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PRECURSORS AND THE FUSION REACTIONS IN POLARISED Pd/D-D_2O SYSTEM: EFFECT OF AN EXTERNAL ELECTRIC FIELD

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The effect of an external electric field on the physical appearance of the Pd/D electrode in an operating cell is discussed. It is shown that the individual globules of the “cauliflower – like” structure undergo a shape change exhibiting two distinct features, *viz* those that require energy expenditure that can be extracted from the applied external field (*eg* re-orientation, separation of individual globules, dendrite formation) and those that require energy expenditure far in excess of one that can be supplied by the electric field alone (*eg* exhibiting features usually associated with the solidification of a molten metal under liquid or the presence of localized catastrophic events leading to the formation of craters). It is shown, by energy-dispersive X-ray method, that the needed energy is provided by nuclear events occurring in the region close to the electrode surface. The nuclear events are of the type: precursor → unstable nucleus → stable nucleus.

1.0 Introductory remarks

Apart from an excess enthalpy generation, there are other reported manifestations of unusual activities in the negatively polarised Pd/D-D_2O system[1]. Among them (i) changes in surface morphology far greater than those associated with the lattice expansion[2] and (ii) accumulation of impurities in the surface (sub-surface) region that exceeds the amounts that can be transferred from the cell components during prolonged cell operation[3]. In what follows, we shall demonstrate that both these features are magnified if an operating cell is placed in an external electrostatic field. Furthermore, we shall show that the accumulation of “impurities” is, in fact, the result of nuclear activities yielding elements not originally present.

To provide rational interpretation, one must (i) define the system and its initial conditions, (*ie* the conditions just before the cell placement in an electric field), (ii) consider the interaction of the field with the system and, in particular, with a conductor, liquid dielectric and the relationship between the surface forces and the bulk response, (iii) examine the effect of the field on the operation of individual components of the electrochemical cell.

1.1 System and its behavior

An operating cell is viewed as a system consisting of three subsystems, *viz* the electrolyte, the interphase and the bulk Pd/D. The interphase itself is an assembly of non-autonomous layers as defined by van Rysselberghe[4]. The electrolyte, an ionic conductor, is treated as a dielectric with added extraneous charges (positive and negative ions). The Pd/D material is a conductor containing, in addition to free electrons, mobile positive particles, the D^+ complexes. Just before the application of an external field, all intensive state variables are constant in time, *ie* all irreversible processes inside the system occur continuously (there is continuous exchange between the system and surroundings). The processes involved are: reduction of D^+/D_2O ions/molecules and the evolution of deuterium. The mechanism of these reactions is not important except to say that all operating driving forces remain constant in time.

The system's reference state is maintained by an overpotential, η. The vanishing of all mass fluxes (at the reference state) demands that all chemical potentials be equal. The overpotential acts as an external potential, *ie* it determines the distribution of all mobile charges as well as their electrochemical potentials. The ionization $D^{(l)} \rightarrow D^{+}$, complex and precursor formation occur in an s-electron rich environment, *ie* where $q^{+} << q^{-}$.

The IR imaging of the electrode surface shows that excess heat is generated at discrete locations which, in turn, implies the formation of domains. The existence of hot spots indicates the presence of highly energetic fast reactions which, in turn, produce pressure and temperature waves traveling through the electrode. Indeed, such waves were observed by the response of a pressure sensitive material onto which the Pd/D films were deposited[5].

1.2 System far from equilibrium

The characteristics of systems far from equilibrium are: (i) the formation of new structures is always the result of an instability which may be due to either internal or external fluctuations to the system, (ii) fluctuation is always followed by the response which may bring the system to its original conditions or may produce a new structure, (iii) the system's stability is determined by a complex interplay of kinetic and thermodynamic quantities (*ie* no statement can be made that is independent of kinetic considerations), (iv) chemical instabilities lead to spontaneous "self-organization" if the system is able to exchange part of the energy or matter with the outside world in order to establish a microscopic internal order (an open system must be maintained, if self-organization is to occur), (v) as the overpotential is increased, the probability of cluster formation increases (increase in the rate of formation of hot spots).

Parenthetically, in systems far from equilibrium the complexes can be viewed as "supermolecules" where the physical laws, as formulated for systems at or near equilibrium, may not apply. To quote: "....there exist new dynamic states of matter induced by a flow of free energy far from equilibrium. Such states are governed by a new physical chemistry on a supermolecular level, while all laws referring to the molecular level, remain essentially unchanged. In all cases considered, the coherent behaviour on the supermolecular level corresponds in fact to an amplification of specific molecular properties (such as kinetic constants) in far from thermodynamic equilibrium conditions" [6, p. 290].

1.3 Field interactions with cell components

(i) Conductors. Introduction of an uncharged conductor into the field reduces the total energy of the field. An uncharged conductor located outside the field is attracted towards the field. A conductor, charged or not, when placed in an electric field cannot remain in stable equilibrium. Consequently, if a conductor is constrained then it will suffer shape change, either reversible or permanent, depending upon conditions at the surface and the time involved.

(ii) Electrolyte. The electrolyte phase contains mobile positive and negative ions distributed in a manner that assures charge neutrality (except at boundaries). It is known that an ion in contact with

water is solvated, which means that the central ion is surrounded by an oppositely charged ionic cloud. When subjected to an electric field, each ion is acted upon with a net force representing the difference between the accelerating force arising from the applied field and the opposing forces, *viz* (i) the electrophoretic contribution associated with the structure of the moving entity and (ii) the force connected with the relaxation of the ionic cloud[7].

(iii) Interphase. Charging of the Pd lattice with hydrogen isotopes by electrochemical means occurs through a number of consecutive processes, *ie* charge transfer, adsorption, absorption *etc*. These processes define the thermodynamic structure of the interphase (as opposed to its physical structure). The set of processes involved is as follows: $D^{+(b_1)} \rightarrow D^{+(r_1)} \rightarrow D^{\theta} \rightarrow D^{(b_2)} \rightarrow D^{(l)} \rightarrow D^{(r_2)} \rightarrow [(D^{+} \cdot e^{-})_n - D^{+}]$ denoting charge transfer, adsorption, absorption, placement in Pd lattice, ionization, complex formation[8].

(iv) The bulk Pd/D. Any charge on a conductor must be located at its surface. Charged mobile species (D^+ complexes) are also present in the bulk Pd/D material. In general, they will not be affected by an external field, since no field can exist there. However, in the present case, they might be affected by the field generated by the flow of the cell current, *ie* the electro-diffusion might occur.

(v) Internal stresses - shape change. The relationship between the surface forces and the bulk response is given by

$$\int divA\,d\tau = \oint A_n\,d\sigma \qquad (1)$$

where the *div* operator derives a vector from tensor. The left side term is the algebraic sum of all sources/sinks continuously distributed over the volume element. The right side defines the outflow, if positive and the inflow, if negative. Equation (1) indicates that forces acting on any finite volume in a body can be reduced to forces applied to the surface of that volume and *vice versa*. Consequently, it follows that the shape change at constant volume is associated with motion due to internal forces acting on the surface. Thus, the deformation will be determined by the distribution of surface forces, while the rate of deformation by their magnitude.

Internal stresses can be present without the presence of external loads, *eg* due to inhomogeneities, imperfections, *etc* a likely situation in the co-deposited film and the continuous evolution of deuterium.

(vi) Location/size. The presence of discrete, randomly distributed sites (hot spots, craters, boulders, *etc*) implies the existence of volumes within the electrode material where conditions promoting the highly energetic reactions exist. In estimating their magnitude, one must make a certain number of assumptions, *eg* (i) energy per single event is that of the reaction D + D → He, (ii) the number of single events to produce a crater is on the order of 10^4 or higher, depending upon its radius[9], (iii) the number of single events needed to generate the “hot spot” displayed by IR imaging is on the order of 10^4 or higher, depending upon its size and brightness. Under these conditions and assuming the loading ratio greater than unity, one can calculate the radius of this volume to be on the order of 100 Å or higher. The events take place within the bulk material in the close vicinity to the contact surface.

2.0 Experimental/Results

An operating PdD//D_2O, 0.3 M LiCl//Pt cell was placed in an electrostatic field generated by a parallel plate capacitor where the field strength was maintained and controlled by setting the potential difference at a specified level. The cell geometry is shown in Fig. 1. The Pd/D electrode was prepared by the Pd deposition onto an Au foil from a solution of 0.03M $PdCl_2$ + 0.3M LiCl dissolved in D_2O. The electrodeposition was under galvanostatic control with the current profile as follows: 1.0 mA cm^{-2} for 8 hrs, 3mA cm^{-2} for 8 hrs and at 5.0 mA cm^{-2} until all Pd^{2+} ions were reduced. Upon completion of the Pd deposition, the cell current was increased to a value needed to maintain a visible gas evolution (usually 30 - 50 mA cm^{-2}) for the next 2 - 3 hrs followed by placement in an external electric field (1000 - 3000 V cm^{-1}) with the cell current increased to about 100 mA cm^{-2} for the next 48 hrs or longer.

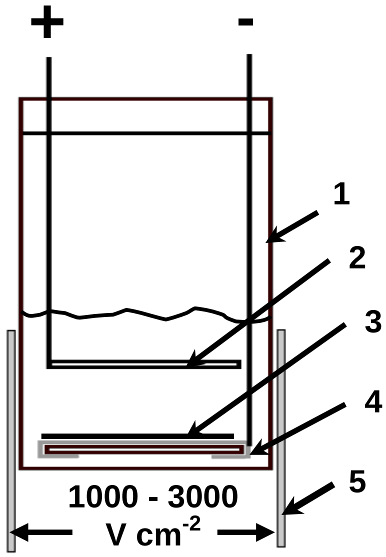

Figure 1. An electrochemical cell. 1 - clear plastic (acrylic) wall. 2 - Pt screen. 3 - Co--deposited PdD layer. 4 - Au foil. 5 - Cu foil. Cell connected to a galvanostat; electric field maintained by a regulated high voltage source (not shown).

The surface morphology and the bulk structure of the co-deposited Pd/D film, shown in Fig. 2a, undergoes substantial changes when the operating cell is placed in an external electrostatic field. This is illustrated in a series of SEM photographs taken from various runs. In the absence of an electric field, the electrode structure consists of globules, 3 - 7 μm in diameter, arranged in short columns. Each of the individual globules is an aggregate of much smaller, almost spherical units, having a diameter in a sub-micron range. This structure is uniform throughout the electrode.

2.1 Morphological changes - minor deformations

The first noticeable effect, seen shortly after placing the cell in an electric field, is swelling of the co-deposited material followed by displacement toward the negative capacitor plate. The re-orientation without substantial change in their size is shown in Fig. 2b. We selected examples of various structures to emphasize the complexity of the system as well as to indicate the impossibility of a quantitative analysis. The selected examples include minor deformation of the original structure, definitive shape change, unusual structures to a deformation associated with, what appears to be, a localized catastrophic event.

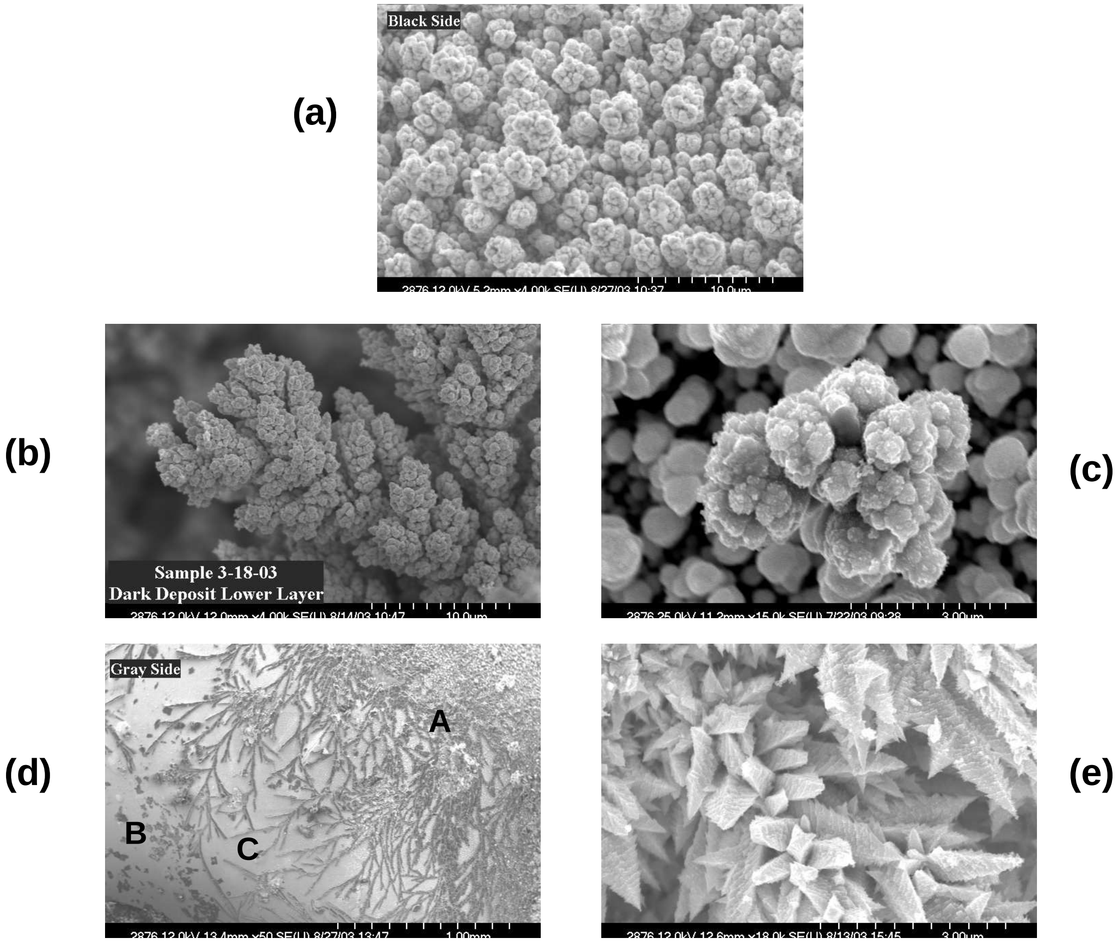

Figure 2. An illustration of minor morphological changes. a - reference morphology (no field). b - re-orientation. c - disintegration. d - branches (fractals). e - dendritic growth.

Another example of the disintegration of the Pd/D structure is shown in Fig. 2c. This figure illustrates the breaking of the bonds holding together the individual globules. The breaking of the bonding and the separation of globules may be due to action of the electric field alone or may be due to combined action of electrical and mechanical forces arising from the bulk material response to the changing magnitude of the surface forces.

A different set of processes appears to be responsible for the structural changes, *viz* (i) formation of branches (fractals), Fig. 2d and (ii) the production of dendritic growth, Fig. 2e. In what follows, we argue that these two very different forms may have a common origin, namely that they are the result of a combined action of the current flow through a porous structure, the presence of evolving deuterium, and the electric field on the separated micro-globules suspended in the electrolyte and restricted by the porous structure.

The observed morphological and structural changes occur during the reduction of D^+/D_2O ions/molecules at the porous electrode. Thus, at least three factors should be considered: (i) the external field, (ii) the distribution of the cell current and (iii) the presence of gaseous deuterium within the confines of the structure. Since the depth of current penetration (for a given electrode kinetics, current density, *etc*) into electrode depends on pore size and assuming that all factors are involved, a different response to the field is expected at different sites of the Pd/D material. At sites of a relatively large pore size, the micro-globules are acted upon by two factors, the electric field and the convective flow due to mixing by the evolving deuterium. The electric field redistributes the surface charges while the evolving gas brings micro-globules in contact with each other. Viewing Fig. 2d we identify three areas having distinct features: area A with high density of branches and un-attached micro-globules, area B which is sparsely populated by micro-globules and area C where the un-attached micro-globules are absent and where branches are well defined. The latter indicates that the growth of branches by addition of micro-globules leading to an apparent reversal of the action of an electric field.

Entirely different situations exist in small pore sizes; the pore wall may be covered by gaseous deuterium, thus shifting the cell current deeper into the porous structure. If a micro-globule is placed into the current path, and if the potential drop over the length of the micro-globule in the electrolyte is greater than the sum of cathodic and anodic overpotentials needed to dissolve Pd and deposit the Pd^{2+} ions, then the dendritic growth is possible[11].

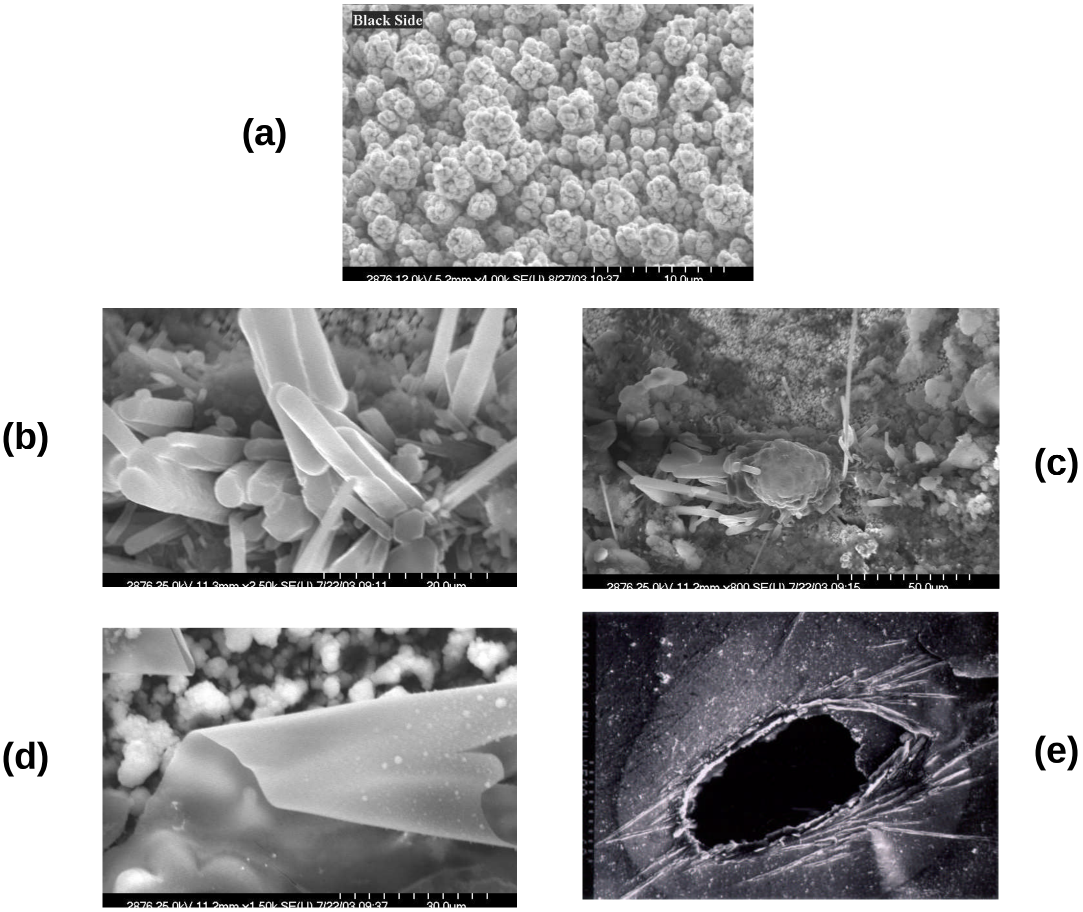

Figure 3. An illustrattion of significant morphological changes. a - reference morphology (no field). b - circular and square rods. c - boulder and long wire. d - folded thin layer. e - crater.

2.2 Morphological changes - shape changes

The transition from the “cauliflower-like” morphology to other forms is expected due to an interaction of the electric field and the response of a solid to the action of surface forces. While the morphologies shown in Figs. 2b - 2e can be accounted for, those in Figs. 3b - 3e suggest that additional factors are involved in producing the observed shape changes. Of the great variety of forms, we selected those illustrating the re-shaping of the spherical globules into (i) rods (circular and square), (ii) long wire, (iii) folded thin film and (iv) a crater, the latter suggesting the presence of a violent event. These structural changes require substantial energy expenditure, far in excess of that that can be extracted from the electric field. One such source is of nuclear origin as first suggested by Fleischmann *et al* [12]. and supported by the emission of soft X-rays[13], charged particles[14] and tritium[15] and helium[16] production.

The SEM photographs, Figs. 3b-3e, show well defined areas that seem to represent solidification of molten metal occurring under a liquid. If, as suggested earlier (*vide supra*) that the energy needed to melt a metal is of nuclear origin, then the chemical analysis of these distinctly different areas should reflect it. To illustrate, we selected three morphologically different cases, *viz* (i) a thin layer detached from the Au substrate, Fig. 4, (ii) boulder-like region, Fig. 5, and (iii) a place where, most likely, a catastrophic event has occurred, Fig. 6.

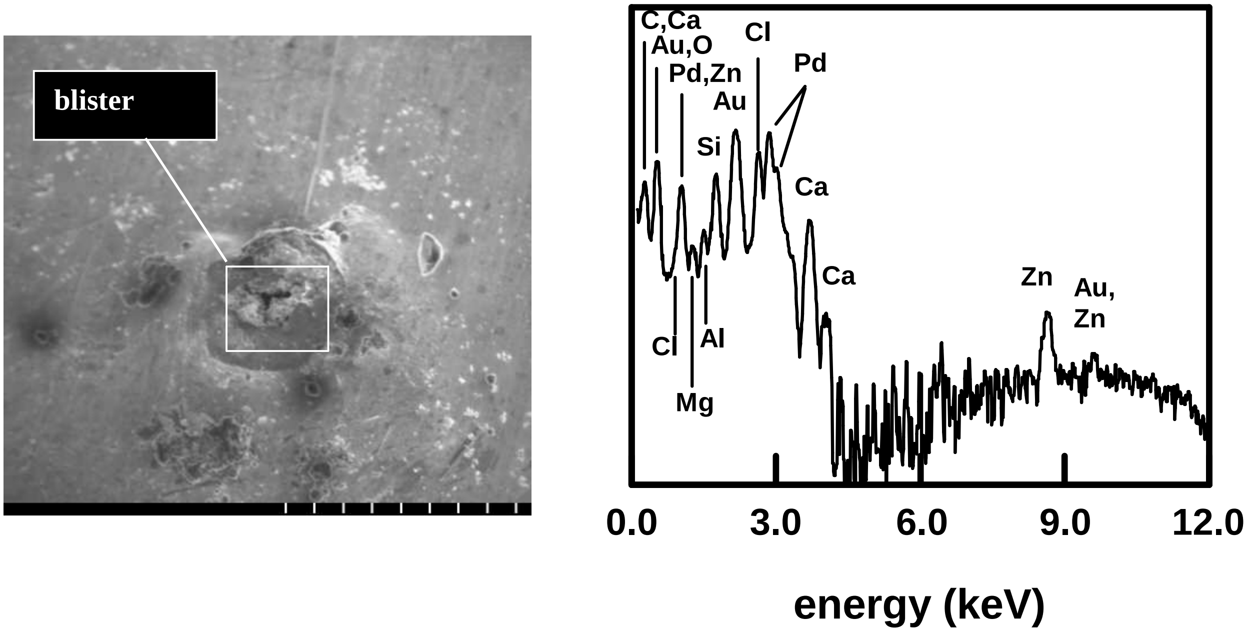

Figure 4. SEM of Pd/D electrode, after being placed in an external electrostatic field, showing a “blister-like” deformation. XRF spectra showing the chemical composition of the blister.

Analysis of the detached thin film, Fig. 4, showed the presence of Ca, Al, Si, Mg, Zn and Au, O and Cl. Since the latter three elements are present in the cell components, they cannot be attributed to nuclear events (futher experiments are needed for verification). The presence of these new elements on the electrode surface, after a long term polarization, was claimed to be due to the concentration of impurities[2,3]. While we cannot express an opinion as to the validity of such statement, we can show unambiguously that in our experiments this is not the case. The impurities, whether originating from solution or from cell components should be uniformly distributed over the electrode surface and not concentrated in clearly recognizable spots. In addition, to minimize the notion that they are the result of contamination, initiated in either solution or cell components, we selected two cases: the boulder-like, Fig. 5 , and the crater-like segments of the electrode surface, Fig. 6. Analysis of the boulder-like segment showed the presence of a single element, Al, and that resembling a crater, the presence of two elements, namely Mg and Al. Without the aid of a Maxwell demon, it would be difficult to argue that such directed motion of impurities can take place. The only sensible answer is that they were produced in the course of electrolysis of D_2O in a cell placed in an external electric field by nuclear events.

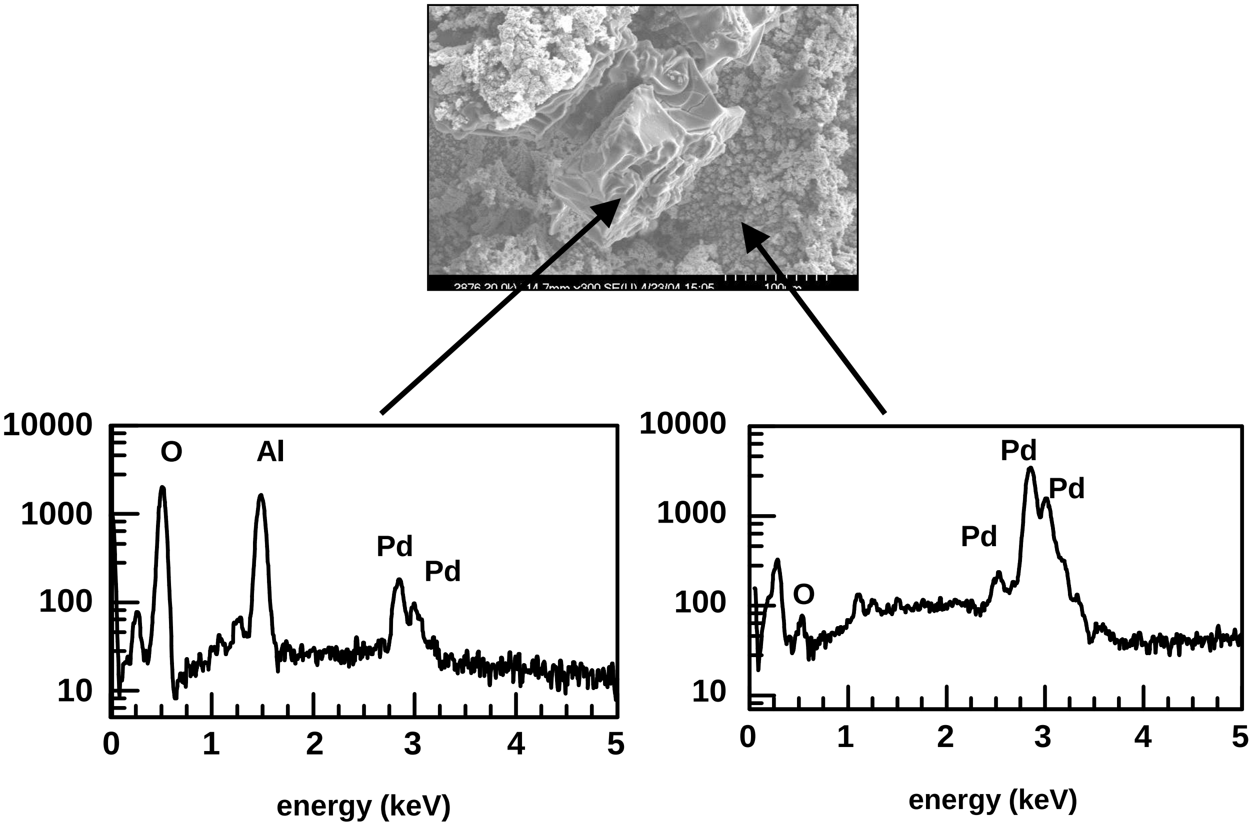

Figure 5. SEM of Pd/D electrode, after being placed in an external electrostatic field, showing a "boulder-like" deformation. XRF spectra showing the chemical composition of the boulder and the area adjacent to the boulder.

2.3 More about reaction sites

The progression of an experimental research, *experiment* → *interpretation of results* → *conclusions* → *new experiment* → *etc*, is illustrated in Figs. 7a - 7c. In a separate study[10], we showed that the excess heat is not produced continuously over the entire electrode volume but at isolated, randomly distributed in time and space, reaction sites. The short lived "hot spots", Fig. 7a, are, in fact, "mini—explosions" arising from fast and highly energetic reactions. Such "mini—explosions" can be displayed by bringing an excess heat generating electrode in contact with an appropriate sensor.

Indeed, by co-depositing the Pd/D film onto a piezoelectric substrate, one can display the pressure and temperature waves, originating within the bulk electrode, as they arrive at the sensor's surface, Fig. 7b.

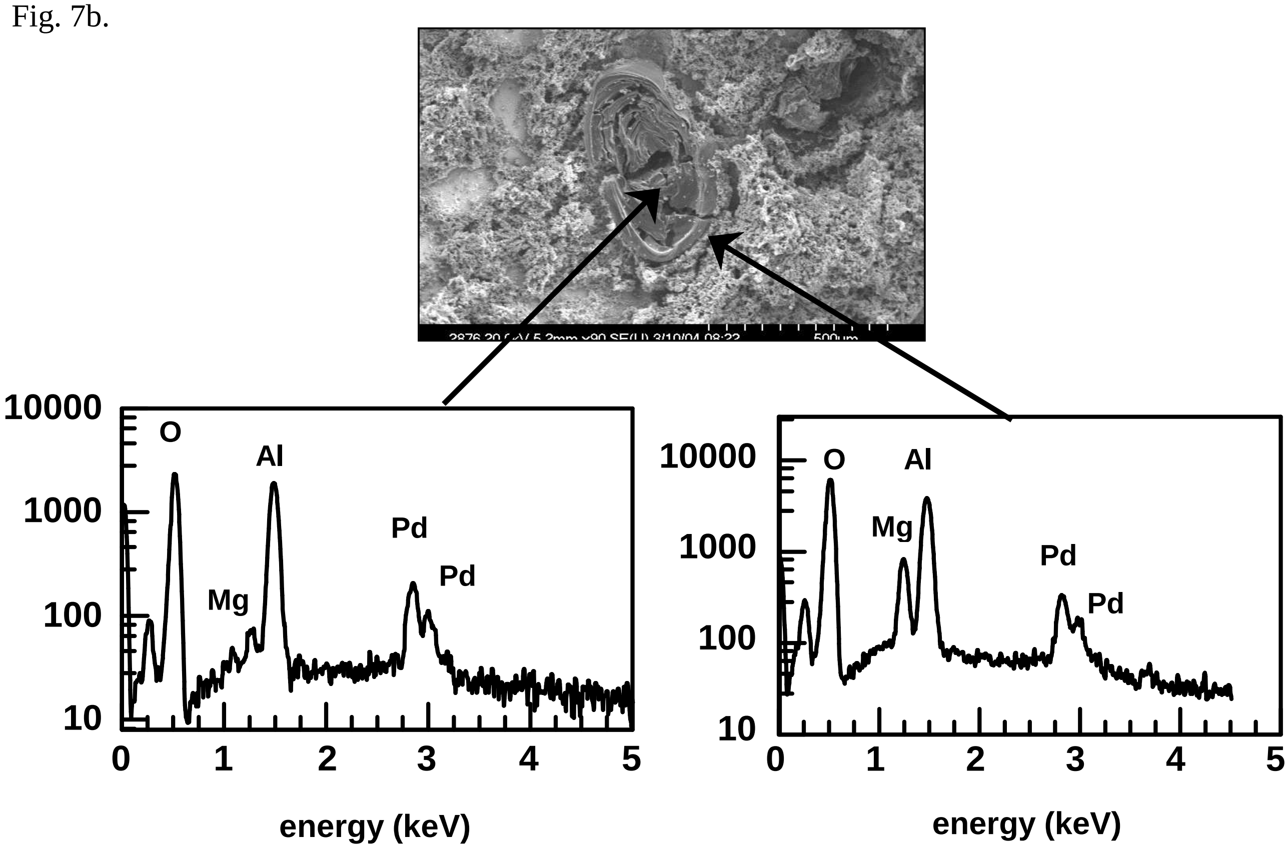

Figure 6. SEM of Pd/D electrode, after being placed in an external electrostatic field, showing a "crater -like" deformation. XRF spectra showing the chemical composition of the inside and outer rim of the crater.

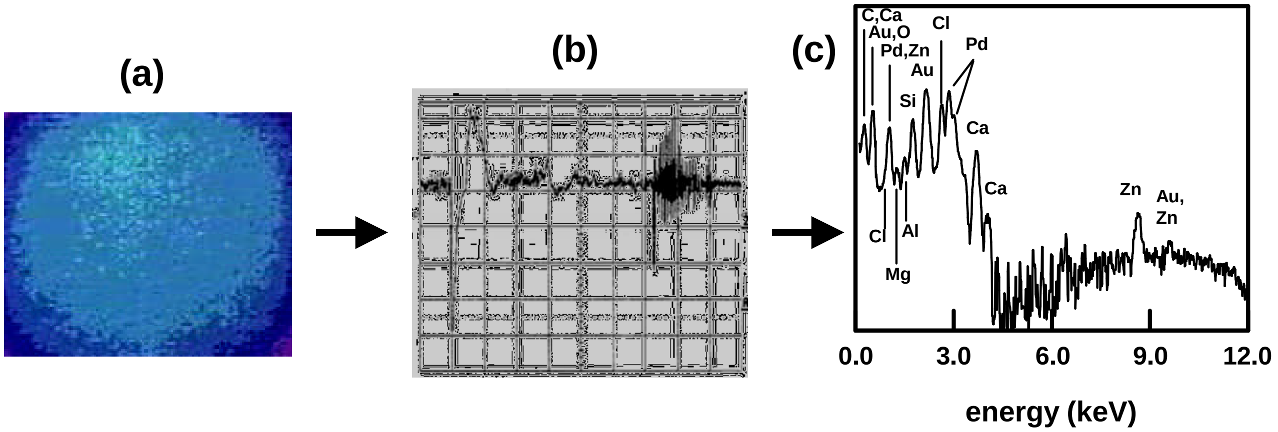

Figure 7. Sites and energetics of events. a - discrete hot spots. b- mini-explosion(s). c - chemical composition indicating nuclear origin.

In accordance with the concept that one experiment leads to another we noted the following: An analysis of experimental results suggests that events occurring at the contact surface of the interphase region influence the events in the bulk, *ie* influence the intensity and type of the nuclear events through the interactions between the D^+ complexes and the Pd lattice assisted by the stress fields at the reaction sites. Consequently, by placing an operating cell in an external electric field one would expect to see effects quite different from those observed in the absence of field. This is illustrated in Fig.7c.

3.0 Discussion

The variety of forms/structures resulting from the exposure to an electric field can be divided in two groups *viz* those that arise from the co-operative and/or competitive interaction between cell components, relevant processes and their driving forces and those that require substantial energy expenditure.

3.1 Search for precursors.

In a previous communication[17] we examined the the behavior of the Pd/D-D_2O system using cyclic voltammetry. An analysis of voltammograms indicated the presence of what we have interpreted as D_2^+ species in analogy to the existing H_2^+ molecule-ion. The H_2^+ molecule-ion was first considered in electrochemical systems by Horiuti[18] and was modeled by Gryzinski[19]. Basically, it involves injection of an s-electron into an orbit in a manner so that $[(H^+\cdot e^-)\text{-}H^+]$ molecule-ion is formed. Here, the s-electron effectively shields one of the H^+ ions. The s-electron injection can be written as follows: $H^+ + H^+ + e^- \rightarrow [(H^+\cdot e^-)\text{-}H^+]$ indicating that (1) the reaction is of the electron-ion recombination type and that (2) shielding of one of the originally close H^+ ions removes the Coulomb barrier and creates chemical bond.

(i) Formation of $[(D^+\cdot e^-)_n\text{-}D^+]$ molecule-ion. Using the same arguments, we have

$$D^+ + D^+ + e^- \rightarrow [(D^+\cdot e^-)\text{-}D^+]$$

and, by addition of another D^+ ion

$$[(D^+\cdot e^-)\text{-}D^+] + D^+ + e^- \rightarrow [(D^+\cdot e^-)_2\text{-}D^+]$$

or, in general

$$[(D^+\cdot e^-)_n\text{-}D^+] + D^+ + e^- \rightarrow [(D^+\cdot e^-)_{n+1}\text{-}D^+]$$

Similarily, an addition of two complex molecule-ions can occur yielding

$$[(D^+\cdot e^-)_m\text{-}D^+] + [(D^+\cdot e^-)_n\text{-}D^+] + e^- \rightarrow [(D^+\cdot e^-)_{m+n}\text{-}D^+]$$

These complexes interact with the Pd lattice – this is symbolically indicated as $Pd\cdots[(D^+\cdot e^-)_n\text{-}D^+]$. Each of these reactions occurs with the rate constant that is affected by an electric field.

(ii) Complex distribution. The multiple reaction paths result in a distribution of complexes of varying number of $(D^+{\cdot}e^-)$ units. Two factors would have to be considered when assessing the distribution pattern: the reaction rate constants and the stability (mechanical) of the complex $[(D^+{\cdot}e^-)_n\text{-}D^+]$.

(a) Reaction rate. The reaction path can be viewed as an electron-ion recombination occurring in an external electric field. The effect of an electric field on the rate constant of such reactions was examined by Wojcik and Tachiya[20]. Evidently, the rate constant is affected by an external field in a way that depends on the conditions outside the molecule-ion boundary. In particular, the action of an external field may either accelerate or slow down the electron-ion recombination reaction.

(b) Mechanical stability. The mechanical stability of the $[(D^+{\cdot}e^-)_n\text{-}D^+]$ as well as the stability of a domain (of complexes) $Pd{\cdots}[(D^+{\cdot}e^-)_n\text{-}D^+]_N$ can be examined using the liquid drop analogy, *ie via* the energy considerations and, in particular, by the change in the potential energy associated with the deformation of the spherical drop. The energy of the complex molecule-ion (represented as a liquid drop) consists of two parts:(i) binding energy (energy needed to take the complex apart) and (ii) surface (capillary) energy while that of a domain includes also the electrostatic energy. To evaluate, one can employ the liquid drop model and carry out calculations in a manner similar to that used in assessing the stability of a nucleus.

(c) Distribution. Two distributions are considered (i) that of a $[(D^+{\cdot}e^-)_n\text{-}D^+]$ complex and (ii) that of a $Pd{\cdots}[(D^+{\cdot}e^-)_n\text{-}D^+]_N$ domain. In both cases, the stability conditions are derived from energy considerations associated with the shape change resulting from the motion of components (charged or not) that occur within the molecule-ion or the domain. In both cases, capillary energy plays an important role. The shape changes arise from fluctuations which, in turn, modify the magnitudes of the potential and kinetic energies of the molecule-ion, respectively the $Pd{\cdots}[(D^+{\cdot}e^-)_n\text{-}D^+]_N$ domain. The interaction with an environment (the Pd lattice and/or s-electrons) occurs in a coherent way.

3.2 Fusion reactions

(i) Fusion of light elements, T, He. The production of light elements (T and He) occurs *via* the following set of events:

(i) An s-electron is captured by the molecule-ion, $[(D^+{\cdot}e^-)\text{-}D^+]$, so that the precursor $[(D^+{\cdot}e^-)\text{-}D^*]$ is formed, $([(D^+{\cdot}e^-)\text{-}D^+] + e_s^- \rightarrow [(D^+{\cdot}e^-)\text{-}D^*])$. The electron capture (K-capture) is favored at the “heavy end” of the periodic table where the K-orbits are small and the probability of an electron to be at nucleus is large. In our case, the high probability is assured by high concentration of energetic s-electrons within the domains. The rate of transmutation of the molecule-ion to a precursor increases with an increase in the chemical potential of s-electrons. This can be demonstrated as follows: for the reaction ${}_ZM^A + e_s^- \rightarrow {}_{Z-1}X^A + \nu$ at equilibrium, the chemical potentials must be equal. The chemical potential of a single molecule (here, the precursor) is just its internal energy, $-\varepsilon$. Consequently, $-\varepsilon_M + \mu(e^-) = -\varepsilon_X$. Now, since the neutrino leaves the system, its chemical potential does not appear and furthermore, an increase in the s-electron concentration or their energies, tends to increase the e_s^- capture. Following the s-electron capture the electrostatic energy of the complex molecule-ion is reduced causing its collapse to the precursor.

(ii) The electron capture effectively changes the nature of the force acting between the shielded deuterons, *ie* change from chemical bonding to nuclear forces, to form $[(D^+\cdot e^-)\cdots D^*]$ or ${}_1(X)^4$, a highly excited nucleus.
(iii) The excited nucleus can decay *via* the β emission to He: ${}_1(X)^4 - e^- \rightarrow {}_2He^4$
and *via* the proton emission followed by β emission to T: ${}_1(X)^4 - p^+ \rightarrow {}_0(X)^3 - e^- \rightarrow {}_1X^3 = T$
(emission of charged particles was observed).

(ii) Fusion of heavier elements, qualitative observations. Fusion of heavier elements, *eg* Al, Mg, Si, Ca, Zn, *etc*. occurs (in our system) when an operating cell is placed in an external electric field. Qualitatively, the newly fused elements are found to be randomly distributed over the electrode surface area indicating highly localized reaction sites. The analysis of the reaction sites show either a single element, *eg* Al, or more than one element, *eg* Al and Mg. There appears to be some correlation between the structure of the reaction site, as displayed by SEM, and the number of fused elements present. A common feature exhibited in both cases (presence or absence of field) is the presence of highly localized reaction sites (Note the hot spots displayed by IR imaging in the absence of field).

(iii) Proposed fusion mechanism for heavier elements. In formulating the fusion mechanism, we note the following:
(a) Fusion must be a single event in the sense that it follows the reaction scheme:
precursor + trigger → unstable "nucleus" → stable nucleus.
One triggering mechanism might be due to e_s^- -capture assisted by local conditions, *eg* stress field, electric field, *etc*.
(b) Fusion must involve events within the precursor as well as to provide the balancing charge of electrons in the K,L,M,N,.. orbits.
(c) Fusion to heavier elements (in our system) requires the presence of an external electrostatic field. The fields used in our experiments were on the order of 10^3 V cm^{-1}, *ie* too small to affect chemical bonding within the precursor. Consequently, there are a number of questions that need to be answered, *viz* how the field interacts with the system as a whole to produce precursors containing a large number of $(D^+\cdot e^-)_n$ elements within the $[(D^+\cdot e^-)_n\text{-}D^+]$ complex. Is the fusion reaction leading to multiple elements due to a single large precursor which disintegrates when in an excited state to yield multiple elements, or is a number of precursors present within the domain?

4.0 Concluding remarks

1. The most obvious effect of an external electric field is the shape change of the individual globules of the "cauliflower" structure of the co-deposited material. With the shape change there is a change in the defects density as well as in the stress field intensity. Both these factors affect the interaction between the D^+-complexes and the Pd lattice, *ie* they contribute to the formation of the $Pd\cdots[(D^+\cdot e^-)_n\text{-}D^+]_N$ domains.

2. The concentration of the D^+-complexes is determined by the overpotential. The effect of an external electric field is minimal.

3. Excess enthalpy is generated by highly energetic fast reactions that resemble "mini-explosions".

This view is supported by IR imaging (hot spots), by the response of the pressure/temperature sensitive substrates (piezoelectric material) onto which the Pd/D films are co-deposited and by SEM examination and analysis of selected isolated spots showing elements not originally present.

4. The formation of precursors as well as the fusion reactions is of the type: $A + B \rightarrow C + D$. As written, this statement implies conservation of matter - otherwise, both the reactants and products are not constrained. In practice however, the initial conditions of the reactants are specified by the experimental protocol while those of products by energy considerations and the rate constants. If such reaction occurs in, *eg* the Pd lattice, additional constraints are operative. Consequently, in the reaction: ${}_{Z}M^{A} + e_{s}^{-} \rightarrow {}_{Z-1}X^{A} + \nu$, the particles are constrained by an interaction with the Pd lattice. This, we indicate by writing $Pd\cdots {}_{Z}M^{A}$, *etc*. It is with this in mind that we examine the effects of placing an operating cell in an external electrostatic field.

5. The triggering activities (to initiate fusion reactions) are located within the first few atomic layers and, most likely, involve changes in the electronic structure of this region. These changes are transferred deeper into the Pd lattice where the nuclear events occur.

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