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Practical Techniques In CF Research – Triggering Methods

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A collection of useful techniques for triggering CF events is presented which are gleaned from 14 years of CF research and thousands of experiments by the authors. Special attention is give to those techniques that trigger excess heat by dynamic conditions that are imposed upon CF systems. These triggering techniques include changes in cell temperature, pulsing the current to electrolytic systems, acoustical stimulation of gas systems, chemical triggering of electrolytic system, pressure changes, radio frequency excitation, magnetic field variations and laser stimulation. Laser stimulation is found to be a potentially fruitful technique to trigger heat events, to probe the cathode surface by scanning for active locations and to compare products from at active and inactive regions.

1 Background

1.1 Static Equilibrium Often Produces Sporadic Results

The study of nuclear events at low temperatures often has resulted in frustrating investigations. The field of cold fusion has often been marked with sporadic and non-reproducible work. Critics have often pointed to the sporadic nature of the heat generation in electrolytic systems as indication of poor experimental procedure. However, it now seems that the sporadic nature of the results is a characteristic of an electrolytic system, which is initially near equilibrium, and slowly loaded to a transition point which is best described by the mathematical term as a chaotic transition. For example: slowly loading palladium can be driven between beta and gamma states and cause internal fluxes of deuterium.

Electrolytic cells using bulk palladium often require loading times of 10 to 20 times longer than would be expected by diffusion times of deuterium within the metal before they be expected to produce excess heat.[1] This was likely the cause of failure of early researchers who rushed to replicate Fleischmann's and Pons' early work.[2] In the first few years after the announcement, it was easier for a researcher to rush to print and claim negative results than to patiently wait until the system was fully loaded and driven into internal transitions that drive the reactions. As a result, early work more often than not failed to see excess heat.

This work will illustrate methods that will help drive CF systems off equilibrium and trigger internal events that lead to production of excess heat. The viewpoint taken here is that a system must be allowed to depart from static equilibrium before the required reactions can take place.

1.2 Theoretical Limitations

Most simple theoretical models fail to predict that nuclear reactions within a deuterated metal lattice can take place at significant rates. Such models rely on reaction rates that are based on equilibrium placement of deuterium within a metal lattice or on wave functions based on such placements. In particle models, the global average of the deuterium density within the metal is on the order of an Angstrom or more even for extreme loading ratios of D/Pd. It is clear that deuterium at such remote nuclear separations would not be expected to lead to nuclear events.

The imposition of dynamic conditions can cause the local separations of deuterium to be significantly different from the value predicted by the global density alone. It also seems that dynamic conditions provide ways for coupling of energy to drive the reactions and impurities within the lattice can allow for spin exchanges required for spin selection rules. It is a surety that the energy required to drive any nuclear events and energy released from such events are much larger than any external energy available to the deuterium based on a per atom division of energy.[3] This means that any external energy driving the possible nuclear events must act in a coherent way to channel energy from a large region of many atoms to the active sites.[4,5,6] This coherent channeling must involve over 10^8 atoms and likely many more. The experimental conditions then must make use of non-equilibrium events acting on a system that has some group coherent nature. The methods described here are simple and practical methods that can be used to produce such dynamic conditions, which may lead to the desired nuclear events. The assumption here is that the reactive nuclear species must be driven to a dynamic active state before the desire events can produce excess energy within the system.

2 Practical Triggering Methods Background

2.1 Variation in temperature

Good calorimetry often requires that the system under study be held at constant temperatures for long times. These are often run near room temperature to help control the environment around the systems. However, this is not beneficial in observing excess heat from CF cells. The electrolytic CF systems generate more heat at higher temperatures and maintaining them at or near boiling often yields greater excess power levels.[7] One simple method that is often useful in triggering excess power is the employment of a calibration resistor within the cell.[8] After the metal has been loaded slowly for times at least 10 times the calculated diffusion rates, power is supplied to a calibration resistor within the cell, raising the temperature of the cathode. Afterwards the baseline temperature of the cell may be seen to rise. (Figure 1) In other words, the heat pulse to the cell has triggered events within the cathode, which cause it to run hotter after the pulse for the same input power. The baseline temperature of the system is higher after the pulse than before. Some researchers have been known to reset their baseline after such events mistaking it for calorimeter drift- in effect throwing out the very signal that they seek.[9] This effect can also be seen occasionally in flowing electrolyte systems when the flow is pulsed instead of using a continual flow. The pulsing of the fluid flow allows the system to have temporary temperature rises. Many early experimenters falsely assumed that a continual flow through a bead bed system was better than the prescribed pulsed flow. Future researchers need to be aware of the heat trigger effect, plan for it and design for it.

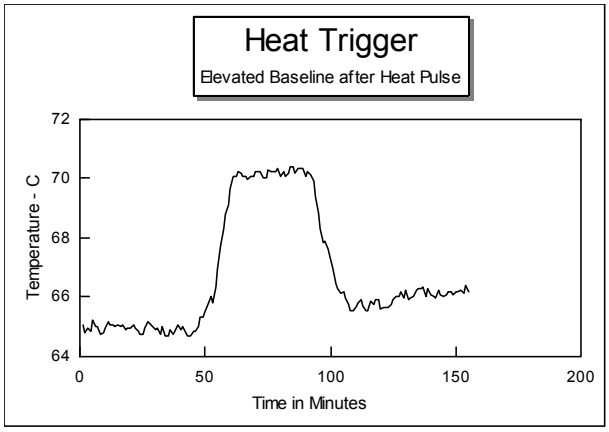

Figure 1. Baseline is elevated after a pulse to the calibration resister illustrating that more heat is now released from the cell with the same input power. Pd on Ag screen with Co, Re, and Th in LiOD using a 0.5 W pulse on 10W of electrolytic power.

Operating the cells at elevated temperatures is also beneficial in seeing excess heat effects.[7] The temptation is to use temperatures near room temperature for setting up CF systems. The elevation of the author's laboratory limits the temperature of liquid electrolytes due to its altitude of 2650 meters. This means that water based systems are limited to about 92 C in this lab due to the boiling point of the natural water control cells. One way around this is to run the cells at boiling. Fitting them with a reflux column so that they can run continually at their boiling points can help. As seen in Figure 2, there is an increase in the power output of the cells as their operating temperatures are elevated. Flow calorimetry can be done on such systems when connected to the water flow used in the condenser coils.

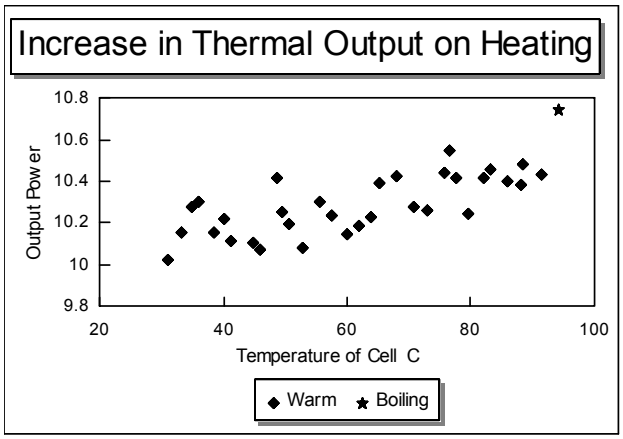

Figure 2. The cell's thermal output is seen to increase with increase in its operating temperature. This cell was a codepostion of Pd on to Ag with additives of Rh, Th, and Sm. The system is a flow system where water flows in both the condensing tube above the cell and about the cell. Changing the inlet temperature of the recovery water system controlled the temperature reached by the electrolyte.

2.2 Pressure

Pulsing the deuterium pressure to CF systems can occasionally trigger gas systems. This can be done by either gas supply systems or by acoustical excitation. The goal is to cause a flux of deuterium in an out of the system and across a gradient of chemical potential. For example, palladium black was prepared from solution by hydrazine reduction in which Ni was also included. This caused the palladium black to have an outer surface containing more Ni than the interior due to their relative chemical reactivities. The material was placed within an epoxy encased glass tube and deuterium gas was supplied to the material. The

temperature of the palladium black was found to rise upon the cycling of deuterium gas between 500 and 15,000 torr. In a separate experiment was conducted using a standing acoustical signal of 5,000 Hz by exciting a similarly filled tube. Temperature variations were found between the node and anti-node regions.

2.3 Current

Pulsing the current to palladium metal that has been loaded with deuterium can also trigger the release of excess heat. One author, Letts, has successfully triggered excess heat by superimposing RF signal on top of the electrolytic supply to electrolytic system.[10] This work was done at near 82 MHz. In a separate system a frequency near 25 MHz was used. First getting RF spectra of an active cell and then supplying the frequency that was being emitted by the active cell chose this.

Supplying pulsed current from end to end of a palladium wire used in an electrolytic system can also generate excess power. This results in electro migration of deuterium down the length of the wire.[11,12,13] Placing defects along the length of wire can enhance this effect. This can be achieved by ion implantation into the wire. The idea is to cause a "choke point" for the deuterium that is forced to migrate down the length of the wire. The deuterium flux undergoes both spatial and temporal changes as the wire is pulsed down its length.

The triode system also allows for a flux of deuterium with the host metal lattice. Two anodes are used in that design with different currents and voltages. The voltages are switched from side to side so that the deuterium within the cathode is not at equilibrium. A simpler design is to have the anode on only one side of the cathode and push the deuterium through the metal. In this configuration, it is best for the deuterium to transverse a chemical potential difference. For example, palladium can be coated thinly with another metal such Ni, Au, or other material in which the deuterium is at a higher chemical potential than the bulk palladium or other material used as the cathode. A simple and easy way to have a gradient is to temporarily reverse the current in the early stages of the electrolysis so that a resultant black or tan coating is applied to the cathode. However, the codeposition of palladium with additives such as Th and Co is usually beneficial to help the production of excess heat. The pulsing of the deuterium flux through the chemical potential seems to trigger the release of excess power (Figure 3). Some theoreticians have surmised that phonons are generated as deuterium falls from one chemical potential to another and those phonons coherently allow for the activation energy required for the assumed nuclear processes.

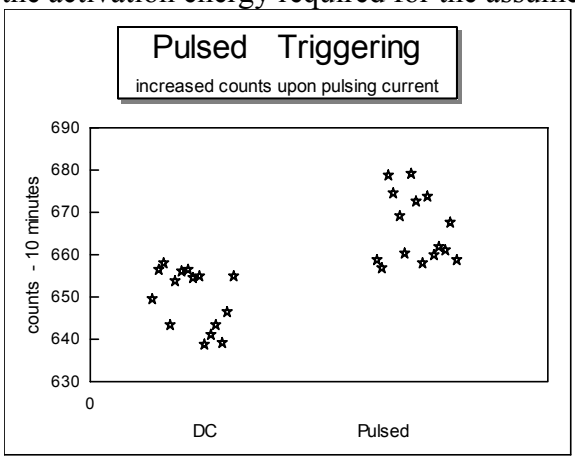

Figure 3. Both the excess power and radiation counts increase upon pulsing the current to an active cell. A cell using LiOD electrolyte and a cathode produced by codeposition of Pd black on Ag was used. Additions of Ni, Re and Th were used. The current was pulsed at 400 Hz with a 20% duty cycle. The average input power was 10W as read by a Clark Hess. The average 10-minute counts were elevated from 651 to 668 or about a 0.6 sigma signal. The excess heat of the cell also changed from 120 mW to and average of 287 mW.

2.4 Chemical Triggering

Often cells are run in pristine conditions with highly refined LiOD, Pt and Pd. The cathode is normally seen to remain in a clean shiny condition and no excess is seen. The addition of Pd salts with additives into such a system often will help trigger the production of excess power.[14,15,16,17] The rational is that there needs to be a gradient in the deuterium's chemical potential for the production of excess power. It seems that the effect requires the deuterium flux to transverse between energy levels before the onset of the excess heat phenomena. Additives that have strong magnetic properties or elements with quadrapole moments seem to be beneficial in triggering the excess power events. A systematic search was taken to see what materials might increase any excess power production. The search was conducted by adding a range of metal salts to the Pd salts and codeposit them onto Ag. Chemical limitations due to chloride precipitation limited the uniformity of the method between elements but a general trend is seen in Figure 4, which is based on a range of chemical methods on the same mechanical system. Only a few of the cathodes have been analyzed to check what materials where actually plated out of solutions (Figure 5) and results in Figure 5 are based on pre-deposition compositions.

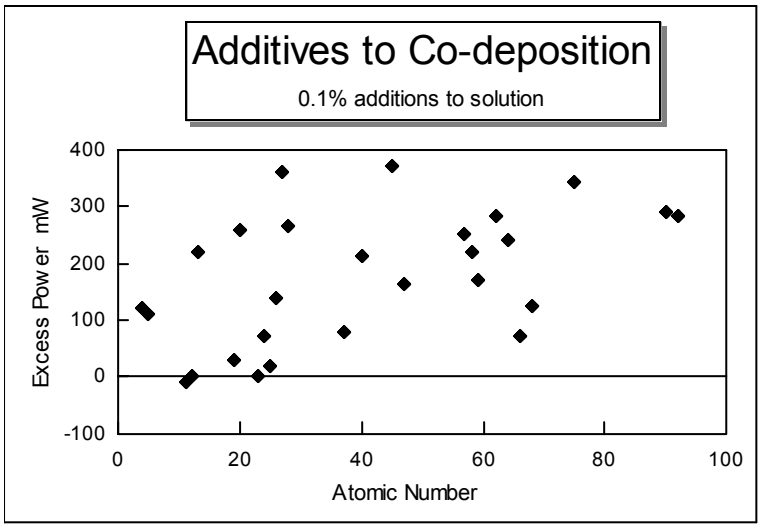

Figure 4. Relative effects of adding metals to during co-deposition of Pd on to Pt cathode. Excess power normalized for mW per cm^2 using 10 Watts of electrolytic power. Materials deposited from chloride salts where metal chlorides possible. Some elements required changes in plating chemistry. The elements of Rh, Re, Co, Th and U seem to be especially good for doping co-deposition systems.

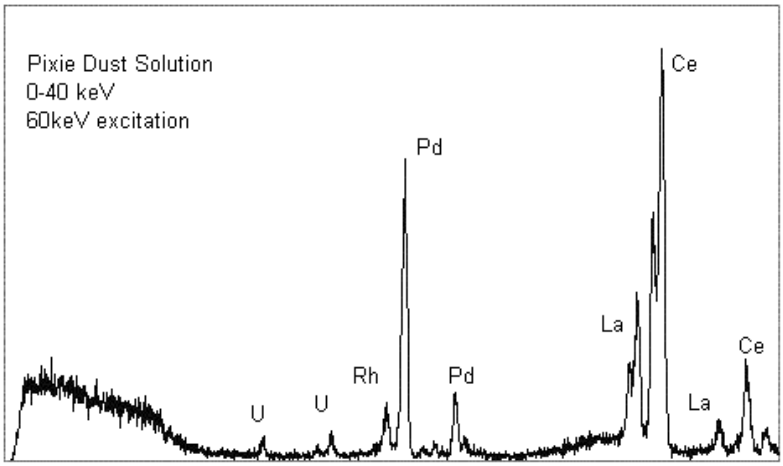

Figure 5. XRF analysis of cathode after codeposition of Pd with additives of U, Rh ,La and Ce. The U was added for increased D occupation at near lattice sites and the Rh to increase the absorption of D within the Pd black. The La and Ce where added to allow for spin exchanges to aid spin conservation terms for wave functions in the D + D> He nuclear channel.

Some theorists have proposed that the inclusion of He within the lattice structure is required for the D+ D > He reaction to proceed. Many of the chemical and laser triggering tests replaced air and any evolved gases with He before the triggering agent was employed. This assured that the triggering would not be of any chemical events with trapped oxygen and evolved hydrogen or similar events. Also some trials were made with He added during the codeposition process to see if He could be trapped within the deposition and affect any rates. No effects were seen by such He additions. This seems to rule out the possibility that the triggering was of some chemical reactions from the gas phase. Helium was also used in a similar manner to rule out hydrogen recombination effects here and in other systems presented here. However, it was not possible to test samples totally void of all He due to the ubiquitous He within all atmospheric and metal samples. Thus we could not see if the He was a necessary condition for excess heat production.

2.5 Magnetic Triggering

Changing the magnet field in the region of the cathode seems to often trigger the release of excess power. It is unclear at this time if this is truly a magnetic effect or if the changed magnetic field alters the flow of ions during electrolysis due to the Lorentz forces on the ions in solution and thus change the heat flow within the cell. However the effect is also seen in flow systems that are less subject to the location of heat production. The effect is most often seen when the cell is loaded with the magnetic field in one direction and then it is either reversed or placed 90 degrees from its original orientation when the cell is run at higher current densities. The effect was not seen when the magnetic field at the cathode drops below 200 gauss or when the magnetic field is uniform across the entire cell. The presence of small additions of Co and similar magnetic materials within codeposited systems seem to enhance the effect.

The important feature of the apparent magnetic effect is that the magnetic field be changed. However it is very difficult to run a well-controlled system when magnets are employed. This is because their orientation and placements close to the cell changes the "heat fin" effects when permanent magnets are used. The ion flows within the cell severely limits the certainty of isoperabolic systems unless stirring is employed and magnetic stirring

cannot be used in these systems. In short, the effect is not clearly shown and quantified at this time. It is illustrated here just to show other possibilities for study of the triggering of CF events. The effect deserves to be carefully studied by a specialized calorimeter that can be used despite the complications that the magnets bring to the problem.

2.6 Laser Triggering

Laser triggering of cold fusion events holds great promise as both a heat production method and as an investigative probing method. The cathode is first slowly loaded by electrolysis or by co deposition. It is then given a very thin overcoat of Au. At this time the current to the cathode is normally maintained at around 0.5 A/cm^2. Once in equilibrium, it is irradiated with a laser of specific frequency. The irradiation often produces a shift from equilibrium and the triggering of excess power. It should be noted that the system often responds at higher gains when the cathode is loaded for longer times (for example weeks) and that even a temporary stops in the electrolytic currents of 10 seconds is enough to de-load the cathode and prevent observation of the effect. Investigators are encouraged to maintain the cathode at 0.05A/cm^2 or better at all times once they are deposited with black and over-plated with Au. The use of uninterrupted power supplies is recommended to avoid the loss of a good cathode once identified.

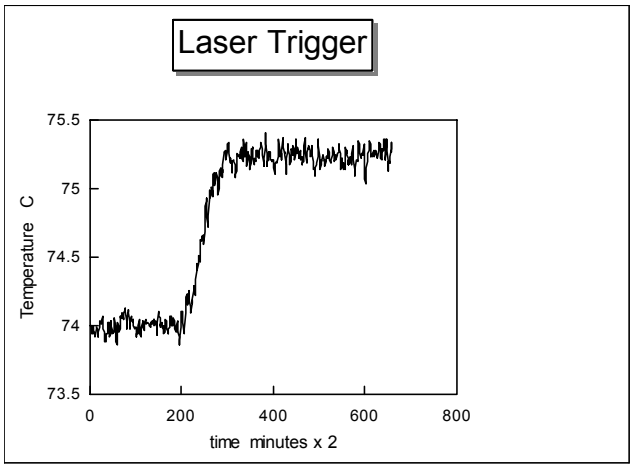

Figure 6. A laser of 670 nm is irradiated on a codeposition of Pd black containing additives of Co, Rh, and U placed on Ag. The temperature of the cell increases by 1.24C while the input power remains constant at 10 W. The laser power is 20 mW over an approximately 2mm spot diameter.

The cathode is first slowly loaded from a 1M LiOD solution over 3 to 5 days. It is then covered with a codeposited layer of Pd by adding Pd salts and any additives to the solution. It is quickly transferred to a new container for calorimetric studies after it acquires the Pd black surface. It is then loaded for at least a day to assure that it is fully loaded. A thin layer of Au is plated over the Pd black surface. A base line is obtained for the system and then the laser is applied to a spot on the cathode's surface. This normally results in about 200 to 300 mW of apparent excess power from the 30 mW of laser power. The excess power sometime reaches 500 to 800 mW of excess. It should be noted that some systems have run long enough to rule out all possible chemical reactions and recombinations as the source of the effect. Some excess power normally remains for a few hours even after the laser is removed. The addition of multiple lasers applied to the same spot on the cathode does not seem to increase the excess power signal above that expected from the addition of the laser power alone. This

would seem to indicate that the excess power is not proportional to the incident laser power but that it triggers the excess power events.

Our investigations are still underway at this time. However, there seems to be some indications that the polarization of the laser beam with respect to the external magnetic field may play a role in the level of excess power. At the present it seems that the excess power has a term that goes as E x B. The magnetic field is held fixed and the laser beam rotated by rotating the laser housing or by the insertion of quarter wave and half wave plates in the beam. The effect is not large but it is hard to think of a conventional explanation of why the polarization of the beam should affect the cell's temperature. Seeing the excess heat change by rotating the laser housing outside the calorimeter seems to rule out trivial conjectures as to the internal heat source. However the Poynting vector from such radiation would be directed in and out of the cathode's surface and could affect the deuterium flux in near surface areas. The optimum configuration at this time seems to be when the B field is parallel to the cathode's surface and more than 200 gauss as measured in the region of the cathode within the cell, and the laser beam is linearly polarized perpendicular to the B field and directed toward one of the corners where there is maximum loading gradients. There also seems to be a frequency reliance on the effect as addressed the authors' companion article in the proceedings. These effects deserve greater study.

3 Conclusion

We have omitted the details of the individual experiments due to space limitation but have seen that dynamic conditions are beneficial to observing the excess heat effect in CF system. The temptation is to design CF systems that have little or no variation in input conditions and temperatures. This is because of the restraints placed on experiments by good calorimetry. However, it is possible to do reasonable calorimetry and at the same time produce the required dynamic conditions that trigger the production of anomalous heat. It is important that future researchers realize that non- equilibrium events are often required for the effect to by initiated. Variations of input currents, operating temperatures, light intensity; magnetic fields, gas pressures, and chemical potentials all play a role in triggering the CF events.

Laser stimulation of CF cathodes is a promising approach that allows for surface probing and comparisons between surface conditions on the same cathode. The stimulation of the excess heat effect seems to be more a triggering of events than absolute requirements. Once triggered by the laser the excess heat can last for several hours.

References

1. McKubre, M.C.H., et al. *Excess Power Observations in Electrochemical Studies of the D/Pd System; The Influence of Loading*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan (1992).
2. Fleischmann, M., S. Pons, and M. Hawkins, *Electrochemically induced nuclear fusion of deuterium.* J. Electroanal. Chem. **261**: p. 301 and errata in Vol. 263 (1989).
3. Schwinger, J., *Nuclear energy in an atomic lattice.* Prog. Theor. Phys., **85**: p. 711 (1991).

4. Chubb, S.R. and T.A. Chubb. *Theoretical Framework for Anomalous Heat and 4He in Transition Metal Systems*. in *8th International Conference on Cold Fusion*, Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy(2000).
5. Chubb, T.A. and S.R. Chubb. *Radiationless Cold Fusion: Why Small "Crystals" Are Better, N(cell) Requirement, and Energy Transfer to Lattice*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. Lake Toya, Hokkaido, Japan: Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. (1996).
6. Hagelstein, P.L., *Coherent fusion theory.* J. Fusion Energy, **9**: p. 451(1990).
7. Cravens, D. *Factors Affecting Success Rate of Heat Generation in CF Cells*. in *Fourth International Conference on Cold Fusion*. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304(1993).
8. Fleischmann, M. *The Experimenters' Regress*. in *5th International Conference on Cold Fusion*. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France (1995).
9. Mallove, E., *MIT Special Report.* Infinite Energy, **4**(24): p. 64 (1999).
10. Bockis, J., Sundaresan, R., Letts, D., Minevski, Z., Triggering of Heat and Sub-Surface Change in Pd-D Systems, *Fourth International Conference on Cold Fusion*. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304 (1993).
11. Celani, F., et al. *Measurement of Excess Heat and Tritium During Self-Biased Pulsed Electrolysis of Pd-D2O*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan (1992).
12. Celani, F., et al. *High Power μs Pulsed Electrolysis for Large Deuterium Loading on Pd Plates*. in *Fourth International Conference on Cold Fusion*. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304(1993).
13. Celani, F., et al., *Deuterium overloading of palladium wires by means of high power microsecond pulsed electrolysis and electromigration: suggestions of a "phase transition" and related excess heat.* Phys. Lett. A, **214**: p. 1(1996).
14. Miles, M., K.B. Johnson, and M.A. Imam. *Electrochemical loading of hydrogen and deuterium into palladium and palladium-boron alloys*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan (1996).
15. Miles, M. *Calorimetric Studies of Palladium Alloy Cathodes Using Fleischmann-Pons Dewar Type Cells*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy.
16. Szpak, S., et al., *Electrochemical charging of Pd rods.* J. Electroanal. Chem., **309**: p. 273 (1991).
17. Szpak, S., P.A. Mosier-Boss, and J.J. Smith, *On the behavior of Pd deposited in the presence of evolving deuterium.* J. Electroanal. Chem., **302**: p. 255(1991).