



Research Article

Possible Role of Oxides in the Fleischmann–Pons Effect

Jean-Paul Biberian*

Aix-Marseille University, Jardin du Pharo - 58, bd Charles Livon -13284 Marseille Cedex 07, France

Iraj Parchamazad[†] and Melvin H. Miles[‡]

University of LaVerne, 3rd St, La Verne, CA 91750, USA

Abstract

The mechanism of the Fleischmann–Pons effect is not yet fully understood. It appears that in many occasions an oxide layer or an insulating layer covers the surface of the active material. In this paper, we list a number of experiments displaying such situation and suggest possible roles of these oxide layers.

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1. Introduction

It is well known that the Fleischmann–Pons effect needs specific situations where nuclear cold fusion reactions occur [1]. It has been established that high loading is necessary in order to observe excess heat [2]. However, this condition is not sufficient. For example, the variation of the flux of the deuterium through the surface of the palladium electrode is also a necessity [2]. In order to understand the mechanism of Cold Fusion many theories have been developed to explain the effect, but none of them is completely satisfactory. However, from an experimental point of view there are indications that the metals involved in the reaction are rarely free of impurities. Various oxide films often cover their surfaces. It is very possible that these layers play a role in the reaction. In this paper, we review some experimental results showing the existence of such oxide films on the active metal surfaces. The existence of these oxide layers has been observed both in electrolysis experiments and in gas-loading studies.

*E-mail: jpbiberian@yahoo.fr

†E-mail: iparchamazad@laverne.edu

‡E-mail: mmiles@laverne.edu

2. Electrolysis Experiments

2.1. The original Fleischmann and Pons experiment

The original Fleischmann and Pons experiments were performed in Pyrex cells using LiOD as an electrolyte. This solution being basic slowly etches the walls of the Pyrex container, and the etched material then deposits on the palladium cathode. This behavior has been discussed in details by Lonchamp et al. [3]. Analysis of the deposit on the electrode showed the presence of silicon, carbon, and oxygen [4]. The role of the oxide layer has been confirmed by the impossibility of getting excess heat with Teflon cells unless oxide materials were added [5]. Studies using polymer coated glass cells also failed to give any excess heat effects even when previously active electrodes were used [6].

The mechanism of formation of the oxide film can be described as follows: LiOD reacts with the Pyrex glass producing lithium silicates in the electrolyte solution. Silicon and lithium based deposits form on both the cathode and anode. Such deposits result in the production of a higher over-voltage on the electrodes. As a consequence, the input power increases due to the fact that most experiments are performed at constant currents; the temperature may then gradually rise up to boiling. On the other hand, the consequence of the cathodic deposit is an increase of the D^+ electrochemical potential at the cathode, which in turn increases the loading of deuterium. As mentioned previously, the higher loading helps the excess heat generation. This mechanism explains why long electrolysis times are required.

Fleischmann has proposed another approach to the role of the oxide layer [7]: the silicate deposit at the palladium cathode blocks the surface and prevents the flow of the current for most of the surface of the electrode. The current is then restricted to small regions of cracks in the silicate layer. In these regions, the current density becomes very high, and because the over-voltage increases with the current density, the deuterium loading greatly increases. Another advantage of the silicate layer is that it prevents de-loading by blocking the recombination of deuterium atoms at the palladium-solution interface. The deuterium atoms enter through the cracks and are blocked elsewhere by the silicate layer, therefore increasing the loading ratio, and this helps in producing excess heat.

2.2. Fleischmann/Imam/Miles

In order to help to create this surface oxide layer, Fleischmann/Imam/Miles [8] have added boron and cerium to the palladium. With this method, excess heat has been obtained nearly every time [8]. The boron composition ranged from 0.25 to 0.75 wt%, with boron/palladium atom ratios as high as 1:7. Excess power was observed much earlier than normal and was readily measurable during the first 57 h of electrolysis in an isoperibolic calorimeter [9].

3. Gas Diffusion Experiments

3.1. Yamaguchi and Nishioka

As early as 1990, Yamaguchi and Nishioka [10] observed a gigantic neutron burst of $(1-2) \times 10^6$ neutrons/s from deuterated palladium plates with heterostructures in a vacuum chamber. An explosive release of D_2 gas, biaxial bending of the samples, and excess heat was also observed at the same time. It was concluded that these phenomena are caused by the cooperative production of deuterium atoms accumulation layers at the palladium surfaces due to the controlled out-diffusion of deuterium atoms. Figure 1 shows a schematic of the palladium sample, with a thin film of manganese oxide on one side and a gold film on the other.

3.2. Lipson et al.

Lipson et al. [11] have shown the production of 3 MeV protons, X-ray emission when deuterium desorbs from Pd/PdO films. These observations are in agreement with those of Yamaguchi and Nishioka described above.

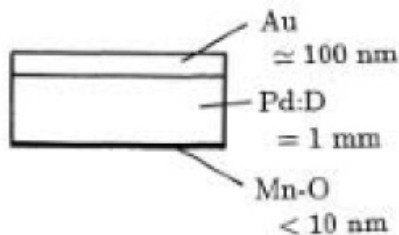


Figure 1. Schematic of the palladium sample involving a thin film of manganese oxide on one side and a gold film on the other side.

3.3. Iwamura et al.

Iwamura et al. [12] have observed the transmutation of cesium into praseodymium and strontium into molybdenum by permeation of deuterium gas through a palladium foil where a multilayer of palladium and CaO is deposited. Cesium and strontium were deposited on the surface of the last palladium layer as shown in Fig. 2. Further experiments showed the transmutation of barium into samarium [13].

3.4. Arata and Zhang

Arata and Zhang [14] using palladium and Pd–Ni nano-crystals embedded inside a zirconium oxide matrix have observed excess heat as well as production of helium-4 without any input energy. Figure 3 shows that the Pd–Ni nano-crystals produce more energy than the pure palladium. On the contrary no excess heat was observed with hydrogen.

3.5. Nickel–Copper–ZrO₂

At 523 K, Miyoshi et al. [15] have shown that Ni–Cu–Zr oxide compound + deuterium produces an excess heat of 300 eV/nickel atom, whereas the hydrogen run was endothermic.

3.6. Zeolites

Zeolites are interesting oxides containing substrates for LENR. They are micro-porous crystalline inorganic hydrated alumino-silicate materials having a highly regular structure of pores and chambers with extremely large surface areas.

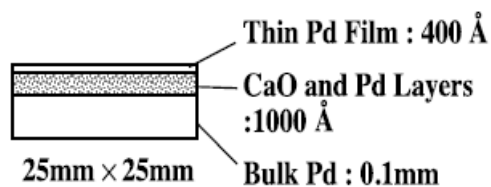


Figure 2. Transmutation experiments using multilayers of deposited palladium and calcium oxide.

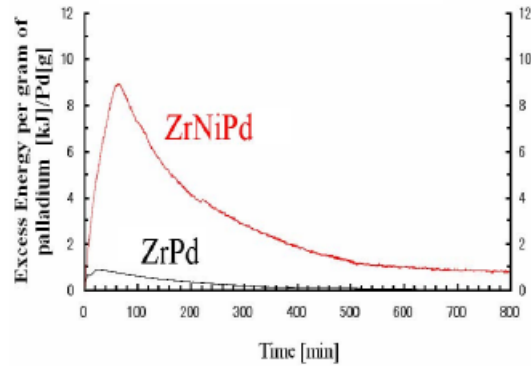


Figure 3. Comparison of excess heat results using palladium or Pd–Ni nanocrystals embedded inside a zirconium oxide matrix.

The zeolite framework structure encloses cavities or pores occupied by cations such as sodium, potassium, cesium, ammonium, and other ions. Figure 4 shows a schematic view of a zeolite.

Large internal electrostatic fields are present in the zeolite cages, making it an interesting nano-reactor to study the possibility of deuterium fusion at room temperature. Zeolites have a three-dimensional pore structure with strong electrostatic fields of 3 V/nm.

Addition of nano-particles of palladium in zeolite cavities produced significant temperature effects in the presence of deuterium gas, whereas no increase in temperature was observed in the presence of hydrogen [16].

3.7. Palladium in alumina

Excess heat was observed in an alumina powder impregnated with palladium upon loading of deuterium in the compound. No excess heat was observed when hydrogen was used [16].

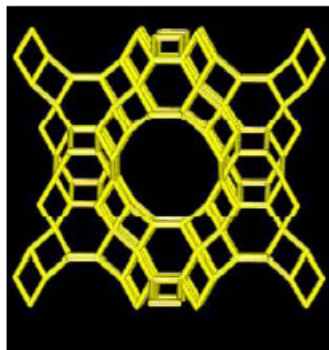


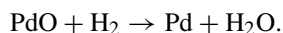
Figure 4. Schematic view of cavities and pores in a zeolite/oxide structure.

4. Discussion

Both electrochemical and gas phase experiments show that an insulating oxide layer on the palladium metal plays an important role. In the first experiments performed by Fleischmann and Pons, Johnson-Matthey palladium was prepared under cracked ammonia:



Hydrogen converts oxides to H₂O during melting



The palladium oxide is converted to H₂O vapor, minimizing PdO in the bulk palladium. This is probably the cause of the good success for excess heat in the first experiments of Fleischmann and Pons. These results also suggest that the oxides need to be present at the cathode surface rather than in the bulk palladium.

In the case of boron-doped palladium, the boron would react with and remove oxygen from the palladium bulk in the form of the substance, B₂O₃, which would skim off the metal surface during the arc-melting process. It is possible that some boron remains on the surface as B₂O₃. This may explain why it is not necessary to have long-term electrolysis to produce excess heat in the Pd–B system.. Good reproducibility has been observed with this system.

Several experiments have shown that an insulating oxide layer also plays an important role in gas-loading experiments.

5. Conclusion

It seems important not to have any metal oxide inside the metal, whereas an oxide film at the surface of the metal is favorable for LENR. Excess heat has been observed in glass cells, but not in Teflon cells or polymer coated glass cells. In glass cells, a long loading time is necessary in order to build the silicon oxide layer at the surface of the cathode, or by adding aluminum oxide powder in the electrolyte in order to quickly build an insulating oxide layer.

The oxide layer has several roles that can be important. On one hand, the electric field at the interface can be very high and create conditions for LENR. On the other hand, it is difficult to say if the heat producing reactions occur mainly at the interface or at the near surface of the metal. However, important effects due to deuterium in the bulk palladium should not be ruled out.

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