NUCLEAR BATTERY USING D-CLUSTERS IN NANO-MATERIALS --- PLUS SOME COMMENTS ABOUT PRIOR H_2-Ni POWER CELL STUDIES

George H. Miley[1,3], Xiaoling. Yang[1] , Heinrich Hora[2]

1, Department of Nuclear, Plasma and Radiological Engineering, Univ. of Illinois, Urbana, IL

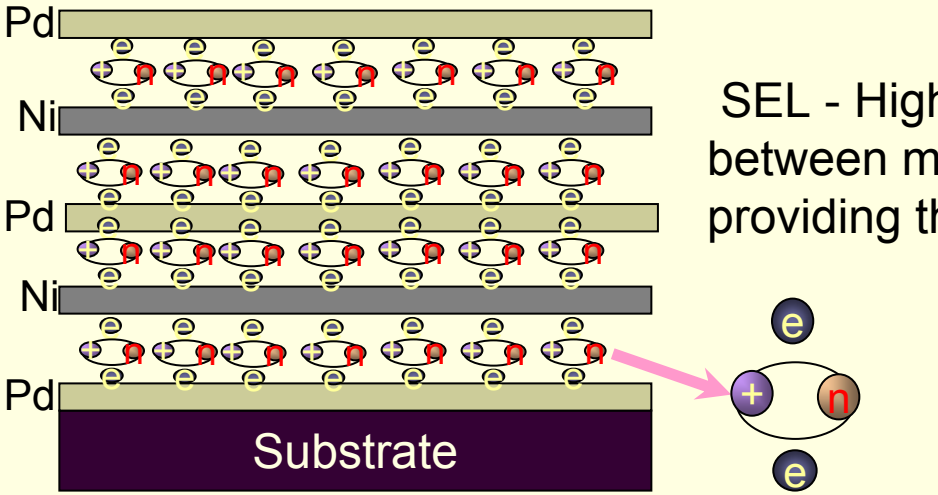
2. Dep. Theoretical Physics University of New South Wales, Sydney, Australia

3. NPL Associates, INC., Champaign, IL 61821

Outline

- Comments re prior light water Ni studies – Patterson Cell
- More recent experiments using thin-film plate type electrodes conditioned for cluster formation.
- Evidence for D-clusters and comments about theory
- Possible triggering methods the initiate nuclear reactions in these high density clusters
- Preliminary gas loading nanoparticle experiment
- Road Map and Future goal of the LENR study for Nuclear Battery applications

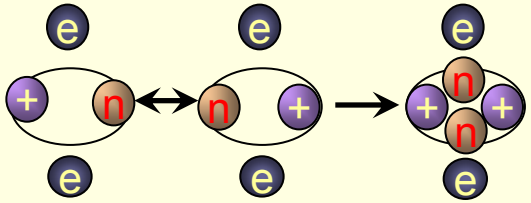
SEL Theory lead the design of our early experiments. Patterson had already used multilayer films so that work fit right in also. Electrolytic loading used instead of gas pressure – but once loaded the mechanisms should be much the same.



Swimming Electron Layer (SEL) Theory

Zoom-in View

SEL - High density electron clouds – exists between metals of different Fermi energy, providing the necessary screening



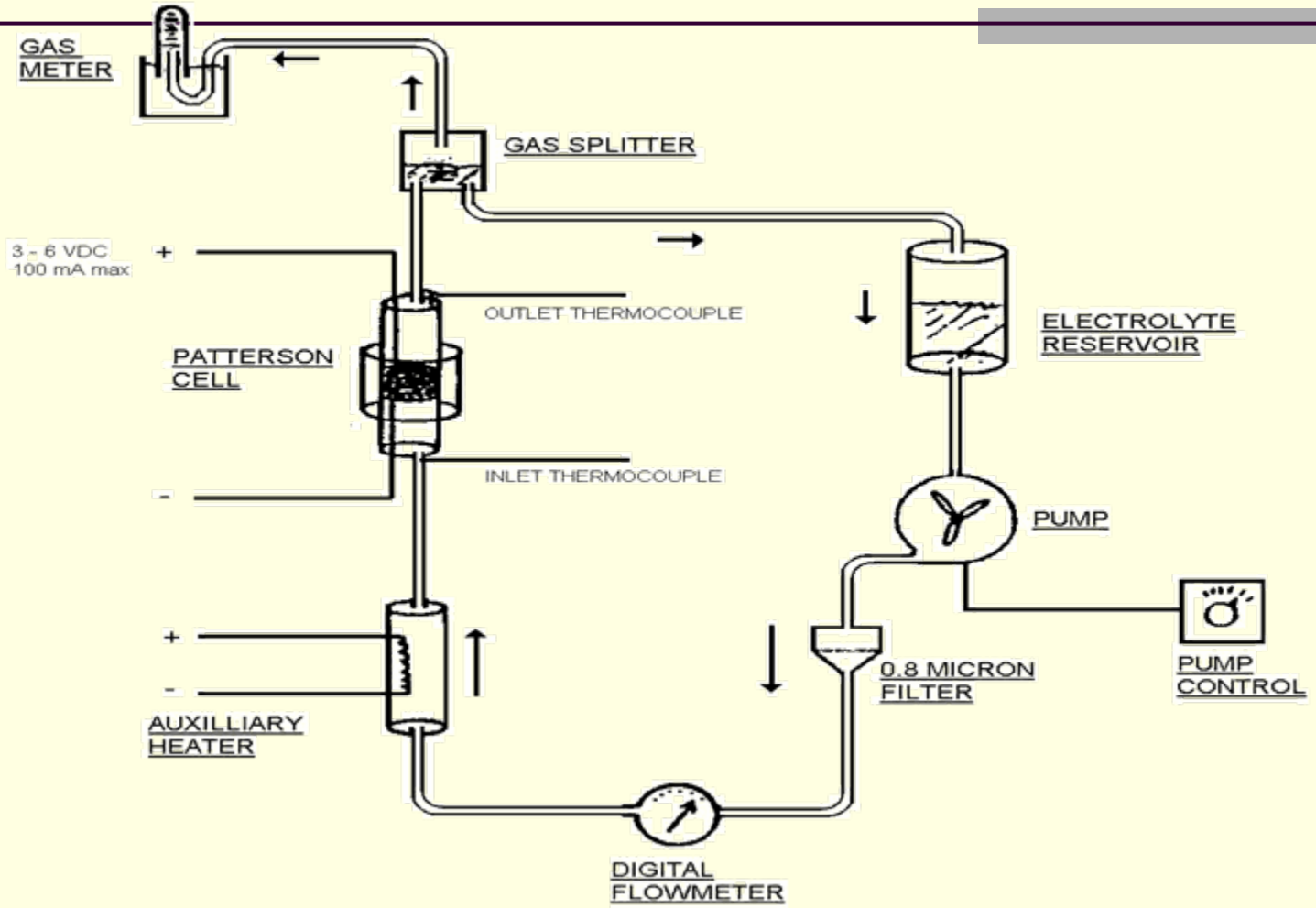
Comments – Patterson Cell Studies – Light water- Ni system

Key point – identification of reaction products and connection to heat release.

[Jim Patterson and his grandson, Jim Redding, founded CETI to develop this power cell. Various demonstrations of a 1-kW unit were done and Jim appeared on the “today” TV show. They had a contract with a hot water heater company as a first “application”. Avoided energy conversion integration problems. His grandson’s sudden death, followed several years later by Jim’s ended their efforts. But the results are documented and I was involved in the work as reported here.

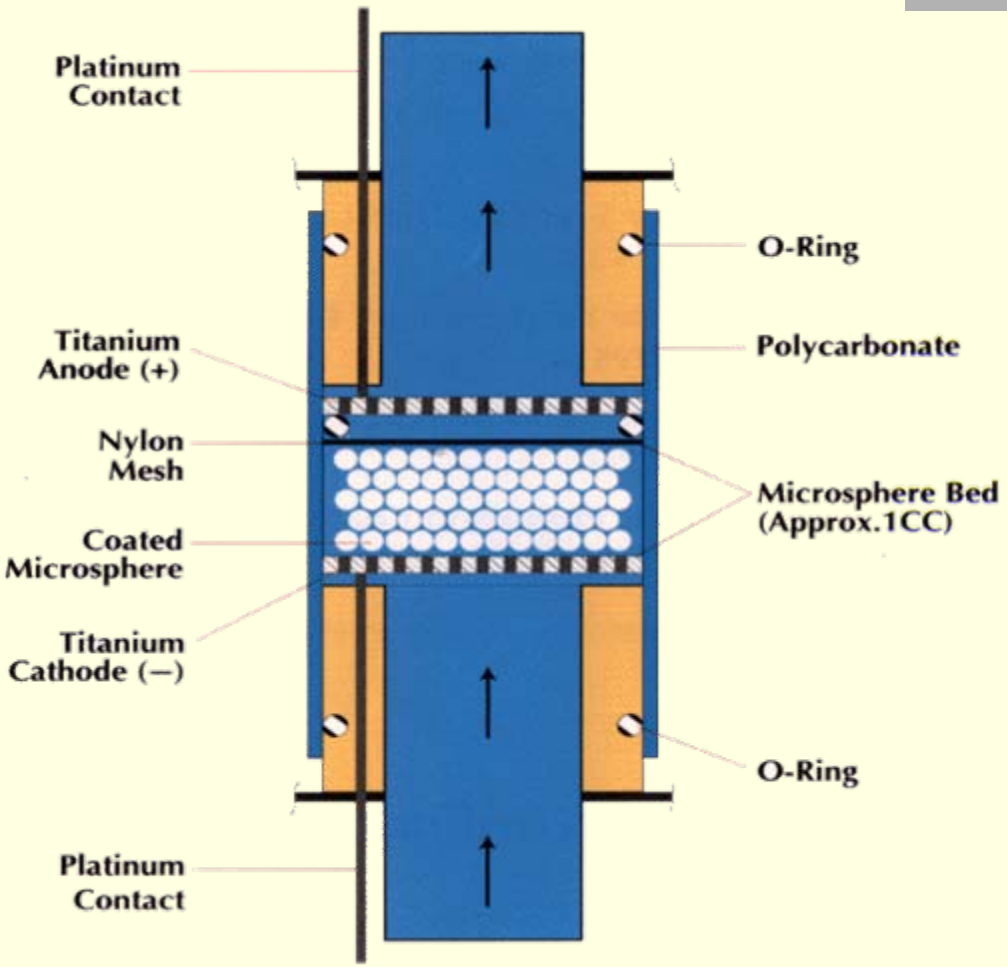
EXPERIMENTS

Process Flow Sheet of Electrolysis



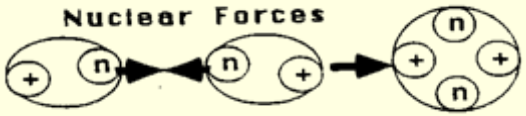
EXPERIMENTS

Patterson Power Cell™ Design

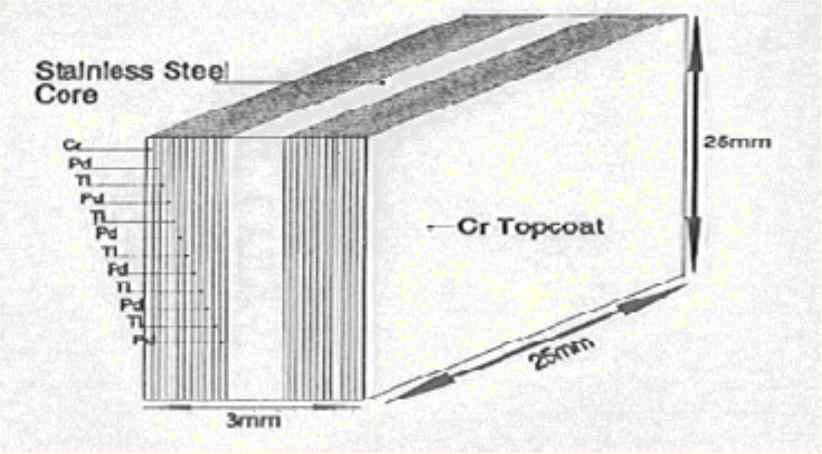


SEL Theory and Experiments to Design Multilayer Thin-film Electrodes

BACKGROUND



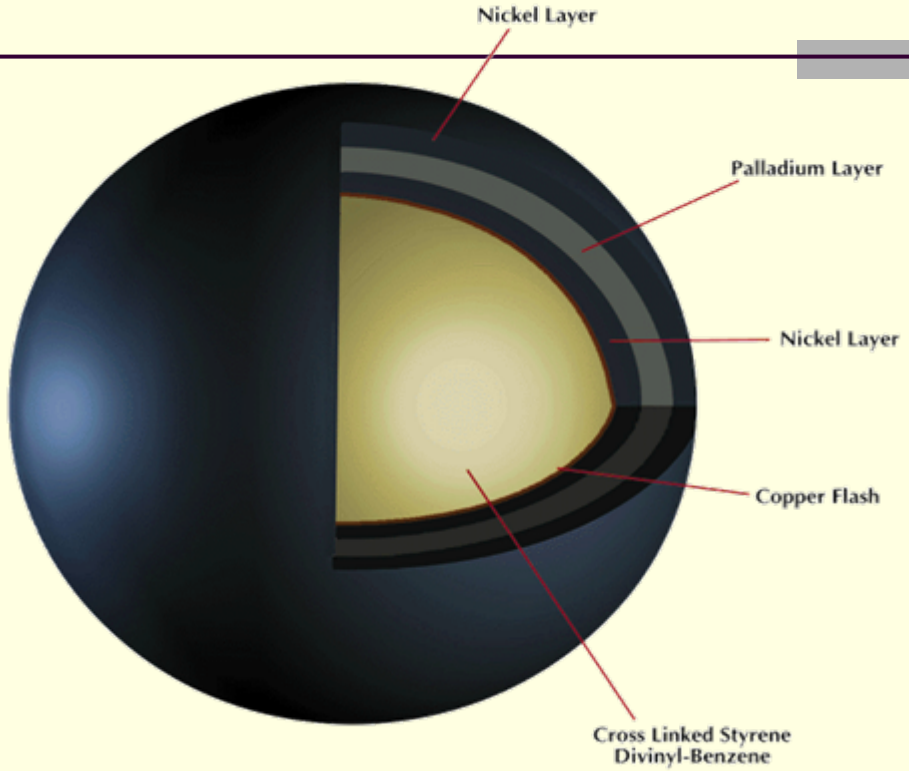
Fusion of two nuclei, shielded by the swimming electron layer



Multilayer thin-film electrode design with alternating layers of Pd & Ni or Ti with a topcoat of Cr

Microsphere Design

BACKGROUND



CETI uses an electrolytic coating process to coat metals on the microspheres. My sputter coating technique achieves better control of coating thickness and sharp interfaces compared to the electrolytic process. – however the ecess heat is cut by an order of magnitude!

EXCESS HEATS OF 1-2 KW WERE CONSISTENTLY PRODUCED WITH THESE CELLS. HOW? LIGHT WATER AND NI SHOULD NOT PRODUCE A REACTION!! THE NEXT SLIDES EXPLAIN MY SEARCH FOR AN ANSWER. I PROPOSE THAT SIMILAR STUDIES SHOULD BE DONE FOR ROSSI'S CELL.

Rational for Combined SIMS-NAA

- Analysis for a large number of isotopes needed.
- NAA is time consuming and was limited to nine elements with appropriate cross sections where reference standards were available.
- SIMS, with ultra low detection limits, could detect all isotopes rapidly, but it provides relative isotope concentrations and abundance ratios are more precisely than it does absolute concentrations.
- Thus the SIMS concentration values were normalized to the more accurate NAA results.

SIMS Analysis

- Initial runs done in low resolution.
- conditions (off-set voltage, entrance/exit slits, field aperture, energy slit) optimized to minimize interferences.
- Isotopes of interest with possible interference then selected for high resolution.
- Error analysis considers interference effects, fractionalization, non-uniformity, small sample numbers.

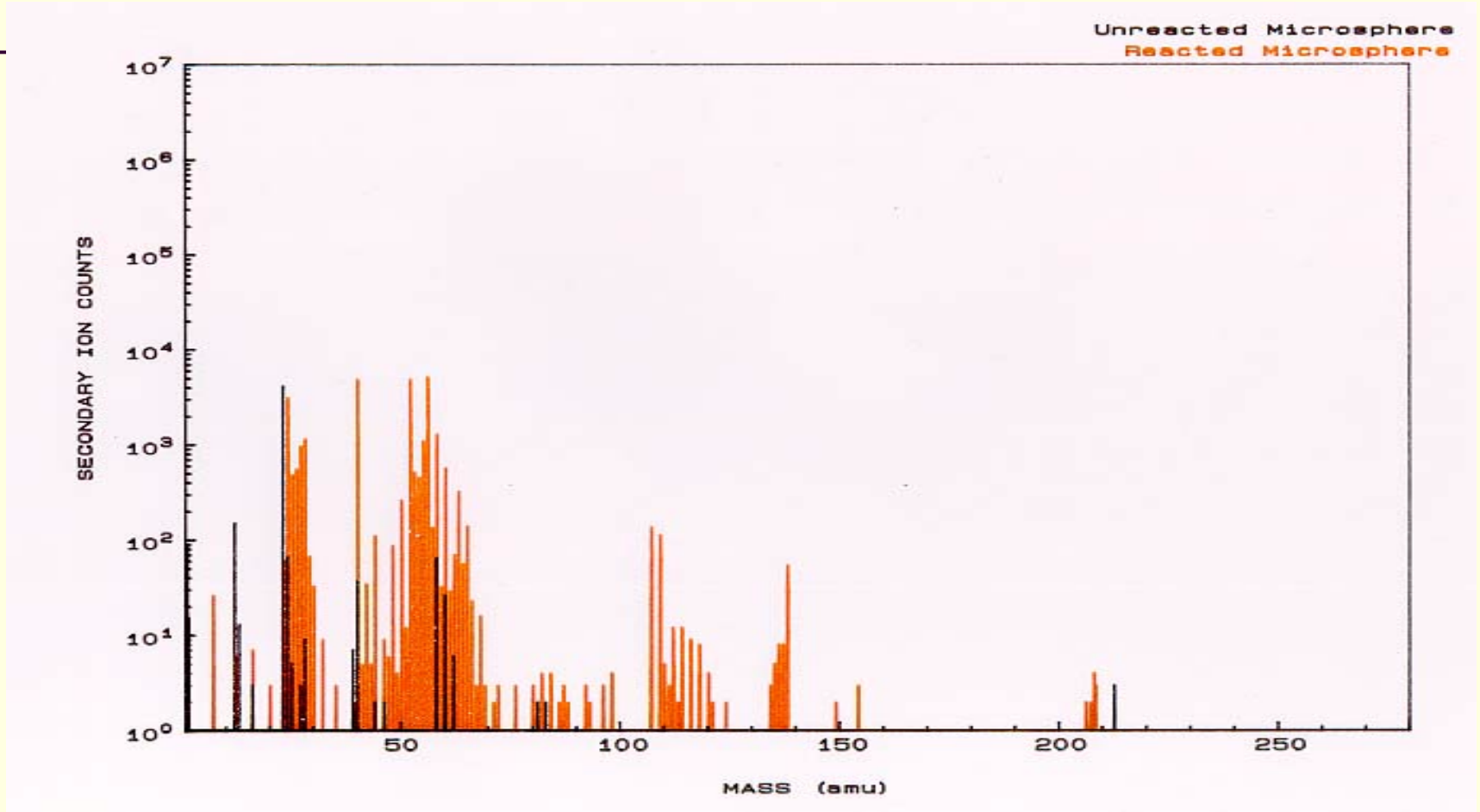
Operating Characteristics of Dual Focusing SIMS (CAMECA IMS 5f)

primary ions: 10 to 40 μm O_2^+ at 14.5 keV
primary ion raster size: 125x125 μm^2
primary ion current: 10 nA (25-100nA ocassionally used)
mass resolution ($\frac{M}{\Delta M}$): 300 low and 5000 high resolution mode
secondary ion polarity: positive
field aperture: 400 μm ; contrast diaphragm aperture: 150 μm
sample chamber pressure: $\leq 5 \times 10^{-10}$ Torr

Table 2.2. Experimental conditions for SIMS analysis.

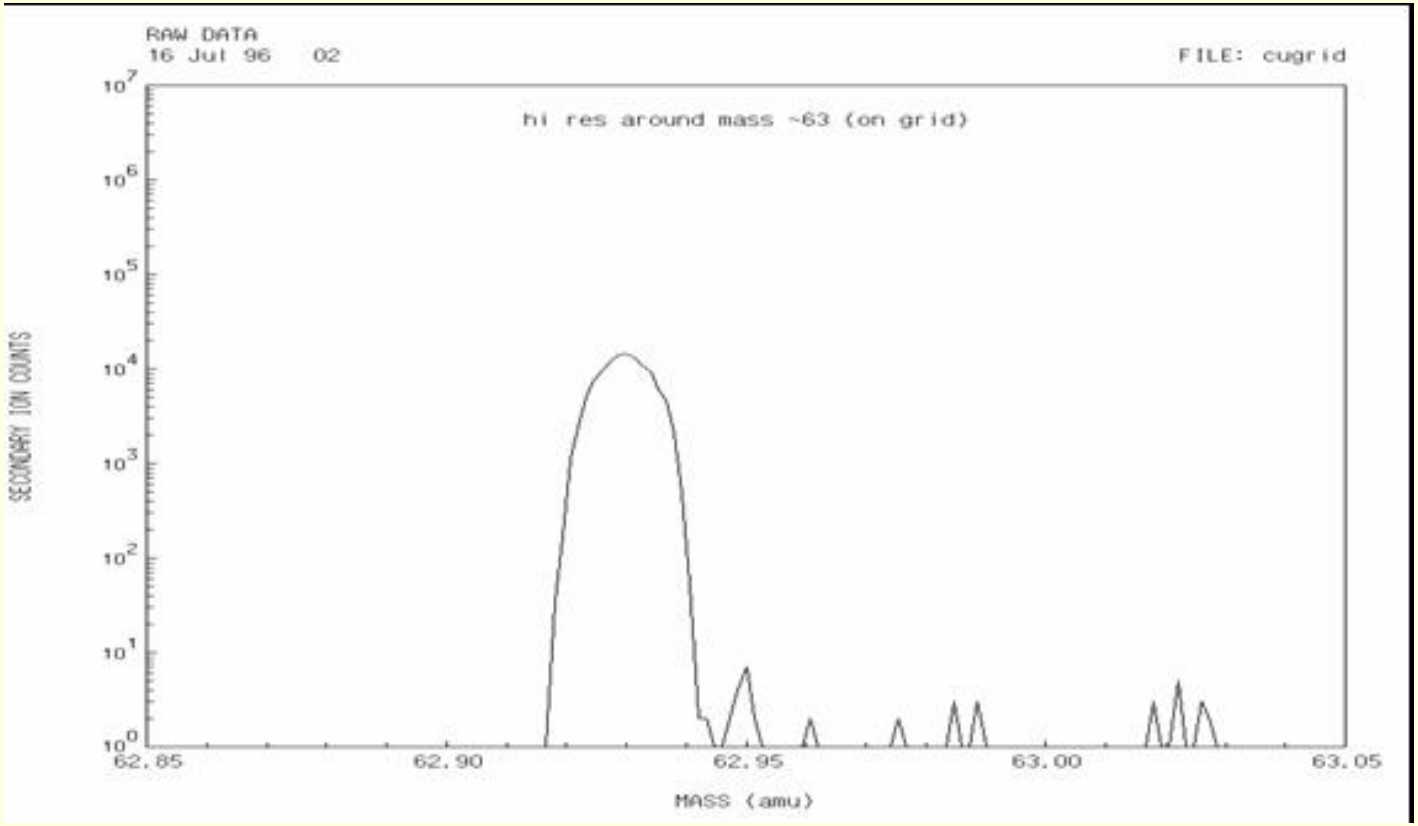
Quantification of Isotopes by Combined SIMS & NAA

DIAGNOSTICS



Mass Spectrum of a sample, indicates relative concentrations of species. Compare spectrum before and after electrolysis.

High-Resolution Mass Spectrum for 63Cu Isotope Identification. The Mass Range Analyzed is 62.85 to 63.05 amu, with a Total of 150 Channels, Going of ~4625.



Parameters for NAA Runs

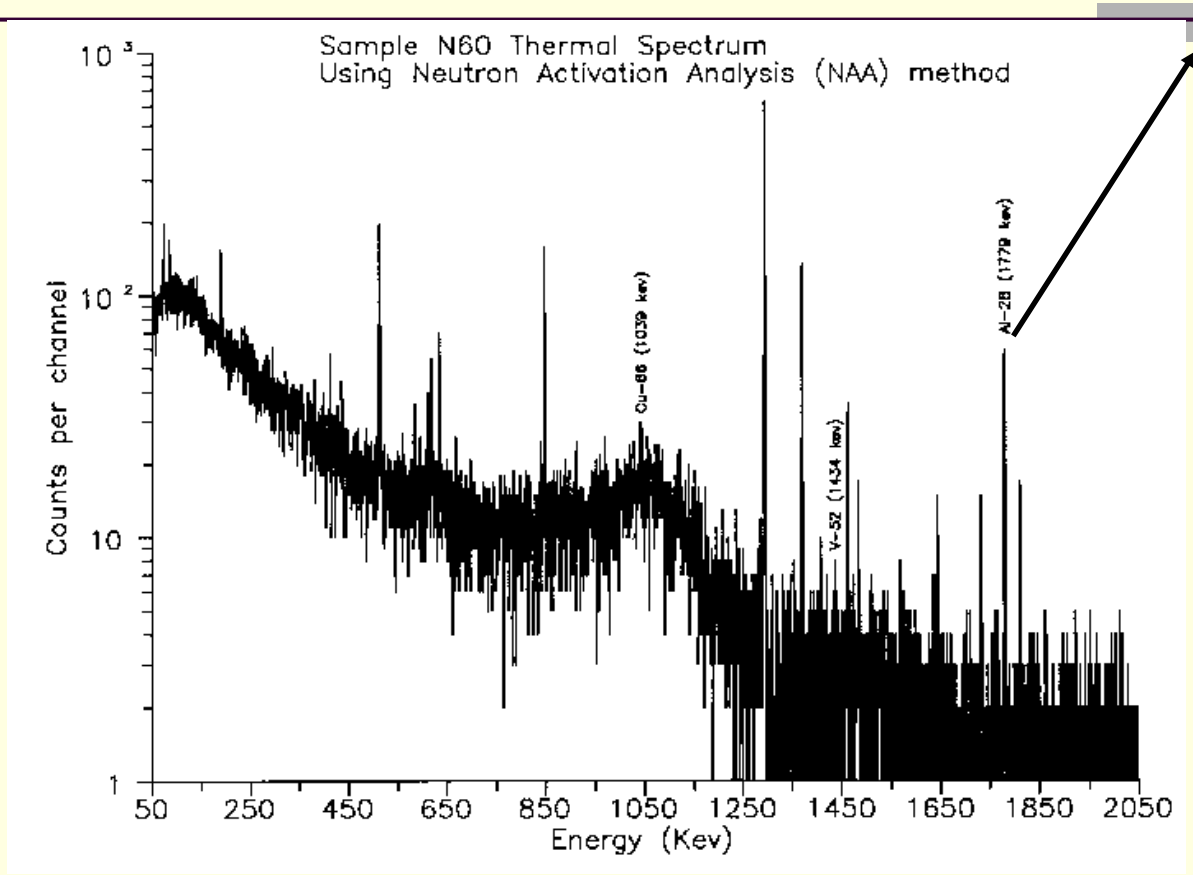
Method	Irradiation facility (flux, n cm^{-2} s^{-1})	Analytical Procedure		
		Irradiation time	Decay time	Counting time
Thermal short-lived	PS (3.7E+12)	10 - 300 sec.	5 - 20 min.	10 - 20 min.
Epithermal medium-lived	CLNAT (2.1E+11)	2 - 8 hrs.	2 - 5 days.	1 - 10 hrs.
Thermal long-lived	LS (3.4E+12)	2 - 6 hrs.	15 - 35 hrs.	3 - 6 hrs.

NAA Detection System and Analysis

- The gamma-ray detector system had: a liquid N2 cooled high purity germanium (HPGe) crystal detector with an 18% relative efficiency (1.9-keV resolution for the 1332-keV photopeak of 60Co); A large NaI(T1) crystal ring detector outside the main detector; An ORTEC ADCAM PC-based mutichannel analyzer.
- Compton suppression was used to further minimize the background.
- A reference standard method was used to determine the comparative method for measuring the concentration of the element(s). This used simultaneous irradiation and -counting of a prepared NIST sample (one standard for each element to be estimated) along with the test sample.
- The spectrum data was processed using the Neutron Activation Data Analysis (NADA) code. The output included concentration values in %, ppm, g or ppb units and associated errors.
- Flux variations, high deadtime corrections, counting geometry, spectral and nuclear interference, as well as uranium fission interference were accounted for in analysis.

Typical NAA Spectrum

DIAGNOSTICS



NAA Result

Sample ID	ppm
Ag (ppm)	125.4
Al (ppm)	11.2
Cu (ppm)	27.0
V (ppm)	0.1
Cr (ppm)	2.9
Ni (ppm)	1821.0
Fe (ppm)	217.2
Zn (ppm)	15.4
Co (ppm)	0.6

Gamma spectrum with sample chart of concentrations. The spectrum of gamma-rays is used to identify and quantify the element that emitted it, using a reference sample in the same run.

NAA Results Before and After Run Shows Large Increase in Nine Elements Selected

Element	**Concentration** (ppm)	**Error** (ppm)	**Detection Limit** (DL) (ppm)
Ag	1.88	0.14	0.02
Al	40.66	2.75	1.60
Cu	< DL		24.62
V	< DL		0.19

Table 5.7(a). NAA result of microspheres from batch #prior to run #15.

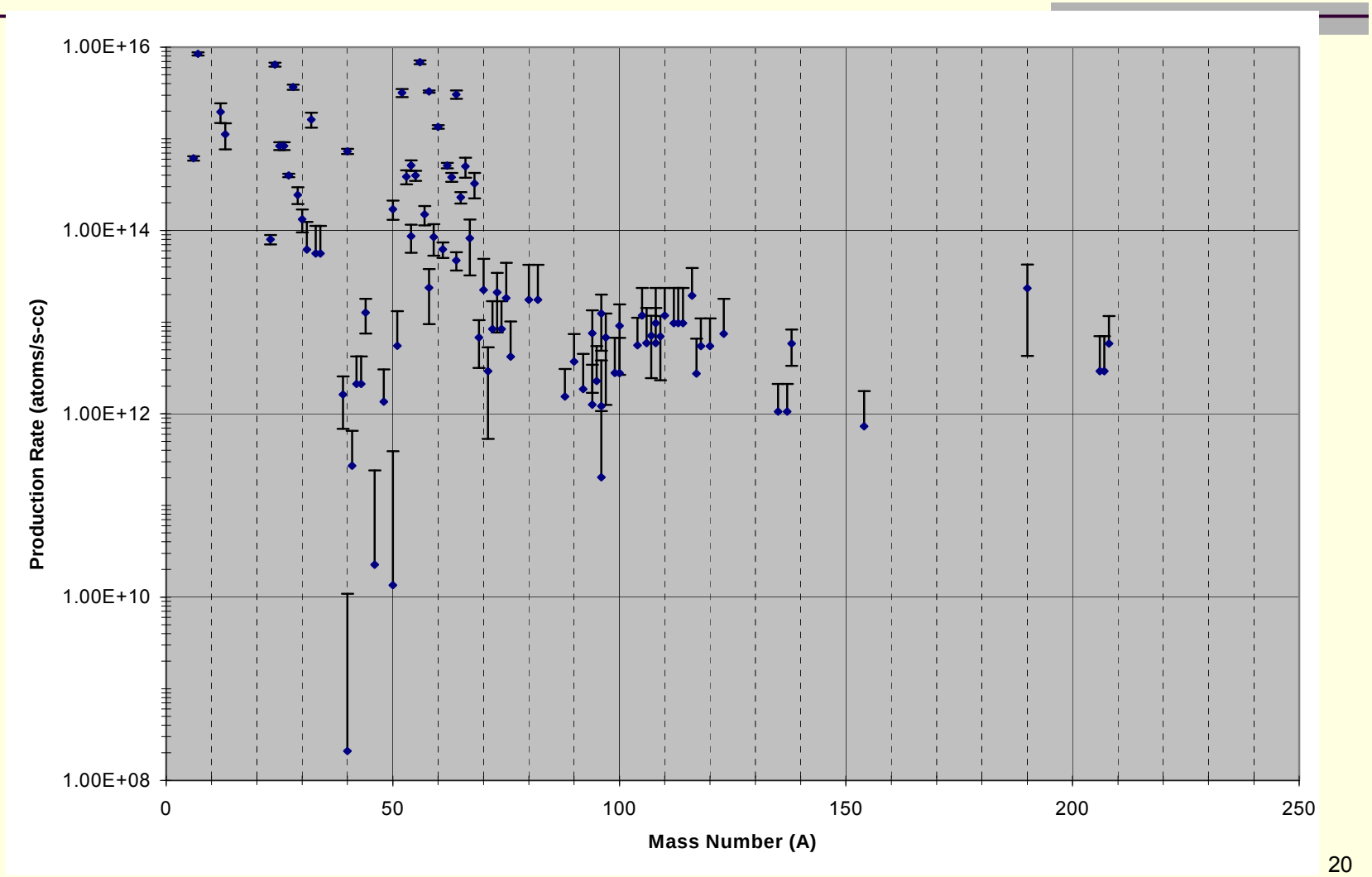
Element	**Concentration** (ppm)	**Error** (ppm)	**Detection Limit** (ppm)
Ag	5.53	0.38	0.47
Al	39.17	3.24	4.21
Cu	141.54	26.79	79.10
V	1.02	0.15	0.32
Fe	1528.83	59.93	135.47
Cr	722.79	7.63	3.81
Co	18.23	0.29	0.21
Ni	1123.88	18.46	24.99

Table 5.7(b). NAA result of microspheres from batch #15.1.1 after run #15.

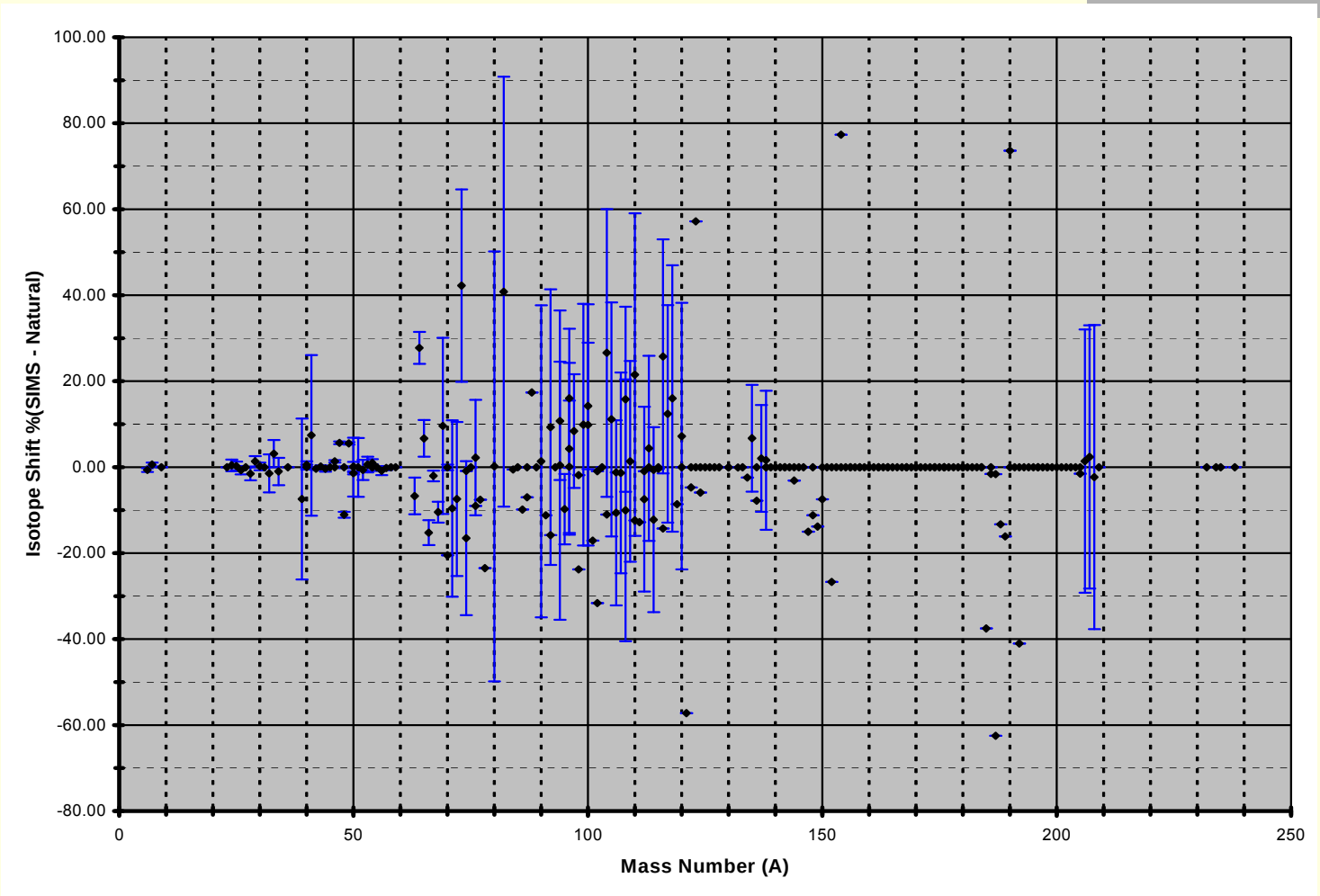
Results

- Large increase in number of isotopes found after a run.
- Four regions (“peaks”) of mass number have higher concentrations.
- Concentrations appear to be much larger than possible due to impurities in cell.
- Concentrations divided by run time defined as reaction production rate.
- Isotopes in 39 elements show significant deviations from natural abundance.

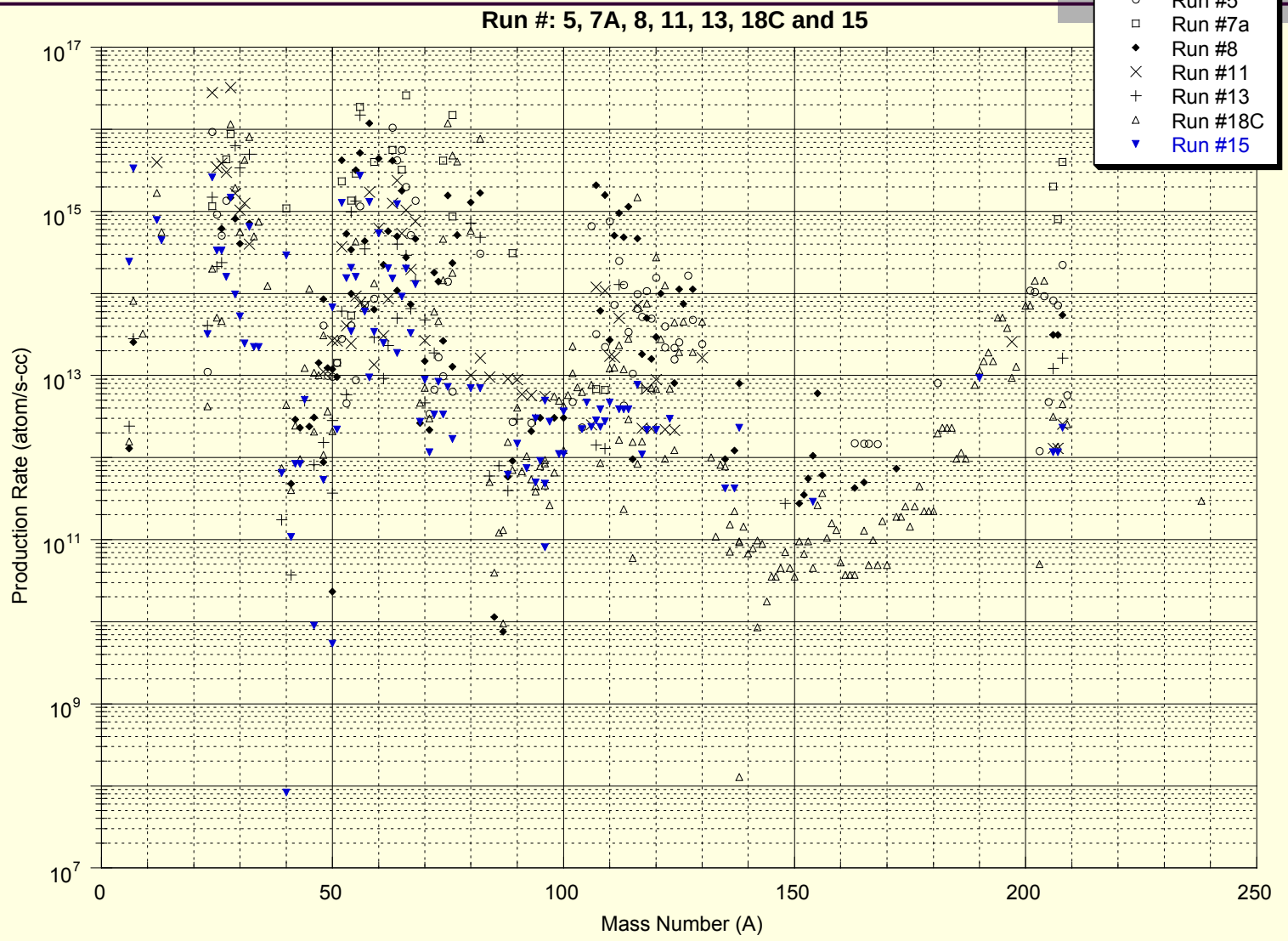
Isotope Production Rates Show Large Yields of Key Elements and 4 “peak” Pattern



39 Elements Show Significant Isotope Shifts from Natural Abundance



Comparison of Ti Run with Prior Data for Other Coatings Such as Ni



Conclusions and relation to Rossi

- To summarize, this research developed a unique SIMS-NAA analysis technique for studies of isotopes in thin films after undergoing electrolysis in a packed bed cell.
- This technique combines the broad coverage of elements with SIMS and the absolute precision capability of NAA.
- This technique should be applicable to a broad range of analysis problems of interest.
- I would suggest that this technique be applied to the Rossi cell
- A key issue – are these product & associated reactions responsible for the excess heat? As shown in later slides, the answer seems to be that these reactions are a major contributor.

Ideal smoothed coated films not as good as “rough” ones. Implied local defects played a role. Reaction products highly concentrated near interfaces, perhaps due to anchoring of dislocations there.

OTHER LESSONS LEARNED

Outline

- Comments re prior light water Ni studies – Patterson Cell
- More recent experiments using thin-film plate type electrodes conditioned for cluster formation.
- Evidence for D-clusters and comments about theory
- Possible triggering methods the initiate nuclear reactions in these high density clusters
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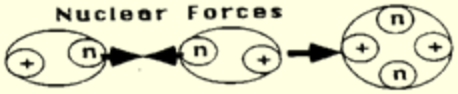
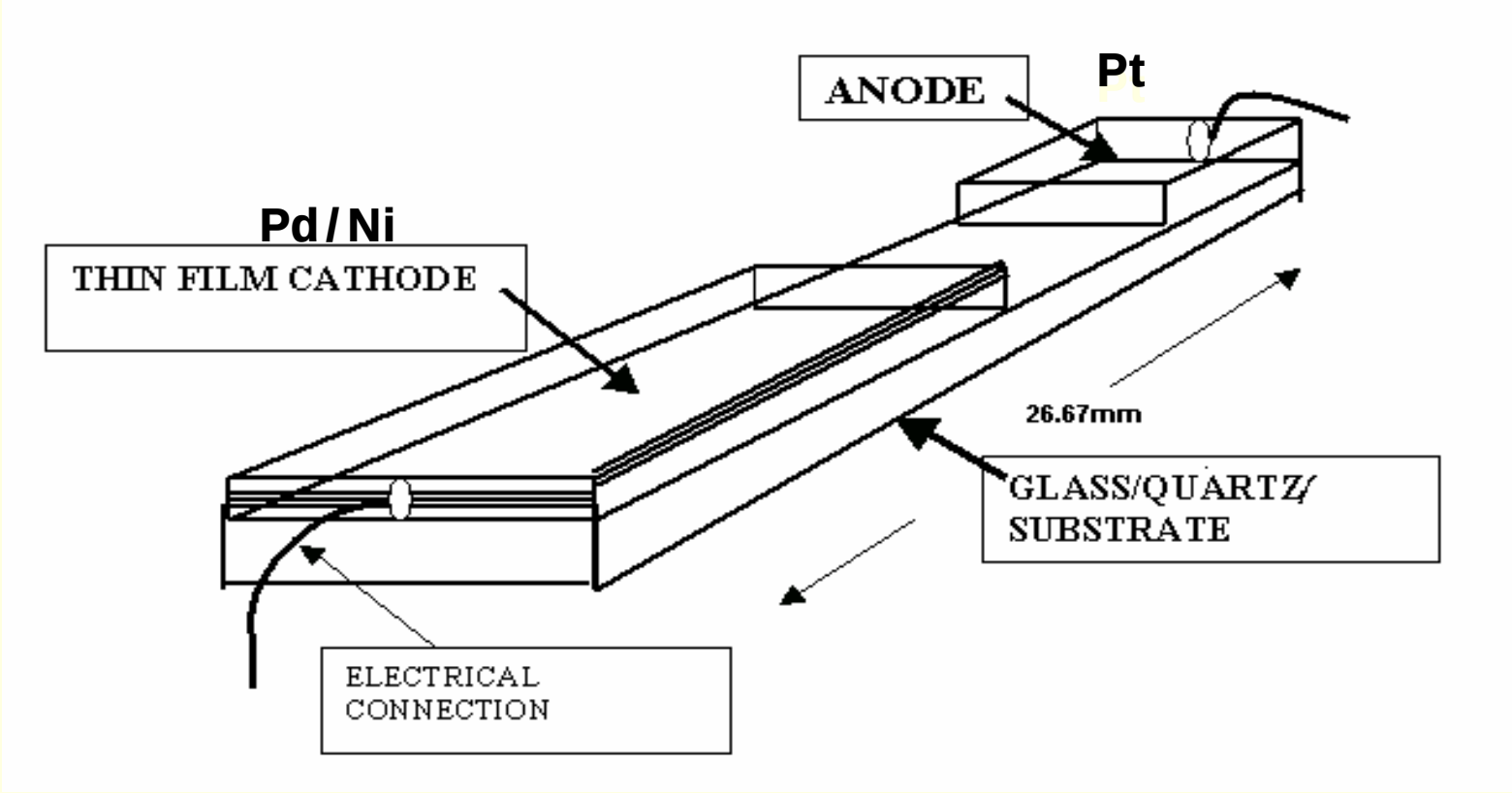
SEL Theory Lead to Multilayer Thin-film electrodes- went to flat plates vs. beads to obtain better control over manufacturing film & defects

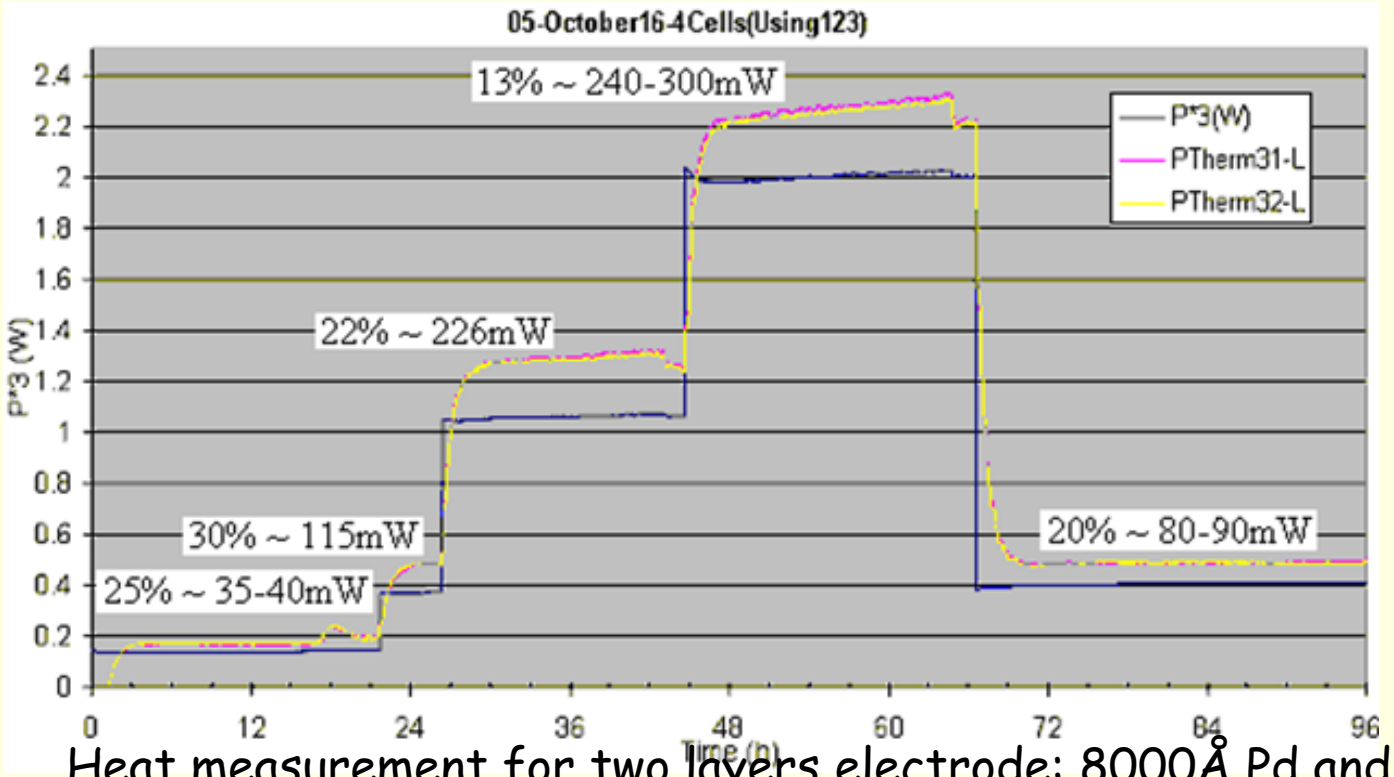
- Concept





Multilayer thin-film electrode design with alternating layers of Pd & Ni. Planar A-K structure used to maximize H2 concentration via electrodiffusion

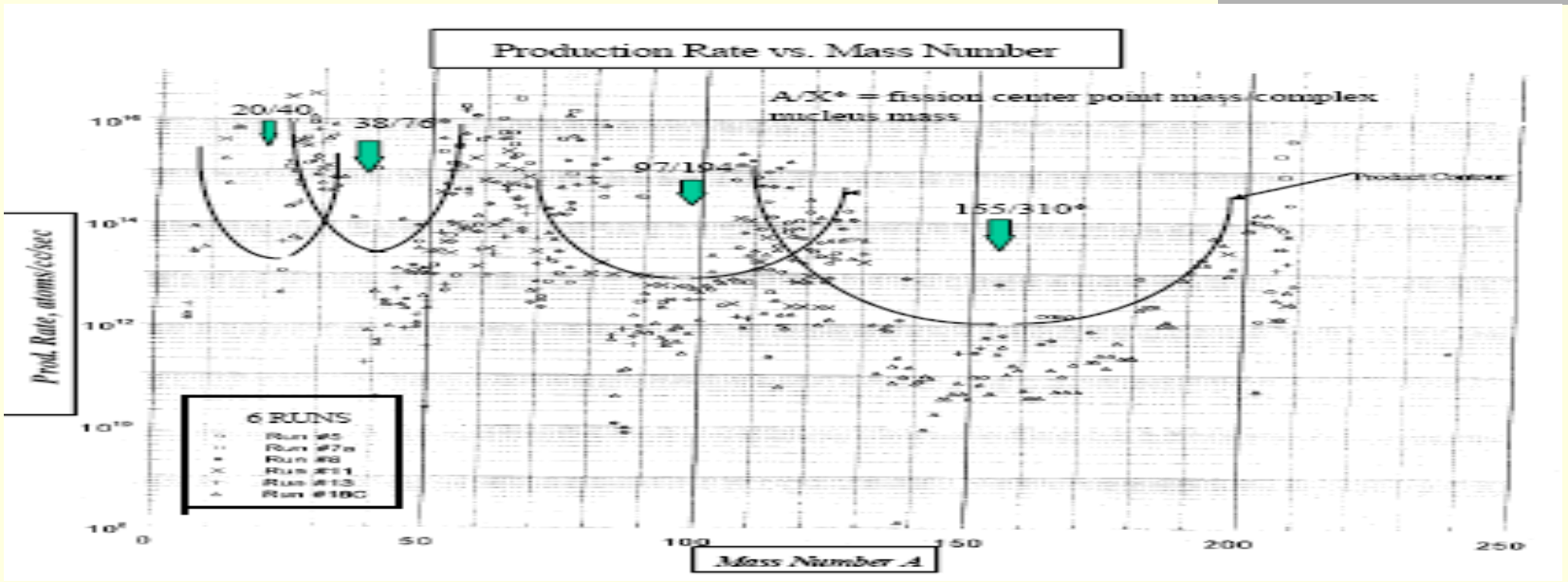
Results #1 -- Calorimetry Shows During Electrolysis Thin-Film Electrodes Produce Significant Excess Heat



Heat measurement for two layers electrode: 8000Å Pd and 1000Å Ni on Alumina.

P_{therm}: Measured Heat power;
$P^*=I(U-U_0)$: Input electrical Power

Results #2 -- Transmutation Products



Reaction Product Yield vs. Mass Curve

D-D Reactions

		hot fusion	% branching "P-F" type
D-D →	T + p	50	< 0.1
	He-3 + n	50	$< 10^{-6}$
	He-4 + gamma	$< 10^{-5}$	99+

Transmutations

proton + metal → products or "fission" product

Computation of excess power from reaction product measurements gives order of magnitude agreement with measurement.

$$\left[\sum_{RPs}(RP * BE/n) - \sum_{\substack{metal\ atom,\\ p\ burned}}(fuel * BE/n)\right]/run\ time = P_{out}$$

$$\Xi\ W_{excess}$$

Computation of Excess Power from measured reaction products and binding energies where:
RP = reaction product yield or atoms of product formed nuclei
BE /n= Binding energy per nucleon for RP or fuel
fuel = metal nuclei + protons reacted (from nucleon balance)
p = proton

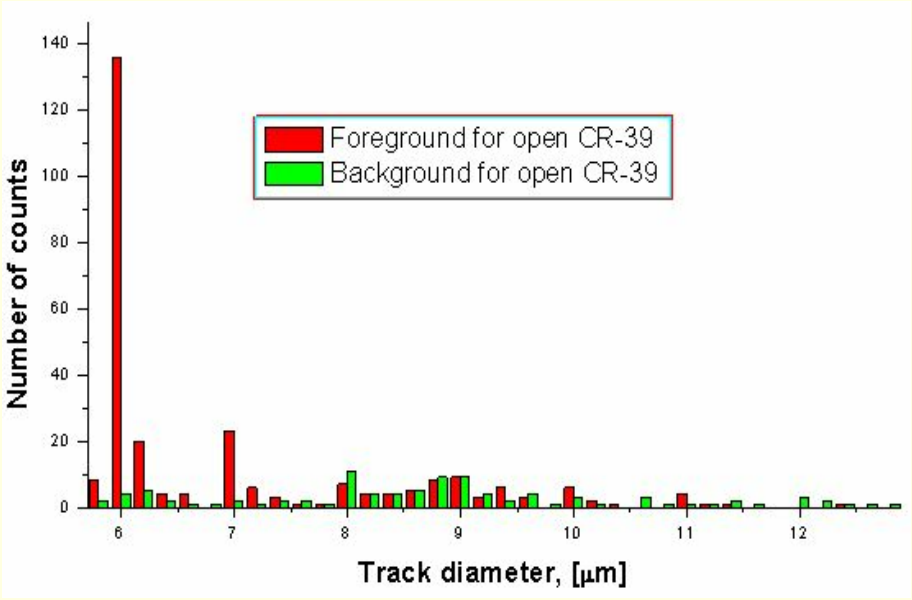
Equation

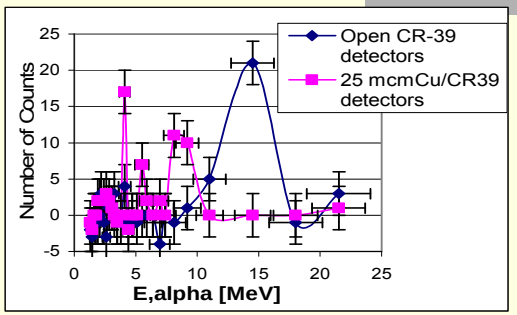
Run Number	*Excess Power (W)*	
	Calculated	Measured
#7	1.9 ±0.6	4.0 ±0.8
#8	0.5 ±0.2	0.5 ±0.4
#18	0.7 ±0.3	0.6 ±0.4

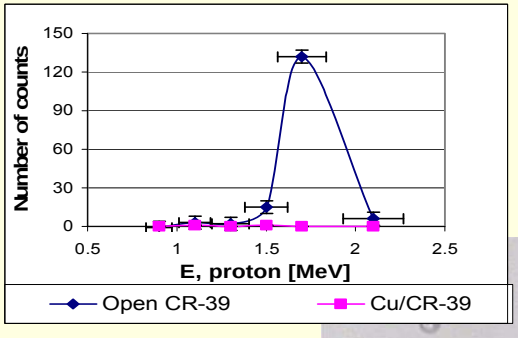
Results from Energy Balance Calculations for Three earlier Thin-Film experiments.

All experiments used Li_2SO_4 in H_2O for the electrolyte and thin-film Ni coated cathodes.

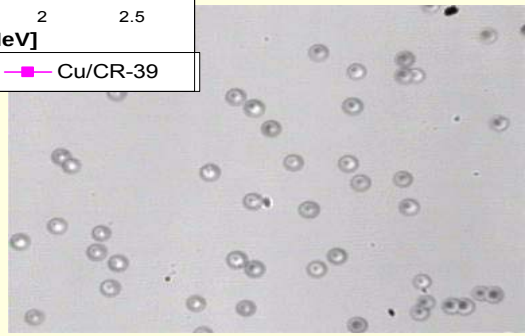
Results #3 -- MeV charged-particles Alpha-Particles and Protons







High-energy charged particles: After background subtracting 16 MeV alphas, 1.5 - 1.7 MeV protons and 11-



Tracks in CR-39 from 12.0 MeV α-particles; image area S= 0.2x0.2 mm, (X 700)

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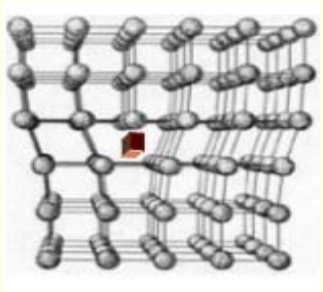
Comment -

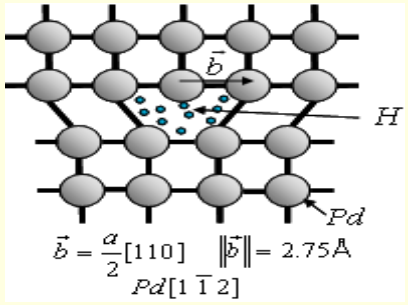
Propose search for charged particle and soft x-ray emission from Rossi

Our Recent Dislocation-Loop-Cluster Studies

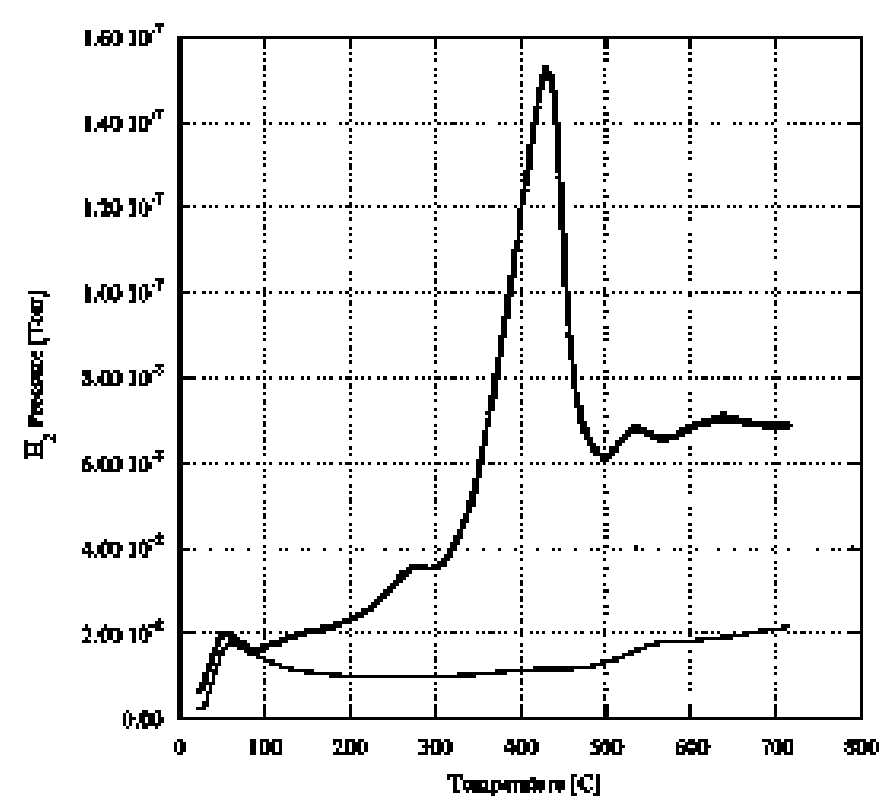
- Pd thin foil – 12 μm
- Loading and unloading deuterium/hydrogen was done by cyclically cathodizing and anodizing Pd foil → dislocation loop and cluster formation

PdO
Pd
PdO





Temperature Programmed Desorption (TPD) Experiment

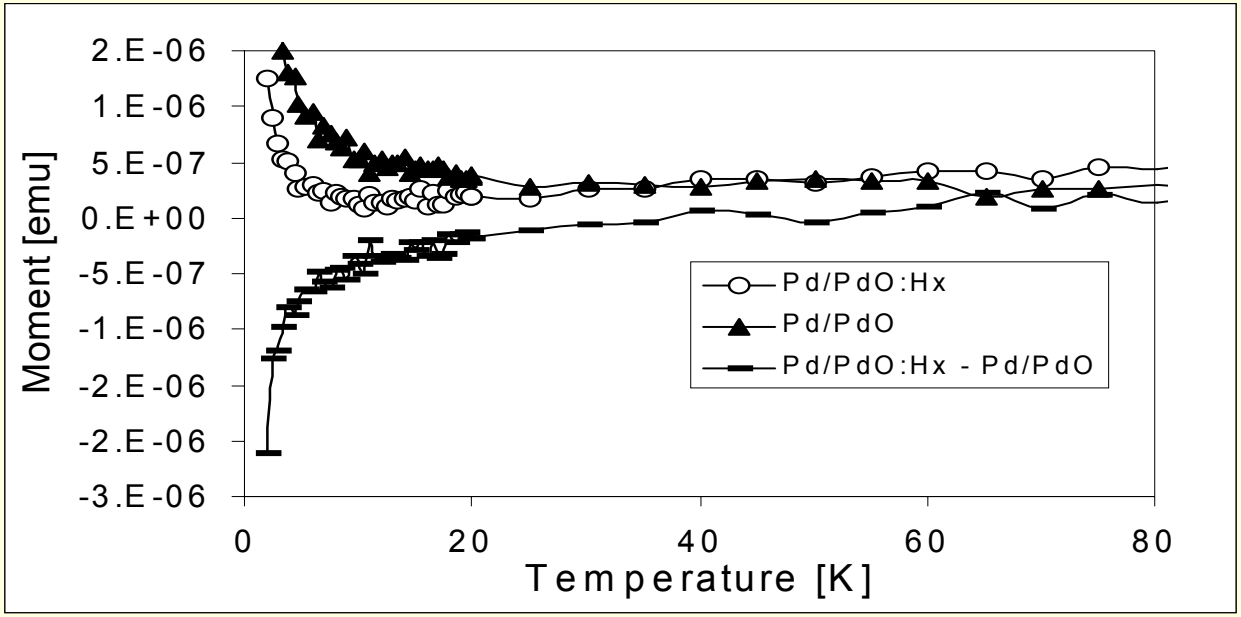


Binding Energy calculation – close to the binding energy between hydrogen and dislocations

$$\varepsilon_H = k_B \frac{T_2 T_1}{(T_2 - T_1)} \ln(P_2 / P_1) = 0.65eV$$

After the loading foil was annealed under 300 ^{o}C for 2 hr, the temperature was ramped from 20 ^{o}C to 800 ^{o}C at 9 ^{o}C /min.

Experimental Magnetic Moment Measurements of Pd:H sample show superconducting state



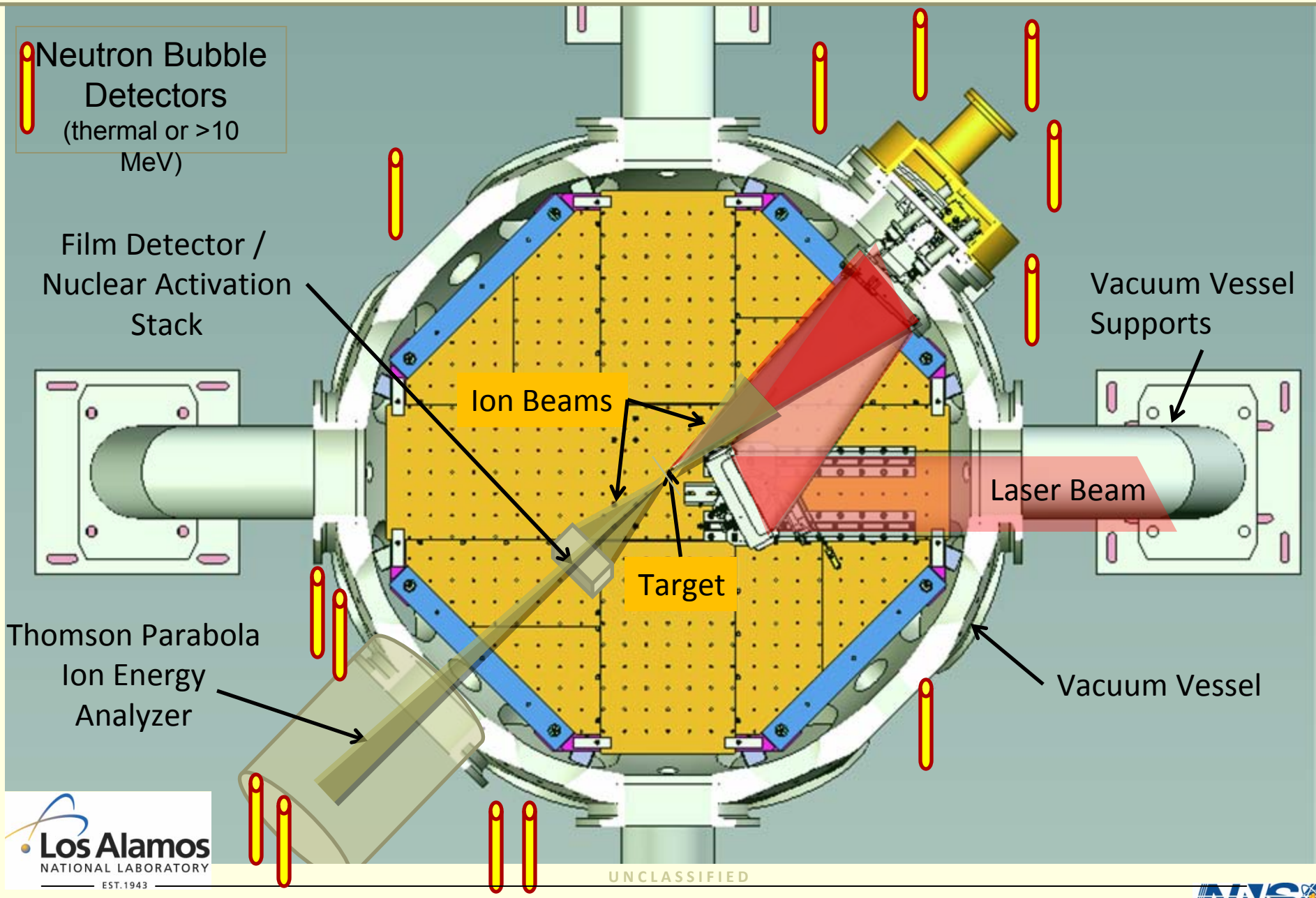
The magnetic moment of H_2- cycled PdHx samples in the temperature range of $2 \leq T < 50$ K is significantly lower than M(T) for the original Pd/PdO.

A. Lipson, B.I. Heuser, C. Castano, G.H. Miley, B. Lyakov & A. Mitin, **Physical Review B 72**, 212507/1-6 (2005):

We are funded to do experiments at LANL to study the extraction of MeV D+ ions from these clusters using the TRIDENT petawatt laser

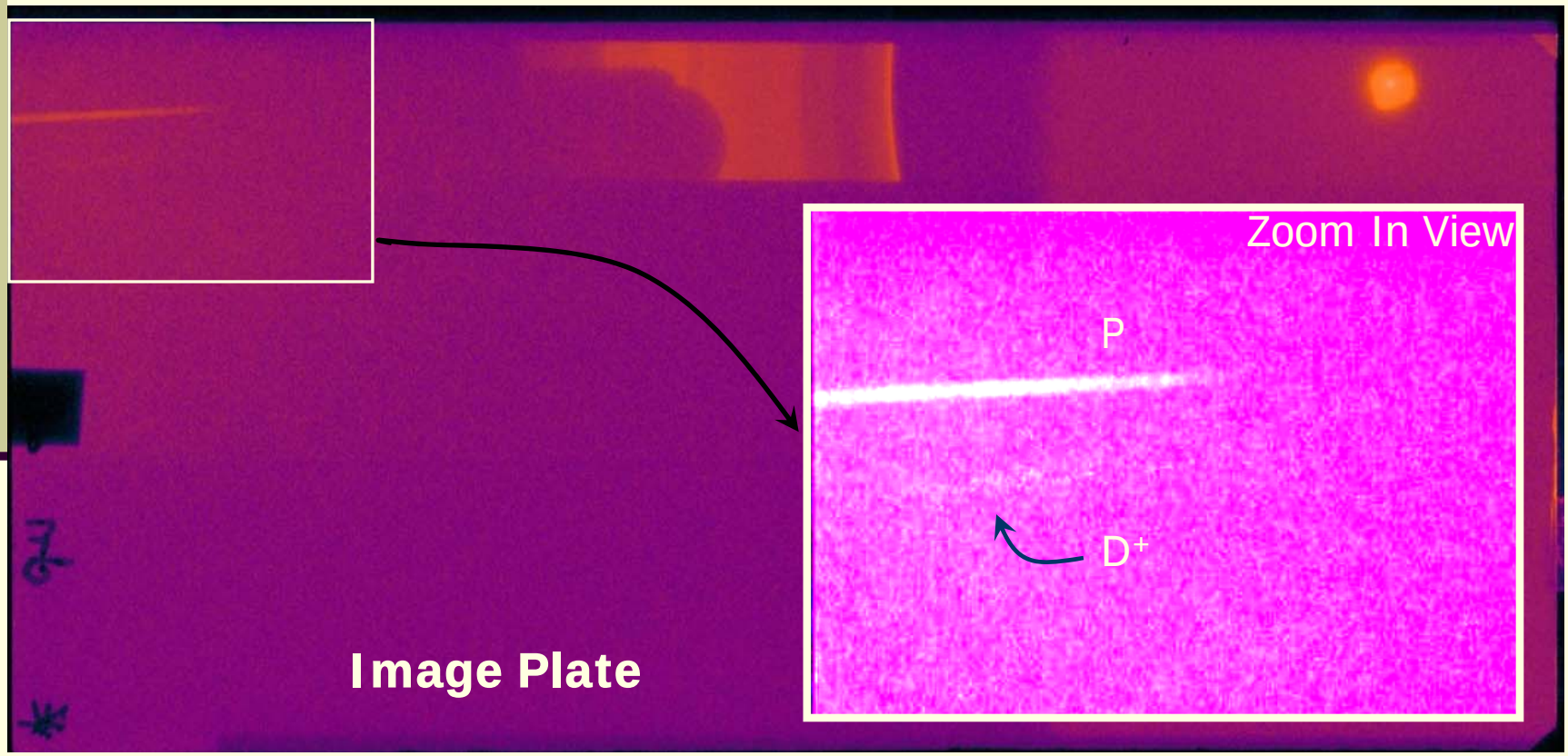
ANOTHER PROOF OF CLUSTERS – PETAWATT LASER BEAM EXTRACTION

Deuteron Acceleration Experiment In LANL



Ion Trace of PdD Separated by Thompson Parabola WITH Ti Filter

Laser Energy in 81.9 J out 67.1

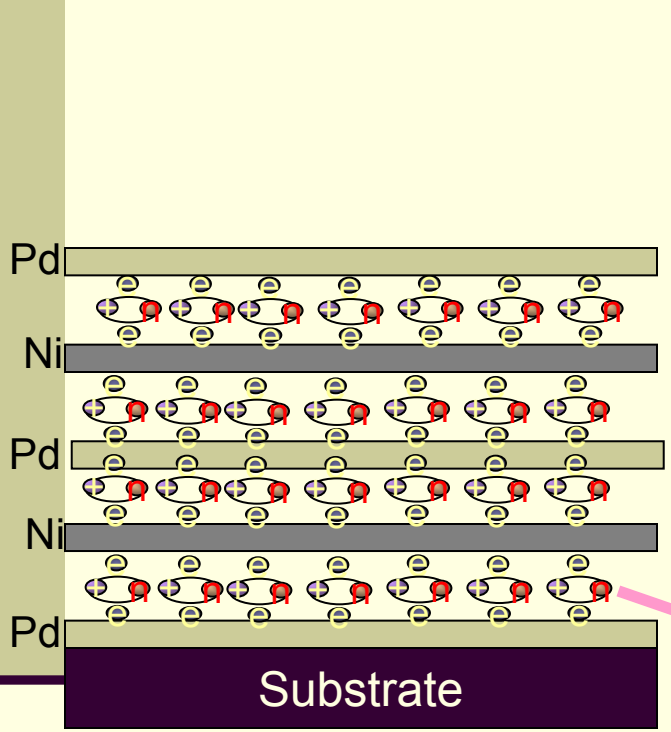


Comments –TRIDENT results

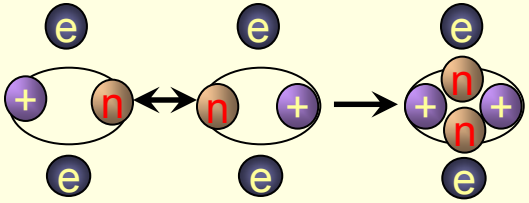
- Demonstrate acceleration from clusters
- Flux and energy depressed, probably by impurity protons (and C?)
- Next experimental campaign
  - Continue to improved cluster packing fraction
  - Reduce contamination (p and C).
  - Obtain more insight from ongoing supporting simulation studies.

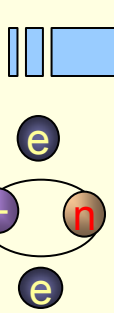
Conclusion: High density deuterium cluster formation (Pseudo Bose-Einstein Condensation) at room temperature occurs and is fundamental as a way to create nuclear reactive sites for LENR

Theory

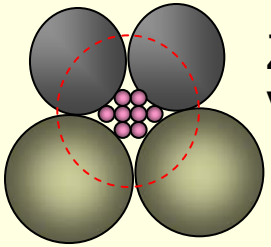


Swimming Electron Layer (SEL) Theory



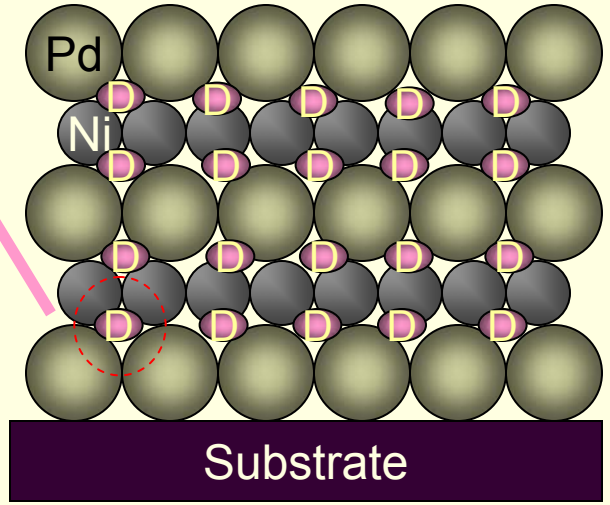


Zoom-in View



Zoom-in View

Bose-Einstein Condensation in a sub-nano scale



Anchored D Loops

Yeong E. Kim, Theory of Bose–Einstein condensation mechanism for deuteron-induced nuclear reactions in micro/nano-scale metal grains and particles, Naturwissenschaften, 96(7):803-11 (2009)

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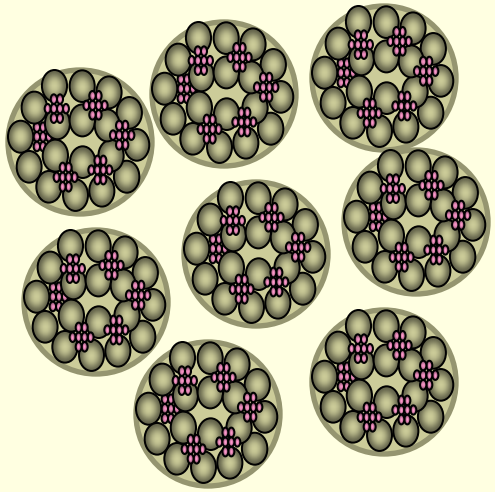
Recent work is designed to extend the thin-film technique to nanoparticles.

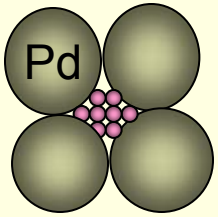
For applications this will allow high temperatures with gas loading – i.e. improved performance when energy conversion is integrated into the cell

Cluster Formation in Nanomaterials

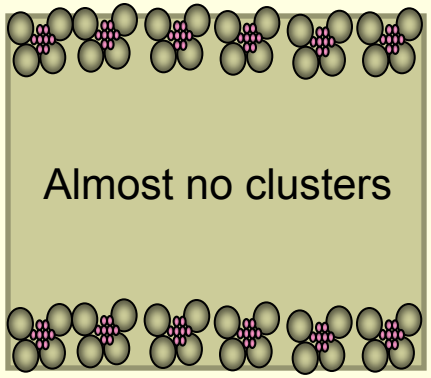
- Clusters mainly forms at the places that is close to the material surface.
- Nanomaterials have more surface area, thus have good ability to form abundant clusters



Nanoparticles



Clusters zoom in

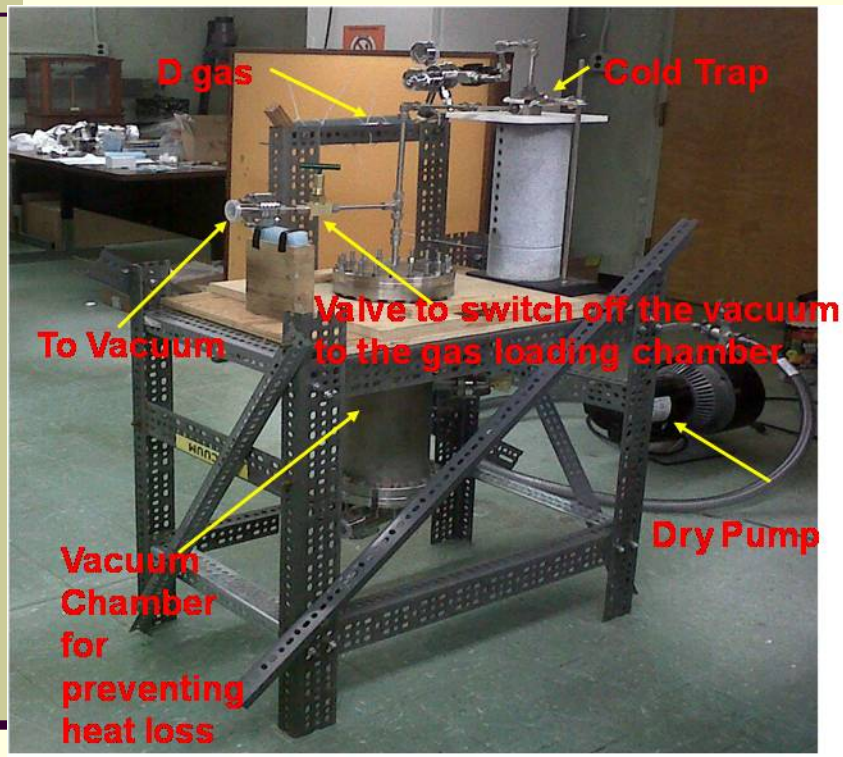


Bulk material

Triggering The Reaction

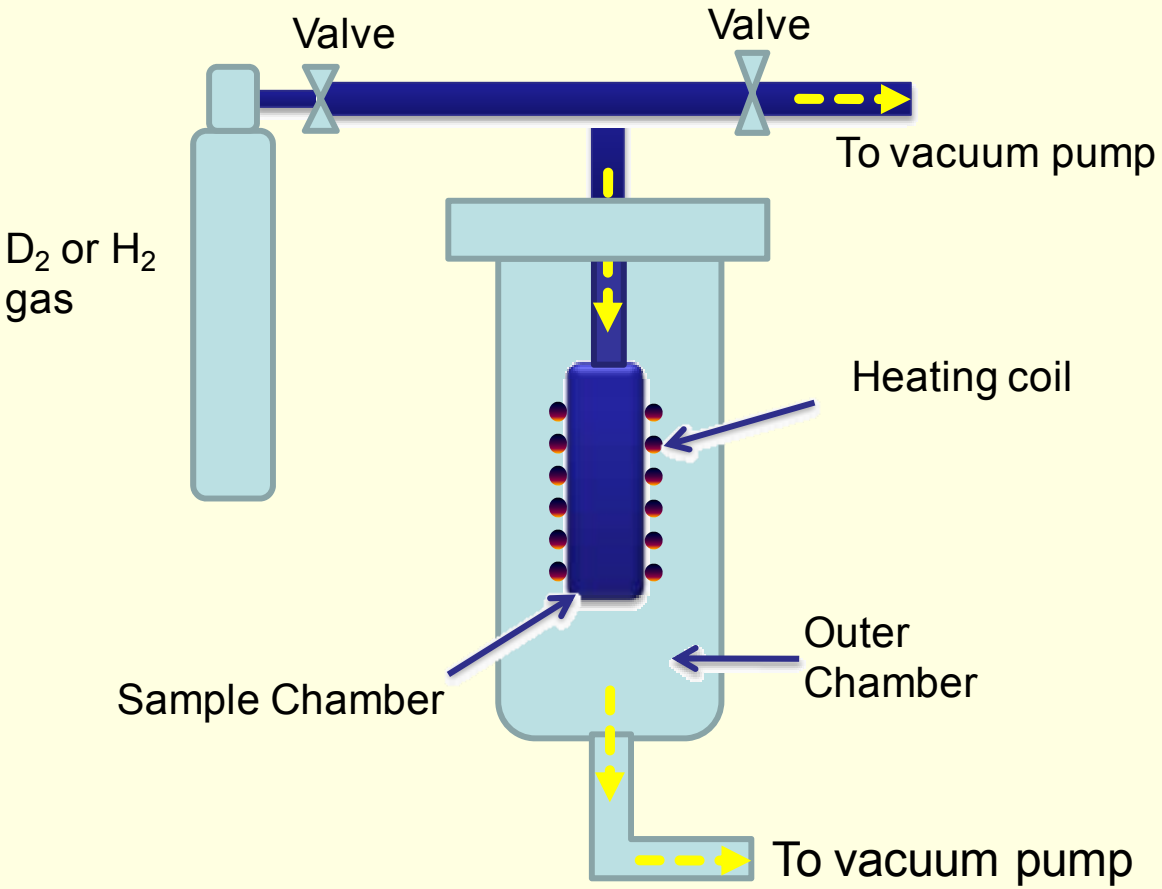
- Electrolysis (pulse or ramp)
- Gas loading (pulse pressure)
  - Smaller heat capacity
  - Higher temperature change as compared with an electrolysis system.
  - Without the constraint of being limited by the boiling temperature of the fluid
- Glow Discharge (bombardment)
- Low energy laser; ultrasound; em radiation,….

Our Gas Loading System



2.2cm inner diameter
25cm^3 total volume

Inside View


Valve
Valve
To vacuum pump
D_2 or H_2 gas
Heating coil
Outer Chamber
Sample Chamber
To vacuum pump

Preliminary Excess Heat Measurement Using Our Gas Loading Calorimetry System

High purity (99.999%) D_2 gas at 60 psi

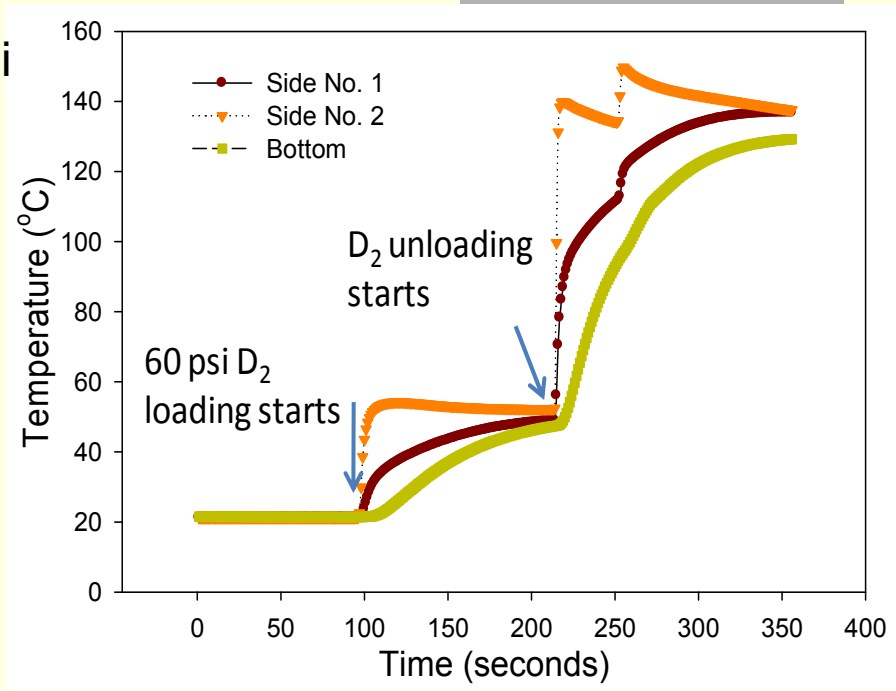
20g ZrO_2Pd_{35} nano powder

Gas loaded under room temperature and then unloaded.

exothermal energy from chemical reaction --- **690J**

Calculation: Energy = $\Delta H \times M_{D2}$

ΔH = -35,100J per mole of D_2 for the formation of PdD_x for $x < 0.6$;
M_{D2} is the total moles of D2 that combined with Pd



Actual measured energy -- **1479J**

Calculation: Energy = $\Delta T(M_{chamber}\, S_{chamber} + M_{powder} S_{powder})$

Δ T is temperature change, M is mass, and S is the specific heat

The result show was from June – we have continued this work but I do not have slides to show of this work in progress

Most effort has been to develop improved nanoparticles by comparing and down selecting a series of triple alloys.

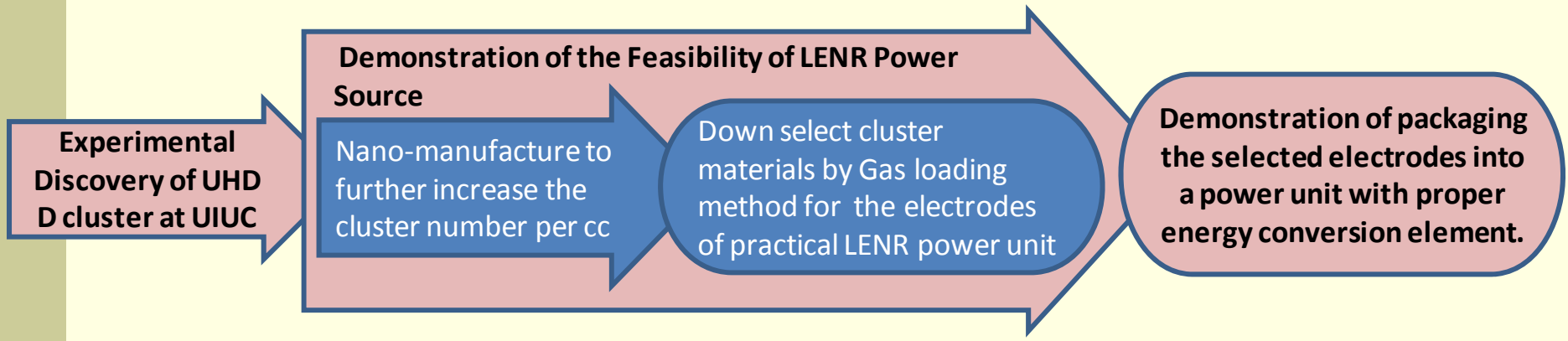
Summary – gas loading

- Experimental evidence confirms cluster formation in dislocation loops.
- Methods to fabricate high loop density under study.
- Further experiments should consider nanomaterials of different size and composition

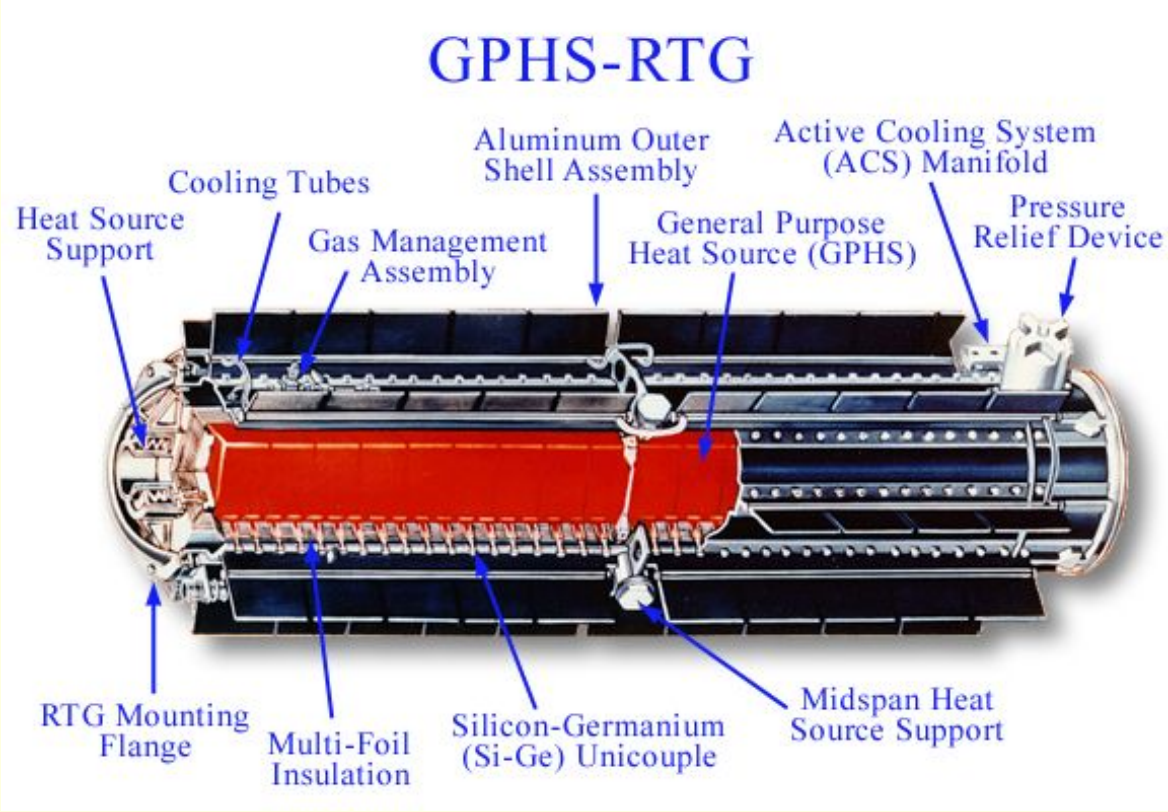
Outline

- Comments re prior light water Ni studies – Patterson Cell
- More recent experiments using thin-film plate type electrodes conditioned for cluster formation.
- Evidence for D-clusters and comments about theory
- Possible triggering methods the initiate nuclear reactions in these high density clusters
- Preliminary gas loading nanoparticle experiment
- Road Map and Future goal of the LENR study for Nuclear Battery applications

Road Map to a Prototype LENR Unit Development



The LENR power cell is well suited for use as a “New Type RTG” with the LENR cell replacing the PU238



Drawing of an GPHS-RTG that are used for Galileo, Ulysses, Cassini-Huygens and New Horizons space probes.
source:http://saturn.jpl.nasa.gov/spacecraft/safety.cfm

Many issues remain

- What is the energy producing reaction and can it be optimized?
- Alternate metals (reduce costs, improve operation, etc.
- Alternate gaseous fuel? H2,D2, Tritium, D-T, etc?
- Are there any radioactive products?
- Any emissions? Soft x-rays, charged particles, gammas?
- Lifetime issues – radiation damage to the electrode materials? Effect of reaction production structure and also on stopping later reactions?
- Burn up of fuel? Burn up of fuel in local sites?
- Is there any direct energy conversion possibility?
- If heat, what is the optimum temperate-conversion method.
- Control methods?
- ……..

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FOR FURTHER INFORMATION, CONTACT

GEORGE H. MILEY
GHMILEY@UIUC.EDU
217-3333772

XIAOLING YANG
XLYANG@ILLINOIS.EDU