Excess Energy and Nuclear Products

Excess Heat Production and Nuclear Ash in PdO/Pd/PdO Heterostructure after Electrochemical Saturation with Deuterium

A.G.Lipson, B.F.Lyakhov, D.M.Sakov, V.A.Kuznetsov, T.S.Ivanova

Institute of Physical Chemistry,
The Russian Academy of Sciences, Moscow 117915 Russia

Abstract

Heat production, nuclear ash and electrophysical processes in PdO/Pd/PdO (Au/Pd/PdO) heterostructures electrochemically saturated with deuterium (hydrogen) have been investigated. It was shown in afterelectrolysis period a strong heat flash with duration of 2-7 s and energy density of 60-100 J/cm^2 was observed for Pd/PdO:D(H) sample placed in air atmosphere. The thermal energy of each flash was approximately 2-5 times higher than the energy supplied to the sample during electrolysis. Neutron- and γ-emissions accompanying the heat production have been investigated.

1. Introduction

The results of 6-years cycle of investigations, that was trained on determination of the nature of excess heat and nuclear ash generation in Pd/PdO(Au/Pd/PdO) geterostructure, electrochemically saturated with hydrogen (deuterium) will be presented. In contrast to traditional (for CF-experiments) systems that are massive Pd samples saturated with D [1-3], the system under consideration has some essential advantage in terms of obtaining of reproducible and controllable results:

a. short saturation time and absence incubation period, that precedes to excess energy generation;

b. low current density in electrolysis process; control of H(D)-content in Pd-sample at any time;

c. high reproducibility of excess (in contrast to applied in electrolysis) energy in each cycle of saturation of Pd-sample with H(D);

d. possibility of H(D) concentration in a small volume onto Pd-PdO interface, that is cause of high loading ratio (x) as well as local high elastic energy density in Pd lattice, i.e. non-equilibrium phonon generation [4].

Therefore, application of thin Pd/PdO heterostructure as a cathode in CF-experiments can bring some advantage to achieve minimum distance between deuterons (protons) and, simultaneously, high concentration of non-equilibrium phonons. Both effects lead to increase of nuclear reactions probability in Pd-lattice with D(H) participation.

2. Experimental technique

Electrolysis was carried out in a glass cell with subdivided cathodic and anodic spaces (electrolyte volume of about 250 cm^3). The electrolytes used: 1 M KOH in H_2O for Pd/PdO:H_x production; 1M NaOD in D_2O for Pd/PdO:D_x production. Current density used of about j=10-30 mA/cm^2 .

Samples : cold-rolled Pd-foils with thickness of 30-50 μm and working area of about S=4.5 cm^2 for PdO/Pd/PdO (S=2.2 cm^2 for Au/Pd/PdO).

Samples preparation : 1) annealing in vacuum at temperature 600°C for 3 hours with slow cooling (1°C/min) to room temperature; 2) metered annealing in oxygen flame at a temperature of about 1000° C, that leads to PdO layer formation having a thickness of about 200-500 A; 3) electrochemical deposition of Au on the one side of PdO/Pd/PdO heterostructure: thickness of gold coating of about 2000 A.

Research methods

1. H(D)-concentration in the samples was determined by vacuum thermodesorption technique at 400°C and $P=10^{-6}$ mm Hg.

2. A gas thermometer was applied to record the afterelectrolysis thermal effect. The schematic diagram of that gas thermometer is presented in Fig.1. The quantity of heat (Q), evolved by the sample in the pulse regime, was recorded by a U-shaped mercury pressure gauge with an analytical volume of the exposure chamber (2), $V=69$ cm^3, which was filled either by air or by O_2 or Ar under atmospheric pressure. The value Q of the Pd-samples was estimated by integrating over the pressure-time (P-τ) curve within a range limited by the pulse origin moment, and by the moment of intersection by it of the time axis τ. Thereafter, for the purpose of quantitative estimation, a comparison of pulses, being obtained on thermal bursts with calibration pulses from a nichrome spiral (8) was carried out. The measurement error of Q did not exceed ±20 %.

3. A specially developed set up on the basis of electromagnetic displacement transducer with sensitivity of about $2.5*10^{-6}$ cm was applied to determine in situ changes in the length of thin Pd samples in the hydrogenation-dehydrogenation processes.

4. A block of 7 proportional NWI-62 neutron counters ($B_{10}F_3$) placed into a tank containing vacuum oil and covered by Cd sheet 1 mm thickness, was used to neutron detection in deuterated Au/Pd/PdO samples (neutron detection efficiency: $\varepsilon_n=2.9*10^{-2}$).

5. To detect a γ-radiation upon thermal effect in afterelectrolysis period semiconductor γ-detector (pure Ge) GEM1-20180P by EG&G ORTEC was used (efficiency of γ-detection $\varepsilon_\gamma=3*10^{-3}$).

3. Experimental results.

Excess energy

On the electrolysis process, at the electrolysis time $\tau<40$ min in Au/Pd/PdO heterostructure the one-side bending of sample is observed (Fig.2). The degree of bending is depend upon electrolysis time. This bending is a cause of deuterium (H) storage on the Pd-PdO interface [5]. At electrolysis time $\tau>40$ min the straighten of sample takes place due to deuterium (H) breakdown into the sample bulk.

The free energy (elastic deformation) stored up in the sample due to electrolysis may approximately be estimated with the formula [6]

$$F=\int \psi_2 (U_{\alpha\beta})ds$$

where $U_{\alpha\beta}$ is 2-dimension deformation tensor; $\psi_2=Eh(\xi/l)4$ here E - is Young modulus of Pd, h - sample thickness; ξ - sample mean deflection, l - length of the sample. For $h=3*10^{-3}$ cm, l=4.5 cm, s=4.5 cm^2 and electrolysis time $\tau=30$ min we have $\xi=5$ mm (Fig.2). And then $F=76$ cal/cm^2. It should be noted that energy value applied upon electrolysis time was $W_{el}=7.8$ cal/cm^2. Therefore the elastic energy stored up by

Au/Pd/PdO:D_x (H_x) sample is excess of electrolysis energy applied about one order of magnitude.

When the electrolysis is interrupt at pause (τ<40 min for h=50 μm) after the drying of sample there takes place the thermal burst (in air, Ar , atmosphere or vacuum). Which is accompanied by the heating of sample up to temperature a of 900 ^{o}C (Fig.3a).

In the case of electrolysis carried out for 5 hours (Fig.3a, curve 4), the monotonous increase in the pressure of the gas thermometer is due to movable excess hydrogen which easily leaves the Pd lattice have been took place.

When the hydrogenated Pd/PdO samples are placed into the chamber at t=20^{o}C, the dependence ΔP- τ is of the extremum character (Fig.3a, curves 1,2,3). The retardation of the thermal effect (when O_2 or air is present in the chamber) is limited by the sample drying time, and may range from a few seconds to several minutes. The pressure increase being accompanied by the visible heating of the Pd sample (e.g red or white glow) up to temperatures higher than 900^{o}C (the thermocouple reading) during 3 to 4 seconds, and by its axial bending. Then the chamber is evacuated, which is due to the consumption of O_2 for the reaction with hydrogen in the Pd sample, and for condensation of water vapor.

The Pd/PdO system, which has been electrolytically deuterated for the same time intervals, behaves itself somewhat differently (Fig. 3b). When a sample is put into the analytical volume at room temperature, strong deformations take place in it, as well as in hydrogenated samples: however, no thermal burst is observed. When the sample is preheating by the aid of an electric lamp up to a temperature of 35 to 40^{o}C the behaviour of the Pd/PdO:D samples becomes similar to that of the Pd/PdO:H samples at room temperature. In this case, the character of a thermal pulse is more prolonged, the growth time about 7 to 10 sec, the vanishing time about 40 sec), while the integral thermal effect is approximately by a factor of 1,3 to 1,4 higher than that in the Pd/PdO:H system.

The integral mean values of heat evolution, Q both for Pd/PdO:H system (at t=20^{o}C) and for the Pd/PdO:D system (at t=40 ^{o}C), were estimated by carrying at calibration measurements with a nichrome spiral. For 100 thermal bursts, these are equal to Q_H =15.1 ±3.5 cal/cm^2 , Q_D =20.3 ±4.8 cal/cm , respectively. The reproducibility of the effect is extremely high, so that one sample gives not less than 150-200 thermal bursts in succession with consecutive hydrogenation cycles. In Fig.4 are presented in the form of histograms the results obtained for 100 bursts in succession on one of the Pd/PdO:H samples. In 5 cases from 100 there were observed very powerful bursts attaining the value of 40 to 45 cal/cm^2 . Let us note that the energy transmitted to the sample directly on electrolysis W_E =8.0 ±1,5 cal/cm^2 . Therefore, the observable thermal effect $Q_{H,D}$ may be considered as being anomalous.

The magnitude of thermal effect can be increased essentially when specific surface of heterostructure samples will be strongly increased too. For this purpose it was Pd-black (r^{-4}=10 cm) deposited by electrochemical method onto PdO surface. At saturation time τ =30 min, the mean Q value is increased of about 2 times (in contrast to samples without Pd black) and became of about 35 ±3.6 cal/cm^2 (Fig.5). The reproducibility of this thermal burst at room temperature is equal to 100 %.

Nuclear ashes

To determine correlation between thermal and nuclear processes in Au/Pd/PdO:D(H) heterostructure the simultaneous detection of excess heat production and nuclear radiations was carried out. The registration was began from the moment

of sample's drying and was finished to the moment of total gas desorption from the sample.

The experiments have shown no statistically noticeable emission of neutrons is observed on the Au/Pd/PdO:H control samples (with the thermal effect), while the distribution of neutron events is well consistent with the Poisson distribution of the natural (cosmic) background (Fig.6, curve 2).

In the same time thermal effect (and deuterium desorption) from the sample Au/Pd/PdO:D_x is accompanied by a neutron emission (Fig.7). The maximum of neutron counts is observed in the beginning of D-pressure jump, when strong plastic deformation of sample is taking place. In this time interval the neutron bursts are observed with multiplicity i=6-17 (in the time gate of about 1 ms) or with intensity n=100-500 n/(s*cm^2) Pd (Fig.6, curve 1). The residual plastic deformations that occurs on the D_2O condensation process are accompanied by weak neutron emission too. The neutron emission decay to background level takes place after 5-6 min (from the beginning of D-gas desorption). After finishing of the process the loading ratio value is $x\sim10^{-3}$ [7]. However, neutron emission can be prolongated during 15-20 min, if Au/Pd/PdO sample will be loaded by mechanical stress (by hanging up to the one end of the sample a weight of about M=40 g). The rate constant of dd-reaction in Au/Pd/PdO:D_x heterostructure $\lambda_{DD}=2*10^{-21}$ s^{-1} per dd-couple (for x=0.72) and $\lambda_{DD}=10^{-18}$ s^{-1} per dd-couple (for $x=10^{-3}$). It should be noted that the sample with $x\sim10^{-3}$ posses of residual elongation of about 1/3 from elongation at x=0.72, accordingly with the date obtained from electromagnetic displacement's transducer measurements. It has been discovered that this elongation is due to quasimetallic clusters of hydrogen [7].

The same samples of Au/Pd/PdO:D_x and Au/Pd/PdO:H_x (x=0.72) after electrolysis procedure was used for γ-emission tests in the energy range of 2.0-10.0 MeV. In the spectrum of Au/Pd/PdO:D_x samples (Fig. 8) there are 3 plainly expressed maxima with positions $(E_\gamma)_1=2.225\pm0.005$ MeV; $(E_\gamma)_2=3.8\pm0.5$ MeV; $(E_\gamma)_3=6.3\pm0.3$ MeV. The narrow line $(E_\gamma)_1$ (half width of about 10 keV) could be ascribed to p+n reaction, because its position is in a good agreement with γ-line (E=2,225 MeV) obtained upon PE-irradiation by thermolized neutron from Cf^{252} -source (Fig.9). The $(E_\gamma)_3$ maximum can be give rise to γ-quanta from d+n reaction (E_γ=6.25 MeV). In fact this peak increases of about 2 times upon the sample irradiation by thermalized neutrons. The nature of $(E_\gamma)_2$ maximum is not clear. However as it was proposed earlier [8] the E_γ=3.8 MeV peak can be exhibition of the first excited state of He nucleus that may form with phonon participation [9].

In contrast to deuterated heterostructure the samples of Au/Pd/PdO:H generate only one - maximum with position of about $E_\gamma=4.6\pm0.3$ MeV. Under the irradiation of the sample by thermalized neutrons the maximum E_γ=4.6 MeV is increasing in intensity more than 5 times and shifted on 0.3 MeV into the high energy band. The nature of this γ-emission is unknown now.

Therefore excess energy generation in Au/Pd/PdO:D(H) heterostructure is accompanied by γ-emission. The γ-emission intensity depends upon the thermal neutron background [10].

Moreover, as it shown by A.Roussetski (this volume of ICCF-6 Proceedings) desorption process in heterostructure of Pd/PdO type (both H and D saturated) is accompanied by emission of charged particles (protons and possibly α-particles). Intensity of proton emission of about I_p=0.8 proton/s in 4π.

4.Conclusion

Simultaneous generation of excess energy and weak nuclear radiation in Au/Pd/PdO:D_X (H_X) heterostructure as well as strong plastic deformation in it are indicate on the possibility of phonon laser action in system of this type. Really, the main process that determines heterostructure's properties in afterelectrolysis time is an intensive exothermic desorption of hydrogen (D) from the sample. This effect, from other side, is a main condition to phonon laser operation on Pd-PdO interface in the high loading ratio zone (clusters of quasimetallic hydrogen [7]). In this zone coherent multiphonon excitations can initiate an anomalous energy transfer and, simultaneously lead to coherent neutron transfer reactions [11]. As result, both excess heat and weak nuclear radiation are observed. In this connection the short electrolysis process for heterostructure saturation with H(D) can be considered as pumping up procedure of phonon laser.

References

1. Fleischmann M, Ponce S, Hawkins M J.Electroanal. Chem. 261 , p.301 (1989).
2. McKubre, M.C.H. Crouch-Baker S. Hauser A.K. Proc. of ICCF-5. Monte-Carlo, p.17 (1995).
3. Storms E. // Fusion Tech. 20 , p.433 (1991).
4. Hagelstein P.L. // Trans. Fusion Tech. 26 , p.461 (1994).
5. Yamaguchi E., Nishioka T. // Jap.J.Appl.Phys (Part 2) 29, (4), p.L666 (1990).
6. Landau L.D., Lifshitz E.M. Theory of Elasticity Moscow, Nauka, s.202 (1965).
7. Lipson A.G., Lyakhov B.F., Sakov D.M., Kuznetsov V.A. // Rus. Solid State Phys, 38 (6), 1657 (1996).
8. Lipson A.G., Bardyshev I.I., Sakov D.M. // Rus.J.Tech.Phys.Lett. 20 (23), p.53 (1994).
9. Takahashi H. in Anamalous nuclear Effects in Deuterium/solid systems, Ed by S.E.Jones et. al, AIP.Conf.Proc. N 228, p.884, New York (1991).
10. Kozima H. // Nuovo Cimento 27A , 1781 (1994).
11. Hagelstein P.L. // Proc. of ICCF-5, Monte-Carlo, p.327 (1995).

Captions to figures

Fig. 1. Experimental set up with gas thermometer and neutron detector: 1 - PE(Co) ; 2 - chamber with atmosphere ; 3 - gas thermometer (Mcleod) ; 4 - sample ; 5 - neutron counters ; 6 - moderator ; 7 - Cd; 8 - heater.

Fig. 2. Au/Pd/PdO sample: initial (a) and deformed (b) after electrochemical hydrogenation during τ =30 min ; ξ - is mean deflection.

Fig. 3a. Thermal bursts for Au/Pd/PdO:H_X : saturation time : 10 min - curve 1 ; 20 min - curve 2 ; 30 min - curve 3 ; 5h - curve 4 ; calibrating pulse from nichromium coil - curve 5.

Fig. 3b. Thermal burst for Au/Pd/PdO:D_X saturation time : 30 min - curve 1 ; 5h - curve 2 ; calibrating pulse - curve 3.

Fig. 4. Distribution of the heat production events (n_Q) with respect to the heat evolution energy Q for Au/Pd/PdO:H_X -system.

Fig. 5. Distribution of n_Q with respect to Q for [Au/Pd/PdO+Pd-black]:H_X system.

Fig. 6. Distribution of the number of neutron events (n_i) with respect to the multiplicity of neutron pulses (i) for Au/Pd/PdO:D_X heterostructure for $\Delta\tau$=120 s time intervals preceding the heat burst (N=100 experiments) - curve 1 ; Poisson distribution for neutron events with N=100 - curve 2.

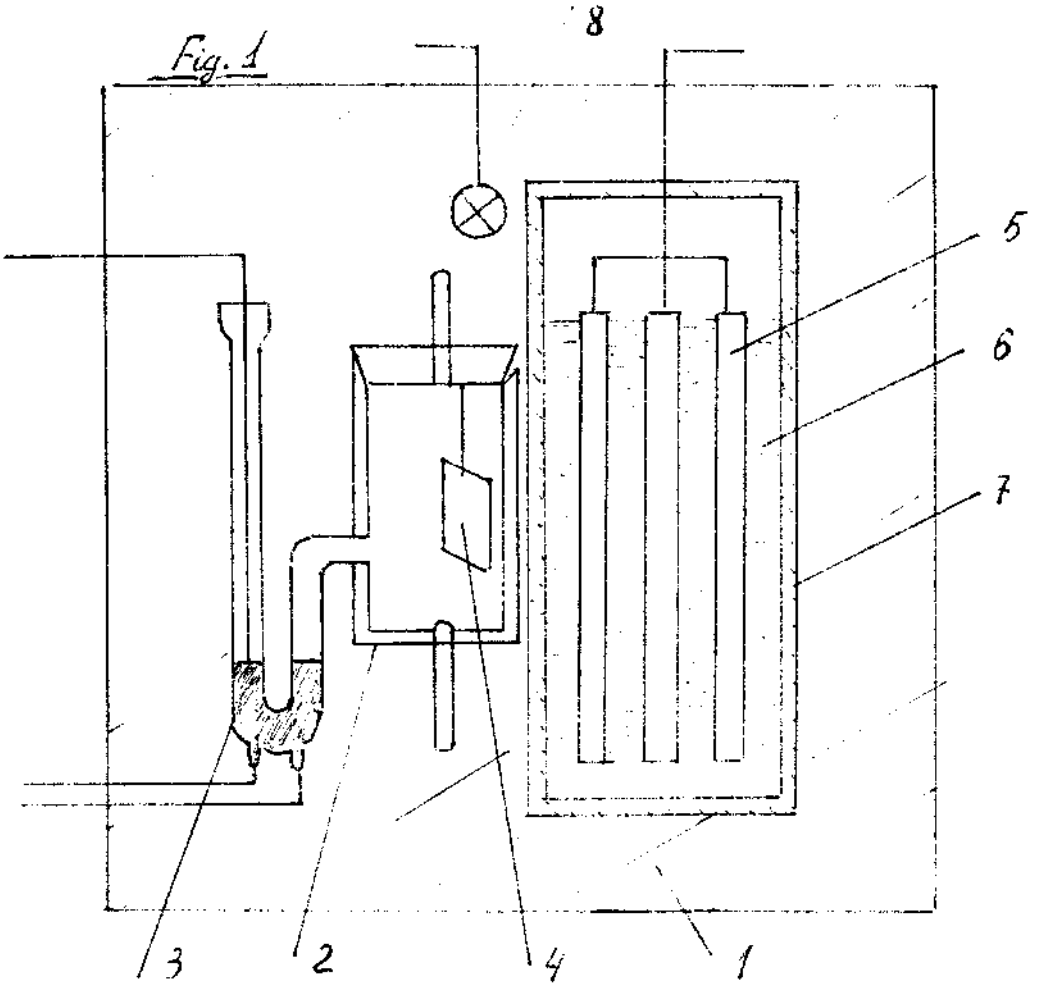
Fig. 7. Excess heat generation (curve 1) and neutron emission (curve 2) in Au/Pd/PdO:D_X heterostructure (simultaneous registration) for 100 experiments. Locations of neutron burst with n>100 n/cm^2 marked by vertical lines (curve 3).

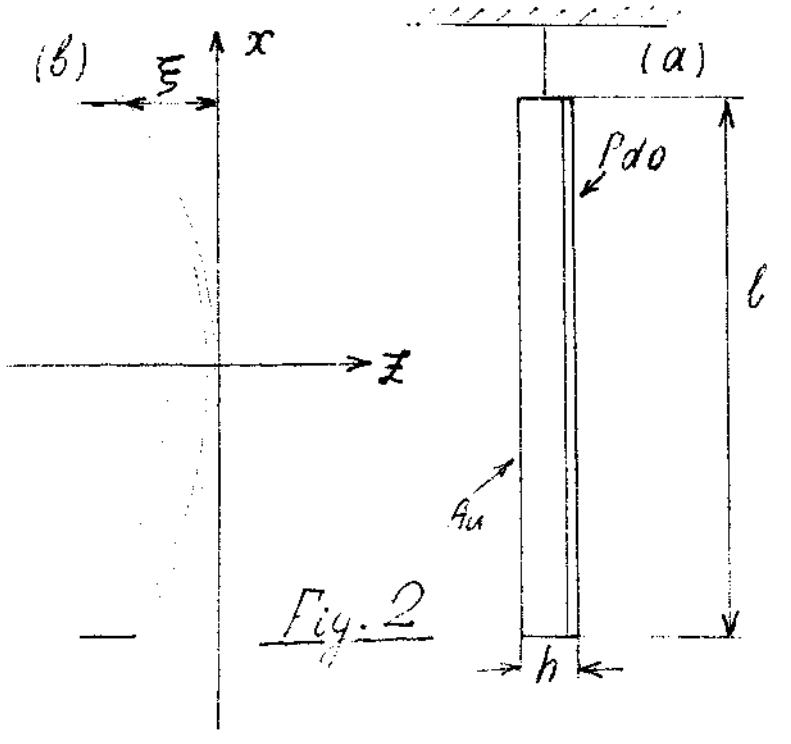
Fig. 8. γ-emission for Au/Pd/PdO:D_X heterostructure after 30 min electrolysis (with subtraction of γ-background) in cosmic neutron background (curve 1) : during irradiation by thermal neutron (I_n ~2 n/s*cm^2) (curve 2).

Fig. 9. γ-spectrum of 2.225 MeV maximum (curve 1) and γ-peak from thermal neutron capture in polyethylene (curve 2).

Fig. 10. γ-spectrum for Au/Pd/PdO:H_X heterostructure after 30 min electrolysis (with subtraction of γ-background) in cosmic neutron background (curve 1) : during irradiation by thermal neutron (curve 2).

Excess Energy and Nuclear Products





Excess Energy and Nuclear Products

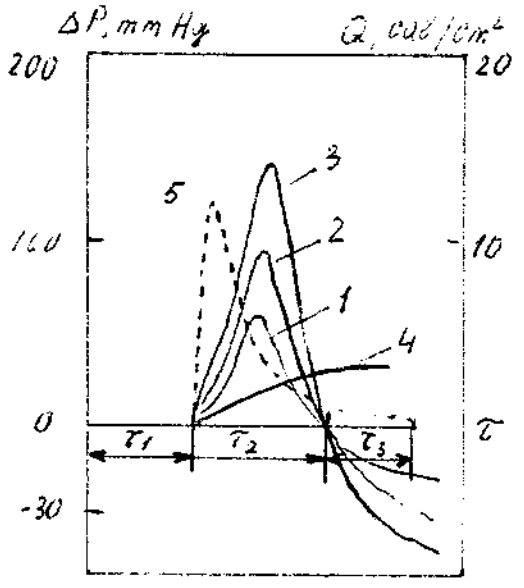


Fig. 3a

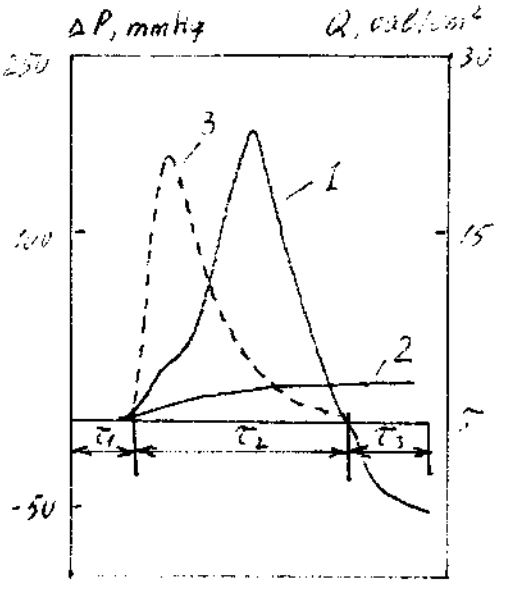


Fig. 3b

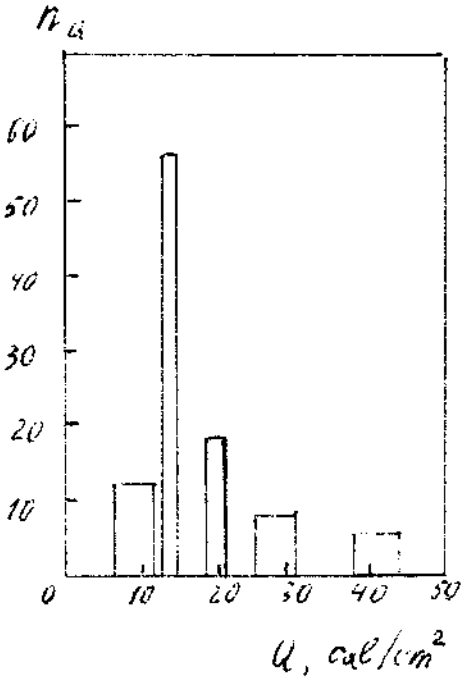


Fig. 4

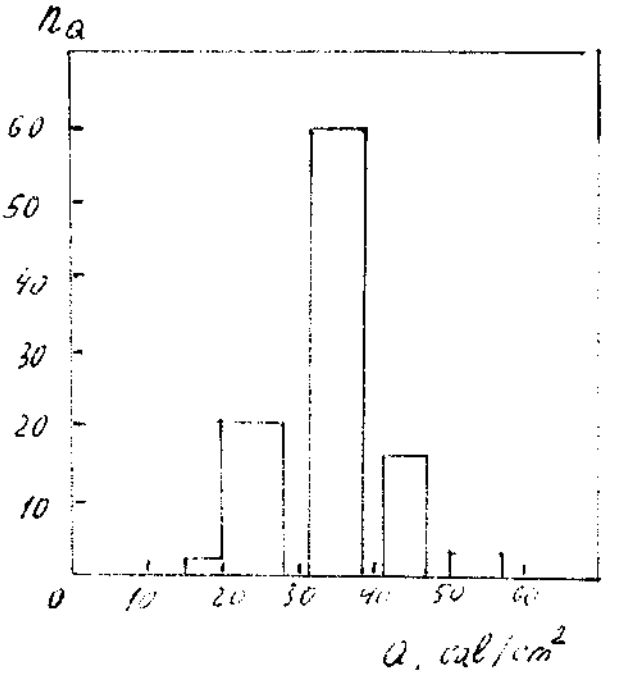


Fig. 5

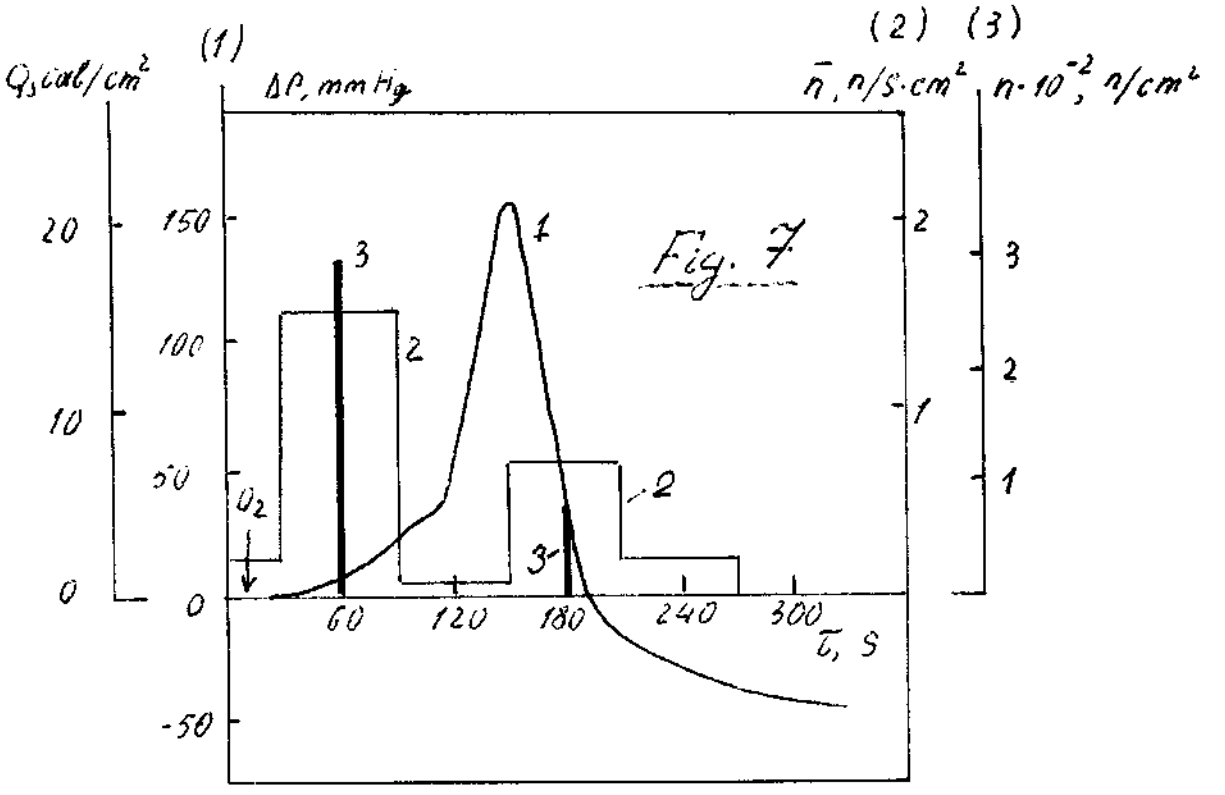

(1)
(2)
(3)
Q_s cal/cm²
ΔP, mm Hg
$\bar{n}$, n/s·cm²
n·10⁻², n/cm²
20
10
0
150
100
50
0
-50
2
1
3
2
1
1
2
3
O_2
60
120
180
240
300
τ, s

Fig. 7

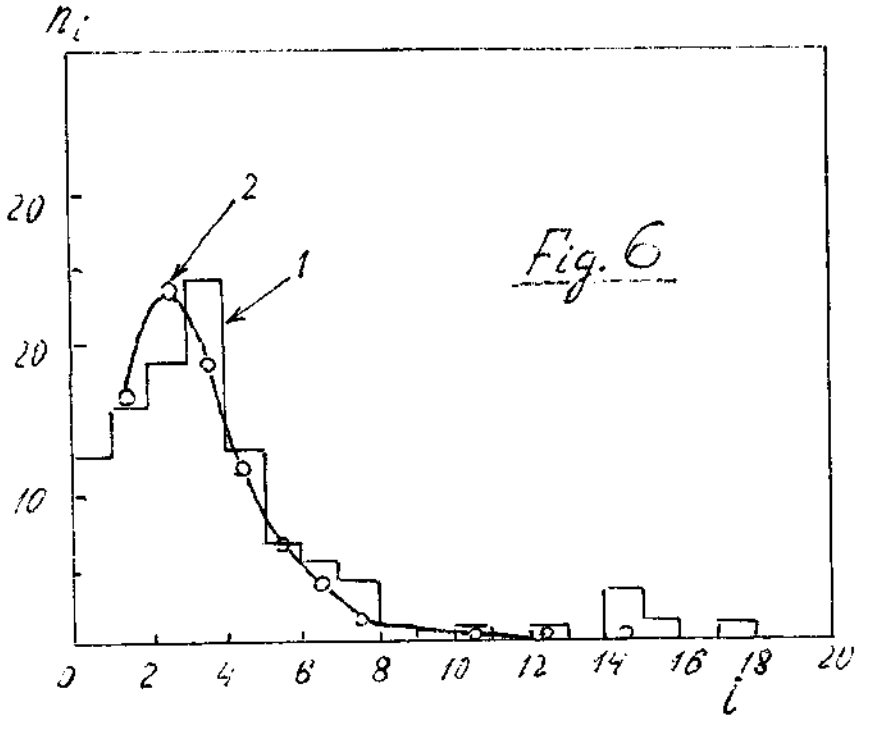

n_i
20
10
2
1
0
2
4
6
8
10
12
14
16
18
20
i

Fig. 6

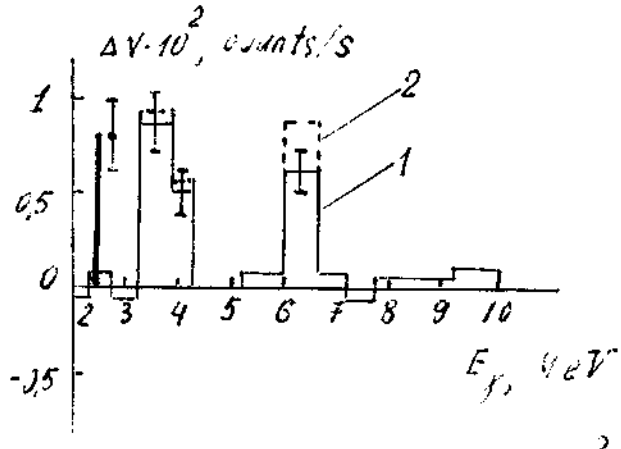


Fig. 8

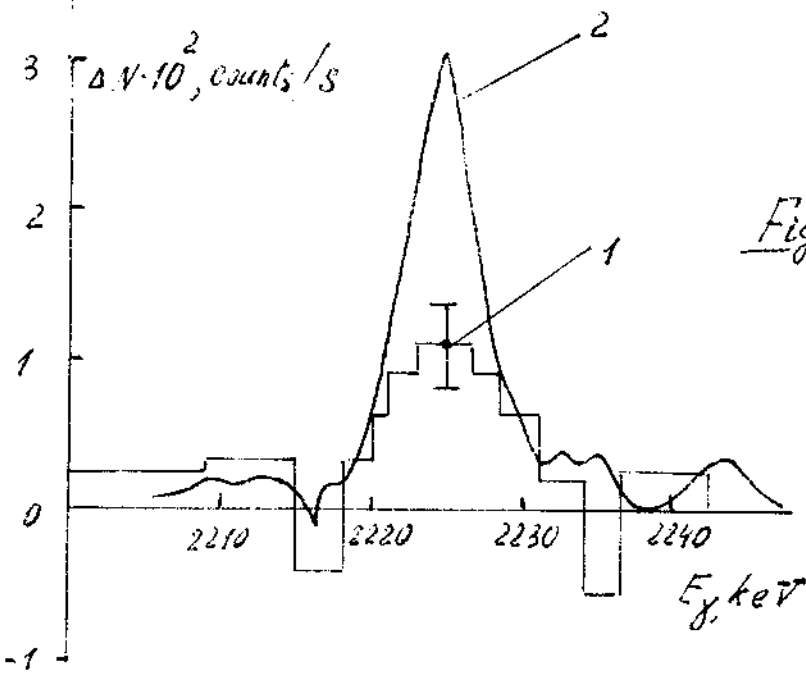


Fig. 9

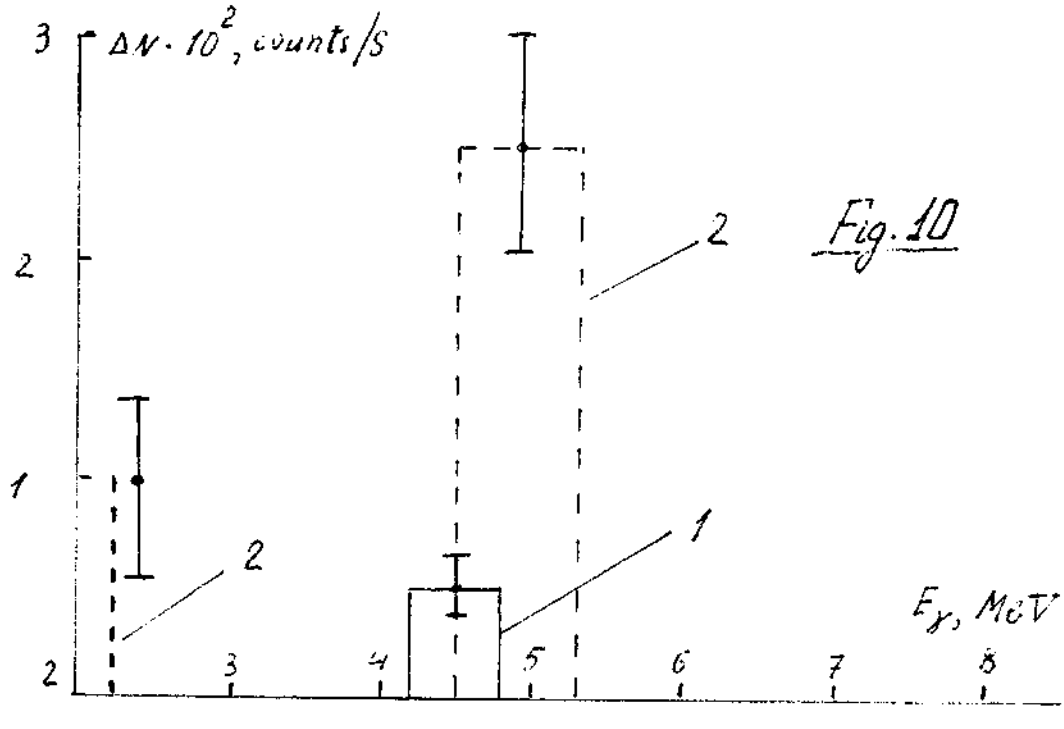


Fig. 10

DYNAMIC MOVEMENT OF HYDROGEN ISOTOPES IN PULSE MODE ELECTROLYSIS

Y.Oya, H.Ogawa, O.Aruga, T.Ono, M.Aida and M.Okamoto
Res. Lab. Nucl. Reactors, Tokyo Institute of Technology
Ookayama, Meguro-City, Tokyo 152 Japan
Tel: 81-3-5734-3065, Fax: 81-3-5734-2959

Abstract

The movement of the hydrogen isotopes in Pd-LiOD(H) electrolysis has been studied by monitoring the hydrogen loading ratios based on the electro-resistance measurement. The movement of the hydrogen isotopes in Pd was found to be influenced strongly by the conditions of the electrolysis, such as the current density, the repetition time. The dynamic absorption/desorption movement can be realized by the pulse mode electrolysis with the current density higher than 200mA/cm^2 and the repetition time longer than 3 hours. In these dynamic movement of the hydrogen isotopes, anomalous isotope effects have been observed and discussed with respect to the new hydrogen energy research.

Introduction

As has been discussed, the anomalous accumulation of deuterium in Pd surface and the dynamic movement of deuterium in the surface should be recognized as the key factors to initiate the deuterium based on nuclear reactions and the anomalous phenomena as new hydrogen energy[1]. The dynamic movement of deuterium has been also discussed in SRI empirical equation for the excess energy generation with the term of δ X/ δ t and they reported the dynamic movement of deuterium in their stepwise rise up of the current density in their electrolysis[2]. While we and Takahashi et al. have applied the square pulse mode electrolysis to elucidate the correlation between the excess energy generation and the nuclear effects, resulting the high reproducibility of the new hydrogen energy production[3][4][5][6].

In the present work, the movement of the deuterium and hydrogen in Pd electrode has been studied by means of the monitoring of the loading ratios (D/Pd, H/Pd) based on the electric resistance method to determine the conditions of the pulse mode electrolysis for realization of the dynamic movement of the hydrogen isotopes, to find the isotope effects in such a dynamic movement of the hydrogen isotopes, and to understand the threshold value of the current density discussed in the SRI empirical equation.

Experimental

Excess Energy and Nuclear Products

The block diagram of the experimental system is shown in Fig.1. The electric resistance was measured by use of a milli-ohm meter PH4338A purchased by HEWLETT PACKARD Co. Ltd. The resistance measurement was performed with 4 points method as shown in Fig.2. The electrolyte volume in the electrolysis cell was kept to be 100 mℓ by addition of the electrolyte throughout the electrolysis. The cell was placed in a thermostat water bath with a constant temperature of 23℃. The Pd electrodes used were 4N Pd plates and were annealed for 2 hours under vacuum (< 10-8Pa) before use. The size of the Pd electrodes was 25mm × 10mm × 0.5mm. The electrolyte was 1 mole/ ℓ LiOD or LiOH. The loading ratios were evaluated by use of the calibration curves reported by Kunimatsu et al. from the electric resistance data[7].

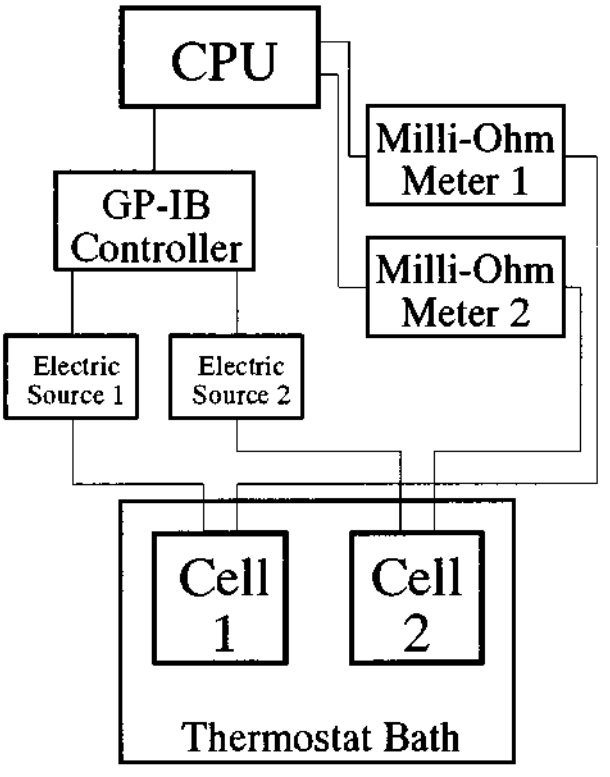


Fig.1 Schematic drawing of experimental system.

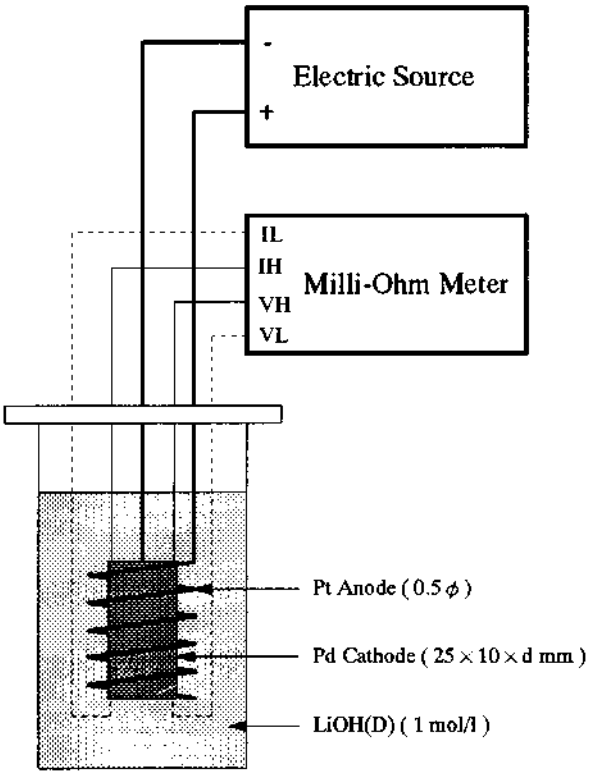


Fig.2 Electrolysis Cell for Pd resistance measurements

Results and discussion

To confirm the performance of the above technique of the loading ratio evaluation, a series of on-off mode electrolysis has been carried out using the Pd plates with the thickness of 0.5mm and 1.0mm at the several current densities from 40 to 800mA/cm^2 in LiOH or LiOD electrolyte. The dynamics of the loading ratios obtained are illustrated in Fig.3 and Fig.4 , for LiOH and LiOD respectively.

From these curves in these figures, it can be said that the present technique for the evaluation of the loading ratio has adequate response as the monitor of the dynamic movement of the hydrogen isotopes in Pd-LiOD or LiOH electrolysis. The loading rates were evaluated from the first stage of the loading process, the linear part of the loading curves, and the rates are plotted vs the current

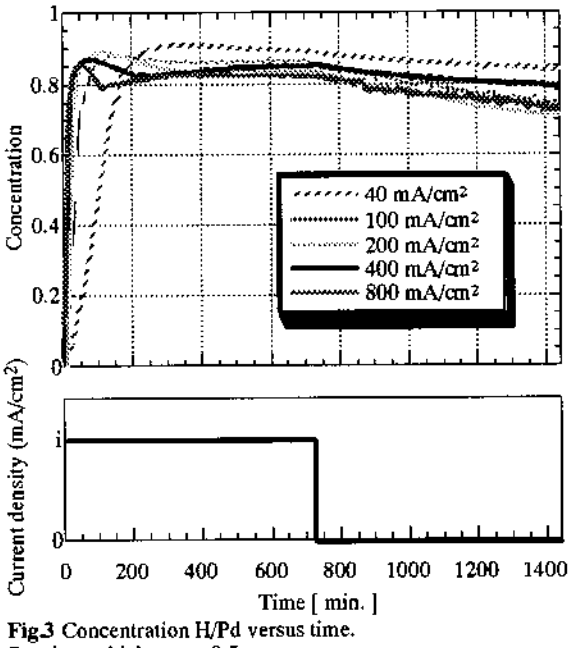


Fig.3 Concentration H/Pd versus time.
Specimen thickness = 0.5 mm,
Constant current density i = 40, 100, 200, 400, 800 mA/cm².

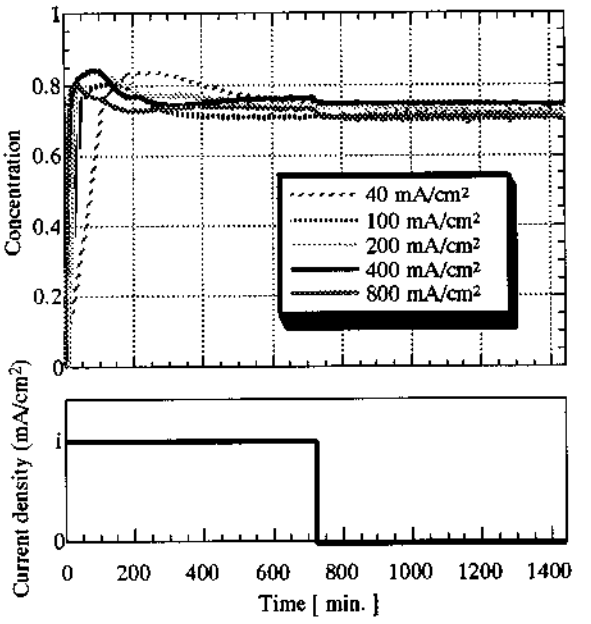


Fig.4 Concentration D/Pd versus time.
Specimen thickness = 0.5 mm,
Constant current density i = 40, 100, 200, 400, 800 mA/cm².

density in Fig.5. The solid line with no marks represents the loading rate calculated by the Faraday`s law. The loading rates obtained in the current density lower than 200mA/cm² correspond to the solid line, while the rates over the current density. This fact indicates that the current density of 200mA/cm² is a critical current density in the our electrolysis as discussed by SRI group. The reason why the loading rates become constant over the 200mA/cm² is now under study.

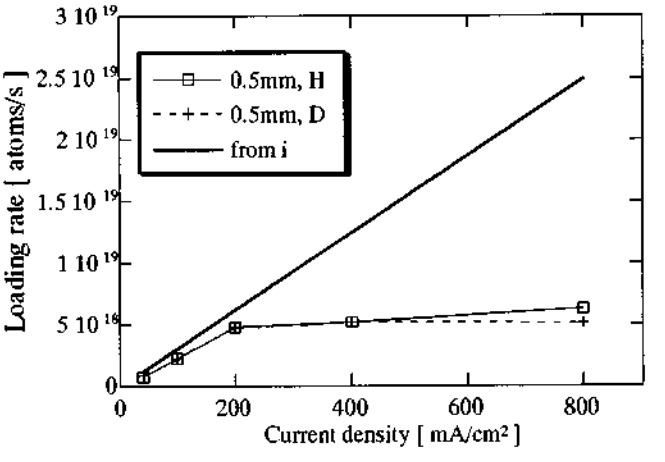


Fig.5 Loading rate versus current density curve.

The loading ratios observed in a series of pulse mode electrolysis are displayed in Fig. 6 for LiOD and LiOH. The electrolysis were carried out in two high-low pulse modes with 20mA/cm²-200mA/cm² and 40-400, and the repetition time was three hours. From these curves, we can find very interesting points as follows.

(1) The loading ratios obtained in LiOH electrolysis are larger than those obtained in LiOD electrolysis as usual.

(2) The loading ratios obtained in 20-200mA/cm² pulse mode electrolysis are almost constant without any response of the high-low pulse mode in LiOH and LiOD.

(3) The loading ratios obtained in the higher current density pulse mode, ie 40-400mA/cm², indicate the evident dynamic movement with clear response to the high-low current density in LiOD electrolysis, while in LiOH electrolysis, the dynamic movement is slight with reversal response to the high-low current density as just opposite to LiOD electrolysis. It can be said that the evident

dynamic movement of deuterium can be realized by the electrolysis of LiOD with Pd cathode with 40-400mA/cm^2 high-low pulse mode and with 3 hours repetition time. These facts should be recognized as the anomalous hydrogen isotope effects occurred in Pd-LiOD(H) electrolysis.

To confirm the reliability of the 3 hours repetition time, the Pd-LiOD electrolysis has been carried out with the same high-low pulse mode but with 6 hours repetition time. The result obtained here is displayed in Fig.7 along with the above data of the 3 hours repetition time. In the case of the 6 hours repetition time, the dynamic movement of the deuterium in Pd electrode could be observed as shown in Fig.7. However, the direction of the response is just opposite to that of 3 hours repetition. It means that in the case of the 6 hours repetition pulse mode the deuterium was desorbed at the high current density and was absorbed at the low current density electrolysis. This movement can not be explained by the bases of the electrochemistry. From the facts mentions above, it can be concluded that the conditions; high/low pulse mode electrolysis of LiOD with Pd cathode, high current density over 400mA/cm^2 and 3 hour repetition time which have been employed by the present authors to perform the deuterium based anomalous phenomena are reasonable.

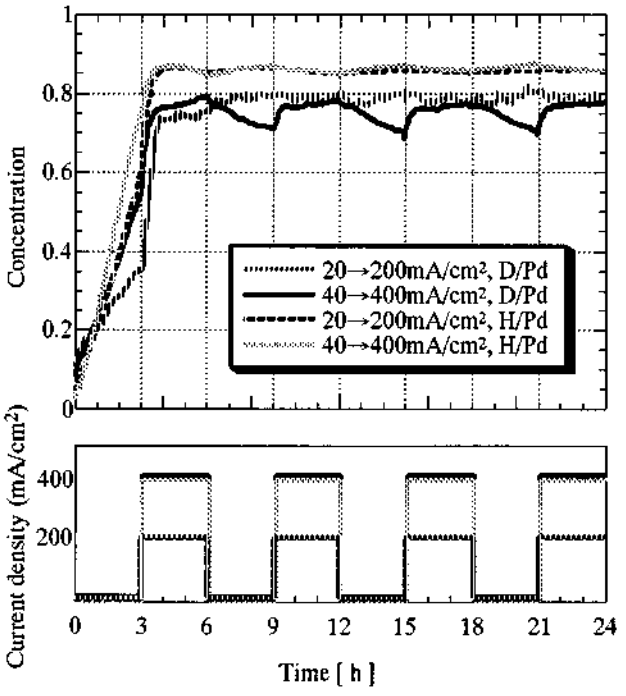


Fig.6 Concentration H(D)/Pd versus time on pulse mode. Specimen thickness = 0.5 mm, high current density = 200 mA/cm^2, low current density = 20 mA/cm^2, and high current density = 400 mA/cm^2, low current density = 40 mA/cm^2

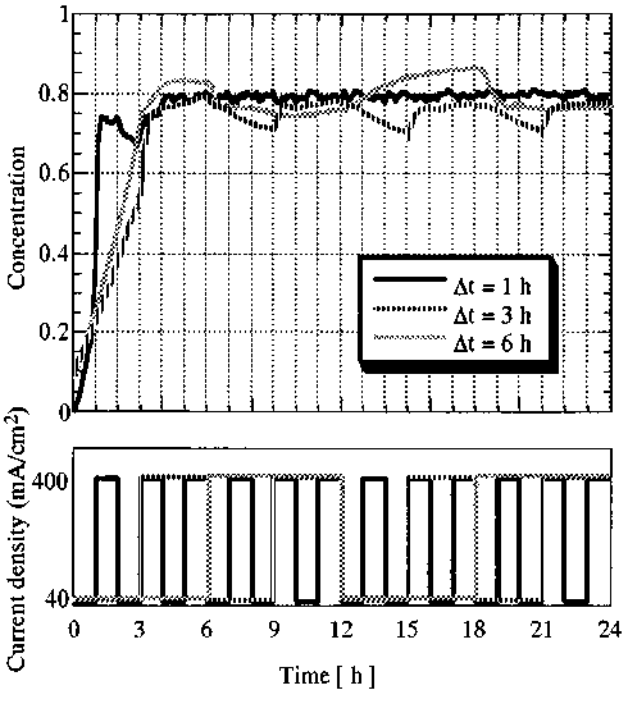


Fig.7 Concentration D/Pd versus time on pulse mode. Specimen thickness = 0.5 mm, high current density = 400 mA/cm^2, low current density = 40 mA/cm^2, and Pulse period Δt = 1, 3, 6 hour.

Conclusion

The reliability of the dynamic movements of the hydrogen isotopes in LiOD(H)-Pd electrolysis have been investigated under the high/low pulse mode electrolysis by varying the current density and the repetition time. The very clear and reasonable response of the loading ratios to the pulse mode could be confirmed in LiOD electrolysis with 3 hours repetition time and high current density like 400mA/

cm^2. While only the slight and reversal direction responses were detected in LiOH electrolysis and longer repetition time like 6 hours even in LiOD electrolysis gave clear response but with reversal direction.

The evidently different response between LiOD and LiOH is significant to elucidate the anomalous phenomena occurred in LiOD-Pd electrolysis.

The conditions realized the dynamic movement of the deuterium in Pd electrode were identified and found to be well consistent with high reproducibility of the anomalous reported by the present authors[8].

Reference

[1] M.Nakada, T.Kusunoki and M.Okamoto, "Energy of the Neutrons Emitted in Heavy Water Electrolysis", Frontiers of Cold Fusion, Tokyo: Universal Academy Press Inc., 581～586 (1992) [Book]

[2] M.C.H.McKubre, S.Crouch-baker, A.K.Hauser, S.I.smedley, F.L.Tanzella, M.S.Williams, S.S.Wing, "Concerning Reproducibility of Excess power Production", Proceedings of the Fifth International Conference on Cold Fusion, 17～33 (1995)

[3] M.Okamoto, Y.Yoshinaga, M.Aida and T.Kusunoki, "Excess Heat generation, Voltage Deviation and Neutron Emission in D_2O-LiOD Systems", Proceedings of Fourth International Conference on Cold Fusion, EPRI, **2**, 3-1～3-6 (1994)

[4] M.Okamoto, T.Kusunoki, Y.Yoshinaga, H.Ogawa and M.Aida, "Excess Heat Generation, Neutron Emission and Cell Voltage Change in D_2O LiOD-Pd Systems", Trans. Fusion Tech., **26**, 176～179 (1994)

[5] H.Ogawa, S.Yoshinaga, Y.Yoshida, M.Aida and M.Okamoto, "Correlation of Excess Heat and Neutron Emission in Pd-Li-D Electrolysis", proceedings of The Fifth International Conference on Cold Fusion, 116～119 (1995)

[6] H.Miyamaru, Y.Chimi, T.Inokuchi and A.Takahashi, "Search for nuclear Products of Cold Fusion", Proceedings of Fourth International Conference on Cold Fusion, EPRI, **2**, 2-1～2-10 (1994)

[7] J.Minato, T.Nakata, S.Denzumi, Y.Yamamoto, A.Takahashi, H.Aida, Y.Tsuchida, H.Akita and K.Kunimatsu, "Materials/Surface Aspects of Hydrogen/Deuterium Loading into Pd Cathode, Proceedings of the Fifth International Conference on Cold Fusion, 383～410, (1995)

[8] In this Proceedings