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## What Conditions Are Required To Initiate The Lenr Effect?

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Accumulating evidence indicates that previous understanding of the environment in which the Pons-Fleischmann effect occurs is wrong. The environment is not highly loaded beta-PdD. Instead, it is a complex alloy that may or may not contain palladium. In addition, the size of the domains in which the nuclear reactions take place is critically important. This new insight requires different explanations and experimental approaches than have been previously used.

### 1 Introduction

Initiation of anomalous nuclear reactions by the process called cold fusion, low energy nuclear reactions (LENR), or chemically assisted nuclear reactions (CANR) is sensitive to the nature of the physical environment in which these reactions occur, the so-called nuclear active environment (NAE). Therefore, any explanation or theory must take into account the physical and chemical environment, in addition to the nuclear mechanism. The challenge is to identify where this environment is located within the experiment environment so that attention can be focused on where the nuclear events are actually occurring. Each method used to initiate nuclear reactions will have its own unique location. Only the Pons-Fleischmann effect is discussed here.

Understanding of the environment in which the Pons-Fleischmann effect (P-F) occurs has evolved over the last 14 years. Initially, the nuclear reactions were proposed to take place within the bulk of a palladium cathode after it had been electrolyzed for a time sufficient to achieve an average high D/Pd ratio [1]. An observed relationship between average bulk composition and anomalous power supported this interpretation[2-5], even though high loading sometimes did not produce excess energy [6, 7]. The long delay in producing excess power was thought to result from a slow approach to the critical D/Pd ratio[8]. However, measurements frequently reveal that the bulk material reaches its composition limit long before anomalous energy is observed. Gradually, attention shifted to the surface of the cathode after the initial suggestion by Appleby et al. [9], where the highest D/Pd ratio is present[10-12]. The surface composition is in excess of D/Pd = 1.5[11, 13], a value far greater than the measured average composition. Deposition of impurities was thought necessary to reach the required high D/Pd in the surface region[14, 15]. Recently, attention has moved out of the palladium surface region and into the impurity layer [16-18] itself; the long delay for heat production resulting from slow deposition of this layer.

This impurity layer is found to contain Pt[19-21], Li[22-26], Si[21, 27], and many other elements[28-34], some of which result from deposition of impurities found in the electrolyte and some are claimed to result from various nuclear transmutation reactions [20, 21, 23, 35] occurring within the layer. In addition, significant protium is present in the layer even when 99.9% D in D<sub>2</sub>O is used [36]. Sometimes so much deposition can occur that very little palladium is found in the surface region [21, 37]. Deposition of material contained in the electrolyte is expected to grow dendrites on the surface as well as create a diffusion gradient within the substrate material. Only the latter effect has been given much attention. This paper suggests that the former effect is the more important one. Thus, the deposited “crud” theory of cold fusion is being proposed.

## 2 Discussion

Two questions need answers:

1. Why should we believe that the nuclear-active-environment (NAE) lies near the cathode surface, in contrast to being throughout the bulk metal, and

2. Why should we believe that the NAE exists in dendrites or nanocrystals deposited on the surface, in contrast to being within the palladium surface region itself?

### 2.1 Answer to question #1:

1.  $^4\text{He}$  [38-40] and tritium [41] are produced in a P-F cell. Most helium is found in the  $\text{D}_2 + \text{O}_2$  gas mixture rather than being contained in the palladium cathode. For this to be the case, the helium must form near the surface because experience has shown that  $^3\text{He}$  deposited within palladium by tritium decay is trapped and can be released only by heating the metal near its melting point [42, 43]. Ion implantation studies are also consistent with this conclusion. Therefore, only helium atoms located within a few microns of the surface are able to leave the palladium without extensive heating or melting.

2. Tritium generated in a P-F cell is mainly found in the electrolyte rather than in the gas. Studies have shown that tritium contained in palladium will be flushed out during electrolysis and into the gas [44]. Only tritium residing at the surface can enter the solution as tritium ions. Of course, separation of tritium into gas molecules or dissolved ions is only observed when recombination does not occur within the cell.

3. When transmutation products are observed, they are found to have the highest concentration near the surface [21, 34, 45-47], with a decreasing concentration away from the surface.

4. Heat bursts are observed that must originate near the surface because their observed size is very small [48-50]. Very small melted regions are also seen [51]. Heat generated deep within the metal would appear as general heating of the entire cathode.

5. Finally, when thin films are purposely deposited on the surface of an inert substrate, excess energy comparable to that produced using bulk material is observed [17, 52, 53], without the customary delay.

### 2.2 Conclusion:

The cited behavior is consistent with energy and nuclear reactions being generated in the near surface region. No evidence exists supporting heat production within the bulk material.

Granted this conclusion is correct, why is such a long delay required before excess energy is observed? A slow approach to the required composition is not a strong argument because the surface region, where the high composition must be located, loads very rapidly. Furthermore, once loaded, this region is not beta-PdD, but has a composition consistent with a compound similar to the general compound  $\text{MD}_2$ . In addition, the region is very rich in Li and Pt. At the very least, the P-F effect has been attributed to the wrong structure and chemical compound.

If bulk palladium is not important, why do certain batches of palladium produce excess energy and others are inert? A proposed answer is that palladium is relatively transparent to deuterium. Therefore, the critical composition of deuterium in the surface can not be achieved unless loss from the backside of the surface is blocked. This loss can only be blocked by forcing bulk material to achieve a high D/Pd ratio. In addition, certain batches form cracks upon loading and these enhance loss from the surface. Use of platinum or copper for the cathode completely eliminates this problem because diffusion of deuterium through these metals is very slow.

### 2.3 Answer to question #2:

Recently, anomalous behavior has been observed using palladium having a particle size in the nanometer range [54-56]. Even nanometer sized particles imbedded in a deposited palladium layer are found to be active [17]. If we assume that all anomalous energy is generated in material having a similar particle size, we then need to find where such particles exist in a P-F cell. Deposition of material onto a cathode from a "starved" electrolyte, i.e. one in which the deposited ion has a very low concentration, typically produces dendrites that can start with sizes in the nanometer range. Several attempts to produce such nanodomains on a cathode have produced anomalous energy. Szpak et al. [48] plated palladium onto a copper cathode from a  $\text{PdCl}_2$  solution and Storms [18] deposited Pt from a Pt anode on to a Pt cathode, both *in situ*. Storms [17] also coplated nanoparticles of several materials on to platinum metal outside of the cell, samples that were subsequently found to produce anomalous energy. In addition, his paper given at this conference shows that plating Pd from a Pd anode onto various substrates also produces anomalous energy. Bockris et al. [57] observed behavior while making tritium that is consistent with the active

material being copper dendrites deposited on palladium. Once deposited, all of these surface layers generate anomalous energy immediately upon application of electrolytic current.

#### **2.4 Conclusion:**

Slow growth of dendrites and other fine particles on the cathode is very common during electrolysis. When these deposits are produced on purpose, anomalous energy is observed, without the expected long delay. The observed behavior is consistent with an active layer slowly forming on whatever material is used as the cathode, followed by fast generation of energy once this layer is present. The substrate material appears to be unimportant. While palladium can be one of the elements present in the deposited layer, it is not the only one that can initiate the effects. The only condition that seems to be universal to the LENR effect is the existence of small domains of material. These can exist as dendrites growing from a surface, as suitable sized grains imbedded in palladium, or as grains imbedded in other materials that are relatively transparent to hydrogen. Dendrites deposited on the cathode during gas discharge experiment might be the source of nuclear activity using this method. It is even conceivable that small grains of material broken from the cathode might become active while floating within the electrolyte.

### **3 Conclusion**

Bulk palladium, to which so much study has been directed, is not the location of the NAE and is irrelevant to the production of anomalous nuclear reactions. Any inert metal will provide an effective substrate on which a nuclear-active layer can be deposited. The one characteristic of the layer known to be important is the size of domains attached to the surface. When formed during electrolysis of a conventional P-F cell, these domains are proposed to be mainly alloys of platinum and lithium, when platinum is used as the anode. Depositing palladium on to an inert substrate can also produce active domains, but such a deposit is expected to be a complex alloy. Other elements, such as silicon, might also be present and important.

Much work has been devoted to examining how the novel nuclear reactions might occur in pure beta-PdD having an especially high D/Pd ratio. While such a simple and ideal environment is attractive to theoreticians, the material actually present where the nuclear reactions are observed has very little relationship to this ideal. Therefore, explanations based on this assumption are expected to have little relationship to reality and little value in predicting behavior.

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