The 13th Meeting of Japan CF-Research Society

# JCF13 ABSTRACTS

December 8-9, 2012

Meeting Room 1209, Wink Aichi, Nagoya

Japan CF-Research Society

# Program of JCF13 Meeting (2012/12/03 Updated)

**Japan CF-Research Society**

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**Date: December 8-9, 2012**

**Place: Meeting Room 1209, Wink-Aichi, Nagoya, Japan; http://www.winc-aichi.jp/**

**Paper presentation: Oral 25min (discussion;5min )/ *20min (dis.;5min)/ **30min (dis.;5min)**

**Language: English or Japanese**

**Book of Abstract: Only available at JCF home page;** http://jcfrs.org/

## December 8 (Saturday), 2012

12:00-13:00 **Registration**

13:00-13:10 **Opening Address** (T. Hioki, Toyota Central R & D Labs.)

**Theory-1** (Chairman: N.D. Cook, Kansai Univ.)

13:10-13:35 **JCF13-1** K. Tsuchiya (Tokyo National College of Technology) et al., "The quantum states of the system including two species of charged bosons in ion trap I"

13:35-14:00 **JCF13-2** S. Kikuchi (Tokyo National College of Technology) et al., "The quantum states of the system including two species of charged bosons in ion trap II"

14:00-14:25 **JCF13-3** A. Takahashi (Technova Inc.) et al., "Nucleon halo model of $^{8}$Be"

**Experiment-1** (Chairman: Y. Iwamura, Advanced Technology Research Center, Mitsubishi Heavy Industries, Ltd)

14:25-14:50 **JCF13-4** S. Narita (Iwate Univ.) et al., "Measurement of low energy nuclear reaction in deuterium discharge experiment"

14:50-15:15 **JCF13-5** S. Ohshima (Toyota Central R & D Labs., Inc.) et al., "Verification of excess heat from PdDx irradiated by infrared laser"

-----**break** (15min) -----

**Experiment-2** (Chairman: A. Kitamura, Kobe Univ.)

15:30-15:55 **JCF13-6** G. Hosokawa (Iwate Univ.) et al., "Characterization of deuterium loading/unloading behavior for various types of multi-layered metal sample"

15:55-16:15 **JCF13-7*** N. Takahashi (Toyota Central R & D Labs., Inc.) et al., "Study on nuclear transmutation of Cs into Pr (1): Detecting Pr by SOR-XRF "

16:15-16:35 **JCF13-8*** S. Kosaka (Toyota Central R & D Labs., Inc.) et al., "Study on nuclear transmutation of Cs into Pr (2): Detecting Pr by ICP-MS "

16:35-17:00 **JCF13-9** Y. Iwamura (Advanced Technology Research Center, Mitsubishi Heavy Industries, Ltd) et al., "Increase of transmutation products in deuterium permeation induced transmutation"

17:00-18:00 **JCF Annual Meeting** (+ Reception Preparation)

18:00-20:00 **Reception (@Meeting Room 1209, Wink-Aichi)**

**December 9 (Sunday), 2012**

**Theory-2** (Chairman: K. Tsuchiya, Tokyo National College of Technology)

| | | |
|---|---|---|
| 9:30-9:55 | **JCF13-10** | Norman D. Cook (Kansai Univ.), "Quantum Nucleodynamics (QND) : Nuclear "models" are no longer necessary" |
| 9:55-10:20 | **JCF13-11** | T. Sawada (Nihon Univ.), "Restriction on the nuclear CF arising from the energy-momentum conservation" |
| 10:20-10:40 | **JCF13-12*** | H. Kozima (Cold Fusion Research Laboratory), "Characteristics of Solid-State Nuclear Track Detectors for Heavy Charged Particles" |
| 10:40-11:00 | **JCF13-13*** | H. Kozima (Cold Fusion Research Laboratory), "Emission of Charged Particles in the Cold Fusion Phenomenon" |
| 11:00-11:25 | **JCF13-14** | H. Miura, "Computer simulation of hydrogen states near T site in Pd metal" |

-----**lunch** (11:25-13:00)-----

**Experiment-3** (Chairman: S. Narita, Iwate Univ.)

| | | |
|---|---|---|
| 13:00-13:25 | **JCF13-15** | H. Sakoh (Kobe Univ.) et al., "Heat release characteristics of Ni-based samples absorbing hydrogen isotopes at high temperature" |
| 13:25-13:50 | **JCF13-16** | A. Kitamura ( Kobe Univ. ) et al., "Hydrogen isotope absorption / adsorption characteristics of mesoporous-silica-included samples" |
| 13:50-14:15 | **JCF13-17** | T. Hioki (Toyota Central R & D Labs., Inc.) et al., "Influence of Pd-particle size on isotope effect for heat generation upon pressurization with hydrogen isotope gases" |

-----**break** (15min)-----

**Theory-3** (Chairman: A. Takahashi, Technova Inc.)

| | | |
|---|---|---|
| 14:30-14:55 | **JCF13-18** | T. Sawada, (Nihon Univ.) "Magnetic monopole as the catalyst of the nuclear CF reaction" |
| 14:55-15:25 | **JCF13-19**** | H. Kozima (Cold Fusion Research Laboratory), "Cold fusion phenomenon in open, nonequilibrium, multi-component systems" |
| 15:25-15:50 | **JCF13-20** | H. Numata (Tokyo Institute of Technology), "Macroscopic view of electrified and magnetized interface under long-term evolution of deuterium in 0.1M LiOD" |

**Adjourn**

# The quantum states of the system including two species of charged bosons in ion trap I

Ken-ichi Tsuchiya, Soichiro Asami and Shinnosuke Kikuchi
Tokyo National College of Technology

In this study, we have considered the new method how to perform the numerical calculations for the problem on the mixtures of the positively charged bosons in ion trap, which was proposed by Kim et al. [1]. The system including the two species of positively charged bosons is characterized by two potentials. One is the electro-static repulsive interaction between the charged particles, which is written as the density functional of each boson. The other is the harmonic potential which expresses the confinement ability of the ion trap. If we know both of them, we can solve this problem completely. However, the electro-static potential and the number density of each boson are linked with each other and we cannot solve it by usual simple method. Therefore, we should introduce a self-consistent iterative calculation for the coupled two equations corresponding to the two species of positively charged bosons. In this method, the Schrödinger's equation and the Poisson's equation are solved alternately. We have shown them and defined the formulas for the numerical calculations.

These studies lead to understand the Bose-Einstein condensation of the mixture of charged bosons in ion trap. Similarly, the problem of the charged bosons trapped in the crystal is approximately characterized by the harmonic potential around the trapped site [2]. Therefore, we can estimate the nuclear reaction rate in solids by our method through the calculations of the wave functions and their overlaps.

References

[1] Y.E.Kim and A.L.Zubarev, "Mixtures of Charged Bosons Confined in Harmonic Traps and Bose-Einstein Condensation Mechanism for Low Energy Nuclear Reactions and Transmutation Process in Condensed Matter", Condensed matter Nuclear Science, Proc.of ICCF11, France, pp.711-717

[2] K.Tsuchiya, "Quantum States of Deuterons in Pd", International Journal of Hydrogen Energy, vol.29, pp.1513-1519, 2004

# The quantum states of the system including two species of charged bosons in ion trap II

Shinnosuke Kikuchi, Soichiro Asami and Ken-ichi Tsuchiya,
Tokyo National College of Technology

Using the theory by Y.E.Kim et al. for the mixtures of condensed charged bosons [1], we have considered the algorithm for the numerical calculation in order to obtain the self-consistent states of the system including two species of charged bosons in ion trap. The flow chart for the calculation is roughly sketched in Fig.1, where each boson is labeled by i=1,2. Here, the physical quantities $W_i$ and $n_i$ mean the electro-static repulsive potential and the number density for each kind of charged boson, respectively. It is easy to understand that the quantities are connected in parallel. Therefore, we should solve this problem by iterative calculations beginning from the initial potentials.

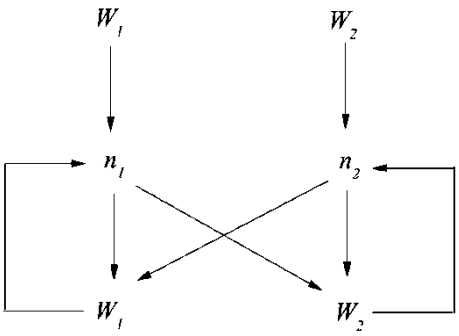


Fig.1 The flow chart for the iterative calculations

We have tried the calculation for the mixture of $D^+$ and $^6Li^+$. Then, the self-consistent solutions have been obtained successfully. This result shows that the two species coexist at a time in an ion trap. In near future, we will apply our method to the estimation of the nuclear reaction rate in solids.

Reference

[1] Y.E.Kim and A.L.Zubarev, ”Mixtures of Charged Bosons Confined in Harmonic Traps and Bose-Einstein Condensation Mechanism for Low Energy Nuclear Reactions and Transmutation Process in Condensed Matter”, Condensed matter Nuclear Science, Proc.of ICCF11, France, pp.711-717

# Nucleon Halo Model of $^{8}$Be*

Akito Takahashi[1*] and Daniel Rocha[2]

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A model of final state interaction for $^{8}$Be* of 4D/TSC fusion is proposed. The $^{8}$Be*(Ex=47.6MeV) may damp its excited energy by major BOLEP (burst of low energy photons) process from <n-h-h-n> nucleon-helion halo state to the $^{8}$Be-ground state. Intermediate decay states from the nucleon-halo states are scaled by number of effective binding PEF values for mean strong field interaction. Analogous states to A=8 ground state nuclei as $^{8}$He, $^{8}$Li and $^{8}$B which are typical neutron-halo states with rather long life times as 838 ms for $^{8}$Li are discussed, to speculate that the life time of <n-h-h-n> halo sate of $^{8}$Be*(Ex=47.6 MeV) may be as long as a few ms or more and the dominant BOLEP electro-magnetic transition will be sustained. More quantitative QM analysis is to be done to know the detail of discrete energy states for the very deformed halo state.

A complex decay scheme is proposed. Major decay channel is modeled as an electro-magnetic transition of BOLEP to the $^{8}$Be-ground state which breaks up to two 46 keV alpha-particles with 0.067fs life time. BOLEP is modeled as emission of rather slow (in a few ms) and stochastic burst events of ca. 1.5 keV averaged energy photons due to strongly coupled bosonic (nuclear phonon) states of many high spin quanta by the rotation-vibration coupled motion of very deformed <n-h-h-n> halo state of $^{8}$Be*(Ex=47.6 MeV). Minor channels are modeled as BOLEP transitions to lower even spin-parity excited states (Ex = 34, 27.5, 22.98, 22.0, 20.1, 16.6, 11.4 and 3.04 MeV), from where two-alpha break-up channels open. Minor two-alpha break-up channels emit characteristic discrete kinetic energy alpha-particles at 17, 13.8, 11.5, 11, 10, 8.3, 6.9, 5.7 and 1.55 MeV, which meets wonderful coincidence with observed data by Roussetski et al. The asymmetric break-up from the Ex = 34 MeV state has a branch to emit 5.2 MeV triton, which will induce secondary D-t reaction in deuterium contained metal to emit 9-19 MeV (En) neutrons that would have induced the 3-alpha tracks of CR39 detector by $^{12}$C(n,n')3α reaction as observed by Boss et al. X-ray burst data observed by Karabut et al may be photons by BOLEP. Further confirmation data by experiments for checking such consequences of the present work is expected.

[Note: this is abstract submittal to JCF-13 JCFRS-Meeting, December 8-9, 2012, Nagoya, Japan]

# Measurement of low energy nuclear reaction in deuterium discharge experiment

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It is desirable to investigate a low-energy DD-reaction rate in a metal for clarifying the mechanism of cold fusion phenomenon. Several researchers have reported the existence of non-negligible screening effects in low energy DD-reaction, which were observed in deuterium bombardment to solid-state targets. Kasagi *et al.* measured the DD-reaction rate in several metal and metal-oxide targets using an accelerator beam with the energy of $E_d$=2.5 keV [1]. In the case of using Pd target, the screening potential was found to be 310 eV, and it was much larger than that measured for gaseous targets. Although the accelerator experiment is a useful method to study DD-reaction systematically, the energy range of the deuteron is limited above $E_d$ > 2.0 keV due to drastic decrease of beam current with decrease of $E_d$. Alternatively, a deuterium discharge experiment is a suitable method to measure DD-reaction at the energy below 2.0 keV. Lipson *et al.* measured the screening energy in a deuterium glow discharge with Ti cathode, and it was found to be 610±150 eV in the deuteron energy range of 0.5 < $E_d$ < 2.45 keV [2]. Now it is still interesting to measure low-energy DD-reaction under several conditions.

In this study, we carried out the long-term discharge in deuterium atmosphere using a Pd cathode, and searched for nuclear events. In the experiment, a Pd foil sample (10 mm x 10 mm x 0.1 mm in size, and >99.95% in purity) was placed on the cathode of the discharge cell which is made of stainless steel. The stainless anode was used and the gap distance between the electrodes was set to be ~10 mm. After evacuating the cell to ~$10^{-3}$ Torr, deuterium gas is supplied until inside pressure became 1 Torr, followed by applying DC voltage to expose the sample to discharge with currents of ~1 mA and voltage of ~500 V. A set of CR-39 detectors was placed surrounding cathode to detect particles emitted during the discharge. As the result of performing 150 hours discharge, we found several numbers of three-clustered-tracks on CR-39, which might indicate high energy neutron emission. We will discuss an origin of the clustered tracks in this paper.

[1] J. Kasagi et al., *J. Phys. Soc. Jpn.* **71**, 2881 (2002).
[2] A. G. Lipson et al., *Proc. of ICCF10*, 635 (2006)

# Verification of Excess Heat from $PdD_x$ Irradiated by Infrared Laser

Shigeki Ohshima and Tomoyoshi Motohiro

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It is needed to realize the triple deuterium reaction described as D + D + D → $^4$He +D to produce $^4$He from deuterium. The probability of the triple deuterium reaction in plasma is extremely low because of the random motion of particles. D atoms absorbed in palladium are arranged at the specific site and they vibrate around these lattice points. In general, D atoms in palladium are located at the octahedral site [1]-[2]. However, numerical simulation using DFT (Density Functional Theory) shows that the energy barrier between the octahedral site and the tetrahedral site is 0.25 eV approximately. Therefore, there also are D atoms at tetrahedral site in a normal state. The phonon DOS analysis of $PdD_{0.75}$ where the D atom exists at the tetrahedral site shows peculiar phonon DOS distribution. There are two domains, one is by the vibration of Pd and D atoms, and the other is by the vibration of the D atom only. The frequency range of the latter case is 19~24 THz. Numerical analysis also shows there is counter vibration by three D atoms. If this mode can be generated, triple D reaction may occur.

In order to verify this hypothesis, an experimental apparatus was made. The source for the excitation of phonon is a far-infrared laser (28.3 THz). The measurement of the temperature of $PdD_x$ and $PdH_x$ both irradiated by the laser was done to observe the excess heat. The $PdD_x$ and $PdH_x$ samples were exposed to $D_2$ and $H_2$ gasses during the measurement. When the laser was irradiated, the temperature of both $PdD_x$ and $PdH_x$ rose very quickly, but the rising rate of the temperature of Pd only in the vacuum was relatively slow at the same irradiation condition. This result shows that the energy of the laser light is converted to the phonon effectively. The measurement of the temperature was done after the temperature became a steady state. The experimental results show that the temperature of $PdD_x$ is higher than that of $PdH_x$. But the heat conductivity of $H_2$ gas is larger than that of $D_2$, therefore, the theoretical analysis of the heat transfer was done using a cylindrical model. A new performance index was introduced to eliminate unknown parameters appeared in the analysis. Using this performance index with experimental results, it was confirmed that there was some excess heat from $PdD_x$.

References

[1] H. Okuyama, W. Siga, et al., “Path and mechanism of hydrogen absorption at Pd(100)”, Surf. Sci. 401, 344(1998).

[2] D. K. Ross, V. E. Antonov, et al., “Strong anisotropy in the inelastic neutron scattering from PdH at high energy transfer”, Phys. Rev. B, vol.58, 52591(1998).

# Characterization of deuterium loading/unloading behavior for various types of multi-layered metal sample

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Charged particle emission and anomalous heat evolution have been observed in deuterium loading/unloading process with multi-layered Au/Pd/MnO sample by Yamaguchi et al. [1]. Besides, a selective transmutation was observed in deuterium permeation with multi-layered Pd/CaO complex sample by Iwamura et al. [2]. These phenomena were supposed to be attributed to a low energy nuclear reaction in condensed matter. In addition, anomalous heat evolution was found in deuterium loading/unloading experiment with Pd-Ni binary nano-particles by Kobe-Technova group [3]. Considering these experimental results, we performed deuterium loading/unloading experiments using various types of multi-layered metal samples such as *Au*/Pd/*CaO*, *Pd*/*CaO*/Pd/*Au,* Pd/*CaO*, Pd/*Ni* , Pd/*Ag*.

In the experiment, these samples were fabricated by depositing thin metal layer(s) onto a Pd foil substrate by Ar ion beam sputtering. The multi-layered sample was loaded with deuterium being exposed to 5 atm $D_2$ gas for 20 hours. After loading, D loaded sample was set into the evacuated chamber (~$10^{-4}$ Pa) and applied the DC current to stimulate the deuterium diffusion. The surface temperatures of the sample and the inside pressure of the chamber were monitored continuously for 24 hours. The currents and voltages applied to the sample were also recorded. CR-39 detectors were set in the chamber for detecting charged particles. Then, we searched for anomalous heat evolution and charged particle emission which might be related to a nuclear reaction, and tried to clarify a trigger condition of the nuclear phenomenon in the deuterium loading/unloading behavior.

In this paper, we report the characteristics of the deuterium loading/unloading behavior followed by a possible nuclear phenomenon for various types of multi-layered sample. Furthermore, we will discuss the trigger condition to induce nuclear reaction in terms of the deuterium dynamics.

## Reference

[1] E. Yamaguchi *et al.*, Jp. J. Appl. Phys. 29 (1990) L666
[2] Y. Iwamura *et al.* Jpn. J. Appl. Phys. 41 (2002) 4642.
[3] H. Sakoh *et al.*, Proc of JCF11 (2011) 16.

# Study on Nuclear Transmutation of Cs into Pr (1) Detecting Pr by SOR-XRF

Naoko Takahashi, Satoru Kosaka, Tatsumi Hioki and Tomoyoshi Motohiro

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The selected nuclear transmutation of Cs into Pr has intensively been studied by Iwamura et al. [1, 2]. In 2002, they reported that Cs atoms deposited on top a Pd/CaO multilayer on a Pd substrate were changed to Pr atoms with deuterium ($D_2$) gas permeation through the multilayer system. Few following experiments performed in other laboratories, however, have successfully reproduced their results, probably because the amount of Pr generated from Cs is too small to detect and distinguish from contamination [3, 4].

We have compared the performance of trace Pr detection for several kinds of analysis methods, and adopted ICP-MS (Inductively Coupled Plasma Mass Spectrometry) as a tool to accurately detect small concentrations of Pr in multilayer samples with and without $D_2$ permeation treatments. As a result, we concluded that the amount of Pr in the $D_2$ permeated samples was one order of magnitude larger than those in the non-$D_2$ permeated samples [5]. This fact suggests that Pr detected in the samples after $D_2$ permeation is not due to chemical contamination.

Since ICP-MS is a tool to simply measure the mass of atoms or molecules, it is desired to confirm the result with other analysis methods. We have also tried to detect Pr in the samples treated with $D_2$ permeation using SOR-XRF (Synchrotron Radiation X-ray Fluorescence) [6-9]. In this paper, we will report the results of SOR-XRF spectroscopy.

[1] Y. Iwamura, T. Itoh and M. Sakano, *Jpn. J. Appl. Phys.* 41, 4642 (2002)
[2] Y. Iwamura, T. Itoh, M. Sakano, N. Yamazaki, S. Kuribayashi, Y. Terada, and T.Ishikawa *Proc. ICCF12*, Yokohama, Japan, PP.178-187 (2005)
[3] H. Yamada, S. Narita, T. Taniguchi, T. Ushirozawa, S. Kurihara, M. Higashizawa, H. Sawada, M. Itagaki, and T. Odashima, *Proc. ICCF12*, Yokohama, Japan, pp.196-205 (2005)
[4] T. Hioki, N. Takahashi and T. Motohiro, *Proc. ICCF13*, Sochi, Russia, pp.518-528 (2008)
[5] N. Takahashi, S. Kosaka, T. Hioki and T. Motohiro, *Proc. ICCF17*, Daejeon, Korea (2012)
[6] N. Takahashi, H. Nozaki, S. Yamaguchi, J. Gao, T. Nonaka, K. Dohmae, T. Hioki and Y. Seno, *SPring-8 Experimental Report*, 2008A5071 (2008)
[7] N. Takahashi, S. Kosaka, H. Nozaki, T. Nonaka, T. Hioki and T. Motohiro, *SPring-8 Experimental Report*, 2010B5070 (2010)
[8] S. Kosaka, N. Takahashi, H. Nozaki, T. Hioki and T. Motohiro, *SPring-8 Experimental Report*, 2011B5070 (2011)
[9] S. Kosaka, N. Takahashi, H. Nozaki, T. Hioki and T. Motohiro, *SPring-8 Experimental Report*, 2012A5070 (2012)

# Study on Nuclear Transmutation of Cs into Pr (2) Detecting Pr by ICP-MS

Satoru Kosaka, Naoko Takahashi, Tatsumi Hioki and Tomoyoshi Motohiro

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Nuclear transmutation with deuterium gas permeation through Pd/CaO/Pd multilayer complexes has been claimed by Iwamura et al [1]. They have reported transmutation reactions of Cs into Pr, Sr into Mo, and so on. A serious question for these results has been whether the observed elements are generated by nuclear reaction or are caused by chemical contamination. A difficulty in clarifying the origin of the observed element is the fact that the amount of the element is so small that it is not easy to detect it and distinguish from contamination.

In this study, ICP-MS (Inductively Coupled Plasma- Mass Spectroscopy) was employed as a tool to accurately measure a small amount of element, in order to examine the transmutation of Cs into Pr.

Substrates of Pd (purity: 99.95%) 100μm in thickness were commercially obtained. The as-purchased substrates were heat-treated in vacuum ($5\times10^{-5}$Pa) at 1173K for 15h and subsequently in the air at 873K for 10min to remove impurity atoms. Next, Pd/CaO multi layers were formed on the Pd substrates by pulsed laser deposition (PLD). Then Cs atoms were implanted in the multilayer at 65keV and to a dose of $1.5\times10^{15}$ atoms/cm$^2$. Subsequently, the Pd substrates were heat-treated in the air at 573K for 10min in order to remove carbonaceous materials deposited during the ion implantation. The samples were then subjected to $D_2$ gas permeation treatments at 423K and 9atm for about 250h. The $D_2$ permeation system was the same with our previous report [2]. The up-stream side was filled with $D_2$ of 900kPa. The purity of the $D_2$ gas was 99.995%. The down-stream side was evacuated with a dry pump and a turbo molecular pump. After the $D_2$ permeation, we dissolved the Pd substrates by nitric acid or aqua regia and analyzed them by ICP-MS ( Agilent: 7700X ).

We detected approximately 2.0 x $10^{12}$ atoms/cm$^2$ of Pr by ICP-MS in the $D_2$ permeated Pd/CaO/Pd multilayer samples with ion-implanted Cs atoms. The conversion rates, Pr/Cs, were in the order of 0.1%. On the other hands, the amounts of Pr atoms from the samples of non-$D_2$ permeated or totally resolved Pd substrates were as small as at most 1.0 x $10^{11}$ atoms/cm$^2$. In addition, the amount of Pr atoms from $H_2$ permeated samples was also as small as less than 1.0 x $10^{11}$.

We concluded that the amounts of Pr in the $D_2$ permeated samples were larger than those in the non-$D_2$ permeated comparison samples.

[1] Y. Iwamura, M. Sakano, and T. Itoh, “Elemental analysis of Pd complexes: effects of D2 gas permeation”, *Jpn. J. Appl. Phys.*, vol 41, pp.4642-4648, 2002.

[2] T. Hioki, N. Takahashi, and T. Motohiro, “ XPS study on surface layer elements of Pd/CaO multilayer complex with and without deuterium permeation” *Proc. ICCF-13*, Sochi, Russia, June25-July1, 2007, pp.518-528.

# Increase of Transmutation Products in Deuterium Permeation Induced Transmutation

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Transmutation reactions have been observed in nano-structured Pd multilayer thin film which is composed of Pd and CaO thin film and Pd substrate, induced by D2 gas permeation[1]-[2]. Experimental data that indicates the presence of transmutation have been accumulated and experimental conditions for inducing low energy transmutation reactions are gradually becoming clear, although systematic experimental study is still insufficient. Replication experiments have been performed by some researchers and similar results have been obtained [3]-[5]. The permeation induced transmutation technology would be expected as an innovative nuclear transmutation method for radioactive waste and a new energy source. However, it is necessary to increase the amount of transmutation products for commercialization.

In order to increase the transmutation products, we tired two types of experimental approaches. One is the electrochemical deuterium permeation method to increase the surface deuterium density near the surface of the nano-structured Pd multilayer film. The other is the laser irradiation method for making electron rich state near the surface. The electrochemical deuterium permeation method gave us increased transmutation products, although the effect of the laser irradiation method was not clear. Many kinds of transmuted products were obtained and gamma-ray emissions were observed by the electrochemical deuterium permeation method.

## References

[1] Y. Iwamura, M.Sakano and T.Itoh, "Elemental Analysis of Pd Complexes: Effects of D2 Gas Permeation", Japanese Journal of Applied Physics, Vol.41, (2002) pp. 4642-4650.
[2] Y. Iwamura, T. Itoh, N.Yamazaki, J. Kasagi, Y. Terada, T. Ishikawa, D. Sekiba, H. Yonemura and K. Fukutani, "Observation of Low Energy Nuclear Transmutation Reactions Induced by Deuterium Permeation through Multilayer Pd and CaO thin Film", J. Condensed Matter Nucl. Sci. vol.4 (2011) pp.132–144.
[3] N. Takahashi, S. Kosaka, T. Hioki and T. Motohiro, "Detection of Pr in Cs ion-implanted Pd/CaO multilayer complexes with and without D2 gas permeation", Proc. of ICCF17, to be published.
[4] T. Higashiyama, M Sakano, H. Miyamaru and A. Takahashi, "Replication of MHI Transmutation Experiment by D2 Gas Permeation Through Pd Complex", Proc. of ICCF10, edited by P. H. Hagelstein et al., Condensed Matter Nuclear Science, World Scientific, New Jersey (2006) pp.447-454.
[5] H. Yamada et.al., Producing Transmutation Elements on Plain Pd-foil by Permeation of Highly Pressurized Deuterium Gas, Proc. of ICCF12, ed. by A. Takahashi et al., Condensed Matter Nuclear Science, World Scientific, New Jersey (2006)pp.196-205.

# *Quantum Nucleodynamics (QND): Nuclear "models" are no longer necessary*

Norman D. Cook, Kansai University, Osaka, Japan

In 1937, Wigner showed that the quantum numbers of nucleons in the nuclear Schrodinger equation (Eq. 1) can be defined using their spatial coordinates (x, y, z) in an fcc lattice (Eqs. 2-8):

$$\Psi_{n,j\ (l+s),m,i} = R_{n,j\ (l+s),i}\ (r)\ Y_{m,j\ (l+s),i}\ (\theta, \phi) \qquad \text{Eq. 1}$$

| | | | |
|---|---|---|---|
| $n$ = (\|x\| + \|y\| + \|z\| - 3) / 2 | Eq. 2 | $s$ = spin = (-1)^((x-1)/2)/ 2 | Eq. 6 |
| $l$ = (\|x\| + \|y\| - 2) / 2 | Eq. 3 | $i$ = isospin = (-1)^((z-1)/2) | Eq. 7 |
| $j$ = (\|x\| + \|y\| - 1) / 2 | Eq. 4 | $\pi$ = parity = sign(x*y*z) | Eq. 8 |
| $m$ =\|x\| *(-1)^((x-1)/2)/ 2 | Eq. 5 | | |

As a consequence, if the quantum mechanical structure of a nucleus is known, then its lattice structure is also known because the shell/subshell occupancy of protons and neutrons are ***identical*** in both the "independent-particle model" (IPM) and the lattice. Unlike the gaseous IPM, however, the lattice geometry can be used to deduce the strength of nucleon-nucleon interactions (Tables 1 and 2).

Tables 1 and 2: Nucleon-nucleon binding energies deduced from regression analysis.

| *Multiple Regression* | |
|---|---|
| R | 0.99997 |
| R2 | 0.99995 |
| Corr. R2 | 0.99624 |
| Std. Dev. | 10.681 |
| No. Obs. | 273 |

| | *Coeff.* | *Std. Dev.* | *t* | *P-value* |
|---|---|---|---|---|
| 1st Neighbors | 2.697 | 0.034 | 78.23 | 0.000 |
| 2nd Neighbors | -1.172 | 0.072 | -16.24 | 0.000 |
| 3rd Neighbors | 0.592 | 0.047 | 12.51 | 0.000 |

| *Multiple Regression* | |
|---|---|
| R | 0.99999 |
| R2 | 0.99998 |
| Corr. R2 | 0.99620 |
| Std Dev | 7.4875 |
| No. Obs. | 273 |

| | *Coeff.* | *Std. Dev.* | *t* | *P-value* |
|---|---|---|---|---|
| PP1 | 2.596 | 0.298 | 8.723 | 0.000 |
| PP2 | -0.867 | 0.226 | -3.828 | 0.000 |
| PP3 | 1.363 | 0.168 | 8.113 | 0.000 |
| NN1 | 1.762 | 0.217 | 8.133 | 0.000 |
| NN2 | -0.380 | 0.142 | -2.677 | 0.008 |
| NN3 | -0.605 | 0.117 | -5.191 | 0.000 |
| PN1 | 2.681 | 0.125 | 21.437 | 0.000 |
| PN3 | 0.796 | 0.072 | 11.046 | 0.000 |

The strength of nucleon interactions has been determined from regression analysis (Tables 1 and 2) of the properties of 273 stable nuclei (e.g., Fig. 1). Noteworthy is the fact that the nuclear binding is: (i) distance-dependent, and (ii) 1st and 2nd neighbors (PP1, NN1, PP2, NN2) are attractive and repulsive, respectively, as expected for singlet pairs (⇧ ⇩ ) and triplet pairs (⇧ ⇧) of like-isospin nucleons.

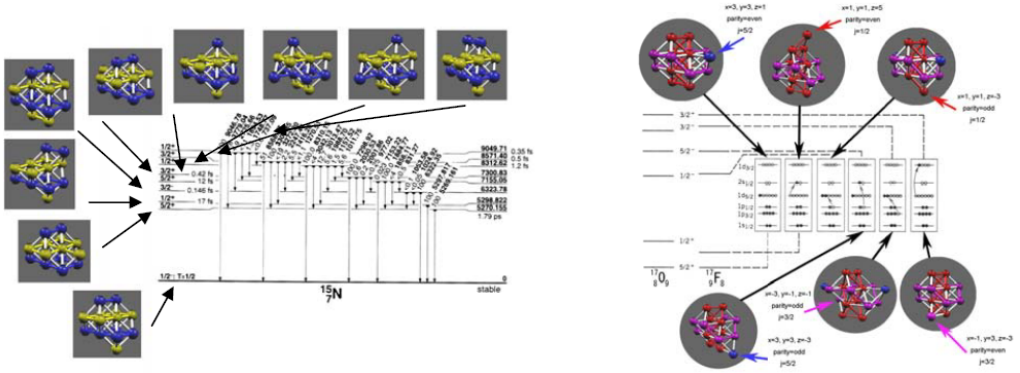

Fig. 1: As a consequence of Eqs. 1~8, nuclear binding energies can be calculated (e.g., $^{15}$N & $^{17}$O).

# Restriction on the nuclear CF arising from the energy-momentum conservation

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The conservation laws of the energy and the momentum are the most important thing to obey when we study the nuclear reaction for example. As Noether's theorem taught us, the conservation law appears from the symmetry of the system. In particular, the translational invariance in time implies the energy consevation, whereas the momentum conservation arises from the homogeneity of the space.

The final states of the d-d reactions in vacuum at low energy are $t + p$ and $^3He + n$ with 50% each in the branching ratio. In the c.m. system, the produced energy $Q$ is shared by the two final state particles by $Q = \vec{p'}^2/2m_1 + (-\vec{p'})^2/2m_2$. On the other hand, in the nuclear CF the reaction changes to $d + d \rightarrow^4 He$. When we examine the conservations, from the momentum conservation the momentum $\vec{q}$ of $^4He$ must be zero, whereas the energy conservation requires $q = \sqrt{2M_4Q}$, where $M_4$ is the mass of $^4He$. Therefore two conservations are not compatible. We know that the homogeneity of the space is often destroyed when the external field exists. Since $Q = 23.9$ MeV., the mementum transfer becomes $q = 422$ MeV./c. In the potential scattering we know the scattering amplitude is the Fourier transformation of the external potential $V(r)$: $a(q) = -(2m/4\pi\hbar)\int d^3r' \exp[i\vec{q}\cdot\vec{r'}]V(r')$. Since $|a(q)|^2$ is the probability of the momentum transfer, the spread of the potential $\Delta r$ must be very small in order to produce such a large momentum transfer. They are related by the uncertainty relation $q\Delta r \sim \hbar$, which means $\Delta r = 0.47$ fm. in our case.

The candidates of the source X of the external field are severely restricted. The external fields, to which the nucleus can respond, must be either electric or magnetic. However X cannot be the electric charge. This is because the electron cloud cannot become as small as $\Delta r = 0.47$ fm., since the size of the electron cloud must be larger than its Compton wave length, which is around 400 fm.. Another candidate of X is the magnetically charged particle (magnetic monopole), since the nuclei with the non-zero magnetic moment can respond to the magnetic field. Because of the charge quantization condition of Dirac, the magnetic field of the magnetic monopole is super-strong, namely $^*e^2/\hbar c = 137/4$. The interaction potential betweem the nucleon and the magnetic monopole is $V(r) = -\kappa_{tot}(e/2m_p)^*e(\vec{\sigma}\cdot\vec{r})/r^3$. This strong potential serves to form the bound states of the monople and the nucleons or small nuclei. For example, the binding energy of the $^*e-d$ system is around 2.4 MeV.. Therefore if the d-d reaction proceeds after two deuterons are trapped by the magnetic monopole, it is energetically impossible to become the $(t+p)$ or $(^3He+n)$ states. This is because the binding energy of $t$ and $^3He$ is 8.5 MeV. and 7.7 MeV. respectively. The only allowed final state is $^4He$, however it must leave the monopole, because the spin of $^4He$ is zero and there is no bound state of the monopole and $^4He$. The magnetic monopole simply plays the roll of the catalyst of the nuclear CF reaction.

# Characteristics of Solid-State Nuclear Track Detectors for Heavy Charged Particles

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## Abstract

Since Silk and Barnes observed the tracks of uranium fission fragments on the mica films, the formation of latent tracks by heavy charged particles in solids has been recognized as one of fundamental phenomena of the radiation damage. The formation of the latent tracks became an important device for detection of charged particles by the success of etch-pit technique developed by Price and Walker.

The technique to identify incident charged particles using their latent tracks in target solid-state detectors, especially CR-39, has been developed enthusiastically and used widely in nuclear physics, nuclear chemistry, nuclear energy, space science, and archeology. While the application of this technique is prosperous, the mechanism of the latent track formation in the target solids has been investigated actively and several proposals have been given. The “ion explosion mechanism” by Fleischer, Price and Walker and the “electron thermal spike mechanism” developed by Merkle, Chadderton and others are two main mechanisms considered as fundamental even if there remain many unknown factors in the relation between the incident particles and their latent tracks in solids.

The technique to use the particle track detector in identification of charge particles is not a finished one and developing rapidly at present as introduced in our paper presented at this Conference. We have to consider that the immediate and visible scientific problems of the particle track field are solid state physics questions not completely solved yet: How does a track form? What atomic processes take place? What is the ultimate atomic configuration along and around a track? Curiously enough these problems remain as some of the least studied, presumably because of the intense interest in the many applications of track etching that has directed attention to the assortment of fields.

The proposed mechanisms of nuclear track formation are summarized and problems in visualization of the tracks by chemical etching and possible application to identify charged particles and to determine their energies emitted in the cold fusion reactions are discussed.

# Emission of Charged Particles in the Cold Fusion Phenomenon

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## Abstract

Charged particles have been one of the main targets of investigation to confirm nuclear reactions in the cold fusion phenomenon (CFP) from the earliest stage of the cold fusion (CF) research after 1989 when Fleischmann et al. declared the discovery of a part of the CFP. It has been very difficult to obtain reliable data of emitted charged particles due to the inevitable energy losses in the passage of the particles from the source to the detector. Solid state detectors, silicon surface barrier detectors, plastic scintillation counters, Geiger-Muller counters, and sometimes proportional counters have been used in this field with difficulty in determination of the species of the charged particles.

Recently, however, the situation was drastically changed by the use of CR-39 plastic detector. This detector is very sensitive to charged particles and convenient to use at the site of the sample where nuclear reactions supposed to occur at. Though the detector has ambiguity in determination of the energies and the species of the charged particle which produced the radiation damage, there are several works that claimed observation of protons, deuterons and alpha particles with energies of several MeV.

The characteristics of detectors for charged particles emitted from CF materials including the CR-39 detector are discussed and species of the observed particles with their energies are compared each other.

Experimental data sets of charged particle emission obtained after 1990 have been summarized and investigated from our point of view that the whole experimental data obtained in the CFP from excess energy to nuclear transmutation through emissions of neutron and light charged particles should be interpreted consistently if these phenomena have a common cause that is the physics of the cold fusion phenomenon.

We confine our investigation in this paper to the experiments where are no excitations by such particles as proton, deuteron or photon with energies more than 1 keV. In our opinion, the physics caused by energetic particles in CF materials belongs to the low energy nuclear physics under the influence of CF materials even if it is a part of the solid-state nuclear physics or condensed matter nuclear science.

# Computer Simulation of Hydrogen States near T site in Pd Metal

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In order to examine which kind of conditions cause more than one hydrogen (H) to gather in condensed matter such as metals for nuclear fusion and nuclear transmutation, we simulated the states of hydrogen in palladium (Pd) metal of face centered cubic lattice using a quantum molecular dynamics on a personal computer. We calculated the total energy, charge density and electronic structure of the host bulk metal by a computer simulation program within Density Functional Theory based on the local density approximation using pseudo-potentials and a plane-wave basis.

Calculations were done about four H atoms located near a T site of Pd metal filled with H atoms in all O sites changing the inter-atomic distances of the tetrahedron surrounding the T site. The periodic boundary conditions were imposed on the computing 2x2x2 super cell of 28 Pd atoms and four vacancies next to some O sites.

We investigated the differences between the total energy when an impurity atom of H or alkali/alkaline-earth metal entered into the T site of Pd metal lattice and the total energy when it did not entered. We observed Ca and Li atoms could move easily from O site to T site under the small deformation of lattice such as thermal vibration. And we observed Ca atom could hop out from the T site being pushed by strong force, and Li atom could hop out by weak force. This seems to cause four H atoms surrounding the tetrahedron could enter into it replacing Ca or Li atom, and finally to cause nuclear transmutation because of collision of condensed four H atoms with other atoms of/in the Pd metal lattice recoiled by hopping out large Ca momentum and nuclear fusion through perfect condensation of four H atoms because of no collision recoiled by hopping out small Li momentum.

# Heat release characteristics of Ni-based samples absorbing hydrogen isotopes at high temperature

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Several researchers, F. Piantelli, B. Ahern, F. Celani, Rossi-Focardi, and our group, claimed excess heat from Ni-based alloy samples instead of expensive Pd-based nano-compound samples under application to gas-phase protium absorption experiments. We have compared hydrogen isotope absorption characteristics of the Cu(8%)-Ni(35%)-$ZrO_2$ (CNZ), the Cu(21.5%)-Ni(21.5%)-$ZrO_2$ (CNZII) and the Ni-$ZrO_2$ (NZ) nano-powders provided by Santoku Corporation, using the apparatus and the method same as those described in ref. [1].

No appreciable absorption by the samples nor heat release were observed at room temperature. We then performed the absorption runs at elevated temperatures. The heat evolution caused by absorption of hydrogen isotopes was measured by comparison of the sample temperatures with those in blank runs using He gases to correct roughly for the cooling effect due to introduction of the cool gas into the reaction chamber kept at high temperature. Correction was also made for possible fluctuation of the electrical input power into the heaters.

We observed heat release from the NZ, the CNZ and the CNZII samples at temperatures higher than 500K. The heat release of 1 W to 4 W continued for more than one week. Absorption of protium was more effective than deuterium absorption for the heat release, and the CNZ sample was more effective than the NZ and the CNZII sample. We infer that the Cu atoms act as a catalyst for hydrogen absorption of the Ni nano-particles to deepen the potential well for the adsorption/absorption.

The $\eta$ value defined as the output energy per one hydrogen isotope atom absorbed/adsorbed showed anomalously large values exceeding 100 eV/atom-H for the CNZ sample, and the integral output energy reached 800 eV/atom-Ni. Since such a large excess energy cannot be caused only by chemical reactions, it is strongly inferred that a nuclear process participates in the phenomena.

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# Hydrogen isotope absorption/adsorption characteristics of mesoporous-silica-included samples

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It has been clarified that reusability of Pd nanopowder samples for heat generation by gas-phase hydrogen isotope absorption can be enhanced by inclusion of the nanopowders into mesoporous materials [1,2,3]. It has also been found that addition of a small amount of Pd to the Ni nanoparticle sample changes the absorption characteristics of Ni drastically to enhance the loading ratio and heat release [4,5].

We have examined effect of mesoporous-silica-inclusion of Pd nanoparticles (PSII) and Pd·Ni nanoparticles (PNS), both supplied by Admatechs Co. Ltd. The former is composed of nanoparticles of Pd and mesoporous-silica with a mean size of 4 μm. The size of Pd ranges from about 3 nm to about 150 nm, with 90 % being in the range of 3 - 10 nm. The PNS sample was fabricated to have a mixture of 3-to-80-nm-diameter nanoparticles of Pd and Ni with a molar fraction of 0.011 and 0.062, respectively, in expectation of the similar function of the Pd atoms in the PNZ2B sample. The preliminary absorption characteristics at room temperature have been discussed in some detail in ref. [3].

The PSII samples have shown distinguishing absorption characteristics at room temperature. The as-received PSII samples showed very large loading ratio D(H)/Pd reaching 3.5 and absorption energy $E_1$ exceeding 2.5 eV/atom-Pd, if they are evaluated as the values per an atom of Pd or Pd·Ni, both being much larger than other Pd nanoparticle samples ever used. Subsequent runs without baking showed almost the same characteristics as those after forced de-oxidation with substantially decreased absorption parameters; D(H)/Pd ≈ 1.0, and $E_1$ ≈ 0.2 - 0.3 eV/atom-Pd. These are slightly larger than or equal to those of bulk Pd. However, forced oxidation recovered large values of D(H)/Pd ≈ 2.2 and $E_1$ ≈ 1.3 eV/atom-Pd.

The PNS samples have also shown interesting characteristics at room temperature. Similarly to the $ZrO_2$-supported PNZ2B sample, Pd atoms are acting as a catalyst for hydrogen absorption of Ni nanoparticles; D(H)/[$Pd_{0.15}Ni_{0.85}$] ≈ 0.4 and $E_1$ ≈ 0.5(0.4) eV/atom-$Pd_{0.15}Ni_{0.85}$. The potential of the hydrogen absorption sites in the present configuration is comparable to or even deeper than in other samples ever tested. Runs at elevated temperatures have shown increasing loading ratio in the saturation phase at temperatures above 473 K, which suggests existence of an additional absorption site with either positive or negative energy, depending on unknown and uncontrolled conditions.

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# Influence of Pd Particle Size on Isotope Effect for Heat Generation upon Pressurization with Hydrogen Isotope Gases

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Use of nanometer size particles of Pd has been recognized to be important for generating excess heat effect in gas loading experiments. Arata and Zhang used a powder sample of nano-Pd particles embedded in $ZrO_2$ matrix and reported that they generated heat arising from D-D nuclear fusion reaction simply by pressurizing the powder sample with deuterium gas [1].

In order to reproduce the excess heat effect reported by Arata and Zhang, we used Pd black and both of γ- $Al_2O_3$ and $ZrO_2$ dispersed with nano-Pd particles. However, we could not observe a marked difference between the heat generation upon pressurization with $D_2$ and $H_2$ [2]. This was probably due to the fact that the Pd particles grew significantly once they were exposed to $D_2$ or $H_2$. This fact means that it is difficult to pressurize nano-Pd samples with hydrogen isotope gases keeping the initial size of the nano-Pd particles. A possible way to prevent the growth of nano-Pd is to occlude Pd particles inside the pores of porous materials.

In this paper, we used zeolite and FSM (Folded Sheet mesoporous Material) as matrices to be dispersed with nano-Pd. The pore sizes of zeolite and FSM used were 1.1nm and 1.5-2nm, respectively. The heat generation during pressurization with $D_2$ or $H_2$ up to 1MPa was measured by a flow calorimeter. The heat measurements were cycled several times or more without exposing the samples to the air. Prior to each measurement the samples were always evacuated at 350℃ for 3 hours.

A large isotope effect for the heat generation was observed in a reproducible manner for both Pd/zeolite and Pd/FSM. The isotope effect decreased as increasing cycle of measurement for Pd/zeolite, while it was maintained up to several cycles or more for Pd/FSM.

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# Magnetic monopole as the catalyst of the nuclear CF reaction

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It is well-known that ,because of the strong Coulomb barrier, the nuclear fusion reaction such as $d + d \rightarrow^4 He$ can "never" occur in vacuum if we start the reaction with zero incident energy. We can check this if we compute the penetration factor P by using the WKB approximation, the value becomes as small as P= $10^{-106}$ in order of magnitude. On the other hand, when the magnetic monopole exists and is fixed at the origin, it attracts the deuteron if the magnetic dipole moment of d orients properly and they form the bound state *e-d. From the variational calculation we know that the binding enery of *e-d is around B= 2 MeV.

It is interesting to consider what happens when the second deuteron approaches to the bound state (*e-d). The second d feels two forces: one is the Coulomb repulsion from the first deuteron, another force is the attractive one between the monopole *e and the magnetic moment of the second deuteron when the spin of the second deuteron orients properly. This attractive force alone can improve the penetration factor P severely.

There is another important improvement to the penetration factor P. When we solve the Dirac equation of the electron in the external magnetic monopole potential, there exists a new energy level at E=-m, where m is the mass of the electron, whose orbital radius is around the Compton wave length of the electron. Because of the shielding by the electron, the penetration of the second deuteron to the (*e-d) system becomes much easier, and the penetration factor increses to the order of P=$10^{-7}$.

Since the radius of the orbit of (*e-d) is several fm., the (d-*e-d) system becomes unstable. Because of the nuclear interaction, two deuterons in the magnetic Coulomb field fuse to become more stable $\alpha$-particle. Since $\alpha$ particle does not have spin, it must leave the magnetic monopole. If we remember the track length of the $\alpha$ particle in the metal such as Pd is around several 100 $\mu$m., the kinetic energy of the $\alpha$ is deposited to the neighboring lattice. The temparature of the lattice increases locally. If we remember the trapping potential of the magnetic monopole in the lattice is proportional to $T^{-1/2}$, it must leave the hot spot and move to the cooler place. This is the hopping of the NAE (nuclear active environment). This phenomemon is in fact observed by Boss and Szpak, when they examined the surface of the cathode with the infrared camera.

# Cold Fusion Phenomenon in Open, Nonequilibrium, Multi-component Systems

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## Abstract

The cold fusion phenomenon (CFP) is known to occur only in specific systems satisfying several necessary conditions. The most important characteristic, which is well-known but sometimes put aside not explicitly taken into consideration, is that the system is open, nonequilibrium, multi-component one. There have been discovered three empirical laws in the CFP; (1) the stability effect of nuclear transmutation products, i.e. the more stable the nuclide, the more often generated by the nuclear transmutation in the CFP, (2) the $1/f$ dependence of the detection frequency on the intensity of the excess heat production, i.e. the number of events producing an excess power $P$ is proportional to the inverse power of $P$ with an index of about 1, and (3) the bifurcation of intensity of events (neutron emission and excess energy production) in time, i.e. the intensity of an event of a phenomenon bifurcates into two, four, eight branches in time and finally reaches a chaotic state if the condition lasts long enough. We are able to investigate the CFP as a complexity referring to the suggestion given by the three laws and conclude that the cold fusion phenomenon belongs to the complexity induced by nonlinear interactions between agents of the system composed of regular arrays of transition metals interlaced with those of hydrogen isotopes in an open, non-equilibrium condition. The characteristics of the CFP such as necessity of high ratio of D/Pd or H/Ni, preference of higher temperature of the system, and occurrence of positive feedback are investigated using our knowledge of the microscopic structure of the CF materials where occurs the CFP consulting to the complexity studied in non-linear dynamics in relation to the three empirical laws.

The controversial lack of reproducibility of the events in the CFP is a natural result of the complexity in which the cause-effect relation is characterized by stochastic processes resulting in statistical reproducibility of a phenomenon. The explosions observed several times in the history of CF research have been another riddle casting serious doubt to the reality of the CFP. This occurrence of tremendous release of excess energy in an instant is explained by the positive feedback of the reaction processes occurring in the system corresponding to the chaotic state of a nonlinear dynamics.

# Macroscopic view of electrified and magnetized interface under long-term evolution of deuterium in 0.1M LiOD

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**Abstract**: During long-term electrolysis for well annealed thick Pd rod (9.0 mm Φ) in 0.1M LiOD, vortex pattern was observed [1-2]. The morphology of the postelectrolysis electrodes revealed the two long faults without any cracks on the surface. N-cycle model was proposed [3-4], where the vortex threads move underbeneath of the surface to understand the CF phenomenon. Further the vortex threads were realized as the continuous flow of hypothetical particles mass from a vessel to a neighboring one in the Scavenger process. We noted that the magnetic configuration underbeneath of the surface layer plays an important role in the simulation of the motion of the hypothetical particles mass flow [5]. It has been demonstrated that there exists a strong electrified interface: double layer on the electrode surface.

In this study, we will discuss the structure of electrified interface under an influence of magnetic field induced by a current flow. Figure 1 shows perspective view of outflow of the hypothetical particles mass and vortex pattern appeared on Pd electrode surface after long-term electrolysis in 0.1MLiOD. In the sub-surface layer (Fig.1) a tunnel structure develops underbeneath of the electrode surface subjected to a long-term deuterium evolution, whereas deuterium bubbles in close proximity to the electrode can affect the macroscopic electric field and magnetic field of an electrolyte. As tentative macroscopic structural model is required to determine precise characteristics of the electrified and magnetized interface consisted of a working medium, solid and liquid, we will presume distributed tunnels inside the electrode and gaseous bubbles on the electrode surface.

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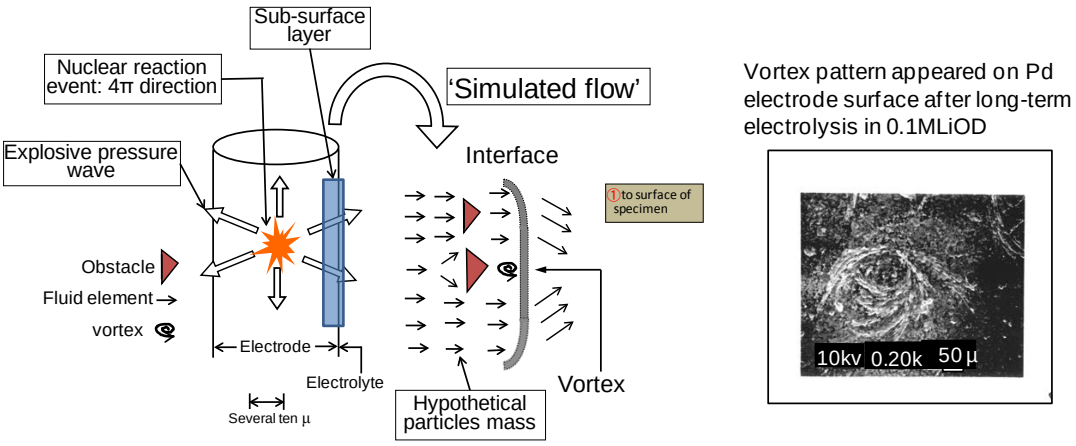


Figure 1 Perspective view of outflow of the hypothetical particles mass and vortex pattern appeared on Pd electrode surface after long-term electrolysis in 0.1MLiOD