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Excess heat and Mechanism in Cold fusion reaction

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Abstract

The authors have proposed a new "Model" which can reasonably explain the existence of Cold Fusion Reaction and also verify the generation of tremendous excess energy in the DS-cathode.which is fifty thousand times higher than chemical reaction energy. The new model is named "Latticequake Model".Cold fusion is caused by high energitic deuterium similar to "hot" fusion.

Key words: Latticequake; cold fusion; molecular dynamics; excess heat; DS-cathode

1. Introduction

The authors pointed out that reactions in a Double Structure cathode (DS-cathode) contained with "Pd-black" continuously generated more than $5x10^4$ times of excess energy expected in chemical reactions.[1] So far many researchers have reported on the excess heat generation and the evidence on the generation of nuclear-reaction products.[3] "Cold fusion", however, has not been generally accepted due to the lack of experimental evidences on the stable and/or continuous generation of large amount of excess heat or nuclear reaction products. Furthermore, poor reproducibility of the experimental data tended to obstacle the determination of conditions for the generation of nuclear reactions. Therefore the theoretical works devoted to explain the mechanisms involved in the cold fusion have been failed because of lack in their stand points based on the experimental results with sufficient reproducibility.

In the present paper, the authors would like to propose a new "model" and to clarify the justifications on the cold fusion.

2. Characteristics of DS-Cathode

The principle of the DS-Cathode is schematically depicted in **Fig. 1**. In moving deuterium from the Pd region A with a deuterium concentration of $[D_A^*]$ ($\equiv D/Pd$) to the other Pd region B, each separated by the space C, the problem to be considered here is what is the most appropriate way to get the concentration $[D_B^*]$ in the region B as high as possible.

Here we have considered to compare the following 4 possible ways as schematically illustrated in **Fig. 2**. First in the case of (a) where the space C is vacuum so that the concentration in the region B becomes $[D_B^*]=0$ and naturally results in the process in the case of (b). In other words, deuterium gas is diffused into the space C and the D_2 gas pressure P_{D2} increases with time. So the concentration $[D_B^*]$ in the region B gradually increases to follow $[D_B^*] = a + b \log P_{D2}$ according to the Sieverts' law. Even with hydrogen gas the condition to achieve $[H_B^*]=0.9$ as shown in Fig. 2 requires the hydrogen pressure higher than at least ten thousand [atm], and approximately 30 times higher pressure is believed to be required to satisfy this condition with deuterium gas. therefore, as fas as experiments performed in the territory of the Sieverts' law, where the high pressure regime is preferred,As has been experienced by many researchers,it is impossible to realize a high concentration of deuterium. Accordingly, they should need a major break-through to get out of this law. Based on these facts, as has been presented by many reports, it should be absolutely unlike to observe the reaction products ($_2^4He$, $_1^3T$, $_1^1P$, $_0^1n$ etc.) and/or the excess heat (excluding the heat caused by the chemical reactions) in the pressure range as low as 1 [atm] during the period of time as short as several days.

The authors [3] have ever pointed out the importance of "micro-defects" to the mechanism of cold fusion. Looking from the bulk material, surfaces are considered to be a kind of the defect. Therefore, it is expected to increase the effects of the surface micro defects with increasing surface area or "relative surface" S^* (= surface area / volume). One extreme state to realize this idea would be powders, which can be considered to be a key factor for the practical development of the cold fusion in future.

Forty years ago when one of the authors hit upon an idea of "Solid-state plasma fusion", he did not believe that the fusion reactions were obtainable only with electrolysis as are presented later by Fleischmann and others.[4] As in the "hot plasma fusion", one of the absolute conditions for the solid-state plasma fusion was believed to be the high-energy state of the deuterium ions confined in the Pd lattice with external shock-energy supply. This idea has raised questions on the Fleischmann's results, however, the recognition of these facts has lead to the "powder vessel" as one of the best vessels based on the above considerations of the characteristics of powders.

The authors immediately started the examination of the Fleischmanns' experiments using the following two ways with Pd powders. One was the way to use powders as a cathode and the other was performed with Pd cathodes spray-coated with Pd powders onto the surface.[3] The former method (not published yet) resulted in a number of troubles, where we examined the characteristics of the powders. As a result, the principal condition for the cold fusion was concluded to be that "surface effect" inherent to the powders enables 'the homogeneous and highly concentrated deuterization and the feasibility of large cathode without any

limitation on size.

Thereafter, significant effects are not expected in the ordinary surfaces on the plate- and/or the rod-configurations with small S^* due to the less chemical reactivity. With powders, on the other hand, S^* considerably and thus the reactivity abruptly increases with decreasing powders size and causes "spill over effect".[5] This causes the powders to function the "Pumping-up action" as shown in Fig. 1 and the powders continuously absorb deuterium up to $[D^*]\approx 1$. Especialy, it is well know that $[D^*]=1$ should instantaneously be achieved in the "cluster" (< 100 Å in diameter).[9] Consequently, characteristics of the deuterium absorption and its variation with pressure are greatly dependent on S^* as shown in **Fig. 3**.

Fig. 4 shows the recent experimental data on the excess-heat generation. These results show that the new "model" for the cold fusion is requested to describe the possibility of the continuous energy generation over 10 [watt/cm^3].

3. Proposal of the New "Latticequake Model" for Cold Fusion

One of the fundamentally important problems involved in the cold fusion is that the deuterium is in the ionic state in the Pd lattice and their motions are strongly limited by the intense constraint force by the Pd lattice, which is completely different from the physical situations in the "Hot" plasma fusion. This means that the position, the direction and the conditions for the fusion reactions are considerably limited, and thus the reaction process is considered to undergo different mechanism from that expected in the hot fusion. Therefore the theoretical approach for the cold fusion is required first to consider the wave function of the O-site (Octahedron), which is the stable site for deuterium, by assuming that the all of deuterium are confined in this site, and second to obtain the probable distribution to find the deuterium from the O-site to the T-site (Tetrahedron) surrounded by the several O-site. Here when we assume that the achievement of the fusion reactions by putting plural deuterium ions to interatomic distances of about 0.1 Å is explicitly driven by only thermal energy, the Pd lattice may explode out. This consideration has lead to a conclusion that the cold fusion is impossible.

However, as indicated in Fig 4 or similar data repeatedly, excess energy of 10 [W/cm^3] is continuously generated and obtained large energy around 100 [MJ] by the use of DS-cathode developed by the authors. The energy is extremely larger when compared to chemical reaction, therefore, no reaction except cold fusion exists. The authors proposed a new model that enables the generation of "CP-CF"(Continuous Powerful Cold Fusion).

Now, as well known, when the motion of atom in lattice exceeds Wigner energy, ε_w, the violent vibration is induced in the lattice as schematically shown in **Fig. 5**. The authors named the phenomena as "Latticequake". Suppose that the reaction occurred one time, as indicated in Appendix, the reaction products with high energy is certainly produced from the well-known two-body collision of deuterium (Rutherford type: [A-type]) to unknown two-body or multi-body collision [B-type]. Therefore, for the sake of simplicity, the reaction products is represented as $_2{}^4$He, and supposing its energy $\varepsilon_{He}=1\sim 20$ [MeV].

The necessary energy to generate "CP-CF", ie., Latticequake is obtained by the collision of $_2{}^4He$ against the atom on Pd lattice that transfers higher-energy to the atom. Then, the energy transfer from high energy $_2{}^4He$ to "cold-Pd atom" is described.

When the A_0 atom in Fig.5(A) moves toward $A_0(O_1)$ or O_3 (Center of O-site) along X_1-X_2 (<100>) axis, the neighboring atoms shift to $B_0 \rightarrow B_1$, $D_0 \rightarrow D_1$, $E_0 \rightarrow E_1$ or $C_0 \rightarrow C_1$, $F_0 \rightarrow F_1$, $G_0 \rightarrow G_1$. If the energy of A_0 atom is larger than Wigner energy, ε_w, A_0 atom jumps over A_1 or C_1 and moves following direction; $A_0 \rightarrow A_1 \rightarrow B_0 \rightarrow \cdots$, or $C_0 \rightarrow C_1 \rightarrow \cdots$, and the neighboring atoms quickly return to the original position. Such behavior of A_0 atom induces the collision of neighboring many atoms, and generate the multi collision phenomena, therefore, the outline could be grasped by "molecular-dynamics". For example, as described above, the following energy for $_2{}^4He$ is supposed.

$$\varepsilon_{He} \approx 1 \sim 20 \text{ [MeV]} \qquad [1]$$

The following energy is assumed as a mean value.

$$\langle \varepsilon_{He} \rangle \approx 3 \text{ [MeV]} \approx 5\times10^{-13} \text{ [J]} \qquad [2]$$

As well known, when a particle with mass of m having energy of $\langle \varepsilon_m \rangle$ collides head-on against a static particle with mass of M, energy $\langle \varepsilon_M \rangle$ of particle M is expressed as the following.

$$\langle \varepsilon_M \rangle = \langle \varepsilon_m \rangle [4mM / (m+M)^2]$$
$$[\fallingdotseq 4 (m/M) \langle \varepsilon_m \rangle]; (M \gg m) \qquad [3]$$

Supposing that m=He, M=Pd, one collision gives about 15% of energy to Pd and He itself is rebounded with 85% of energy, the reaction occurs at O_3-site, if He with $\langle \varepsilon_{He} \rangle$ collides head-on against A_0 atom of Pd along $X_1 \rightarrow X_2$ axis, He atom is rebounded and then goes back and forth several times giving almost $\langle \varepsilon_{He} \rangle$ to A_0 and C_0 atom, and the atoms are emitted toward $A_0 \rightarrow A_1 \rightarrow B_0$ or $C_0 \rightarrow C_1 \rightarrow$ respectively with $\langle \varepsilon_{He} \rangle/2$ along X_1-X_2 axis direction. These A_0, and C_0 atoms give violent vibration on lattice as seismic atom ("S-atom") thus generate "Latticequake". This Latticequake severely crushes the O-site(include deuterium) along X_1-X_2 axis, simultaneously expands the O-site along Y and Z axis, the maximum expansion is as follows; $a_0a_0 \rightarrow a_1a_1$ and $b_0b_0 \rightarrow b_1b_1$. By this expansion both O-site and T-site simultaneously expand and integrates each other forming a cavern more than ten times larger than normal O-site, this a cavern is called "Lattice Hall". If the lattice contains 100% deuterium (D^*=1), "Lattice Hall" accommodate around 10 deuterons. Such "Lattice Hall" can shrinks rapidly to normal O-site size around 10^{-12} s, and severely compress the deuterium clusters with the density of deuterium over 10 times high than its solid one that makes possible

for the achievement of cold fusion. The phenomena is similar to "Laser implosion". Therefore the phenomena could be called as "Lattice implosion". The necessary condition for the achievement of "CP-CF" by this Lattice implosion is $D^* \geqq 1$.

Then, Latticequake moves with "S-atom". The energy of $<\varepsilon> \approx 20\sim30$[eV] (Wigner energy in metals) should be consumed by every movement of S-atom from A_0 to B_0. Generally, the movement distance a^*, movement frequency n^*, traveling length l^* and $<\varepsilon_w>$ are different according to the movement direction of "S-atom". However, In the case of ideal "Latticequake" due to the "S-atom" with the energy $<\varepsilon_{"s"}>$:

$$n^* = <\varepsilon_{"s"}>/<\varepsilon_w>, \quad l^* = (n^*+1)a^* \qquad [4]$$

When the historically evaluated result obtained by Vineyard, et al.[6] as shown in Fig. 5(B) is used, $n^* = 2$ and $l^* \approx 12$ [Å] are determined by giving $<\varepsilon_{"s"}>=40$ [eV], $<\varepsilon_w>20$ [eV] in the {100} plane and <100> direction. This is an example when the zone of ideal "Latticequake" is almost equivalent to the distance of Frenkel pair.

On the other hand, in the case of Pd in the {100} and <100>, when the ideal "Latticequake" due to the "S-atom" with the high energy $<\varepsilon_{"s"}>$ $(= <\varepsilon_{He}>/2)$ is considered according to the [2], [3] and [4] equations,

$$n^* \approx 5\times10^4, \quad l^* \approx 2\times10^{-3} \text{ [cm] } (=20 \text{ [}\mu\text{m]}) \qquad [5]$$

In the case, $<\varepsilon_w>= 30$ [eV] was used. In reality, however, a number of cases require 60~ 80 [eV].

The above description is an example concerning the behavior of an ideal 'Latticequake" due to "S-atom" generated under the ideal conditions. It should be quite important in understanding the "limitation" of practical phenomenon, knowing the events under such ideal enviroments.

As shown in Fig. 5(B), in general, a motion of "S-atom", A_0, is off from an ideal direction as the <100> direction. This indicates the movement of atoms in the (100) plane obtained on the basis of "molecular dynamics" by Vineyard.[6] when a "S-atom" is shot out at an angle of 15° off Y axis (<100>). As understood from this figure, the "S-atom" with the energy more than the Wigner energy produces a "Frenkel pair" and "focusson" etc. in Pd Lattice. That is to say, the <100> and <110> direction are "focusson channels" for the Pd lattice and are regarded as "reaction roads" for deuteriums. Such reaction roads appear at certain points in any collision in the case of "S-atoms" of ultra-high energy. A "S-atom" of high energy should generally induce an intense cascade phenomenon which produces 100~1000 Frenkel pairs instantaneously by chain avalanche collision.[7),8)]

Now let's consider neutron energies generated by the D-D reaction due to hot plasma fusion by way of example. The neutron energies generated by the primary

reaction, ${}_1{}^2D(d,n)_2{}^3He$ and the secondary reaction, ${}_1{}^2D(t,n)_2{}^4H$ are defined as $<\varepsilon_{N1}>$ and $<\varepsilon_{N2}>$, respectively, and they are:

$$<\varepsilon_{N1}> = 2.45\ [MeV],\quad <\varepsilon_{N2}>=14\ [MeV] \qquad [6]$$

In both cases, "S-atoms" with high energy can be produced. In the case of $<\varepsilon_{N2}>$, the energy $<\varepsilon_{"s"}>$ of "S-atoms"is reported to reach 2 [MeV] at maximum (and 0.3 [MeV] on the average). [7] Therefore, such S-atom can supply an energy$<\varepsilon_{"D"}>$ of approximately 40 [keV] (6 [keV] : average) to deuteriums. Moreover, such high energy "S-atom" would generally induce 10 to 20 sub-cascades. which consists of "vacanay clusters" with a concentration of vacascies 20~30%.[7),8)] In the case of Frenkel pair even when only one vacancy is produced, "Latticequake" is induced at the surrounding atoms clustered between a vacancy and internal atom in a Frenkel pair. Consequently, high conncentration of deuterons ara included in the intense cascade and much high energy levels are achieved there, leading to more opportunities of the D-D reaction. t is taken for granted that more defects should cause an intense shake more frequently and the D-D chain reaction would take place more easily.

The above descripitions are summarized in **Fig. 6.** In short, at the condition of the deuterium concentration $[D^*]\gtrsim 1$, only if one 'S-atom" is generated, the energy induces the "Latticequake", which acts as two functions. One is that it crushes "O-site". Thereby "Latticequake" hits the deuterium out of the O-site and supplies the deuterium with the high energy $<\varepsilon_{"D"}>$ as a "Lattice-accelerator". "S-atom" with an energy of 1 [MeV] produces deuterium with an energy of 20 [keV]. The other function of the "Latticequake" is that it makes a cavern, "Lattice-Hall", over 10 times wider than normal O-site by combining with many O-sites and T-sites. Instantly the "Lattice-Hall" accommodates deuterons, it shrinks for an extreme short time of about 10^{-12} [s] and thereby the "Latticequake" accelerates the deuterons toward the center of the "Lattice-Hall" as a "lattice accelerator". This enables the deuterons to be concentrated to the degree of 10 times more than its solid state and achieved nuclear fusion reaction. It seems that this phenomenon in cold fusion is similar to the "Laser implosion" in hot fusion, and we name it "Lattice implosion".

The basic differences between the cold fusion and hot fusion, are summariged in **Fig. 7**. In cold fusion, deuterons are strongly confined by latice field and, by "Latticequake", can attain the kinetic temperature of several million in spite of low lattice temperature. On the other hand, in hot fusion, the deuterium plasma confined by strong magnetic field is heated by high energy electrons in general. Thus, the lattice atoms play the crucial role in cold fusion,while the electrons in hot fusion. Therefore, in order to maintain the chain avalanche reaction stably for each nuclear fusion, the fundamental conditions are $[D^*]\gtrsim 1$ for cold fusion and "stability" for hot fusion. Both fusions require a similar "High Energitic Deuterons" in order to induce nuclear fusion reaction.

Appendix I : [*A-type*]. *Rutherford fusion reaction.*

$$ {}_1^2D + {}_1^2D \quad \left.\begin{array}{ll} {}_2^3He + {}_0^1n\ (3.27\ [MeV]) & (a) \\ {}_1^3T + {}_1^1P\ (4.03\ [MeV]) & (b) \end{array}\right\} \qquad (1) $$

When this reaction is continued, ${}_1^2D\ ({}_1^3T,\ {}_0^1n)\,{}_2^4He$ and ${}_1^2D\ ({}_2^3He, {}_1^1P\ )\,{}_2^4He$ are set as a second reaction.

$$ \therefore\ 6\,{}_1^2D \rightarrow {}_2^4He\ (7.1) + 2\,{}_1^1P\ (17.7) + 2\,{}_0^1n\ (16.55) + (1.8) $$

Assuming that the energy of only charged particles transforms to the lattice, where the energy ε_D for the extinction of one deuterium is produced in lattice

$$ \varepsilon_D \approx 4\ [MeV]\ (=6.6\times10^{-13}\ [J]) \qquad (2) $$

total energy ε_{cc} in Pd lattice of 1 [cm^3] volum with [D^*] =1,

n_{Pd}= 7×10^{22} [atoms/cm3]

$$ \varepsilon_{cc} = n_{Pd} \quad \varepsilon_D \approx 4.6\times10^{4}\ [MJ/cm^3] \qquad (3) $$

Appendix II : [*B-type*]. *Unknow fusion reaction.*

Assuming that the simplest reaction of unknown fusion is

$$ {}_1^2D + {}_1^2D = {}_2^4He + 23.4\ [MeJ] $$

$$ \therefore\ \varepsilon_D \approx 12\ [MeV]\ (\approx 1.9\times10^{-18}\ [MJ]) \qquad (4) $$

$$ \varepsilon_{cc} \approx 1.4 \approx 1.4\times10^{5}\ [MJ/cm^3] \qquad (5) $$

Note:

Since totalenergy in authors experimental data was $\varepsilon_{cc}^* > 100\ [MJ/cm^3]$, it is compared with (3) and (5) equations

$$ \varepsilon_{cc} / \varepsilon_{cc}^* \approx \left.\begin{array}{ll} 500 \text{ for [A type]} & (a) \\ 1500 \text{ for [B type]} & (b) \end{array}\right\} \qquad (6) $$

This means that authors datas correspond to extinguish one deuterium among 1000 (~100) ones.

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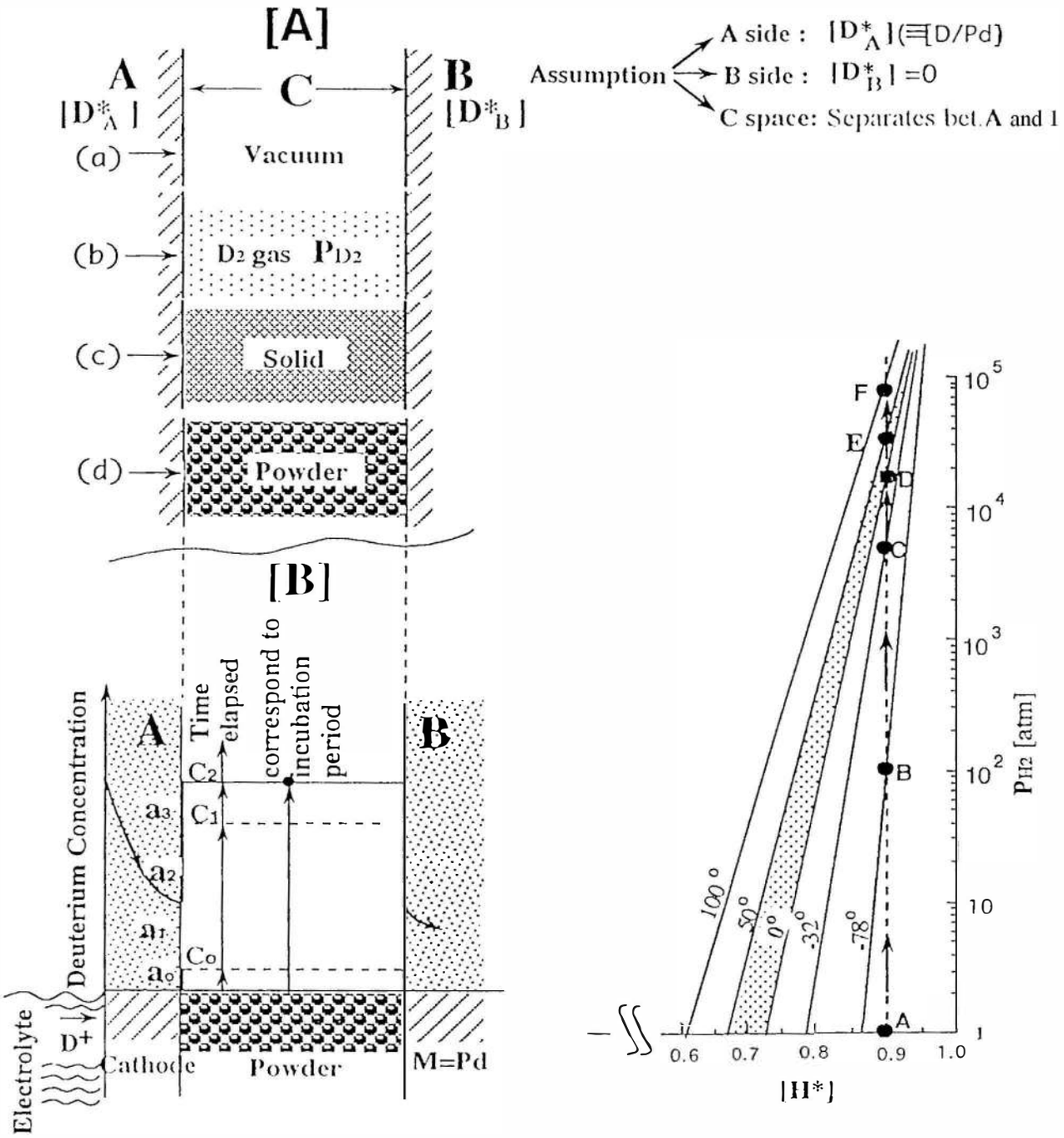


Fig. 1 Schematic diagram for deuterium movement from A to B, which is separated by C-space

Note[A]: Difference between Vacuum, Gas, Solid and Powder for deuterium movement

Note[B]: Illustration of "pumping -up action"(Spillover-effect) of fine powder, where a_0(C_0), a_1(C_1) and a_2, a_3...(C_2) are Deuterium Concentration Curve in outer (and inner) Cathode respectively.

Fig.2 Plot of "P-C-T" relationship at high concentration and pressure after many researchers:[H*](≡ H/Pd)=a+blogPH2, and [D*] requires the pressure around 30 times higher than [H*].

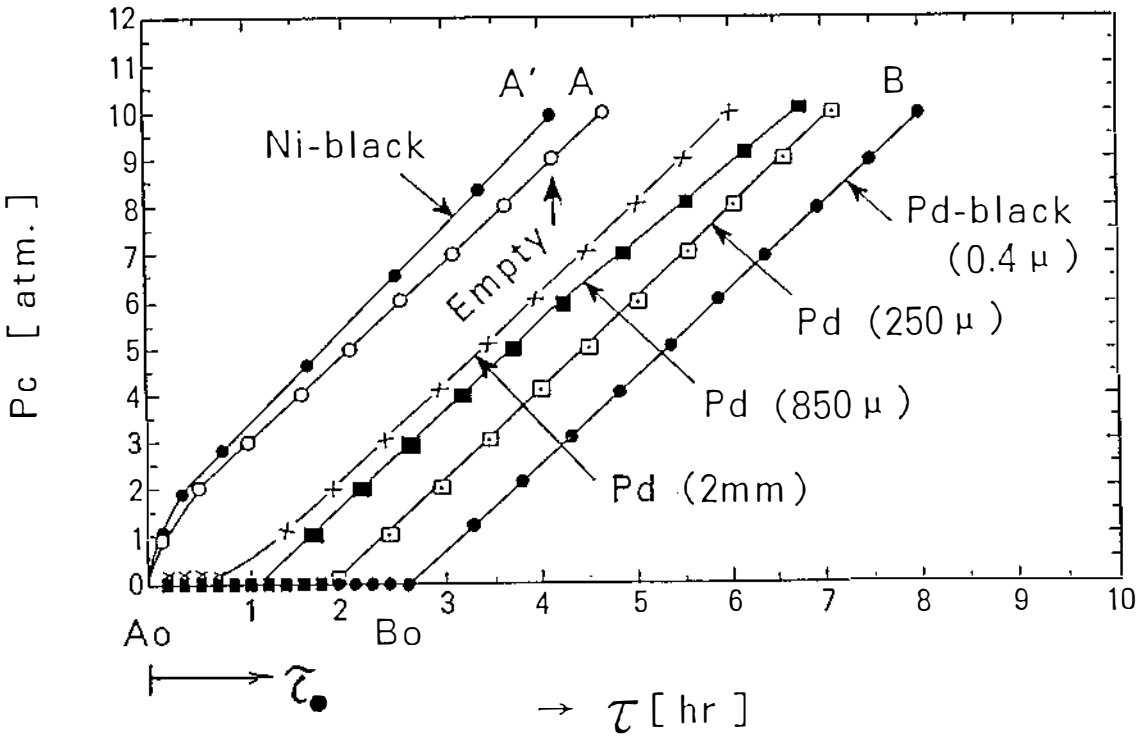


Fig.3 Relatioship between Pc — τ
($\tau_{\bullet}$: incubation period) for a long period.

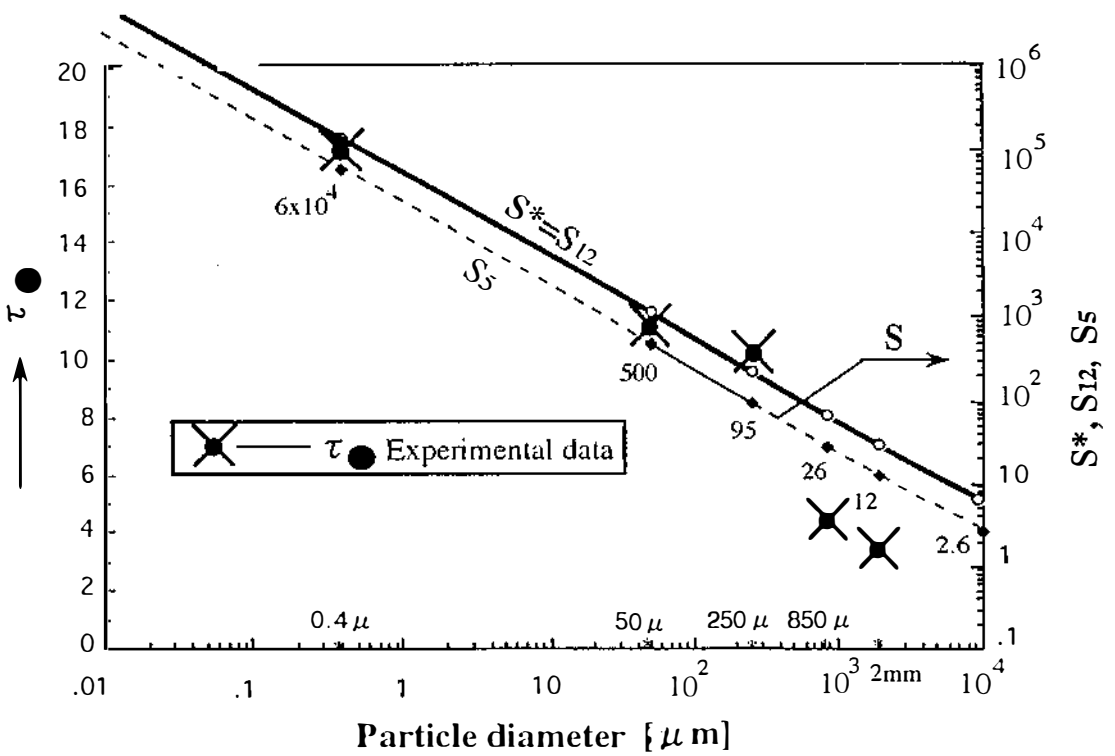


Fig. 3 Relationship between powder and incubation period $\tau_{\bullet}$ relative surface S* and surface area (S_5 and S_{12}). S_5 and S_{12} are Pd 5 [g] and 12 [g] ($\fallingdotseq \rho$: Pd density), respectively. In general,

$$S^* = \frac{\rho}{M_n} S_n \quad (n=1, 2, 3, 4, ---; 12---) \quad \therefore \; S^* = S_{12}, \; (\rho = M_{12} \fallingdotseq 12 \text{ [gr]})$$

where, surface, S_n [cm²] and mass. Mn [gr]. n (=1, 2,- - - -).

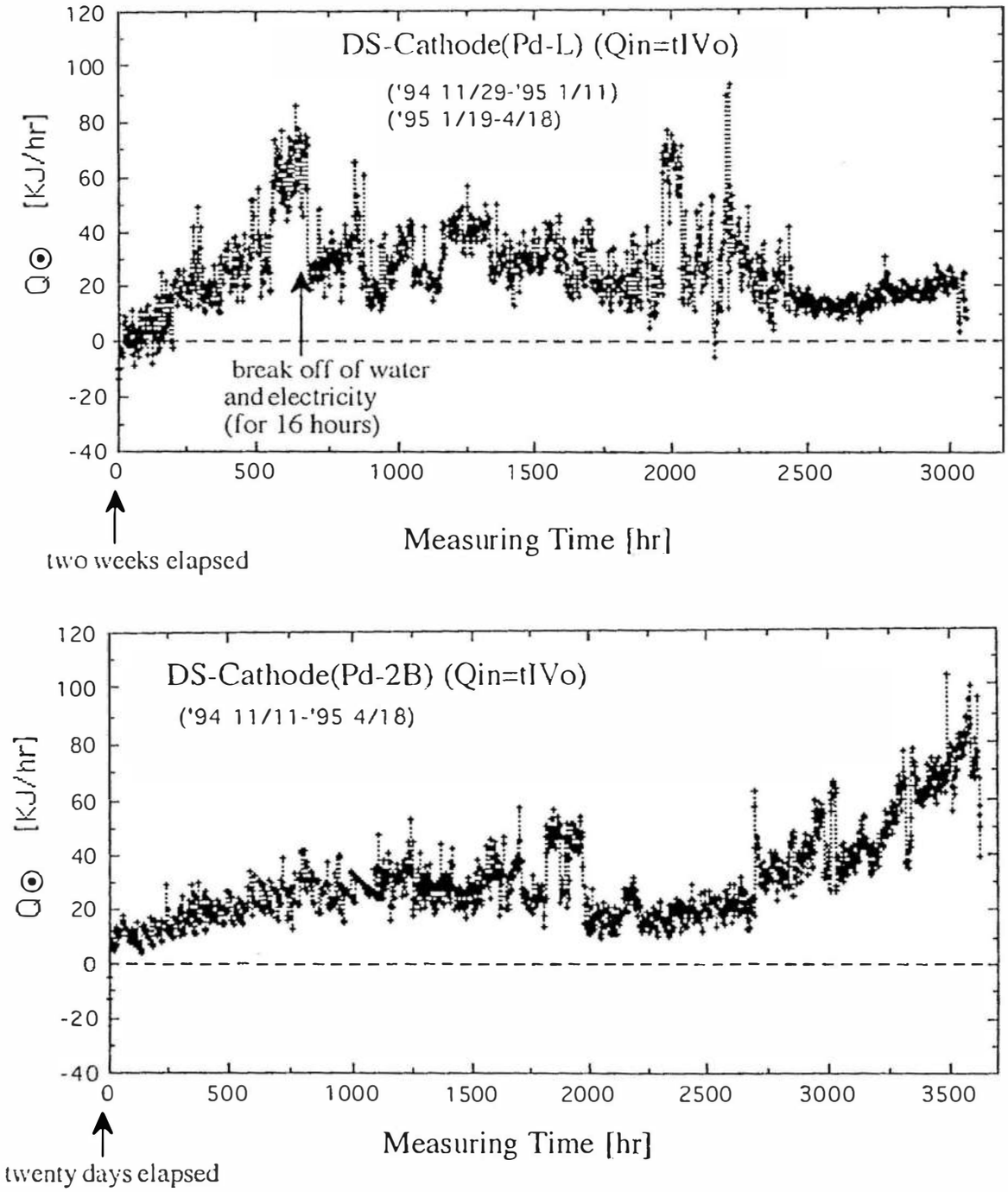


Fig. 4 Excess heat characteristics of two examples for long period. (upper side: Pd 5 [gr], low side: Pd 3 [gr] and excess heat Q⊙= output- input, [KJ/hr]; 10 [watt] = 36 [KJ/hr]

Fig5 [A]

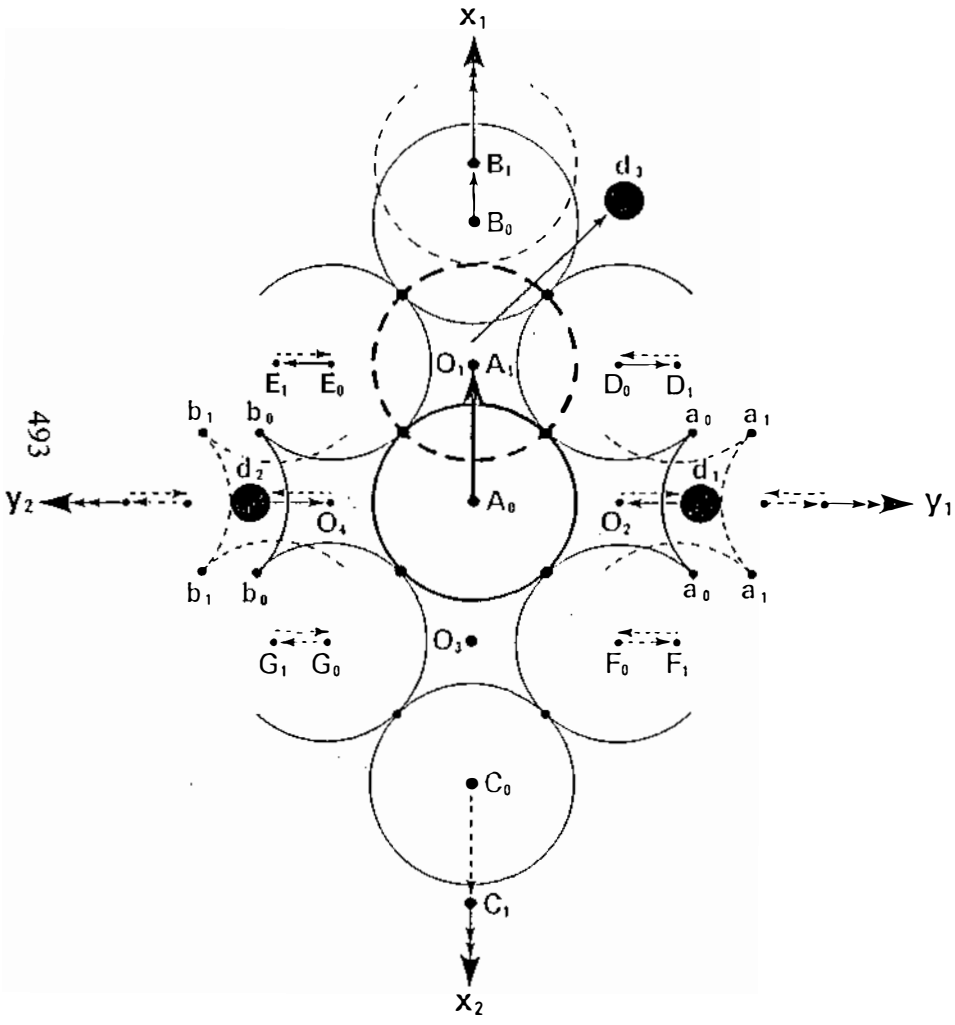


Fig5 [B]

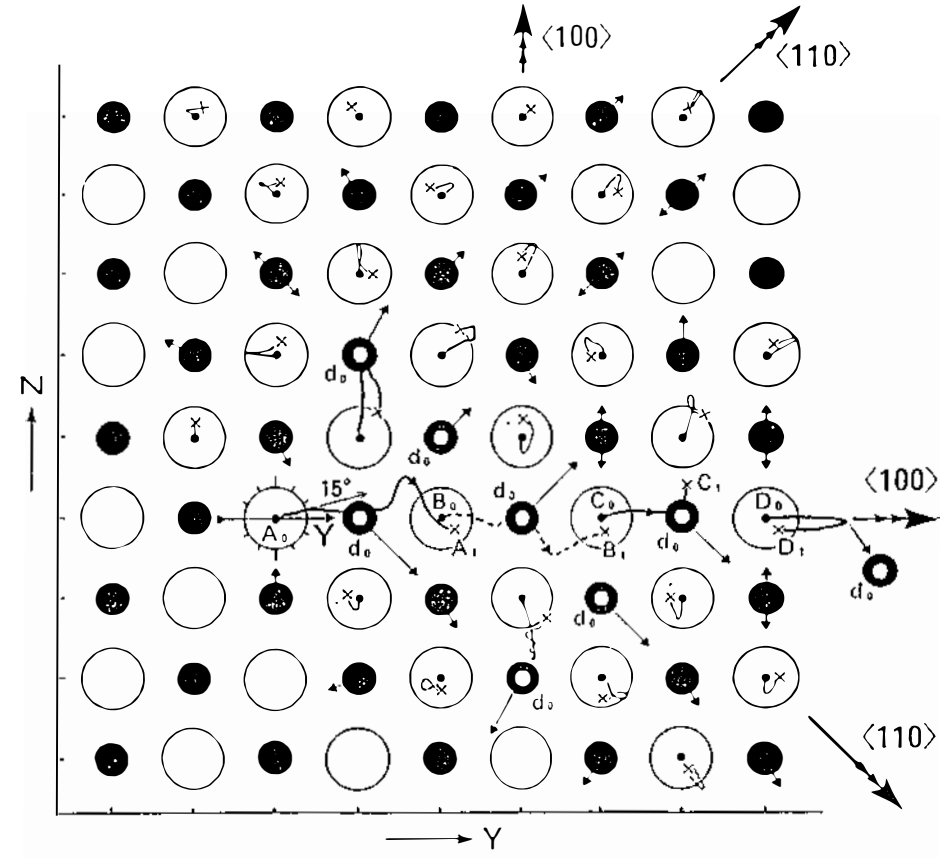
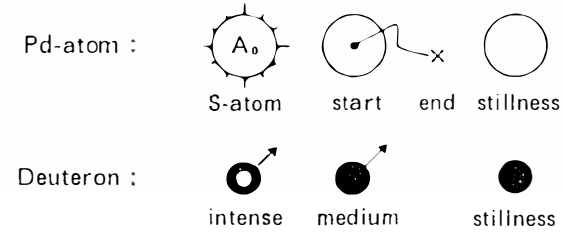


Fig 5 (B) Demonstration of high energy deuterons which were accelerated by "Latticequake" in {100} of Pd-lattice



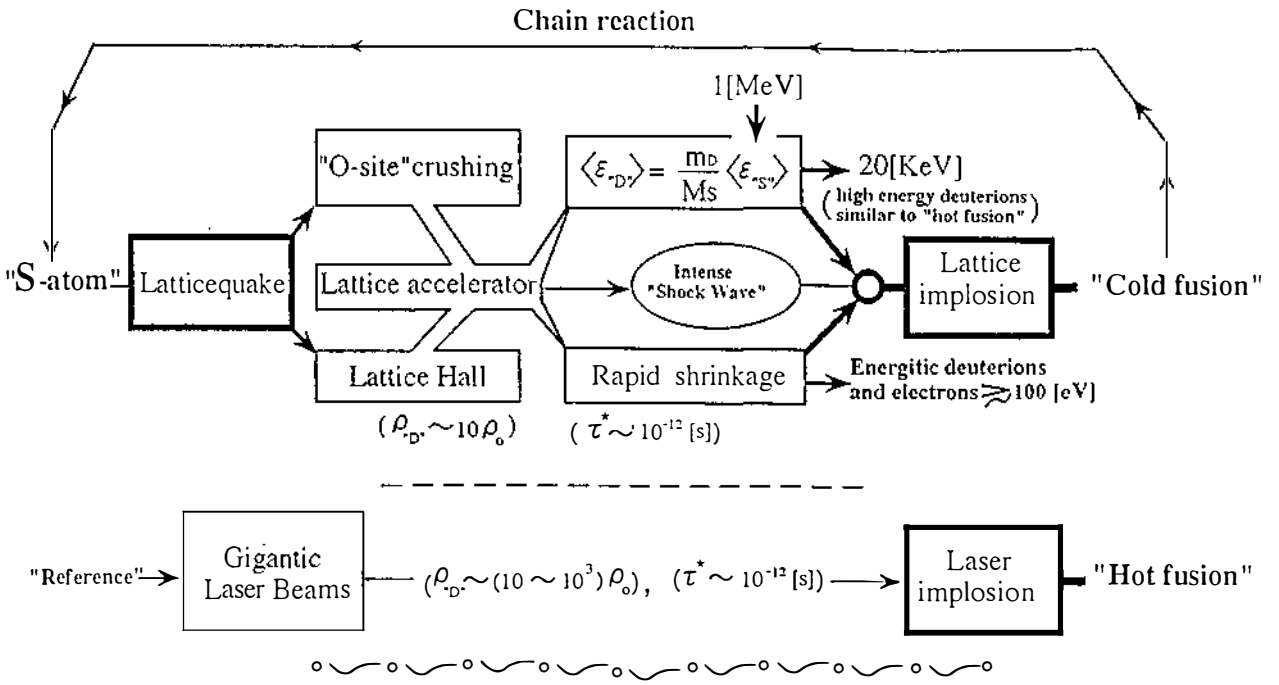


Fig. 6 Schematic digram of "Latticequake Model" for Cold fusion reaction

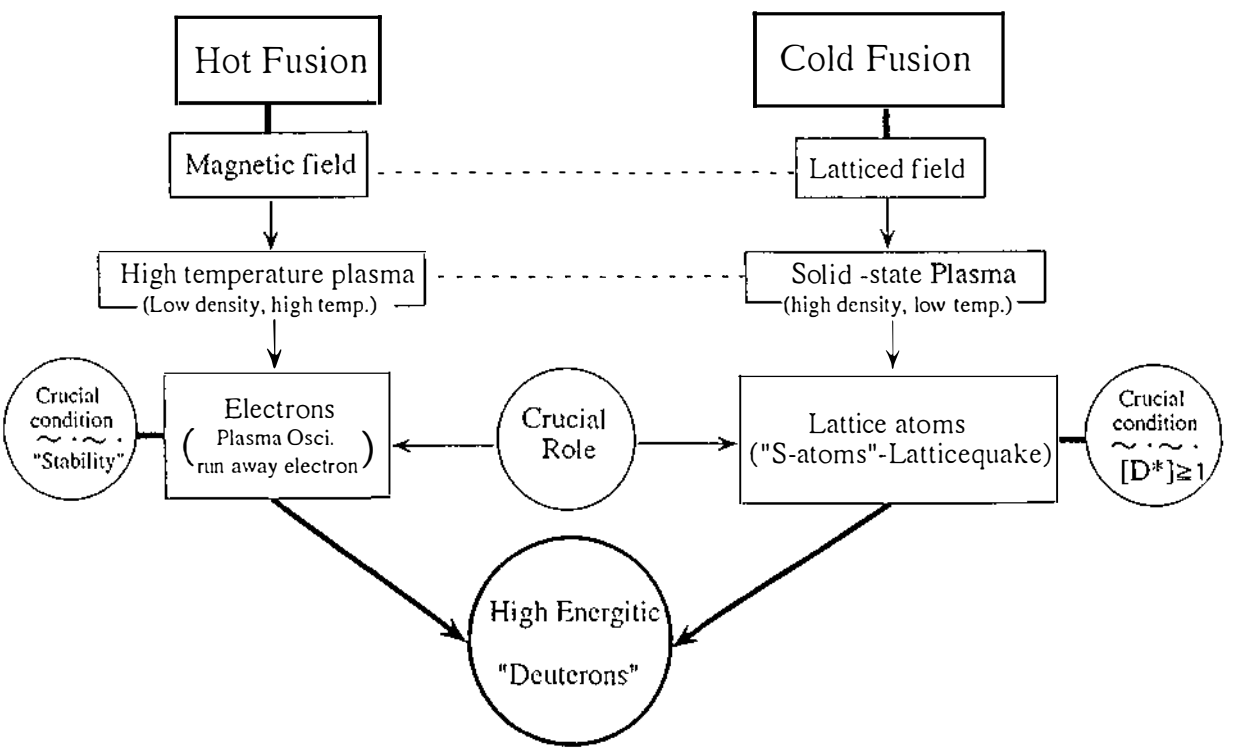


Fig. 7 Relation between Cold fusion and Hot fusion