From the History of Cold Fusion Research, **6**, pp. 1 – 10 (April 2015)

The First Confirmation of Localized Nuclear Reactions in CFP by M. Okamoto et al. (1994)*

Hideo Kozima
Cold Fusion Research Laboratory
597-16 Yatsu, Aoi, Shizuoka, 421-1202, Japan

*This paper was originally published in the *CFRL News* (*Cold Fusion Research Laboratory News*) No. 92 (2015.04.10).

It is a big and controversial problem where the nuclear reactions of the cold fusion phenomenon (CFP) occur in CF materials such as PdD_x(Li) (x~1) and NiH_x(K, Rb) (x~1) in relation to the fundamental nature of the CFP. The first concrete answer to this problem was given by Okamoto et al. in 1993 and 1994 [Nakada 1993, Okamoto 1994].

1. Confirmation of Localized Nuclear Reactions by Okamoto et al.

Let us cite a sentence from the paper by Nakada et al. presented at ICCF3, at first：
"*The depth profiles of Li, D and Pd were observed by SIMS technique for several Pd test pieces cut from the Pd electrodes employed in the study of neutron emission from the heavy water electrolysis using Pd-D_2O-LiOD system. The depth profiles can be classified into two types; one is the profile with a structure and the other is the monotonous profile. The former was observed on the Pd test piece from the Pd electrode with neutron emission, while the latter was from the Pd electrode without neutron emission*." [Nakada 1993 (p. 586)]

They succeeded their experiment and published a more detailed result at ICCF4 almost a year later:

The examples of the depth profiles of D, Li, Pd, Si, and Al are illustrated in Fig. 1.

The profiles with bold line represent the depth profiles of each elements obtained from the Pd sample with the nuclear effect of neutron emission and excess heat generation, the medium line for Pd sample with only neutron emission, and the chain-line for Pd sample with no nuclear effect. The curves shown in these figures are normalized to the secondary ion intensity of Pd obtained in each analysis run to carry out the discussion on the concentrations on the same elements. Evidently from the figures, the depth profiles of the elements with no nuclear effects are monotonous as expected from the electrochemical point of view. (2) While, the depth profiles with some nuclear effects have some of irregular structures, especially in the surface within 2 μm for every element. The depth profiles of lithium and deuterium are very similar in each. This fact indicates that there is a very strong chemical relation between the lithium behavior and the deuterium behavior as discussed in the previous paper." [Okamoto 1994 (p. 14-2)]

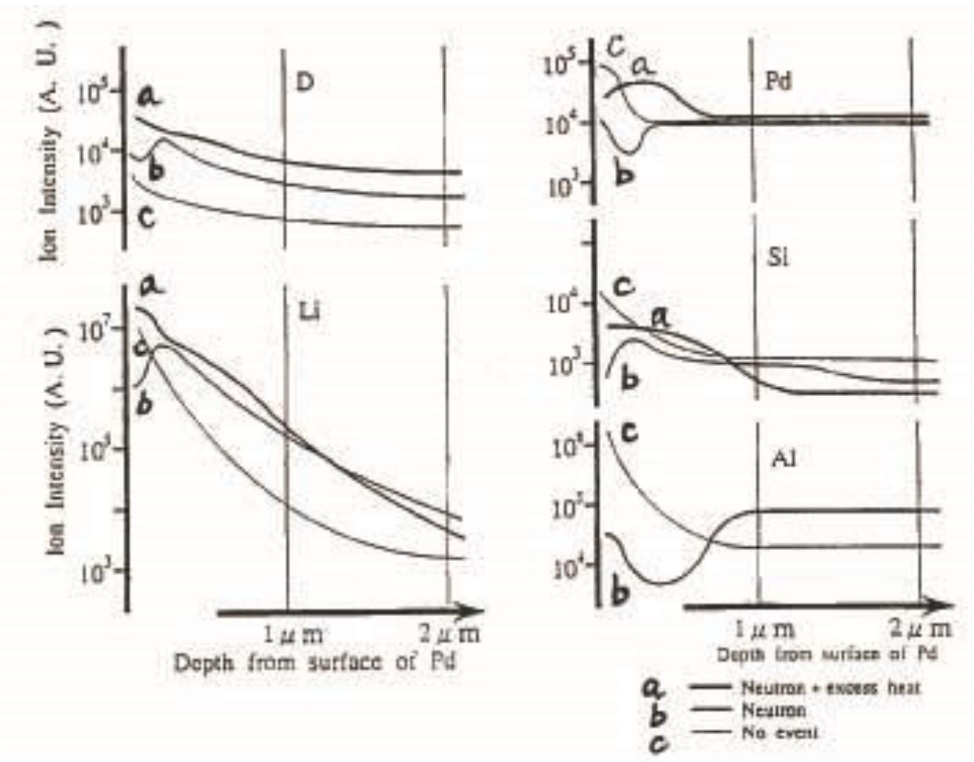

Fig. 1 Examples of depth profiles for each element.

We have explained the decrease of ${}^{27}_{13}$Al and increase of ${}^{28}_{14}$Si observed by Okamoto et al. as a result of the reaction followed by a beta-decay;

$${}^{27}_{13}\mathrm{Al} + n \rightarrow {}^{28}_{13}\mathrm{Al}^* \rightarrow {}^{28}_{14}\mathrm{Si} + e^- + \underline{\nu}_e,$$

where $\underline{\nu}_e$ represents an electron neutrino [Kozima 1996c] [Kozima 1998 (Sec. 11.11e)].

This paper ([Okamoto 1994]) is posted at CFRL website after the CFRL News No. 92:

http://www.geocities.jp/hjrfq930/News/news.html

The essays by Dr. Makoto Okamoto are posted at the CFRL website:

http://www.geocities.jp/hjrfq930/FTEssay/Essays/Okamoto.htm

Almost at the same time, Bockris et al. determined distribution of transmuted nuclei in

surface layers of a few micrometers [Bockris 1995]. The essay "*Cold Fusion 1999*" by Dr. J.O'M. Bockris is posted at CFRL website:
http://www.geocities.jp/hjrfq930/FTEssay/Essays/Bockris.htm

2. Meanwhile Many Researchers Expected the Localization of Nuclear Reactions in the CFP

It is interesting to recollect the transition of the interpretation of events related to the cold fusion phenomenon (CFP) from the first stage of the CF research in the development of the research. In the pioneering experiment performed by Fleischmann et al., they concluded that the nuclear reactions (*d*-*d* fusion reactions and other unidentified reactions) induced the products they observed had occurred in the bulk of the specimen;
"(a) *Excess enthalpy generation is markedly dependent on the applied current density (i.e. magnitude of the shift in the chemical potential) and is proportional to the volume of the electrodes, i.e. we are dealing with a phenomenon in the bulk of the Pd electrodes*." [Fleischmann 1989 (p. 304)]

In the process of development, researchers recognized importance of the surface layer of CF materials. We do not know why but there are many mentions in CF papers before the works by Okamoto et al. was published. For example, there are following sentences in the paper by McKubre et al. discussed in the previous News No. 91:
"*This observation raises the interesting possibility that one or more species, other than deuterium, are required to be present in the cathode in order to observe excess power, species which are not present initially and are thus required to diffuse into the cathode, presumably from the electrolyte. Analyses of used cathodes have revealed the presence of several light elements in the near-surface region (to a depth of several microns); in particular, lithium*." [McKubre 1993 (p. 18)]

The role of the surface layer, however, seems to be considered as subsidiary as above sentence shows and also the following sentence by Okamoto et al. shows:
"The process of anomalous accumulation of deuterium was discussed based on the formation of Pd-Li intermetallic compound in the surface area of Pd electrode." [Okamoto 1994 (p. 14-7)]

In this period, there is an interesting mention on the role of neutrons on the appearance of Ag and Au in the surface of Pd cathode by Dash et al. [Dash 1994]:
"*Palladium cathodes from two experiments were analyzed microscopically after electrolysis in acidified light and heavy water. For both experiments, more excess heat had occurred in the heavy-water cell than in the light-water cell during electrolysis. For the first experiment, there were localized concentrations of Au detected in areas of the*

high-current density on both cathodes; greater concentrations of Au were found on the cathodes from the heavy-water cell. For the second experiment, there were concentrations of Ag detected near sites of surface melting on the cathodes from the heavy-water cell. Although occurring in only a small fraction of cathodes, these unexpected elements correlate roughly with measured excess heat and may have arisen through transmutation caused by neutrons from nuclear fusion reactions." [Dash 1994]

We can add another example of nuclear transmutations. In the case of Ni mesh cathodes with light water based rubidium salt electrolytic cells, Bush et al. observed nuclear transmutations from Rb to Sr as discussed in the CFRL News No. 89:

"*Appendix A provides an interpretation of these from the standpoint of hypothetical strontium production. An interesting finding from the standpoint of the CAF Hypothesis* [1,3,6] *is the fact that, within experimental error, the ratio of the line height for mass number 86 to that for 88 was the same as that for the ratio of the rubidium signals at masses 85 and 87.*" [Bush 1994 (pp. 346 – 347)]

This data was explained by our TNCF model [Kozima 1996a, 1998 (Sec. 11.11b)]

The excellent analysis of Pd cathode provided by Fleischmann et al. to fined ^{4}He in the surface layer of a width of about 40 μm by Morrey et al. had been discussed already in our CFRL News No. 88. It is possible to say that this data obtained by Morrey et al. was the first determination of the local nature of the CFP from our present knowledge as we had discussed there. We have explained their experimental result by our TNCF model where ^{4}He was generated by Li-*n* reactions in the surface layer $PdLi_x$ [Kozima 1996b, 1997, 1998 (Sec. 11.8a), 1999] as suggested by the experimental data obtained by Nakada et al. and Okamoto et al.

3. Investigations of Nuclear Reactions at Surface Layers have been Extensively Performed with Various CF Materials

In the stream of these investigations of nuclear reactions in the surface layers, it should be emphasized that there are a few researchers who pursued the nature of these reactions in relation to the cold fusion phenomenon (CFP). T.O. Passell is one of them and has investigated nuclear transmutations of minor elements in surface layers of cathodes for several years [Passell 1996, 1998, 2002, 2006]. His data sets are fundamentally explained by our TNCF model and an analysis was given in our paper [Kozima 1996d] and book [Kozima 1998 (Sec. 11.11d)].

We have discussed the localization of nuclear reactions in the cold fusion phenomenon

(CFP) already at JCF Meeting and explained almost all experimental data sets by our TNCF model [Kozima 2011a]. The papers by Miley et al. [Miley 1996, 1997], Enyo et al. ([Mizuno 1996a, 1996b] and [Ohmori 1996, 1997, 1999], Qiao et al. [Qiao 1997], and Iwamura et al. [Iwamura 1998, 2005, 2006a, 2006b, 2006c] have been explained by TNCF model and summarized in the above paper [Kozima 2011a].

The essay "*Open Minded Attitudes to the Science*" by Dr. Michio Enyo is posted at the following CFRL website:

http://www.geocities.jp/hjrfq930/FTEssay/Essays/Enyo.htm

Lastly, I want to give a short glimpse at experiments with hydrogen non-occlusive metals. It is, at first sight, impossible to obtain any nuclear reactions from metals that do not occlude hydrogen isotopes. However, there are several positive experiments where observed excess heat and/or nuclear transmutation with Au, W and Pt electrodes. Ohmori et al. observed nuclear transmutations with gold (Au) and tungsten (W) electrodes [Ohmori 1996, 1997, 1999] and Noble et al. observed almost the same amount of excess heat with a Pt cathode coated with Pd and sulfate as that with Pd cathode [Noble 1995].

These data sets together with experiments with thin layers of hydrogen occlusive metals used by Miley et al., Iwamura et al., and Celani et al. [Celani 2010] are suggestive to consider where the CFP occurs in CF materials. The last experiment by Celani et al. was successfully analyzed by the TNCF model [Kozima 2011b].

It should be added an important contribution by Szpak et al. in the SPAWAR Systems Center San Diego. They noticed importance of electrode-electrolyte interface on the cold fusion phenomenon (CFP) and investigated various features of the CFP with electrodes of Ni, Au and Cu co-deposited with Pd-D on their surface [Szpak 1992, 1994, 2004, Mosier-Boss 1999].

References

[Bush 1994] R. Bush and R. Eagleton, "Evidence for Electrolytically Induced Transmutation and Radioactivity Correlated with Excess Heat in Electrolytic Cells with Light Water Rubidium Salt Electrolyte," *Trans. of Fusion Technology* (*Proc. ICCF4*), **26**, 344 – 354 (1994), ISSN: 0748-1896.

[Bush 1994a] R. Bush and R. Eagleton, "Evidence for Electrolytically Induced Transmutation and Radioactivity Correlated with Excess Heat in Electrolytic Cells with Light Water Rubidium Salt Electrolyte," *Proc. ICCF4* (Hawaii, USA, Dec. 6 — 9, 1993), Vol.**3**, 2-1 – 2-17 (1994), TR-104188-V3 (EPRI, Palo Alto, California, USA).

[Bockris 1995] J.O'M. Bockris and Z. Minevski, "Two Zones of 'Impurities' Observed after Prolonged Electrolysis of Deuterium on Palladium," *Infinite Energy,* **5 & 6**, 67 – 70 (1995 – 96).

[Celani 2010] F. Celani, P. Marini, V. Di Stefano, M. Nakamura, O.M. Calamai, A. Spallone. A. Nuvoli, E. Purchi, V. Andreassi, B. Ortenzi, E. Righi, G. Trenta, A. Mancini, A. Takahashi and A. Kitamura, "First measurement on Nano-coated Ni Wire, at Very High Temperature, under He, Ar, H_2, D_2 Atmosphere and Their Mixtures," Paper presented at 9th International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals (Certosa di Pontignano, Siena-Italy; Sept. 17 – 19, 2010).

[Dash 1994] J. Dash, G. Noble and D. Diman, "Surface Morphology and Microcomposition of Palladium Cathodes after Electrolysis in Acidified Light and Heavy Water; Correlation with Excess Heat," *Trans. of Fusion Technology* (*Proc. ICCF4*), **26**, 299 – 307 (1994), ISSN: 0748-1896.

[Dash 1994a] J. Dash, G. Noble and D. Diman, "Surface Morphology and Microcomposition of Palladium Cathodes after Electrolysis in Acidified Light and Heavy Water; Correlation with Excess Heat," *Proc. ICCF4,* Vol. **2**, 25-1 – 25-11 (1994), TR-104188-V2 (EPRI, Palo Alto, California, USA).

[Fleischmann 1989] M. Fleischmann, S. Pons and M. Hawkins, "Electrochemically induced nuclear fusion of deuterium," ***J.** E1ectroanal. Chem.*, **261**, 301—308 (1989), ISSN: 1572-6657.

[Iwamura 1998] Y. Iwamura, T. Itoh, N. Gotoh, M. Sakano and I. Toyoda, "Detection of Anomalous Elements, X-ray and Excess Heat induced by Continuous Diffusion of Deuterium through Multi-layer Cathode (Pd/CaO/Pd)," *Proc. ICCF7* (April 20 - 23, 1998, Vancouver, Canada), pp. 167 – 171 (1998). ($^{57}Fe/^{56}Fe$ ratio increased largely.)

[Iwamura 2005] Y. Iwamura, T. Itoh, M. Sakano and S. Sakai, "Observation of Low Energy Nuclear Reactions induced by D_2 Gas Permeation through Pd Complexes," *Proc. ICCF9* (2002, Beijing, China) pp. 141 – 146 (2005).

[Iwamura 2006a] Iwamura, T. Itoh, M. Sakano, S. Sakai and S. Kuribayashi, "Low Energy Nuclear Transmutation in Condensed Matter induced by D_2 Gas Permeation through Pd Complexes: Correlation between Deuterium Flux and Nuclear Products," *Proc. ICCF10* (2003, Massachusetts, USA) pp. 435 – 446 (2006), ISBN 981-256-564-7.

[Iwamura 2006b] Y. Iwamura, T. Itoh, M. Sakano, N. Yamazaki, S. Kuribayashi, Y. Terada, T. Ishikawa and J. Kasagi, "Observation of Nuclear Transmutation Reactions induced by D_2 Gas Permeation through Pd Complexes" *Proc. ICCF11,* pp. 339 – 349 (2006), ISBN 981-256-640-6,

[Iwamura 2006c] Y. Iwamura, T. Itoh, M. Sakano, N. Yamazaki, S. Kuribayashi, Y. Terada and T. Ishikawa, "Observation of Surface Distribution of Products by X-ray

Fluorescence Spectrometry during D_2 Gas Permeation through Pd Complexes" *Proc. ICCF12* pp. 178 – 187 (2006), ISBN 981-256-901-4.
[Kozima 1996a] H. Kozima, K. Hiroe, M. Nomura, M. Ohta, "Elemental Transmutation in Biological and Chemical Systems," *Cold Fusion* **16,** 30 – 32 (1996). ISSN 1074-5610. This paper is republished as [Kozima 2015].
[Kozima 1996b] H. Kozima, "Excess Heat and Helium Generation in Cold Fusion Experiments," *Cold Fusion* **17**, 4 – 7 (1996), ISSN 1074-5610.
[Kozima 1996c] H. Kozima, M. Ohta, M. Nomura and K. Hiroe, "Another Evidence of Nuclear Transmutation in Cold fusion Experiment," *Cold Fusion*, 18, 12 – 14 (1996), ISSN: 1074-5610.
[Kozima 1996d] H. Kozima, M. Nomura, K. Hiroe and M. Ohta, "Consistent Explanation of Experimental Data obtained in SRI International and EPRI," *Cold Fusion* **20**, 45 – 48 (1996), ISSN 1074-5610.
[Kozima 1997] H. Kozima, S. Watanabe, 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 – 178 (1997), ISSN: 1572-6657 and **445**, 223 (1998) (Errata).
[Kozima 1998] H. Kozima, *Discovery of the Cold Fusion Phenomenon* (Ohtake Shuppan Inc., 1998), ISBN: 4-87186-044-2. For the benefit of the readers, the Sections relevant to this analysis are posted at following pages of the CFRL Website:
http://www.geocities.jp/hjrfq930/Books/bookse/bookse01.html
The "References" in this book [Kozima 1998] is posted at the Cold Fusion Research Laboratory (CFRL) Website;
http://www.geocities.jp/hjrfq930/Books/bookse/bookse.html
[Kozima 1999] H. Kozima, K. Arai, M. Fujii, H. Kudoh, K. Yoshimoto and K. Kaki, "Nuclear Reactions in Surface Layers of Deuterium-Loaded Solids" *Fusion Technol*. **36**, 337 – 345 (1999), ISSN 0748-1896.
[Kozima 2002] H. Kozima, K. Yoshimoto, H. Kudoh, M. Fujii and M. Ohta, "Analysis of Zn and Excess Heat Generation in Pd/H_2 (D_2) System by TNCF Model," *J. New Energy*, 6-3, pp. 97 – 102 (2002), ISSN 1086-8259.
[Kozima 2007] H. Kozima, "An Explanation of Nuclear Transmutation in XLPE (Cross-linked Polyethylene) Films with and without Water Trees," *Proc. JCF8*, pp. 44 – 50 (2007).
[Kozima 2011a] H. Kozima, "Localization of Nuclear Reactions in the Cold Fusion Phenomenon," *Proc. JCF11* pp. 59 – 69 (2011), ISSN 2187-2260. And also *Reports of CFRL* (*Cold Fusion Research Laboratory*), **11-2**, pp. 1 – 20 (January, 2011)**:**

http://www.geocities.jp/hjrfq930/Papers/paperr/paperr.html
[Kozima 2011b] H. Kozima and F. Celani, "Brief Explanation of Experimental Data Set of Excess Heat and Nuclear Transmutation in Multiply Nano-coated Ni Wire," *Proc. JCF11*, pp. 53 – 58 (2011), ISSN 2187-2260. And also *Reports of CFRL* (*Cold Fusion Research Laboratory*), **11-1**, pp. 1 – 8 (January, 2011)**:**
http://www.geocities.jp/hjrfq930/Papers/paperr/paperr.html

[Kumazawa 2005] T. Kumazawa, W. Nakagawa and H. Tsurumaru, "A Study on Behavior of Inorganic Impurities in Water Tree," *Electrical Engineering in Japan* **153**, 1 – 13 (2005).

[McKubre 1993] M.C.H. McKubre, S. Crouch-Baker, A.M. Riley, S.I. Smedley and F.L. Tanzella, "Excess Power Observed in Electrochemical Studies of the D/Pd System," *Proc. ICCF3* (Oct. 21 – 25, 1992, Nagoya, Japan), pp. 5 - 19, Universal Academy Press, Inc., Tokyo, 1993, ISBN: 4-946443-12-6.

[Miley 1996] G.H. Miley, G. Narne, M.J. Williams, J.A. Patterson, J. Nix, D. Cravens and H. Hora, "Quantitative Observation of Transmutation Products occurring in Thin-film coated Microspheres during Electrolysis," *Proc. ICCF6* (1996, Hokkaido, Japan) pp. 629 – 644 (1996).

[Miley 1997] G.H. Miley and J.A. Patterson, "Nuclear Transmutations in Thin-film Nickel Coatings undergoing Electrolysis," *J. New Energy* 1-3, pp. 5 – 34 (1996), ISSN 1086-8259.

[Mizuno 1996a] T. Mizuno, T. Ohmori, T. Akimoto, K. Kurosawa, M. Kitaichi, K. Inoda, K. Azumi, S. Shimokawa and M. Enyo, "Isotopic Distribution for the Elements Evolved in Palladium Cathode after Electrolysis in D_2O Solution," *Proc. ICCF6*, 665 – 669 (1996).

[Mizuno 1996b] T. Mizuno, T. Ohmori and M. Enyo, "Anomalous Isotopic Distribution in Palladium Cathode after Electrolysis," *J. New Energy* **1-2**, 37 – 44 (1996), ISSN 1086-8259.

[Mo 1998] D.W. Mo, Q.S. Cai, L.M. Wang, S.Z. Wang, X.Z. Li, "The Evidence of Nuclear Transmutation Phenomenon in Pd-H System using Neutron Activation Analysis (NAA)," *Proc. ICCF7*, pp. 259 – 263 (1998).

[Morrey 1990] 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) , ISSN 0748-1896.

[Mosier-Boss 1999] P.A. Mosier-Boss and S. Szpak, "The Pd/^{n}H System: Transport Processes and Development of Thermal Instabilities." *Nuovo Cimento*. A**112,** 577 – 585

(1999), ISSN: 0369-3546.
[Nakada 1993] M. Nakada, Tl. Kusunoki, M. Okamoto and O. Odawara, “A Role of Lithium on Neutron Emission in Heavy Water Electrolysis,” *Proc. ICCF3*, 581 – 586 (1993), ISBN: 4-946443-12-6.
[Noble 1995] G. Noble, J. Dash and L. McNasser, “Electrolysis of Heavy Water with a Palladium and Surface Composite,” *Proc. ICCF5*, 136 – 139 (1995).
[Ohmori 1996] T. Ohmori, T. Mizuno and M. Enyo, “Isotopic Distributions of Heavy Metal Elements Produced during the Light Water Electrolysis with Gold Cathode,” *J. New Energy*, **1-3**, 90 – 99 (1996), ISSN 1086-8259.
[Ohmori 1997] T. Ohmori, M. Enyo, T. Mizuno, Y. Nodasaka and H. Minagawa, “Transmutation in the Electrolysis of Light Water – Excess Energy and Iron Production in a Gold Electrode,” *Fusion Technol.*, **31**, 210 – 218 (1997), ISSN 0748-1896.
[Ohmori 1999] T. Ohmori and T. Mizuno, “Nuclear Transmutation Reaction Caused by Light Water Electrolysis on Tungsten Cathode under Incandescent Conditions,” *Infinite Energy*, **27**, pp. 34 – 39 (1999).
[Okamoto 1994] 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. ICCF4* (Hawaii, USA, Dec. 6 — 9, 1993), Vol.**3**, 14-1 – 14-8 (1994), TR-104188-V3 (EPRI, Palo Alto, California, USA).
[Passell 1996] T.O. Passell, “Search for Nuclear Reaction Products in Heat-Producing Palladium,” *Proc. ICCF6*, pp. 282 – 290 (1996), (Published by New Energy and Industrial Technology Development Organization (NEDO) and The Institute of Applied Energy (IAE)).
[Passell 1998] T.O. Passell, “Search for Nuclear Reaction Products in Heat-Producing Pd,” *Proc. ICCF7*, pp. 309 – 313 (1998), (Published by ENECO).
[Passell 2002] T.O. Passell, “Evidence for Lithium-6 Depletion in Pd exposed to Gaseous deuterium and Hydrogen,” *Proc. ICCF9*, pp. 299 – 304 (2002), ISBN 7-302-06489- X/O·292.
[Passell 2006] T.O. Passell, “Pd-110/108 Ratio and Trace Element Changes in Particulate Palladium exposed to Deuterium Gas,” *Proc. ICCF10*, pp. 399 – 403 (2006), ISBN 981-256-564-7.
[Patterson 1997] J. Patterson, “US Patent #5,607,563” *Elemental Energy* (*Cold Fusion*), 22, pp. 3 – 17 (1997).
[Qiao 1997] G.S. Qiao, X.M. Han, L.C. Kong and X.Z. Li, “Nuclear Transmutation in a Gas-Loading H/Pd System,” *J. New Energy*, **2-2**, pp. 48 – 52 (1997), ISSN 1086-8259.
[Szpak 1992] S. Szpak, P.A. Mosier-Boss, S.R. Scharber and J.J. Smith, “Charging of

the Pd/^{n}H System: Role of the Interphase," *J. Electroanal. Chem.*, **337,** 147 – 163 (1992).
[Szpak 1994] S. Szpak, P.A. Mosier-Boss and J.J. Smith, "Deuterium Uptake during Pd-D Co-deposition," *J. Electroanal. Chem.*, **379,** 121 – 127 (1992).
[Szpak 2004] S. Szpak, P.A. Mosier-Boss, M.H. Miles and M. Fleischmann, "Thermal Behavior of Polarized Pd/D Electrodes Prepared by Co-deposition," *Thermochimica Acta*, **410,** 101–107 (2004).