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Formation of condensed metallic deuterium lattice and nuclear fusion

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Abstract: It was confirmed that nanometer-sized metal powder (atom clusters or simply clusters) can absorb an extremely large amount of deuterium/hydrogen atoms more than 300% against the number density of host metal. Within such clusters, the bonding potential widely changes from the center region to peripheral ones, so that the zig-zag atom-chains are always formed dynamically around the average position of atoms and the degree of filling up of the constituent atoms for the fcc type metal reduces to about 0.64 from 0.74 in bulk metal, i.e., vacant space increases to 0.36 from 0.26. As a result, a large amount of deuterium/hydrogen atoms are instantly dissolved into such host-clusters at room temperature. Furthermore, "metallic deuterium lattice" (or hydrogen one) including locally the "deuterium-lump" with the ultrahigh density is formed with body centered cuboctahedral structure which belongs to a unit cell of the host lattice, while such event cannot be realized at all within bulk metals. It seems that nuclear fusion in solid ("solid fusion") takes place in the highly condensed "deuterium-lump" inside each unit cell of the "metallic deuterium lattice" (or mixed hydrogen one) which is formed inside each cell of the host metal lattice. It is considered, therefore, that each unit cell of the host lattice corresponds to minimum units of "solid fusion reactor". In order to achieve "solid fusion", just the generation of the ultrahigh density "deuterium-lump" (simply "pycnodeuterium-lump") coagulated locally inside the unit cell of the host lattice and/or the highly condensed metallic deuterium lattice should be an indispensable condition.

Keywords: Metallic deuterium lattice; deuterium-lump; pycnodeuterium-lump; solid-fusion; pycnonuclear reaction; metallic hydrogen; nanometer-sized particles; host atom-cluster.

Introduction

It is well known that hydrogen gas is not conductive to electricity under atmospheric pressure and temperature. However, it transforms into electrically conductive "metallic hydrogen" under the extraordinarily high density conditions achieved inside the limited stars. In such high density metallic hydrogen, remarkable mutual interference (collision) of waves occurs in the groups of hydrogen nuclei with a long de Broglie's wave length, which is regarded to cause a remarkable nuclear reaction, and this phenomenon is called "pycnonuclear reaction".[1)] Using the p+d reaction ($\rightarrow {}^{3}H_{e} + \gamma$), it was proposed recently that pycnonuclear reaction should be artificially achieved ("artificial pycnonuclear reaction") in the metallic hydrogen of extraordinarily high

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density (20 g/cc) under ultrahigh-pressure of 10^9 atm.[2] Practically, such dream has a weak point: there is no method of sufficiently reducing and/or removing "space charges" of ions because of the necessity of hydrogen only as constituent atoms. It is, therefore, necessary to develop the technology to realize ultrahigh pressure of 10^9 atm pulsating, with constancy and repeatability, which is extremely difficult from the technological viewpoint. On the other hand, it is very important to consider whether there is another method of realizing metallic hydrogen with extraordinarily high density by drastically reducing space charges of ions without using ultrahigh pressure mentioned above. For instance, we clarified that a highly condensed metallic deuterium lattice (or hydrogen one) is produced within a unit cell of host metal lattice as face centered cubic (fcc), because the space charges of ultrahigh density deuterium/hydrogen ions group coagulated locally as "deuterium-lump" (simply "pycnodeuterium-lump") can be strongly reduced by many electrons in this host lattice instead of ultrahigh pressure necessitated in an artificial pycnonuclear reaction mentioned above, so that "solid fusion" takes place in the "pycnodeuterium-lumps" coagulated within the condensed metallic deuterium lattice with the "lattice-quake". Since such metallic deuterium unit cell is included within the host metal unit, cell, the minimum unit of "solid fusion reactor" corresponds to each individual unit cell of the host lattices. These host lattices possessing such function are realized by using nanometer-sized metal powder (host atom-clusters or simply host-clusters), and it was verified that extraordinary amounts of hydrogen and/or deuterium atoms are highly condensed, with more than 300% concentration within such host-clusters. However, it is impossible to achieve such high density conditions in normal bulk metals, because even 100% content cannot be realized (70 ~ 80% in general). The authors have developed the following two methods: one is the electrolysis using DS-cathodes [3] and the other is sono-implantation [4] utilizing ultrasonic energy. These two methods demonstrated the generation of both excess energy and helium (^{3}He and ^{4}He) as reaction-products in many long-term experiments using these methods.

Experiment

The concentration of hydrogen/ deuterium atoms invading into Pd-metal powder specimens were measured by the following two methods, a) and b). ZrO_2, · Pd powder [5] was used as metal specimens constructed with nanometer-sized individual Pd particles embedded dispersively into ZrO_2, matrix, which were made by annealing amorphous $Zr_{65}Pd_{35}$ alloy. Namely the specimens are assemblage of individual Pd host-clusters of about 50 Å in diameter as shown in Photo 1.

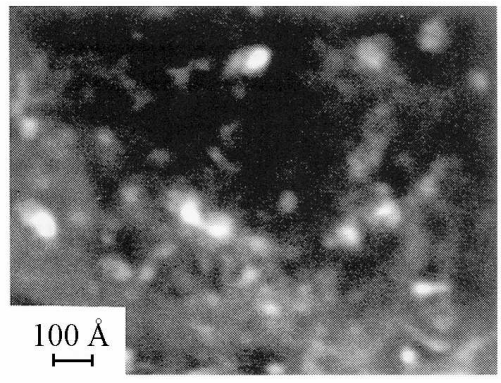

Photo 1. Electron micrograph of nanometer-sized Pd clusters (~ 50 Å in diameter) embedded dispersively inside ZrO_2 powder.

a) *Measurement of H_2/D_2 gas amount dissolved into the specimens kept in. highly evacuated vessel.* We performed experiment through the following two stages. In the first stage, nanometer-sized powder (~50 Å Pd-clusters) was kept for two days inside a high vacuum (about 10^{-7} Torr) vessel made by stainless steel, and then the vessel was immersed in cooling water (22.2 g). In the second stage, H_2/D_2 gas was injected into the vacuum vessel with constant gas flow (υ_G = 20 cc/min). In this process, the inner pressure (Pinn [atm]), sample-clusters temperature (Ts [°C])) and cooling water temperature (T (H_2O) [°C]) against elapsed time (τ [min]), as shown in Fig. 1A. Since the injected gas was absorbed instantly into Pd-clusters, the inner pressure showed almost zero (Pinn ~ 0) until the achievement in the saturation of gaseous atoms invading into the clusters, that corresponds to point A (Pinn << 1 atm) and point B points (Pinn ≈ 3 atm) in both Fig. 1 (A) and (B). Since the total gas volume injected into the vessel (V_G [cc]) is given by υ_G [cc/min] × τ [min], absorbed gas volume inside the clusters is obtained by $V_{GA} = \upsilon_G \cdot \tau_A$ and $V_{GB} = \upsilon_G \cdot \tau_B$, respectively (here each τ_A and τ_B corresponds to τ at point A and point B, respectively). As a result, the concentration of gaseous atoms absorbed into host atom clusters can be obtained as follows: Points A (72 min, under the condition of Pinn << 1 atm) and B (83.5 min in Pinn ≈ 3 atm) as shown in Fig. 1A, corresponds to points A (1440 cc) and B (1670 cc) in Fig. 1B, respectively. Then the absorbed gas volume V_{GA} (1440 cc = 1.44 l) and V_{GB} (1070 cc = 1.67 l) correspond to following mol-numbers of gas molecules (n_{MA} = 1.44 l ÷ 22.4 l/mol ≈ 0.0643 mol) and n_{MB} (≈ 0.0745 mol), respectively, and/or atoms ($n_A = 2n_{MA} \approx 0.128$ mol and $n_B = 2n_{MB} \approx 0.149$ mol). Such Pd atom-clusters absorbed a large amount of H/D-atoms as mentioned above, whereas ZrO_2 powder embedding the Pd atom-clusters did not absorb them at all as shown in Fig. 1C.

Consequently, when η [mol] and n_H [mol] are given to the absorbed amount of H/D-atoms (n_A: point A, n_B: point B) host-cluster (here n_H = 0.0585 mol in applied Pd sample), respectively, their atomic ratio is expressed with $n^* = n/n_H$ here, $n_A^* = n_A/n_H$, $n_B^* = n_B/n_H$, and under the inner pressure bellow 10 atm, each atomic ratio of n_A^* (= n_A/n_H) and n_B^* (=n_B/n_H) is given as follows:

$n_A^* = 2.18$, or $n_A^* \geq 200\%$, (Pinn << 1 atm). (1)

$n_B^* = 2.55$, or $n_B^* \geq 250\%$, (Pinn ≈ 3 atm). (2)

The result demonstrates that H_2/D_2 gases are quickly absorbed more than 200% and 250% in the number density of atoms into Pd-clusters under the conditions of considerably less than atmospheric pressure and around three atm, respectively. Furthermore, an enhancement up to 300% concentration corresponded to C-point (2000 cc) as shown in Fig. 1B under inner pressure as high as 100 atm.

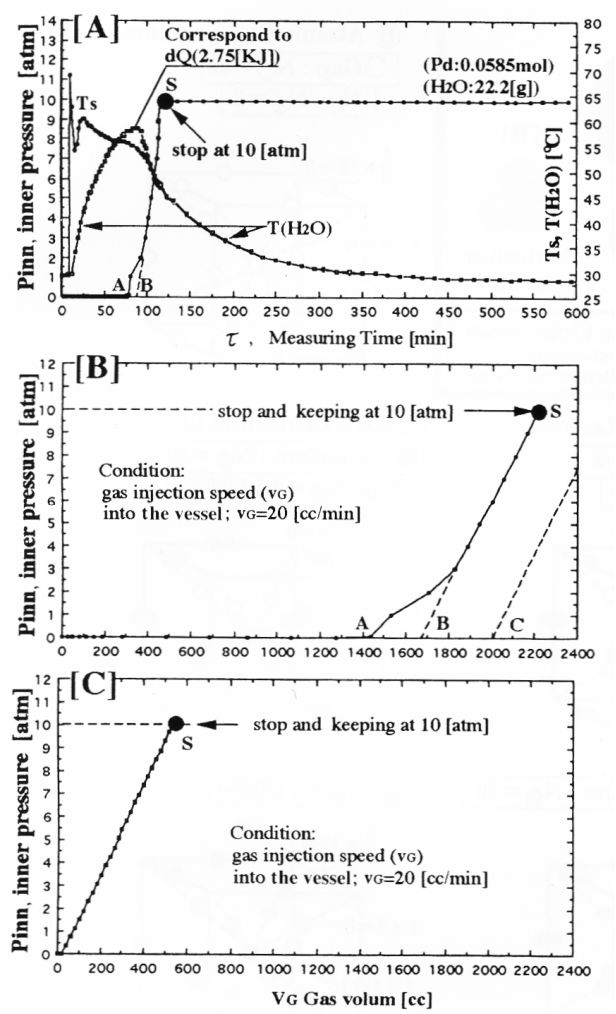

Figure 1. Absorption characteristics of a gas (hydrogen/deuterium) into the ~50 Å Pd host-clusters and ZrO_2 powder set inside a vessel made of stainless steel, and the vessel is immersed in H_2O-liquid (22.2 g). [A] Relation between gaseous inner pressure (P_{inn}), powder temperature (Ts) and chemical reaction energy (dQ) and H_2O-liquid temperature (T (H_2O)) versus measuring elapsed time (τ). [B] Relation between inner pressure (P_{inn}) and absorbed gas volume (V_G) under constant gas injection speed (υ_G = 20 cc/min). [C] Relation between inner pressure (P_{inn}) and gas volume (V_G) injected into the vessel included ZrO_2 powder. As a result, Pd atom-clusters absorbed a large amount of H_2/D_2, atoms as shown in [A] and [B], but ZrO_2 powder did not absorb them as shown in [C].

b) *Measurement of weight-change of the specimen by changing H_2/D_2 gas pressure.* It is well known that the weight of the specimen kept within H_2/D_2 gaseous pressure, P_{inn} [atm], increases with the amount of H/D atoms invading into the specimen according to the Sievertz law. The above mentioned Pd atom-clusters were used as the specimen as well. The weight-change of the specimen was measured and calibrated to the atomic ratio: n* (= H/Pd, D/Pd = number densities of invading atoms against host atoms).

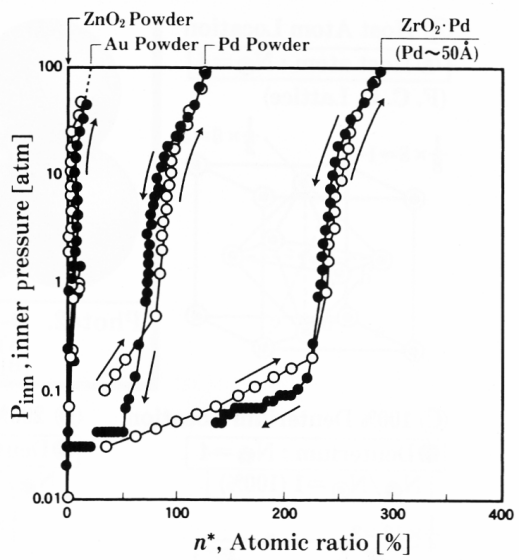

Figure 2. Relation between hydrogen/deuterium gas pressure (P_{inn} [atm]) and amount of the gaseous atoms invaded into host atom-clusters versus number of host atoms (atomic ratio [%]).

Fig. 2 shows the relationship between the inner pressure and the atomic ratio. This result demonstrates that 300% H/D atoms were absorbed into Pd-clusters under around 100 atm. It was consequently concluded that the results of both Fig. 1 and Fig. 2 were almost the same.

Ultrahigh density metallic deuterium/hydrogen

a) *Metallic deuterium lattice (or hydrogen lattice).* The formation of condensed metallic deuterium lattice (hereafter, deuterium means deuterium/ hydrogen) is discussed in Fig. 3. Fig. 3A shows Pd fcc (face-centered cubic) lattice as a typical example of host metallic lattice. While Fig. 3B indicates the location of "atomic gap space" inside the host lattice. The location occupied with deuterium/hydrogen atoms corresponds to that of atomic gap space in Fig. 3B, as seen in Fig. 3C through 3G. Fig. 3C shows an example of (100%) deuterium location, where the number of deuterium atoms is equal to that of host atoms. In the same way, Fig. 3D, E, F and G indicate deuterium locations in the case of (200%), (250%), (300%) and (400%), respectively. Specifically in Fig. 3F (300%) and Fig. 3G (400%), 3 kinds of deuterium atom locations; a), b) and c), are expected. However, the (300%) and (400%) concentration will be realized most likely in the case of a)-lattice and also 300% concentration will be actualized with the mixed state of (200%), (300%) and (400%) lattices. Similarly, in the case of (250%) as shown in Fig. 3E, both the (200%) and (300%) lattices are mixed to realize (250%) concentration rather than the lattice displayed in Fig. 3E.

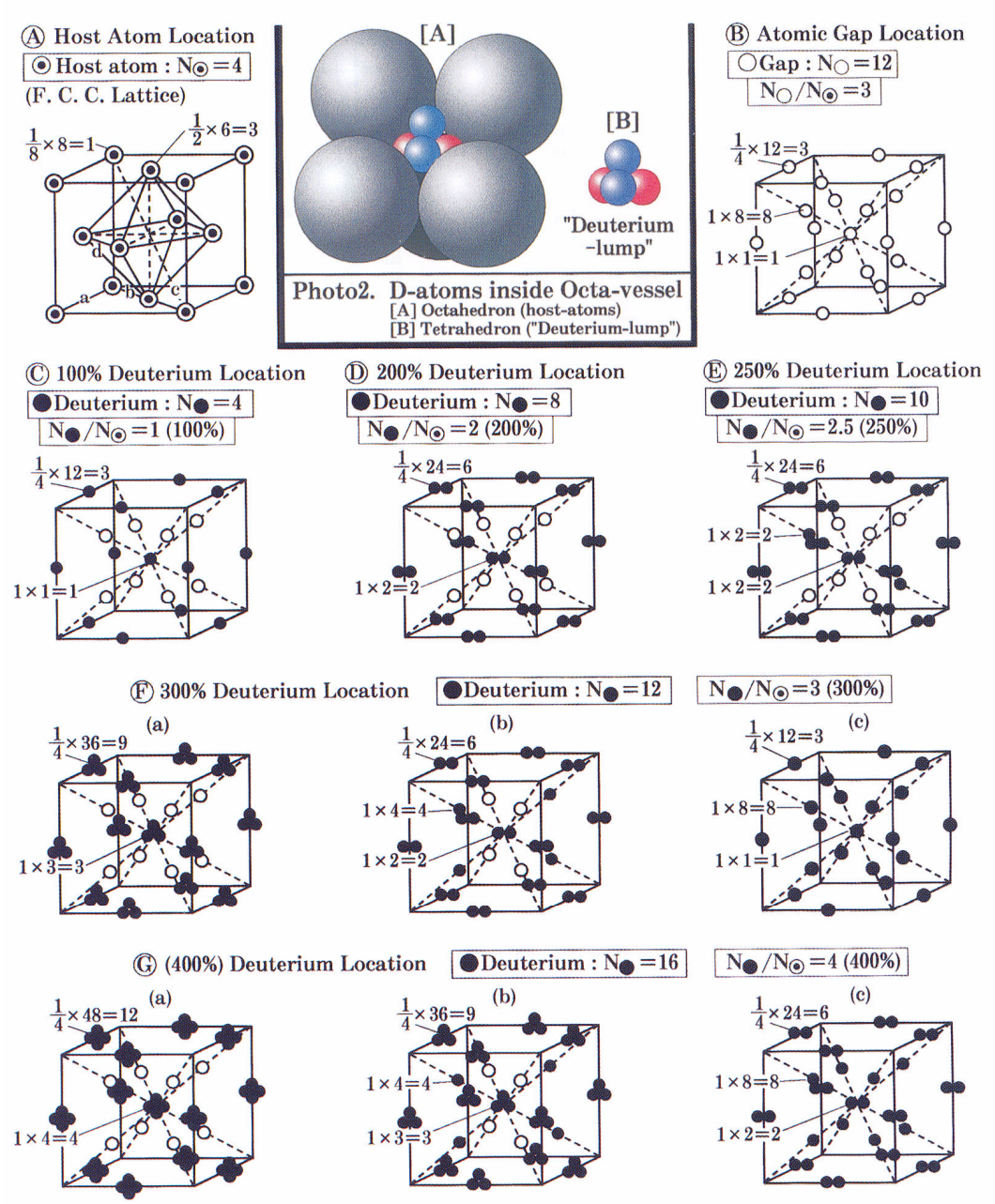

Fig. 3H

Note: Left side figure [H] shows "Metallic Deuterium Lattice" with Body Centered Cuboctahedral Structure (14 = 8 + 6 faces), and deuterium means deuterium/hydrogen in this case. Each 'black circle' ● shows an octahedral site and can include 1 ~ 4 D-atoms (this event is designated Octa-vessel). Tetrahedral sites shown as 'white circles' ○, and each Tetra-vessel can receive 0 ~ 1 D-atoms, but it is very difficult to keep steady stay there in general.

Photo 2. Upper-side in the Fig. 3.

Note: Model of octahedral structure in unit cell of host lattice and the "deuterium-lump" with ultrahigh density (simply "pycnodeuterium-lump") which located with shape of tetrahedral structure inside the Octahedron of the host lattice. Here, this model is constructed using the ratio between actual Pd and deuterium in diameter.

Figure 3. Formation of condensed "Metallic Deuterium Lattice" with body centered cuboctahedral structure. Photo 2 is located in upper-side in this figure.

In such a metallic crystal condition, the density of deuterium atoms is extremely higher than that of the host metal as illustrated in Fig. 3H, that is, unit cell of the "Metallic Deuterium Lattice" including locally the "pycnodeuterium-lump" was constructed with body centered cuboctahedral structure (14 = 8 + 6 faces) which belongs in the Pd-like fcc host unit cell. Such "pycnodeuterium-lump" coagulated inside the "metallic deuterium lattice" plays a main role causing the "solid fusion" and the unit cell of host lattice plays a supporting role for achieving such reaction; that is, many electrons in this host unit cell strongly reduces the space charge of the "pycnodeuterium-lump". If such strong effect of electrons does not work in the host unit cell, not only "pycnodeuterium-lump" but also the metallic deuterium unit cell cannot be sustained, besides to keep such "pycnodeuterium-lump", pressure with level of 10^9 atm must be given to them in unit cell as stated in the introduction.

Each black circle in unit cell of the metallic deuterium lattice as shown in Fig. 3H, shows an octahedral site and each white circle is a tetrahedral site. Here, when the spaces of each black and white circle are designated simply as Octa-vessel and Tetra-vessel, respectively, Octa-vessel can include 1 ~ 4 D-atoms and 0 ~ 1 D-atoms in Tetra-vessel. Specifically in the former Octa-vessel, the possibility of occupation of 1 ~ 2 D-atoms is nearly equal as well as for 3 ~ 4 D-atoms, but the probability of occurrence is considerably smaller in the latter case of 3 ~ 4 D-atoms than the former case (1 ~ 2 D-atoms).

In general, the deuterium atoms can move within the Tetra-vessel, but are not so likely to remain there constantly. If there is a condition in which an atom can steadily stay in the Tetra-vessel, 4 atoms more easily can enter and stay inside the Octa-vessel as a "pycnodeuterium-lump". In this case, therefore, such "pycnodeuterium-lump" should be located with the shape of tetrahedral structure inside octahedron (Octa-vessel) as shown in Photo 2 located in the upper side of Fig. 3, and their deuterium density can be estimated as an ultrahigh-density condition with a value of about 10 g/cc. This condition corresponds to a density of over 50 times higher than that of a deuterium solid with a hexagonal lattice at an ultra-low temperature, and also it is a level similar to that expected in the artificial pychnonuclear fusion as described in the introduction. Consequently, in such condensed "pycnodeuterium-lump" located locally inside the host unit cell with "lattice-quake",[3] "solid fusion" should be easily produced. That is a reason why, we should demonstrate that, in the nuclear fusion in solid, each host unit cell will behave as a minimum unit of nuclear fusion reactor.

b) *Formation mechanism of metallic deuterium lattice (or hydrogen one).* It is well known that nanometer-sized particles (host atom-clusters [6] or host-clusters) display intrinsic different characteristics from those of the corresponding bulk materials. For instance, we consider alloying behaviors of substitutional Cu-atoms within host Au-metal at room temperature, that is diffusion velocity of Cu-atoms within host Au-cluster (~ 50 Å) is more than 10^9 times higher than that of Au-bulk metal,[7] moreover, 300% Cu-atoms instantly can be dissolved into host Au-clusters.[8] These events have been recognized as "instantaneous alloying effect" in metal clusters. We verified that D/H atoms exhibit a stronger effect within host metal clusters and large amount of D/H atoms more than 300% against the host atoms were absorbed within the host-clusters as already mentioned above.

Since the degree of filling up of constituent atoms in a face centered cubic (fcc) unit cell in bulk metal is 0.74, large relaxation of atomic arrangement (or lattice distortion) in bulk crystals must be required in order to obtain such high density of D/H atoms. In the host cluster, however, it is reported as follows: [9] the degree of filling up of constituent atoms in a unit cell decreases

from 0.74 to about 0.64, i.e., vacant space increases from 0.26 to 0.36, and both the local bonding potential energy and the local surface energy widely change from the center region to peripheral ones. Furthermore, the obstacle barrier for diffusion of solute atoms remarkably decreases by softening the phonon mode, and thus the zig-zag atom-chains are always formed dynamically around the average position of atoms. As a result, solute atoms such as a large amount of D/H atoms instantly diffuse into host atom-clusters, and such conception coincides very well with the experimental data as shown in Fig. 1 and Fig. 2.

The surface zone of bulk metal behaves as thin two-dimensional host atom-clusters with a few atomic layers, but the volume is very much smaller than the bulk substance.[3)] Thus, it is concluded that powder of Φ 150 Å (50 Å in embedded powder) and less in diameter can be utilized as host-cluster. However, the surface zone of powders of 200 Å or more in diameter only behaves as two-dimensional host-clusters, so that they do not work so much as host-clusters although range of 200-500 Å looks like a gray zone between cluster and bulk. In our case, nanometer-sized embedded powder with around Φ 50 Å displayed the best results as the host atom-clusters, and thus, we expect that the largest quantity of the "pycnodeuterium-lump" with ultrahigh density inside the unit cell of Metallic Deuterium Lattice with (400%) concentration as shown in Fig. 3G should be constructed under condition of such higher pressure of D_2 gas from several hundreds to thousands. Using such Pd host-clusters inside a DS-cathode with D_2O-electrolyte, Fig. 4 demonstrates one of the newest results revealing definitely generation of "solid fusion". Fig 4A shows DS-excess energy and Fig. 4B shows DS-helium. On the other hand, we can never expect generation of the "deuterium-lump" or "solid-fusion" will take place inside the normal "bulk material".

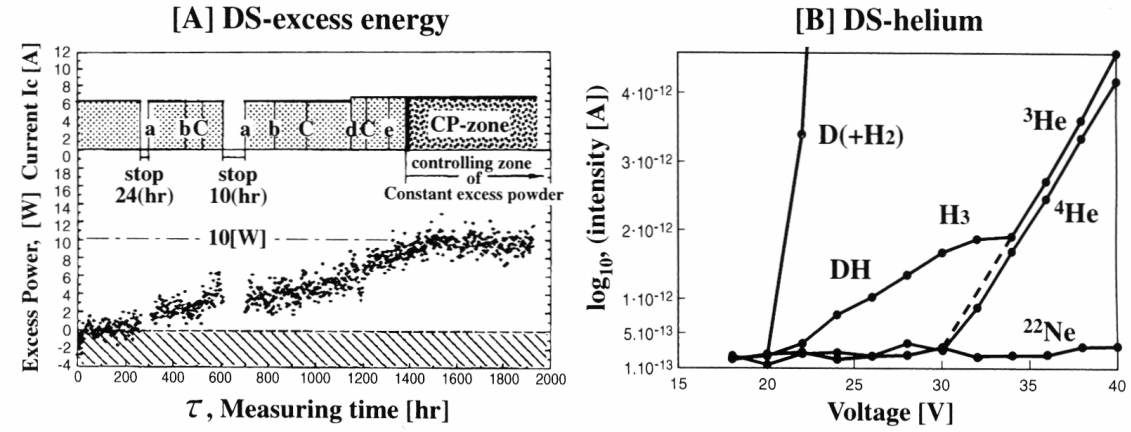

Figure 4. Excess energy and helium (3He, 4He) generated inside "open type DS-cathode" which can measure continuously the change of inner pressure inside DS-cathode, and called shortly "DS-excess energy" and "DS-helium", respectively. [A] DS-excess energy. [B] DS-helium using "Vi-effect". Note: In left side diagram, a: current stop; b: inner gas test; c: inner gas test; d: added 20 cc; e: added 10 cc, renewed 20 cc; and CP-zone: controlling zone to get constant excess power.

Conclusion

In the past we reported a series of electrolysis experiments using double structure Pd cathodes containing fine Pd powders, in which substantial production of excess heat and of helium atoms were observed. In the present paper we have demonstrated that metallic Pd clusters of diameter around 50 Å can absorb extremely large amount of deuterium/hydrogen with over 300% atomic concentration in the Pd lattice. They occupy octahedral sites in the fcc Pd lattice and form Octa

vessels in unit cell of metallic deuterium lattice, in which ultrahigh density deuterium "lumps" are produced. Its density amounts to as high as 10 g/cc, which cannot be produced by hydrogen/deuterium alone. Thus, such ultrahigh density deuterium lumps ("picnodeuterium-lumps") provide an unusual environment for p + d (^3H_e +lattice energy) and d + d (^4H_e +lattice energy) pycnonuclear reactions, and each unit of picnodeuterium lumps is regarded as a "solid fusion reactor".

Acknowledgments

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