Int. J. of The Soc. of Mat. Eng. for Resources Vol. 6 No. 1 68～77 (1998)

Review

The Cold Fusion Phenomenon

by

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ABSTRACT

Present status of cold fusion research is reviewed after almost nine years of its discovery. It is recognized that the events of the cold fusion phenomenon occurring at from room temperature up to about 3000℃ include not inly initially supposed excess heat, neutron and tritium generations but also helium and gamma ray generations and the nuclear transmutation of the heavier nuclei. The experimental evidences of these events have been almost confirmed and primitive application devices have been worked out but theoretical explanation of the phenomenon is not accomplished yet. A trial of consistent explanation for the whole experimental data is introduced in the final section.

Key Words : Cold Fusion, Excess Heat, Tritium, Neutron, Helium

1. INTRODUCTION

In 1989, Fleischmann et al.[1] published a paper announcing the discovery of the socalled Cold Fusion, i.e. generations of the excess heat Q and the nuclear products (tritium t, helium 4 ^{4}He, neutron n, and gamma ray γ) in solids. The excess heat generation was confirmed first in electrolytic system with Pd cathode, Pt anode and D_2O + LiOD electrolytic solution. The amount of the observed excess heat was several orders of magnitude larger than that generated by supposed chemical reactions induced by applied electric field.

The first question raised to reconcile the events with the established knowledge of the material science (Quantum Mechanics) was consistency of the amount of the excess heat and nuclear products accompanied with it. In the inspection of the consistency, it is assumed the nuclear reactions relevant to the cold fusion phenomenon were the same reactions between deuterons as those in vacuum written down as follows :

$$d + d = t\,(1.01\ \mathrm{MeV}) + p\ (3.02\ \mathrm{MeV}), \quad (1)$$
$$= {}^3\mathrm{He}\,(0.82\ \mathrm{MeV}) + n\ (2.45\ \mathrm{MeV}), \quad (2)$$
$$= {}^4\mathrm{He} + \gamma\ (23.8\ \mathrm{MeV}). \quad (3)$$

The branching rations of these reactions have been well established in Nuclear Physics as ～1 : 1 : 10^{-7}. This predicts a following relation between numbers of generated particles ; $N_t = N_n = 10^7 N_{He}$.

Therefore evenly, helium 4 could not be observed and the excess heat should amount to about 3

Received October 29, 1997

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$\sim$ 4 MeV per one tritium (and neutron).

Surprisingly enough for many scientists, those presumptions have been betrayed by the facts obtained by many researchers made in systems similar to and different from that by the pioneers. In fact, the observed relations were $N_t \cong N_{He} \cong 10^4 \sim 10^7 N_n$ and N_Q ($\equiv Q/5$ MeV) $\sim N_t$. This is the first origin of the confusion occurred after the discovery in 1989 and has lasted even until now somewhere in the world.

The second question raised to reconcile the observed results with the conventional physical processes is the question of reproducibility to which the first question relates closely. The simple probable reactions like (1) and (2) are expected to occur with definite probability if enough deuterons are occluded in Pd lattice to a concentration for an alloy PdD and therefore where the deuterium distributes uniformly. Experimentally, however, the reproducibility of the event was very poor as every experimenter knows very well. The presumption of such simple mechanisms could not reconcile with the fact.

Now, almost nine years after the discovery, many facts have been confirmed and are waiting a consistent explanation. It has been recognized that the cold fusion phenomenon contains not only the generation of the excess heat and generations of small nuclei, neutron and the photon but also the nuclear transmutation (NT) including heavy nuclei in metals occluding hydrogen isotopes (D and H) and in compounds including them. The scope of experimental results obtained hitherto is summarized in Table 1. In this table, Q is for the excess heat, the oxide* is a proton conductor and

Table 1 : Typical Matrix Substances, Agent nuclei, Direct and Indirect Events in Cold Fusion Phenomenon. The letter ε signifies an energetic particle and γ position in space.

Matrix Substance	Agent	Direct Event	Indirect Event
Pd	${}^2_1D \equiv d$	γ (ε)	Q
Ti	${}^1_1H \equiv p$	$n(\varepsilon)$	${}^4He$
Ni	${}^6Li$	Transmuted Nucleus ($\boldsymbol{r}$)	${}^3_1T \equiv t$
Na_xWO_3	${}^{10}B$		Nuclear Transmutation
KD_2PO_4	${}^{39}K$		X-ray
TGS	${}^{85}Rb, {}^{87}Rb$		
$SrCe_{0.9}Y_{0.08}Nb_{0.02}O^*_{2.97}$	${}^1_0n \equiv n$		
$YBa_2Cu_3O^{**}_{7-\delta}$			

another oxide** is a superconductor.

As we can see in Table 1, the cold fusion phenomenon has wide spread diversity in its events and also in its fields where the events occur. In short, it is a phenomenon occuring in complex systems composed of multi-component crystals and neutrons in the presence of time varying electric field. Therefore, we have to expect chaotic nature for such events of the phenomenon which reflect stochastic behavior of elemental processes directly in the system (direct events). On the other hand, we can expect qualitative reproducibility for such events of the phenomenon resulting from averaging over microscopic processes in time and space (indirect events). The direct and indirect events in Table 1 represent this difference of their nature in the events.

Typical experimental results of the excess heat, nuclear products (tritium, helium 4, neutron and gamma ray) and nuclear transmutation (NT) will be reviewed in this order and finally the theoretical aspect is explained in short. In the experiments done by now, there are measured sometimes several quantities in an experiment simultaneously. To review those experimental results, we use here classification by event. A work with sereral events will be taken up by its most predominant event.

The reference is not intended to be exhaustive due to the limited space and the weight is on the recent papers. The titles of the cited papers in addition to papers published in this volume will supplement the explanation in this short review.

2. The Excess Heat

At first, we take up the excess heat because of its vast amount of data and its importance in the application of the cold fusion as an energy source though it is an indirect event resulting from thermalization (averaging) of the energy liberated by nuclear reactions in solids. In reality, many data of other events have been observed together with the excess heat and we treat them in the other divisions.

The excess heat has been measured not only in the original electrolytic system[1~9] Pd/D/Li but also in other electrolytic systems[10~15] and in discharge[16] and gas contact[17] systems. Protom conductors[18], superconductors[19] and ferroelectrics have shown also the excess heat generation along with nuclear products and are discussed later.

The most elaborate experiments have been performed on the orogonal Pd/D/Li system. Pons in France is experimenting with a new precision device with success[2]. McKubre in SRI International, USA, has performed elaborate experiment with the same system. They deduced a qualitative formula expressing a dependence of the excess heat on the electric current density, D/Pd ratio x and time rate of x change, $|dx/dt|$.

Qualitative reproducibility of the excess heat generation up to about 50% of input energy has been improved vastly by using materials with a large value of surface to volume ratio S/V. The typical examples are the Patterson multi-coated beads[13,14] and thin wires of Pd[9] and Ni[15] with $S/V \sim 4 \times 10^3$, 4×10^2 and 80cm^{-1}, respectively. (The value of the original work by Fleischmann et al.[1] was $6 \sim 40$cm^{-1}, for instance.)

3. Particle Generation

The so-called nuclear products, particles generated in the phenomenon, expected first by many were neutron and tritium due to reactions (1) and (2) and not helium and gamma ray as discussed in the Introduction. In reality, however, there have been observed much tritium and helium but little neutron by a factor $10^{-4} \sim 10^{-7}$. This is a characteristic of the cold fusion phenomenon.

The charged particles triton, ^{4}He and proton if any in strong interaction with matrix lattice and are not expected to be observed in their original state as born in nuclear reactions. On the other hand, neutron and gamma ray interact weakly with matter and are expected to give direct information of the relevant reactions.

3.1 Tritium

Tritium has been observed[1,19~21] in gases and liquids in the system with sufficient amount to commensurate with the excess heat. It is a common experience of experimenters that tritium is observed more often than neutron in any experiment. In the cases of simaultaneous detection of tritium and neutron, number of the former reached $\sim 10^7$ times that of the latter[1]. A steady tritium generation was observed in a glow discharge experiment with Mo or other metal cathodes and D_2 gas[23].

3.2 Helium 4

In the particles generated in the cold fusion phenomenon, ^4He is comparable to tritium in its amount generated in electrolytic experiments. After the first check[25] of helium generation, many works[26~33] have observed ^4He outside the samples with enough amount to commensurate with the excess heat.

This fact excludes the possibility of nuclear reactions in solids similar to those in vacuum unless the branching ratio of the reaction (3) changes by more than seven orders of magnitude in solids. It is difficult to suppose that the crystal lattice works so strongly on the nuslear reactions between two deuterons in it due to the large differences of the short range $\sim 10^{-13}$ cm of the nuclear force compared with the lattice constant $\sim 10^{-8}$ cm and the large energy ~ 1 MeV to penetrate Coulomb barrier compared with the thermal energy ~ 0.1 eV.

3.3 Neutron

The precise detection[34] of neutrons with 2.45 MeV was the historical experiment done in the presence of the background neutron. There are many evidences[35~42] of neutron generation with energies from 2.45 MeV up to 10 MeV in various cold fusion materials in natural environment. These data shows again that fundamental reactions of the cold fusion phenomenon are not those reactions (1) and (2) supposed first but others.

In addition to above data, it should be noticed that there are many null results done in enviroment with almost zero background neutrons. There are also several works showing positive effects[39, 41, 42, 46] of the thermal neutron on the cold fusion phenomenon. We know that the thermal neutron is a predominant component of the background neutron as the data[34] showed clearly. We have to give our attention on the background neutron.

The experimental data on the neutrons with its wide spread energy spectrum and its rather small number than tritium by $\sim 10^{-7}$ seem to show that we have to change our mind from simple reactions like (1) and (2) to others compatible with experimental data.

3.4 Gamma Ray

First report[43] of the gamma ray generation was followed by another[44] without others for a long period. It has been, however, reported several fine data[45~47] of gamma ray up to ~ 10 MeV are one of most direct evidences of nuclear reactions in the cold fusion. There remains a riddle for scarceness of gamma ray detection for such a long period.

4. Nuclear Transmutation

One of the most spectacular effects in the cold fusion phenomenon is the nuclear transmutation, change of mass and sometimes atomic numbers of nuclei in the cold fusion systems. There are very many exerimental results from small changes of atomic and mass numbers[49~53] to generation of nuclei with large changes of these numbers[54~57].

The nuclear transmution accompanies sometimes change of radioactivity of nucleus dissolved in the solution of electrolytic experiments. This effect may be used to reduce hazardous radioactivity of nuclear ashes remained in nuclear piles.

It is noticed that are evidences that the nuclear transmutation is occuring in biological systems[52]. It is instructive to recollect the situation occured eight years ago when the cold fusion phenomenon was discovered and then many people became indifferent to it. We have to be moderate to judge new phenomenon considering various possibilities in complex systems composed of atoms and background particles on the earth.

5. Conclusion

The cold fusion phenomenon, first investigated mainly from energy point of view, has evolved into a phenomenon showing an existence of a hidden realm in the solid statenuclear physics. It might be a science of thermal neutrons in solids as the experimental facts reviewed above suggest it clearly.

Efforts to improve the qualitative reproducibility and the intensity of the effects have been continued with great success. The factors governing the occurence of the cold fusion phenomenon, especially the excess heat, have been investigated varying such parameters of experiments as composition and quality of the cathodes, electrolytes, the form of applied electric voltages and so on. It is recognized that density of hydrogen isotopes in the material has a threshold value below which almost to phenomenon occurs. It seems effective to vary some parameters with time as experienced in many successful experiments : the parameters were temperature[36], electric voltage[3] and structure of the materials[7, 13, 14, 28, 30, 32, 36, 38, 41, 44]. It is also recognized that the phenomenon occurs both with deuterium and with hydrogen in contrast to the initial supposition that the deuterium is the inevitable agent. This fact put people who adhere to the conventional reactions like (1) and (2) in dilemma between the fact and their obsession.

It has become clear that surface or interface area is very important in realization of the cold fusion phenomenon. This fact is revealed by the localization of the transmuted nuclei confined around the surface area[49, 50, 55, 56] and the detection of ^{4}He outside the cathodes[26~31, 33].

It is noticed furthermore that the cathode material and the electrolyte in electrolytic experiment have a definite optimum combination. The well known paors are Pd and Li, and Ni and K or Rb. This may be a clue to clarify the mechanism of the cold fusion phenomenon in addition to the above mentioned localization of the transmuted nuclei. Also, the preparatory period needed in successful runs before meaningful events occur are widely recognized and ranges from several hours[5, 35] to several months[1, 3, 7].

There are no microscopic theory to explain those complex events consistently yet. A model theory[57~60] has been proposed by the author to interpret the various facts phenomenologically. The model uses several premises with only one adjustable parameter n_n,the density of thermal neutrons in solids. The model has succeeded to explain more than 40 experimental results with reasonable values of n_n determind by experimental data.

In the model, only such well established reactions are used as follows. The reactions between the thermal neurton and other nuclei (trigger reactions) are :

$$n + {}^6\text{Li} = {}^4\text{He}\ (2.1\ \text{MeV}) + t\ (2.7\ \text{MeV}), \quad (4)$$

$$n + d = t\ (6.98\,\mathrm{keV}) + \gamma\ (6.25\,\mathrm{MeV}), \quad (5)$$

$$n + p = d\ (1.33\,\mathrm{keV}) + \gamma\ (2.22\,\mathrm{MeV}), \quad (6)$$

$$n + {}^{7}\mathrm{Li} = {}^{8}\mathrm{Be} + \gamma = 2\,{}^{4}\mathrm{He} + e^{-} + \upsilon_{e} + 16.2\,\mathrm{MeV} + \gamma\,. \quad (7)$$

The energetic particles generated in these reactions, then, can react with other particles in the material and breed neutron and other particles (breeding reactions) :

$$t\ (2.7\,\mathrm{MeV}) + d = {}^{4}\mathrm{He}\ (3.5\,\mathrm{MeV}) + n\ (14.1\,\mathrm{MeV}), \quad (8)$$

$$n\ (\varepsilon) + d = n' + d''\ , \quad (9)$$

$$n\ (\varepsilon) + d = n' + p + n''\ , \quad (10)$$

$$\gamma\ (\varepsilon) + d = n + p, \quad (11)$$

$$d\ (\varepsilon) + d = t\ (1.01\,\mathrm{MeV}) + p\ (3.02\,\mathrm{MeV}), \quad (12)$$

$$= {}^{3}\mathrm{He}\ (0.82\,\mathrm{MeV}) + n\ (2.45\,\mathrm{MeV}). \quad (13)$$

The determined values of the parameter n_n were almost in a range from 10^6 to $10^{12}\mathrm{cm}^{-3}$. This is not absurd values in the high time of reactions if the background neutron is trapped and stocked in the material to induce the trigger reactions and if the breeding reactions work effectively. The preparatory period noticed above may be related with the trapping of the background neutrons. Physical bases of premises in the model should be worked out if the model is successful in the explanation of the otherwise confusing facts. Some predictions done by the model will be checked by experiments.

The science of the cold fusion phenomenon has been making progress steadily in experiment and in theory. Dialogue between experiment and theory will promote research of the cold fusion and establish a new science of solid state-nuclear physics which enables effective application of the phenomenon to energy and radioactivity problems.

References

(1) M. Fleischmann, S. Pons and M. Hawkins, "Electrochemically induced Nuclear Fusion of Deuterium", *J. Electroanal. Chem.* **261**, 301 (1989).

(2) T. Roulette, J. Roulette and S. Pons,"The ICARUS 9 Calorimeter : Summary of Three Year Desiging, Testing and Operation of this Device at the IMRA Europe science Center" *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.85, 1996.

(3) A. Takahashi, A. Mega, T. Takeuchi, H. Miyamaru and T. Ikda, "Anomalous Excess Heat by D_2O /Pd Cell under L-H Mode Electrolysis", *Frontiers of Cold Fusion* (*Proc. ICCF3*), p.79, 1993.

(4) E. Storms, "Some Characteristics of Heat Production using the 'Cold Fusion' Effect" *Trans. Fusion Technol.* (*Proc. ICCF4*) **26**, p.96 (1994).

(5) M. C. H. McKubre, S. Crouch-Baker, R. C. Roche-Filho, S. I. Smedley, F. L. Tanzella, T. O. Passell and J. Santucci," Isothermal Flow Calorimetric Investigations of the D/Pd and H/Pd Systems" *J. Electroanal. Chem.* **368**, 55 (1994).

(6) K. Ota, T. Kobayashi, H. Kabumoto, K. Yamaki, M. Motohira and N. Kamiya, "Heat Measurements during the Electrolysis using Modified Palladium Cathode", *Progess in New Hydrogen Energy* (*Proc. ICCF6*), p.535, 1996.

(7) Y. Arata and Y-C. Zhang, "Achievement of Solid-State Plasma Fusion ("Cold Fusion")", *Proc. Japan Acad.* **70B**, 106 (1994) ; "A New Energy Caused by 'Spillover-Deuterium"', *ibid.* **71B**, 304

(1995).

(8) Y. Iwamura, "Correlation between Behavior of Deuterium in Palladium and Occurrence of Nuclear Reactions Observed by Simultaneous Measurement of Excess Heat and Nuclear Products", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.274, 1996.

(9) F. Celani, A. Spallone, P. Tripodi, D. Di Giacchino, S. Pace, P. Marini, V. Di Stefano, M. Diocianiuti and A. Manchini, "New Kinds of Electrolytic Regimes and Geometrical Configurations to Obtain Results in Pd (M)-D Systems", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.93, 1996.

(10) R. L. Mills, W. R. Good and R. M. Shaubach, "Dihydrino Molecule Identification" *Fusion Technol.* **25**, 103 (1994).

(11) R. T. Bush, "A Light Water Excess Heat Reaction suggests that 'Cold Fusion' may be 'Alkali-Hydrogen Fusion'" *Fusion Technol.* **22**, 301 (1992).

(12) T. Ohmori and M. Enyo, "Excess Heat produced during Electrolysis of H_2O on Ni, Au, Ag and Sn Electrodes in Alkaline Media", *Frontiers of Cold Fusion* (*Proc. ICCF3*), p.427, 1993.

(13) D. Cravens, "Flowing Electrolyte Calorimetry", *Proc. 5th Int. Conf. Cold Fusion* (*ICCF5*), p.79, 1995.

(14) J. Patterson and D. Cravens, "System for Electrolysis", US Patent # 5,607, 563 : *Cold Fusion* **22**, 2 (1997).

(15) J. M. Niedra, I. T. Myers, G. C. Fralich and R. S. Baldwin, "Replication of the Apparent Excess Heat Effect in a H_2O-K_2CO_3-Ni Electrolytic Cell" NASA *Technical Memorandum 107167* (February, 1996) : *cold Fusion* **22**, 18 (1997).

(16) J. Dufour, "Cold Fusion by Sparking in Hydrogen Isotopes", *Fusion Technol.* **24**, 205 (1993).

(17) S. Focardi, R. Habel and F. Piontelli, "Anomalous Heat Production in Ni-H System", *Nuovo Cimento*, **107A**, 163 (1994).

(18) T. Mizuno, M. Enyo, T. Akimoto and K. Azumi, "Anomalous Heat Evolution from $SrCeO_3$-Type Proton Conductors during Absorption/Desorption of Deuterium in Alternate Electric Field", *Proc. 4th Int. Conf. Cold Fusion* (*ICCF4*), Vol.**2**, p.14, 1994.

(19) E. Storms and C. Talcott, "Electrolytic Tritium Production", *Fusion Technol.*, **17**, 680 (1990).

(20) M. Srinivasan, R. K. Rout, S. C. Misra, M. Lai, A. Shyam, P. S. Rao and P. K. Iyengar, "Observation of High Tritium Levels in Aged Deuterated Titanium Targets as Possible Evidence of Cold Fusion", *Fusion Technol.* **18**, 88 (1990).

(21) T. N. Claytor, D. G. Tuggle and S. F. Taylor, "Evolution of Tritium from Deuterided Palladium Subject to High Electrical Currents", *Frontiers of Cold Fusion* (*Proc. ICCF3*), p.217, 1993.

(22) T. G. Will, K. Cedzynska and D. C. Kinton, "Tritium Generation in Palladium Cathodes with High Deuterium Loading", *Trans. Fusion Technol.* (*Proc. ICCF4*) **26**, p.207 (1994).

(23) V. A. Romodanov, V. I. Savin and Ya. B. Skuratnik, "Tritium Generations at Transfusion of Hydrogen Isotopes through Target in Plasma of Powerful Glow Discharge", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.585, 1996.

(24) T. Itoh, Y. Iwamura, N. Gotoh and I. Toyoda, "Observation of Nuclear Products under Vacuum Condition from Deuterated Palladium with High Loading Ratio", *Proc. 5th Int. Conf. Cold Fusion* (*ICCF5*), p.189, 1995.

(25) J. R. Morrey, M. R. Caffee, H. Farrar, IV, N. J. Hoffman, G. B. Hudson, R. H. Jones, M. D.

Kurz, J. Lupton, B. M. Oliver, B. V. Ruiz, J. F. Wacker and A. Van, "Measurements of Helium in Electrolyzed Palladium", *Fusion Technol.* **18**, 659 (1990).

(26) M. H. Miles, R. A. Hollins, B. F. Bush and J. J. Lagowski," Correlation of Excess Power and Helium Production During D_2O and H_2O Electrolysis Using Palladium Cathodes", *J. Electroanal. Chem.* **346**, 99 (1993).

(27) B. F. Bush, "Nuclaer Products Associated with the Pons and Flieischman Effect; Helium Commensurate to Heat generation, Calorimetry and Radiation", *Progress in New Hydrogen Energy (Proc. ICCF6)*, p.622, 1996.

(28) E. Yamaguchi and T. Nishioka, "Direct Evidence for Nuclear Fusion Reactions in Deuterated Palladium", *Frontiers of Cold Fusion (Proc. ICCF3)*, p.179, 1993.

(29) J. O'M. Bockris, C-C. Chien, D. Hodko and Z. Minevski, "Tritium and Helium Production in Palladium Electrodes and the Fugacity of Deuterium Therein", *Frontiers of Cold Fusion (Proc. ICCF3)*, p.231, 1993.

(30) D. Gozzi, P. L. Cignini, R. Caputo, M. Tomellini, B. Balducci, G. Gigli, E. Cisbani, S. Frullani, F. Galibaldi, M. Jodice, and G. M. Urciuoli, "Calorimetric and Nuclear Byproduct Measurements in Electrochemical Confinement of Deuterium in Palladium", *J. Electroanal. Chem.* **380**, 91 (1995); *ibid.* 109 (1995).

(31) T. O. Passell, "Search for Nuclear Reaction Products in Heat-Producing Palladium" *Progress in New Hydrogen Energy (Proc. ICCF6)*, p.282, 1996.

(32) Y. Arata, "Achievement of Solid-State Plasma Fusion ("Cold Fusion")", *Progress in New Hydrogen Energy (Proc. ICCF6)*, p.129, 1996.

(33) E. Botta, "Measurements of Helium Production from D_2-Gas Loaded Pd Sample", *Progress in New Hydrogen Energy (Proc. ICCF6)*, p.29, 1996.

(34) S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne and S. E. Tayler, "Observation of Cold Nuclear Fusion in Condensed Matter", *Nature* **338**, 737 (1989).

(35) A. De Ninno, A. Frattolillo, G. Lollobattista, G. Martpne, M. Mori, S. Podda and F. Scaramuzzi, "Evidence of Emission of Neutrons from a Titanium-Deuterium System", *Europhys. Lett.* **9**, 221 (1989).

(36) H. O. Menlove, M. M. Fowler, E. Garcia, M. C. Miller, M. A. Paconi, R. R. Ryan and S. E. Jones, "Measurements of Neutron Emission from Ti and Pd in Pressurized D_2 Gas and D_2O Electrolysis Cells", *J. Fusion Energy* **9**, 495 (1990).

(37) M. Nakada, T. Kusunoki and M. Okamoto, "Energy of the Neutrons Emitted in Heavy Water Electrolysis", *Frontiers of Cold Fusion (Proc. ICCF3)*, p.173, 1993.

(38) K. Kaliev, A. Baraboshkin, A. Samgin, E. Golikov, A. Shalyapin, V. Andreev and P. Goluburchiy, "Reproducible Nuclear Reactions during Interaction of Deuterium with Nuclear Reactions during interaction of Deuterium with Oxide Tungsten Bronze", *Frontiers of Cold Fusion (Proc. ICCF3)*, p.241, 1993.

(39) B. Stella, M. Corradi, F. Ferrarotto, V. Milone, F. Celani and A. Spallone, "Evidence for Stimulated Emission of Neutrons in Deuterated Palladium", *Frontiers of Cold Fusion (Proc. ICCF3)*, p.437, 1993.

(40) F. Cuevas, J. F. Fernandez and C. Sanchez, "Search for Neutron Emission induced by Electric Currents and Phase Transitions in Titanium Deuteride Films", *Trans. Fusion Technol. (Proc.*

ICCF4) **26**, p.154 (1994).

(41) A. G. Lipson, D. M. Sakov and E. I. Saunin, "Change in the Intensity of a Neutron Flux as It Interacts with a $K(S_xD_{1-x})_2PO_4$ Crystal in the Vicinity of Tc" J. Tech. Phys. Lett. (in Russian), 22, 8 (1996) ; and also V. A. Filimonov" A New Cold Fusion Phenomenon ? ", *Cold Fusion* **7**, 24 (1995).

(42) F. Celani, A. Spallone, L. Libaratori, F. Groce, A. Storelli, S. Fortunati, M. Tului and N. Sparviari, "Search for Enhancement of Neutron Emission from Neutron-Irradiated, Deuterated High-Temperature Superconductors in a Very Low Background Environment", *Fusion Technol.* **22**, 181 (1992).

(43) J. Jorne, "Neutron and Gamma-ray Emission from Palladium Deuteride under Supercritical Conditions", *Fusion Technol.* **19**, 371 (1991).

(44) H. Long, R. Xie, S, Sun, H. Liu, H. an, B. Chen, X. Zhang and W. Zhang, "The Anomalous Nuclear Effects Inducing by the Dynamic Low Pressure Gas Discharge in a Deuterium/Palladium system", *Frontiers of Cold Fusion* (*Proc. ICCF3*), p.455, 1993.

(45) A. G. Lipson, D. M. Sakov and E. I. Saunin, "Heat Production, Nuclear Ashes and Electrophysical Processes in Heterostructure PdO / Pd / PdO saturated with Deuterium by Electrochemical Method" *Proc. RCCFNT4* (May 20-25, 1996, Sochi, RUSSIA) (to be published) ; *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.433, 1996.

(46) Y. Oya, H. Ogawa, T. Ono, M. Aida and M. Okamoto, "Hydrogen Isotope Effect Induced by Neutron Irradiation in Pd-LiOD (II) Electrolysis", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.370, 1996.

(47) R. Notoya, T. Ohnishi and Y. Noya, "Nuclear Reaction Caused by Electrolysis in Light and Heavy Water Solution" *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.675, 1996.

(48) R. T. Bush and D. R. Eagleton, "Calorimetric Studies for Several Light Water Electrolyte Cells with Nickel Fibrex Cathodes and Electrolytes with Salts of Potassium, Rubidium and Cesium", *Proc. 4th Int. Cold Fusion* (*ICCF4*), Vol.**2**, p.13, 1994.

(49) I. B. Savvatimova, "Transmutation Phenomena in the Palladium Cathode after Ion Irradiation at the Glow Discharge", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.575, 1996.

(50) M. Okamoto, H. Ogawa, Y. Yoshinaga, T. Kusunoki and O. Odawara, "Behavior of Key Elements in Pd for the Solid State Nuclear Phenomena Occurred in Heavy Water Electrolysis", *Proc. 4th Int. Conf. Cold Fusion* (*ICCF4*), Vol.**3**, p.14, 1994.

(51) R. Notoya, "Nuclear Products of Cold Fusion Caused by Electrolysis in Alkali Metallic Oons Solutions" *Proc. 5th Int. Conf. Cold Fusion* (*ICCF5*), p.531, 1995.

(52) V. I. Vysotskii, "Experimental Discovery of the Phenomenon of Low Energy Nuclear Transmutation of Isotopes ($Mn^{55} \rightarrow Fe^{57}$) in Growing Biological Cultures", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.680, 1996.

(53) T. Ohmori, "Production of Heavy Metal Elements and the Anomalous Surface Structure of the Electrode Produced during the Light Water Electrolysis on Au Electrode", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.670, 1996.

(54) G. H. Miley, "Quantitative Observation of Transmutation Products Occurring in Thin-Film Coated Microspheres during Electrolvsis", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.629, 1996.

(55) T. Mizuno, "Isotopic Distribution for the Elements Evolved in Palladium Cathode after

Electrolysis in D_2O Solution", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.665, 1996.
(56) H. Yamada, H. Nonaka, A. Dohi, H. Hirahara, T. Fujihara, X. Li and A. Chiba, "Carbon Production on Palladium Point Electrode with Neutron Burst under DC Glow Discharge in Pressurized Deuterium Gas", *Progress in New Hydrogen Energy* (*Proc. ICCF6*), p.610, 1996.
(57) H. Kozima, S. Waranabe, K. Hiroe, M. Nomura, M. Ohta and K. Kaki, "Analysis of Cold Fusion Experiments Generating Excess Heat, Tritium and Helium", *J. Electroanal. Chem.* **425**, 173 (1997).
(58) H. Kozima, "The TNCF Model – A Phenomenological Model for the Cold Fusion PHenomenon" *Cold Fusion* **23**, 18 (1997).
(59) H. Kozima, K. Kaki and M. Ohta, "Anomalous Phenomenon in Solids Described by the TNCF Model" *Fusion Technology* **33** (1998) (to be published).
(60) H. Kozima, *Discovery of the Cold Fusion Phenomenon-Evolution of the Solid State-Nuclear Physics and the Energy Problem of 21st Century* (in Japanese), Otake Shuppan KK., Tokyo, Japan, 1997.