The Material Science Aspects of Low Energy Fusion

Edmund Storms
Kiva Labs, Santa Fe, NM
storms2@ix.netcom.com
Keywords: cold fusion, LENR, clean energy, materials, gap

Abstract

The fusion reaction called "cold fusion" is difficult to initiate. This difficulty has hampered research and slowed acceptance of the effect. Progress requires this unique fusion reaction to be produced with greater reliability. This paper describes the treatments found to improve success.

INTRODUCTION

Thirty-four years ago, Profs. Martin Fleischmann and Stanley Pons(F-P)[1] claimed to produce the fusion of deuterium in PdD using electrolysis of D_2O + LiOD. The claim was soon rejected because most efforts failed to reproduce the claim and the claimed fusion process conflicted with the common understanding of how such nuclear reactions are known to behave. The phenomenon was initially called cold fusion. Now the preferred name is Low Energy Nuclear Reaction (LENR) because nuclear reactions in addition to fusion have been found to occur.

Despite the continued rejection over the last thirty-four years, thousands of studies done in at least 12 countries and in dozens of laboratories have demonstrated that the claimed fusion does indeed occur. The resulting publications can be accessed at www.LENR-CANR.org, where the full text of some papers cited here can be found. In addition, the results of these studies are summarized in many books and reviews. The DOE (Department of Energy) is even providing $10M to study the process.

This nuclear process generates heat energy by forming ^4He[2] without radioactive products other than occasional tritium[3] or harmful radiation. Such a clean and friendly energy would eliminate the generation of CO_2 from the use of fossil fuels and the dangerous radioactive materials when the fission of uranium is used. In addition, the damage to the environment caused by conventional energy sources could be eliminated. Besides these practical benefits, the behavior reveals the operation of a mechanism that is in direct conflict with conventional understanding. This conflict opens the door to a new understanding of how nuclear processes might be made to occur in a chemical environment.

Success in attracting support for further research requires the reasons for rejection to be acknowledged and addressed. Several reasons were used as justification for rejection. As an example, when people tried to replicate the claimed behavior, they failed. They did not realize that most Pd is not able to support the fusion process. Rather than blame their failure on the use of inactive material, they concluded that F–P had made a mistake and the claim was not valid. This paper focuses on the various ways palladium can be made to support the fusion mechanism, thereby making failure less frequent. A universal condition is proposed to be required, which is identified as physical gaps having a critical dimension, not

vacancies[4] or defects[5]. This universal condition can be created in any material using many different treatments with the size of the gap being the critical variable.

DISCUSSION

The mechanism requires a unique and rare condition to form within the material, which is called the nuclear active environment (NAE). The mechanism operating in the location is still unknown, but clearly unusual. Because PdD is the material on which the main effort to cause LENR has been focused, experience using this material will be used here even though other materials have been found to support the fusion reaction.

Over the last 33 years, a large number of treatments has been explored with only a few showing more than random success. Even agreement about the reason for success is lacking. This paper describes several methods and the reason for their success, with citations to the papers where more detail can be found. The goal is to show the reader where to look for more information.

1. Early Experience

Very soon after the discovery of LENR was announced, several people discovered that certain batches of Pd were able to cause it with reliability without additional treatment. For example, Takahashi[6] obtained a sheet of Pd about 1 mm thick from Tanaka Precious Metals, Japan. Most samples he cut from this sheet produced excess power when electrolyzed in D_2O. To test this rare ability, he sent samples to various laboratories including to me at Los Alamos National Laboratory (LANL). This sample was the first one I studied after having designed and built a suitable calorimeter[7]. The 9 W of excess power really got people's attention at LANL. Other people who used his material had similar success. Eventually, the sample stopped working, so I requested another sample. Takahashi no longer had any of the original material, so he had another sheet made. Upon testing, this Pd was found to produce no excess energy. Takahashi discovered that Tanaka Metals had not given this batch of Pd the same treatment as before. A third batch was made using the same treatment as was applied to the first sheet. This batch again made excess power.

This experience provided two important lessons. Active batches of Pd can make excess energy in various laboratories when different calorimeter designs are used, thereby replicating the F-P claim. In addition, when a special treatment is used, the entire batch of Pd will produce excess power. McKubre reported the same experience when a spool of Pd wire produced excess power when most pieces were electrolyzed in D_2O. Fleischman and Pons had the same experience when Johnson-Matthey (J-M), the company that supplied their Pd, was able to produce samples that showed significant success in their hands. Other people had similar success when they used this material.[8]

The treatments used by J-M and Tanaka Metals were never made public. Nevertheless, Fleischmann provided a clue when he revealed that CaB_6 was added to molten Pd to remove the oxygen impurity by the formation of B_2O_3 and CaO, which would float most of the oxygen to the surface as the respective oxides. This purification process would leave small particles of CaO behind as small particles that would be distributed throughout the batch of Pd when the final sheet of metal

was fabricated. These particles are proposed to cause a suitable sized gap to form around each particle after the Pd is reacted with a critical amount of deuterium as determined by the particle size.[9] In this way, the success produced by samples from the entire batch, regardless of the physical form, wire or sheet, can be explained. If true, this explanation would identify the critical treatment and eliminate many of the complex treatments now being used to activate a material.

To test this idea, particles of CaO were melted with Pd. When a mixture of sizes having a maximum size of 34 μm was added to liquid Pd, the metal produced excess energy after being formed into a flat disc and reacted with D_2 gas.[9] A larger collection of sizes failed to activate the Pd. The exact gap size required to cause LENR is still not known.

2. Nature of the gap structure

The fusion process is proposed to involve a unique structure that forms in gaps of a critical dimension by a chemical process to which the Laws of Thermodynamics apply. The gap provides the required environment for the unique structure to form and the structure has the ability to initiate nuclear interaction between all isotopes of hydrogen. [9] The mechanism causing this structure to form is presently unknown. Further descriptions of this proposed process is provided in future papers.

3. Deposit of Impurities on the Surface

Several successful treatments have been used to activate Pd. In 1996, Storms[10] summarized the available information. At that time, McKubre et al.[11] found that the addition of Al metal to the electrolyte containing LiOD increased success. The metal would slowly dissolve by forming AlO+ in the solution. This ion would be attracted to the cathode where it would deposit and form small islands of Al_2O_3, which is stable to reaction with large activity of hydrogen present at the cathode surface. The nano-gaps between the resulting islands are proposed to be the NAE. Other stable deposits, such as uneven deposits of gold[12-14] would be expected to cause similar behavior. Such deposits would produce LENR only at the surface of the sample and within the deposited material.

Oxidation of Pd below 800° C causes the surface to form a layer of PdO, which makes the material very reactive to D_2 gas and occasionally nuclear active.[15, 16] Reaction with D_2 would produce a surface consisting of fine particles of PdD with the gaps being at the contact points between the particles. The effective reaction with D and the resulting large D/Pd ratio might also cause sites in the bulk to become active.

4. Extended Electrolysis

Fleischmann and Pons[17] found that Pd would become active after being electrolyzed for many weeks in an electrolyte containing LiOD. This process would cause Li to react with and dissolve in the PdD forming the alloy Pd-Li-D in which the Li occupies the same lattice locations as Pd. Yamazaki et al.[18] studied this process and found that the amount of dissolved Li increased with increased time and current, as

shown in Fig. 1. Asami et al. [19] reported the same behavior. Heating the cell during electrolysis would increase the reaction rate with Li and the activation process.[20]

According to the phase diagram shown in Fig. 2. This addition would eventually saturate the cubic structure and form another phase, $LiPd_7$, having a different structure (cF32-type). This process would be expected to cause cracks and nano-gaps to form, as was observed. In this case, the fusion reaction would happen only very near the surface where the Li has concentrated.

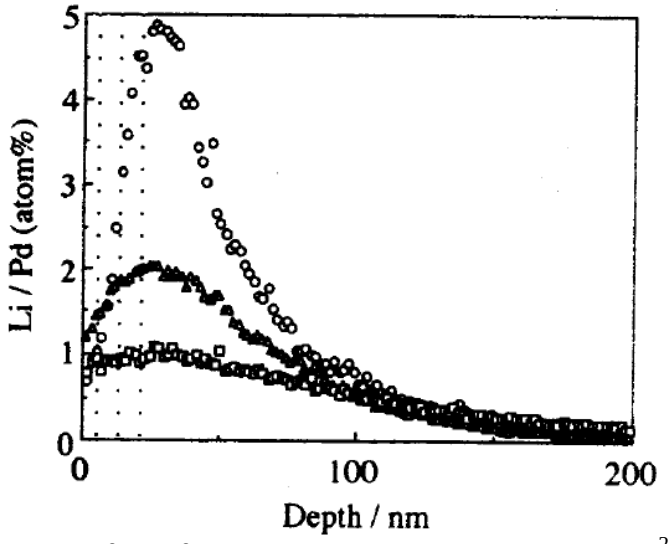

FIGURE 1. Depth profile of the Li/Pd ratio when 500 mA/cm^2, 5 mA/cm^2, and 0.5 mA/cm^2 were applied to Pd in LiOH at 298°C.

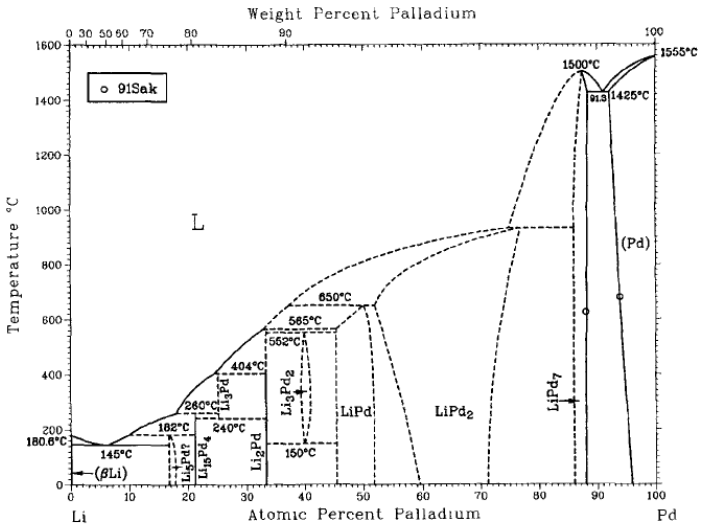

FIGURE 2. Phase diagram of the Li-Pd system [21]

5. Codeposition

The codeposition (Codep)[22, 23] causes small islands of Pd to deposit on the surface of the cathode when an electrolyte containing $PdCl_2$+DCl or LiCl is used. This method is found to produce frequent success. However, the challenge is to keep the

poorly bonded particles from being removed from the surface by bubbles of D_2 generated at the surface. The use of a very low current (~0.5 mA) while the Pd is being deposited largely solves this problem. Gap formation between these small islands of Pd is proposed to be required for success. The deposited Pd can be removed from the electrolytic cell and made to produce energy when exposed to D_2 gas at modest pressures without the formation of chlorine and chlorine oxide adding to the complexity, as is the case when electrolysis is used.

6. Nanoparticles

Particles having dimensions in the nanometer range are unstable to sintering by which larger particles form. For example, Arata and Zhang[24, 25] placed palladium-black, which consists of Pd with a nanometer size, in a sealed container of Pd. This assembly was reacted with D using electrolysis, during which time heat and helium were detected. When McKubre et al. [26, 27] successfully replicated this study, the palladium-black was found to have formed a solid mass in which the original small particles were no longer present. Nevertheless, small gaps would be present in the structure. In other words, the original claim for the particle size being important is no longer justified because the fusion process is unaffected by the change in particle size.

To prevent sintering, Takahashi et al.[28, 29] caused the small particles of a metal to be isolated in ZrO_2. This design has been studied with success with many variations, but with the success being attributed to nano-particles being required. The role of nano-gaps cannot be eliminated by their experience.

Case[30, 31] used coconut charcoal on which small particles of Pd were deposited to produce the fusion reaction. Activation of the wet form of the catalyst required heating to 200° C followed by the sudden release of steam. The resulting small particles of $PdCl_2$ could then be reduced to Pd using D_2 gas. This work was replicated by McKubre et al.[26] using the material supplied by Case. The nuclear reaction probably occurred in the charcoal rather than on the nanoparticles of Pd because the use of a different batch of charcoal failed to produce LENR even when the Pd was applied the same way. The particles of Pd probably were only needed to split the D_2 gas molecule to make D+ ions available to the gaps in the charcoal.

7. Layers of Pd on CaO

Since 1993[13], Iwamura et al.[32, 33] have studied various ways to cause LENR. Methods to cause the production of excess power as well as complex transmutation reactions were explored using sandwiched thin layers of metal on various oxides. These layers are expected to contain suitable gaps formed as a result of stress relief resulting from miss-matched expansion.

8. Large D/Pd Ratio

McKubre et al.[11] emphasize the need to achieve a large D/Pd ratio, which cannot be achieved by most Pd. However, when the Pd was able to reach a D/Pd ratio greater than 0.85 at 20° C, they found that the amount of power increased when the D/Pd ratio was further increased, as shown in Fig. 3. Kamimura et al.[34] reported similar behavior. Storms found that a large D/Pd ratio was not always required when certain samples of Pd were reacted with D_2 gas.[35]

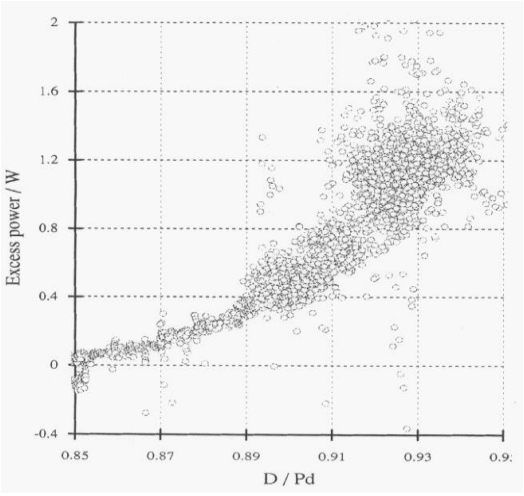

FIGURE 3. Effect of D/Pd ratio on excess power production when samples from an active batch of Pd wire were reacted in an electrolytic cell near 20° C. [11]

9. Effect of Temperature

The increased temperature was known since 1990 to increase power production.[36] Since then, this effect has been studied in greater detail.[35, 37-40] Of importance, most of the samples I have studied made no detectable power at room temperature yet would produce significant power when heated. Perhaps more success would have been reported if the samples had been simply heated.

10. Reaction with D or H

After active material has been made, it needs to be reacted with D or H, both of which will produce LENR at similar rates. Three methods have been used to add these isotopes of hydrogen; electrolysis, direct reaction with the gas, and gas discharge using low-pressure gas to which is applied about 700 v to cause the formation of plasma.

Electrolysis[11, 41, 42] involves using the active material as the cathode (-) and Pt as the anode (+) in a cell containing a conductive electrolyte. Most people use LiOD or LiOH, made frequently by adding Li metal to the respective water. The D/Pd ratio can be determined using the resistivity[43], by measuring the amount of oxygen released when the D reacts with the Pd. The amount of this "orphaned oxygen" can be measured either as a pressure change or as a volume using oil displaced from a reservoir, or by measuring the temperature of the catalyst used in a closed cell. This method has the advantage of producing a very high D/Pd ratio but the disadvantage of having a temperature limit near the boiling point of the electrolyte.

The gas reaction involves allowing the material to remain in contact with the gas long enough to achieve a fully saturated composition. As can be seen in Fig. 4, the ability to achieve a high D/Pd ratio involves the application of D_2 gas at very high-pressure, with 1 atm of D_2 producing a D/Pd ratio near 0.7 at 20°C. Increased temperature causes the pressure to increase. Fig. 5 shows an example of the pressure change when the alpha+beta two-phase region is heated.[44, 45] The amount of the alpha phase will decrease in favor of the beta phase when the two-phase material is heated, with complete conversion to the beta phase occurring near 300 °C.

Unless the cell is designed to hold the pressure, some gas would be released when the pressure limit is reached, causing a loss of D_2 and a change in the D/Pd ratio. I have found that this loss of D does not effect on the ability of the material to support the fusion reaction after the fusion reaction starts.

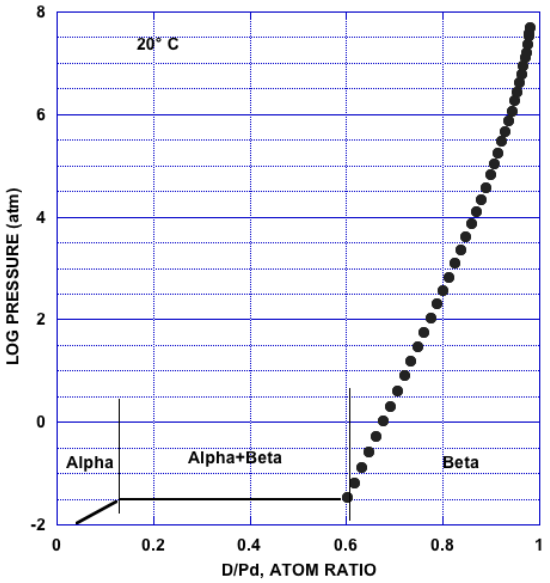

FIGURE 4. Log pressure vs D/Pd for the beta phase at 20°C.

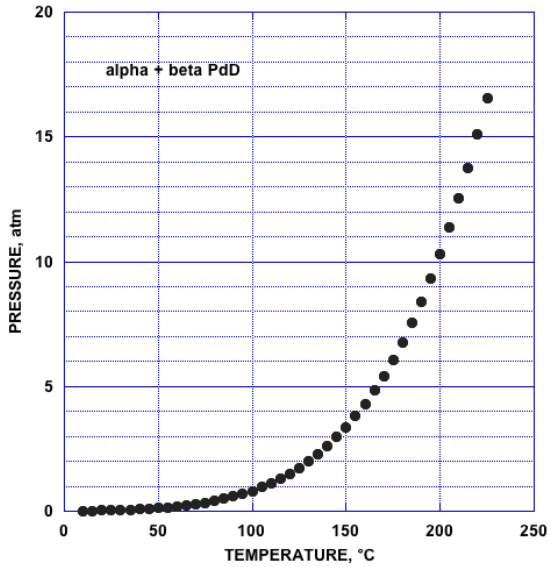

FIGURE 5**.** Log pressure vs temperature when both alpha and beta PdD are present.

Gas discharge involves bombarding a surface with low-energy D+ ions that diffuse into the material to provide fuel for the LENR mechanism. Numerous studies have explored this process over a wide range of applied energy. As energy is increased to perhaps greater than a few thousand volts, evidence for the hot fusion mechanism is observed as the emission of neutrons.[46-50] However, the fusion rate is too low for the heat energy to be measured. In contrast, when cold fusion is triggered at low energy, the

reaction rate is sufficient to produce detectable heat energy[51-54] as well as unusual nuclear radiations[55-59] without neutron emission. In other words, two different mechanisms can be triggered, one at low applied energy and another at greater applied energy. These two reactions have different rates and different nuclear products. Therefore, they would not be caused by the same mechanism.

SUMMARY

The behavior obtained from many treatments points to gaps having dimensions in the nanometer range being required to support the cold fusion reaction. The gaps are proposed to provide a chemical environment in which nuclei and electrons can assemble so that the Coulomb barrier can be overcome by a novel screening mechanism.[60]

Such gaps can be produced in several different ways in Pd and perhaps in other materials as well. They can form as a result of expansion when the material reacts with D or H, they can form as the result of stress relief when impurities are added to Pd, or they can form as gaps between small particles of an inert material deposited on the surface of any material. This description provides a path to improve the ability to cause cold fusion. For example, such gaps might also be created in high concentration with reproducibility by nano-machining the required gap size in a suitable metal. This technique would avoid the many uncontrolled variables that frustrate efforts to cause active sites to form in a chemical environment using a chemical process.

It's important to realize that the fusion reaction takes place only in a few isolated sites in an active material and the measured energy results from the total power produced by these individual sites. Therefore, the measured power would be sensitive to the number of active sites. These sites can be located anywhere in the material, depending on the treatment, and can come and go at random times. This behavior makes a study unpredictable and difficult to interpret.

The use of high temperature and perhaps other stimulations need to be encouraged. These include the application of laser radiation of certain frequencies[61], the use of magnetic fields[62, 63], and the passing of high current through the material.[64]

Although skill and patience are still required to initiate LENR, nuclear reactions can now be made to occur at the rates required for scientific study when the methods described here are followed.

ACKNOWLEDGMENTS

The author is grateful for the editorial suggestions provided by Thomas Grimshaw.

References

[1] M. Fleischmann, S. Pons, M.W. Anderson, L.J. Li, M. Hawkins, Calorimetry of the palladium-deuterium-heavy water system, J. Electroanal. Chem. 287 (1990) 293.

[2] E.K. Storms, The status of cold fusion (2010), Naturwissenschaften 97 (2010) 861.

[3] E.K. Storms, The science of low energy nuclear reaction, World Scientific, Singapore, 2007.

[4] M. McKubre, M.R. Staker, On the role of Super Abundant Vacancies (SAV's) in hydrogen loading and production of the Fleischmann Pons Heat Effect, 13th International Workshop on Anomalies in Hydrogen Loaded Metals, Italy, 2018.
[5] S. Szpak, F. Gordon, The Fleischmann–Pons effect: Reactions and processes, J. Cond. Matter Nucl. Sci. 12 (2013) 143-57.
[6] A. Takahashi, T. Iida, T. Takeuchi, A. Mega, Excess heat and nuclear products by D_2O/Pd electrolysis and multibody fusion, Int. J. Appl. Electromagn. Mater. 3 (1992) 221-30.
[7] E.K. Storms, Measurements of excess heat from a Pons-Fleischmann-type electrolytic cell using palladium sheet, Fusion Technol. 23 (1993) 230.
[8] M. Miles, Excerpts from Martin Fleischmann Letters, JCMNS 19 (2016) 210-8.
[9] E.K. Storms, The Nature of Cold Fusion (Cold Fusion Made Simple), Solid State Energy Summit, ICCF24, www.LENR.org, Mountain View, CA, 2022.
[10] E.K. Storms, How to produce the Pons-Fleischmann effect, Fusion Technol. 29 (1996) 261.
[11] M.C.H. McKubre, S. Crouch-Baker, A.M. Riley, S.I. Smedley, F.L. Tanzella, Excess power observations in electrochemical studies of the D/Pd system; the influence of loading, in: H. Ikegami (Ed) Third International Conference on Cold Fusion, "Frontiers of Cold Fusion", Published by: Universal Academy Press, Inc., Tokyo, Japan, Held at: Nagoya Japan, 1992, pp. 5.
[12] D. Letts, D. Cravens, Cathode fabrication methods to reproduce the Letts-Cravens effect, ASTI-5, www.iscmns.org/, Asti, Italy, 2004.
[13] Y. Iwamura, T. Itoh, I. Toyoda, Observation of anomalous nuclear effects in D_2-Pd system, Trans. Fusion Technol. 26 (1994) 160-4.
[14] Y. Iwamura, T. Itoh, N. Gotoh, I. Toyoda, Detection of anomalous elements, X-ray, and excess heat in a D_2-Pd system and its interpretation by the electron-induced nuclear reaction model, Fusion Technol. 33 (1998) 476.
[15] F. Celani, A. Spallone, P. Tripodi, A. Petrocchi, D. Di Gioacchino, P. Marini, V. Di Stefano, M. Diociaiuti, A. Mancini, Study of deuterium charging behavior in palladium and palladium alloy plates, charging surface treatments, by μs pulsed electrolysis, in: S. Pons (Ed) 5th International Conference on Cold Fusion, IMRA Europe, Sophia Antipolis Cedex, France, Monte-Carlo, Monaco, 1995, pp. 411.
[16] A.G. Lipson, B.F. Lyakhov, V.A. Kuznetsov, T.S. Ivanova, B.V. Deryagin, The nature of excess energy liberated in a Pd/PdO heterostructure electrochemically saturated with hydrogen (deuterium), Russ. J. Phys. Chem. 69 (1995) 1810.
[17] S. Pons, M. Fleischmann, Calorimetry of the palladium-deuterium system, in: F.G. Will (Ed) The First Annual Conference on Cold Fusion, National Cold Fusion Institute, University of Utah Research Park, Salt Lake City, Utah, 1990, pp. 1.
[18] O. Yamazaki, H. Yoshitake, N. Kamiya, K. Ota, Hydrogen absorption and Li inclusion in a Pd cathode in LiOH solution, J. Electroanal. Chem. 390 (1995) 127.
[19] N. Asami, T. Senjuh, H. Kamimura, M. Sumi, E. Kennel, T. Sakai, K. Mori, H. Watanabe, K. Matsui, Material behaviour of highly deuterium loaded palladium by electrolysis, in: M. Okamoto (Ed) Sixth International Conference on Cold Fusion,Progress in New Hydrogen Energy, New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan, Lake Toya, Hokkaido, Japan, 1996, pp. 67.

[20] W.-S. Zhang, Characteristics of Excess Heat in Pd D_2O+D_2SO_4 Electrolytic Cells Measured by Seebeck Envelope Calorimetry, in: V. Violante, F. Sarto (Eds), 15th International Conference on Condensed Matter Nuclear Science, ENEA, Italy, Rome, Italy, 2009, pp. 27-32.
[21] H. Okamoto, Phase diagram of the Li-Pd system J. Phase Equilibrium 124 (1993) 653.
[22] S. Szpak, P.A. Mosier-Boss, J.J. Smith, Deuterium uptake during Pd-D codeposition, J. Electroanal. Chem. 379 (1994) 121.
[23] P.A. Mosier-Boss, L.P. Forsley, F.E. Gordon, Overview of Pd/D Co-deposition, J. Cond. Matter. Nucl. Sci. 29 (2019) 34-40.
[24] Y. Arata, Y.C. Zhang, Helium (^{4}He, ^{3}He) within deuterated Pd-black, Proc. Jpn. Acad., Ser. B 73 (1997) 1.
[25] Y. Arata, Y.C. Zhang, Observation of anomalous heat release and helium-4 production from highly deuterated fine particles, Jpn. J. Appl. Phys. Part 2 38 (1999) L774.
[26] M.C.H. McKubre, F.L. Tanzella, P. Tripodi, P.L. Hagelstein, The emergence of a coherent explanation for anomalies observed in D/Pd and H/Pd system: evidence for ^{4}He and ^{3}He production, in: F. Scaramuzzi (Ed) 8th International Conference on Cold Fusion, Italian Physical Society, Bologna, Italy, Lerici (La Spezia), Italy, 2000, pp. 3-10.
[27] B.W. Clarke, B.M. Oliver, M.C.H. McKubre, F.L. Tanzella, P. Tripodi, Search for ^{3}He and ^{4}He in Arata-style palladium cathodes II: Evidence for tritium production, Fusion Sci. & Technol. 40 (2001) 152-67.
[28] A. Kitamura, Y. Sasaki, Y. Miyoshi, A. Taniike, A. Takahashi, R. Seto, Y. Fujita, Heat evolution from Pd nano-powders exposed to high-pressure hydrogen isotopes and associated radiation measurements, J. Cond. Matter Nucl. Sci. 4 (2011) 56-68.
[29] A. Takahashi————————————, A. Kitamura, R. Seto, Y. Fujita, Taniike, Y. Furuyama, T. Murota, T. Tahara, Anomalous Exothermic and Endothermic Data Observed by Nano-Ni-Composite Samples, JCMNS 15 (2015) 23-32.
[30] L.C. Case, Catalytic fusion of deuterium into helium-4, in: F. Jaeger (Ed) The Seventh International Conference on Cold Fusion, ENECO, Inc., Salt Lake City, UT, Vancouver, Canada, 1998, pp. 48.
[31] L. Case, There is a Fleischmann-Pons effect. The process is electrolytic, but the effect is catalytic., in: X.Z. Li (Ed) The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science, Tsinghua Univ. Press, Tsinghua Univ., Beijing, China, 2002, pp. 22.
[32] Y. Iwamura, J. Kasagi, T. Itoh, T. Takahashi, M. Saito, Y. Shibasaki, S. Murakami, Progress in Energy Generation Research Using Nano-Metal With Hydrogen/Deuterium Gas, JCMNS 36 (2022) 285-301.
[33] Y. Iwamura, M. Sakano, T. Itoh, Elemental analysis of Pd complexes: effects of D_2 gas permeation, Jpn. J. Appl. Phys. A 41 (2002) 4642-50.
[34] H. Kamimura, T. Senjuh, S. Miyashita, N. Asami, Excess heat in fuel cell type cells from pure Pd cathodes annealed at high temperatures, in: M. Okamoto (Ed) Sixth International Conference on Cold Fusion,Progress in New Hydrogen Energy, New

Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan, Lake Toya, Hokkaido, Japan, 1996, pp. 45.
[35] E. Storms, The Nature of the Fusion Reaction in Palladium and Nickel, JCMNS 36 (2022) 377-94.
[36] M. Fleischmann, S. Pons, Calorimetry of the Pd-D_2O system: from simplicity via complications to simplicity, Phys. Lett. A 176 (1993) 118.
[37] T. Kobayashi, J. Shigemura, K. Naitoh, Y. Mori, R. Seto, J. Hachisuka, Temperature and Pressure Dependence of Anomalous Heat
Generation Occurring in Hydrogen Gas Absorption by Metal Powder, JCMNS 36 (2022) 318-26.
[38] Y. Sato, K. Oshima, T. Yamamoto, M. Kishida, M. Uchimura, Study of Sustained Heat Generation from Pd-Ni-Zr Alloys inHydrogen from the Viewpoint of Hydrogen Absorption, J. Cond. Mater. Nucl. Sci. 37 (2022) 1-13.
[39] G. Lonchampt, L. Bonnetain, P. Hieter, Reproduction of Fleischmann and Pons experiments, in: M. Okamoto (Ed) Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy, Published by: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan, Held at: Lake Toya, Hokkaido, Japan, 1996, pp. 113-20.
[40] G. Mengoli, M. Bernardini, C. Manduchi, G. Zannoni, Calorimetry close to the boiling temperature of the D_2O/Pd electrolytic system, J. Electroanal. Chem. 444 (1998) 155.
[41] E. Storms, Anomalous Energy Produced by PdD, J. Cond. Matter. Nucl. Sci. 20 (2016) 81-99.
[42] E. Storms, The Enthalpy of Formation of PdH as a Function of H/Pd Atom Ratio, ICCF-21, Fort Collins, CO, 2018.
[43] M.C. McKubre, F. Tanzella, Using resistivity to measure H/Pd and D/Pd loading: Method and significance, in: A. Takahashi, K. Ota, Y. Iwamura (Eds), Condensed Matter Nuclear Science, ICCF-12, World Scientific, Yokohama, Japan, 2005, pp. 392.
[44] R.P. Santandrea, R.G. Behrens, A review of the thermodynamics and phase relationships in the palladium- hydrogen, palladium-deuterium and palladium-tritium systems., High Temperature Materials and Processes 7 (1986) 149.
[45] P.L. Hagelstein, Statistical Mechanics Models for PdDx and PdHx Phase Diagrams with both O-site and T-site Occupation, J. Cond. Matter. Nucl. Sci. 29 (2019) 401-15.
[46] W.R. Arnold, J.A. Phillips, G.A. Sawyer, E.J. Stovall, J.L. Tuck, Cross sections for the reactions D-T, D-He, T-He, He-He below 120 kev., Phys. Rev. 93 (1954) 483-97.
[47] F.E. Cecil, D. Ferg, T.E. Furtak, C. Mader, J.A. McNeil, D.L. Williamson, Study of energetic charged particles emitted from thin deuterated palladium foils subject to high current densities, J. Fusion Energy 9 (1990) 195.
[48] J. Kasagi, H. Yuki, T. Baba, T. Noda, J. Taguchi, W. Galster, Energetic protons and alpha particles emitted in 150-keV deuteron bombardment on deuterated Ti, J. Phys. Soc. Japan 64 (1995) 777-83.
[49] J. Kasagi, Y. Honda, Screening Energy of the d+d Reaction in an Electron Plasma Deduced from Cooperative Colliding Reaction, J. Cond. Matter. Nucl. Sci. 19 (2016) 127-34.

[50] K. Czerski, New evidence of the cold nuclear fusion – accelerator experiments at very low energies, New Advances on the Fleischmann-Pons Effect, European Parliament, Brussels, 2013.
[51] A.B. Karabut, Production of excess heat, impurity elements and unnatural isotopic ratios in high-current glow discharge experiments, in: P.L. Hagelstein, S.R. Chubb (Eds), Tenth International Conference on Cold Fusion, World Scientific Publishing Co., Cambridge, MA, 2003, pp. 99.
[52] A.B. Karabut, E.A. Karabut, Electric and heat measurements in high voltage electrolysis cell experiments, in: D.L. Nagel, M.E. Melich (Eds), 14th International Conference on Condensed Matter Nuclear Science, Washington DC, 2008, pp. 168-75.
[53] J. Dufour, J. Foos, J.P. Millot, Excess energy in the system palladium/hydrogen isotopes. Measurement of excess energy per atom hydrogen, in: S. Pons (Ed) 5th International Conference on Cold Fusion, IMRA Europe, Sophia Antipolis Cedex, France, Monte-Carlo, Monaco, 1995, pp. 495.
[54] D.G. Letts, D.J. Cravens, Building and Testing a High Temperature Seebeck Calorimeter, J. Cond. Matter. Nucl. Sci. 29 (2019) 334-47.
[55] E.K. Storms, B. Scanlan, Detection of radiation from LENR, in: D.L. Nagel, M.E. Melich (Eds), 14th International Conference on Condensed Matter Nuclear Science, www.LENR.org, Washington, DC, 2008, pp. 263-87.
[56] E.K. Storms, B. Scanlan, Radiation produced by glow discharge in deuterium, in: J. Rothwell, P. Mobberley (Eds), 8th International Workshop on Anomalies in Hydrogen / Deuterium Loaded Metals. 2007., http://www.iscmns.org/catania07/index.htm. The International Society for Condensed Matter Science, Catania, Sicily, 2007, pp. 297-305.
[57] S. Narita, A. Arapi, N. Sato, D. Kato, M. Yamamura, M. Itagaki, H. Yamada, Gamma-ray detection in DC glow like discharge with deuterated palladium electrode, Jpn. J. of Appl. Phys., Part 2: Letters 42 (2003) L1185-L7.
[58] T. Matsumoto, Extraordinary traces produced during pulsed discharge in water, Bull. Faculty of Eng., Hokkaido Univ, 175 (1995).
[59] A.B. Karabut, Y.R. Kucherov, I.B. Savvatimova, Nuclear product ratio for glow discharge in deuterium, Phys. Lett. A 170 (1992) 265-72.
[60] E.K. Storms, The explanation of low energy nuclear reaction, Infinite Energy Press, Concord, NH, 2014.
[61] E.K. Storms, Use of a very sensitive Seebeck calorimeter to study the Pons-Fleischmann and Letts effects, in: P.L. Hagelstein, S.R. Chubb (Eds), Tenth International Conference on Cold Fusion, World Scientific Publishing Co., Cambridge, MA, 2003, pp. 183-97.
[62] M.R. Swartz, Impact of an applied magnetic field on a high impedance dual anode LANR device, J. Cond. Matter Nucl. Sci. 4 (2011) 93-105.
[63] B. Liu, X. Li, L. Yan, L. Ge, Triggering a deuterium flux In Pd wire using electromagnetic field, in: P.L. Hagelstein, S.R. Chubb (Eds), Tenth International Conference on Cold Fusion, World Scientific Publishing Co., Cambridge, MA, 2003, pp. 227.
[64] R.E. Godes, Energy generation apparatus and method, US 2007/0206715 A1, Profusion Energy, Inc., USA, 2007.