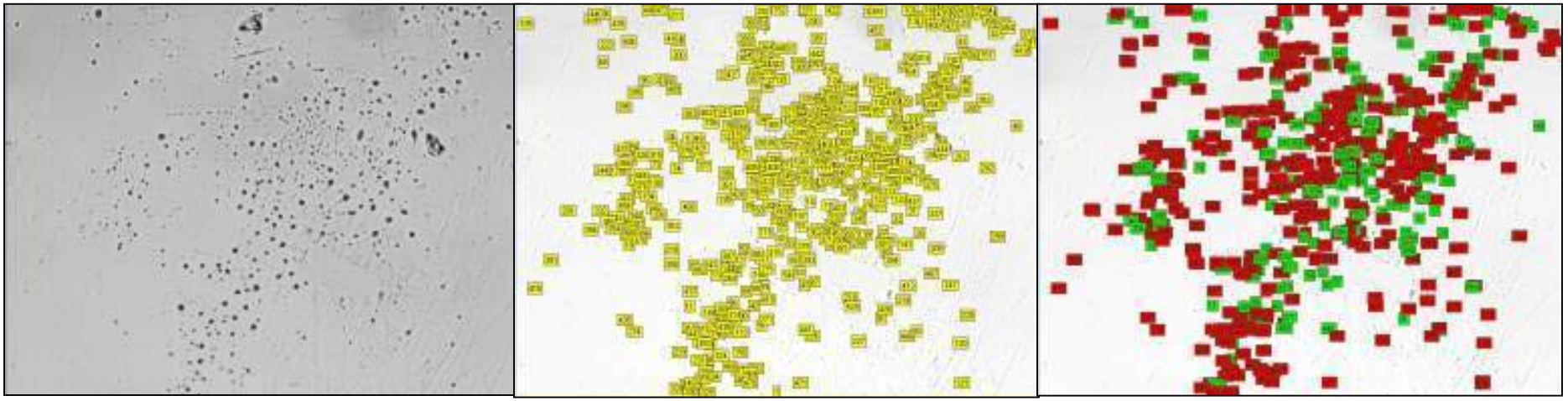
CR-39 Outside the Cell



EPJAP Vol. 44, pp 291-295 (2008)

- No contact between CR-39 and cell electrolyte.
- Nuclear particle tracks scanned and counted by computer

← 600 μm →



Raw image | Computer processed | Computer identified

Tracks not caused by chemical or mechanical damage!

Source: In collaboration with JWK International under CRADA agreement

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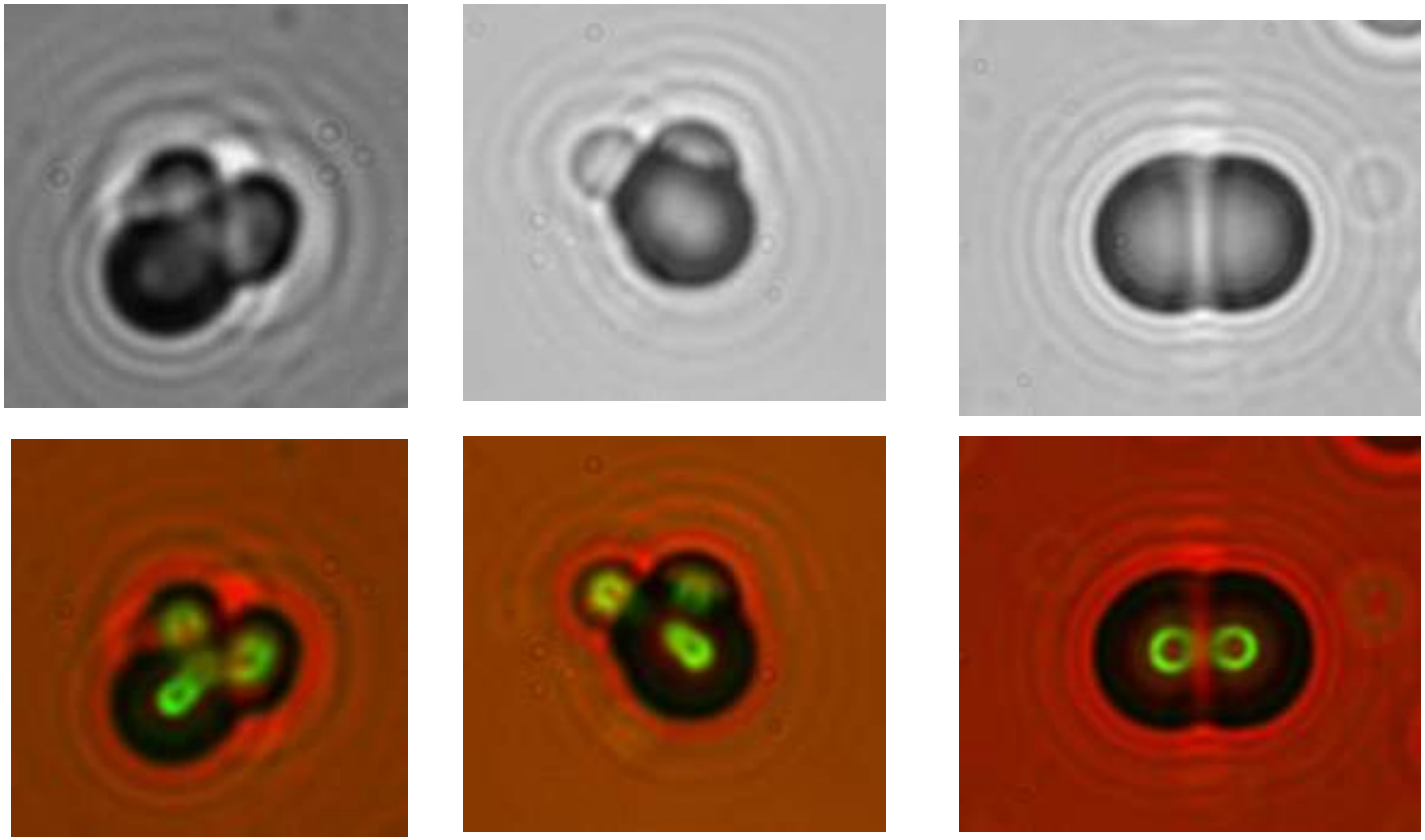
Pd/D Co-Dep Experiment: Triple and Double Tracks

Naturwissenshaften, Vol. 96, pp. 135-142 (2009)



- To form triple tracks in CR-39, the neutron energy has to be greater than 9.6 MeV

Source: In collaboration with JWK International under CRADA agreement

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Peer Reviewed Publications

- ~~22~~ 23 peer reviewed Journal articles and book chapters have been published or are going to print:
  - American Chemical Society Low Energy Nuclear Reactions Source Book
  - Journal of Electroanalytical Chemistry
  - Naturwissenschaften (Germany)
    - *Einstein published here*
    - *First paper on Nuclear Fission published here 70 years ago by Hahn and Strassman*
  - European Physical Journal of Applied Physics
    - *Nobel Prize winners, 2007, for Chemistry and Physics published here.*
  - Thermochimica Acta
  - Journal of Fusion Technology
  - Il Nuovo Cimento (Italy)
  - Physics Letters A

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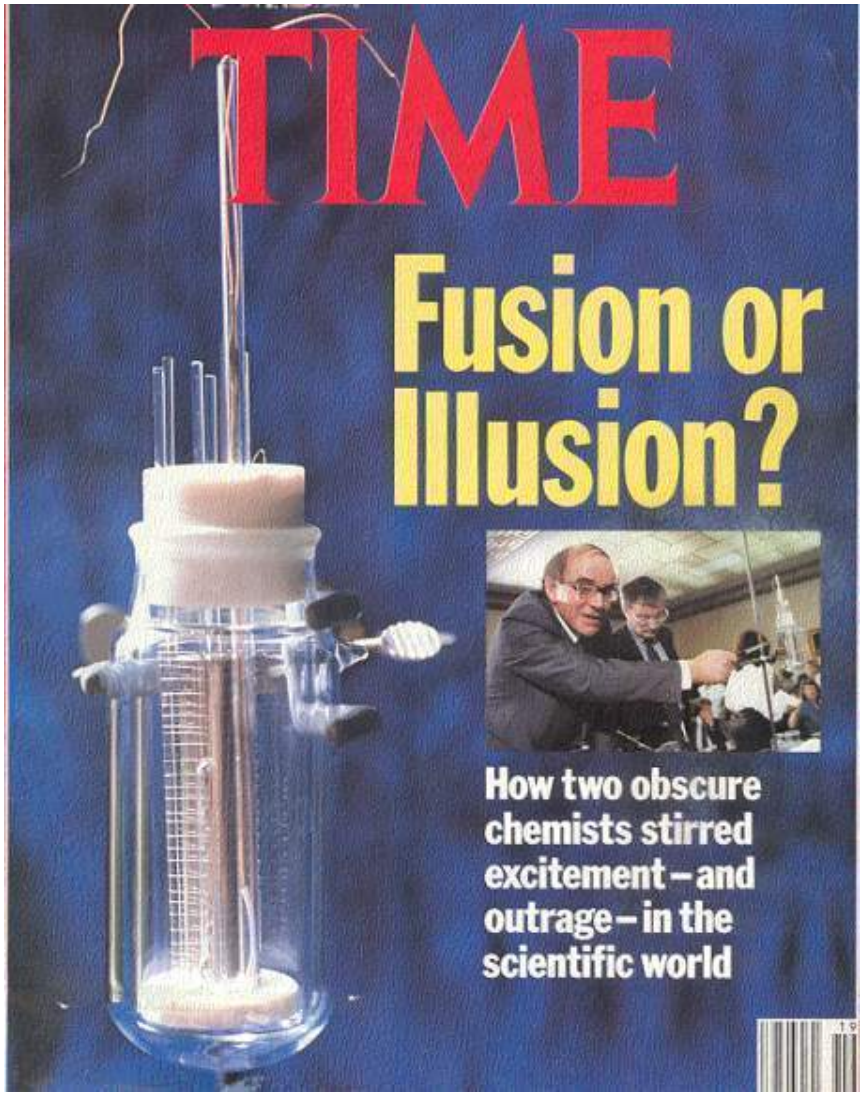
March 23, 1989

- Pons and Fleischmann announce that electrochemical cells are producing more heat than can be accounted for by chemical means and speculated that nuclear reactions must be occurring.
- Physics community notes:
  - the experiments aren't repeatable
  - there aren't any refereed papers
  - the experiments haven't been replicated
  - If it's nuclear, where are the neutrons?"
  - It doesn't match theory
- Thousands of scientists worldwide attempted experiments—most failed



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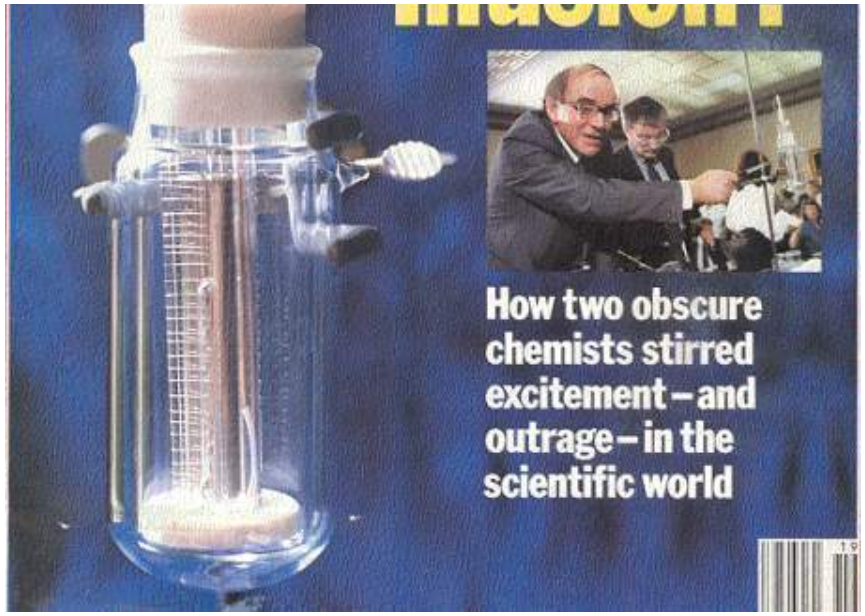

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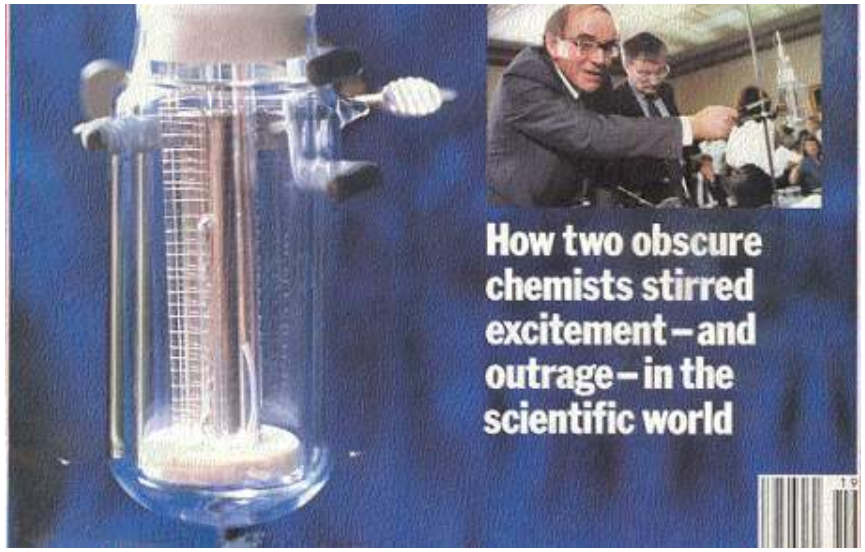

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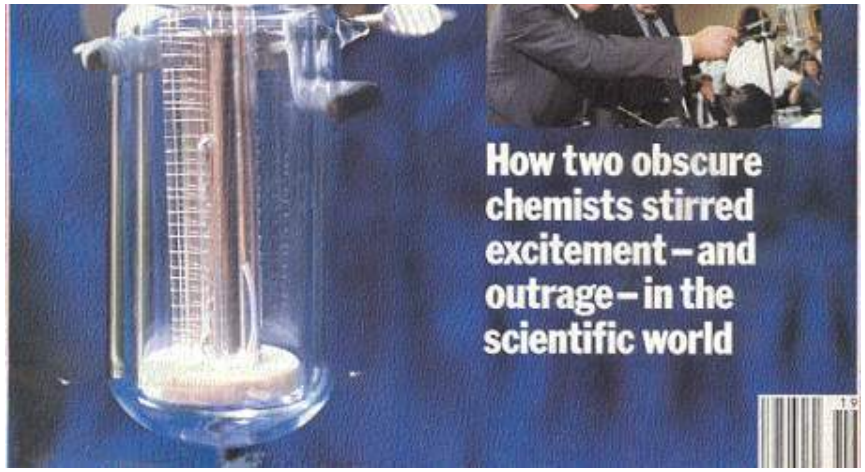

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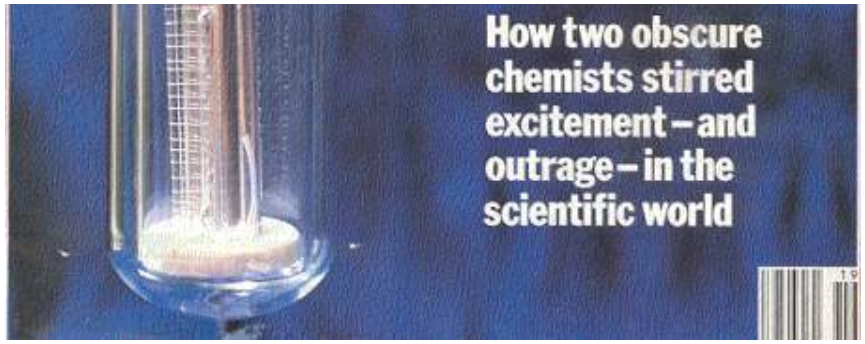

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  - multiple nuclear products, including neutrons have been detected
  - Work to update theory underway
- Groups of scientists worldwide have successfully performed experiments

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Conclusions

- Nuclear events can be triggered by electrochemical means
- More research is needed to understand the phenomena
- New theories are evolving based on experimental results