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Design Considerations for Palladium Electrodes as Suggested by a Deuteron Cluster Model for Cold Nuclear Fusion

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According to our hypothetical model, the essential element for the occurrence of cold nuclear fusion within palladium is the formation of deuteron clusters within the palladium electrodes. There are several factors which can affect the size, density, and rate of cluster formation. These factors are (1) the presence of diffusion barriers at all upstream palladium surfaces that are not immersed in the electrolyte, and which also are not exposed to a sufficiently large electric field to prevent deuteron diffusion from the electrode, (2) the direction and magnitude of the electric field relative to the crystalline lattice, (3) local crystalline temperature excursions that are associated with the fusion events, and (4) the various deuterium diffusion mechanisms within the crystal which are associated with thermal gradients, deuterium concentration gradients, and externally-generated potential field gradients that can enhance interstitial quantum mechanical tunneling along the direction of the associated internal electric field.

KEY WORDS: Cold fusion; deuteron cluster; boson condensation; palladium electrodes.

1. INTRODUCTION

According to our cluster model for cold nuclear fusion[1] the prime mechanism associated with cold fusion is the formation of deuteron clusters. This cluster formation requires the prior occurrence of a number of specific events. A listing of these events and a description of associated physical processes is given later. This is followed with suggestions for the improvement of the palladium electrode design.

2. OVERVIEW

A sequence of processes and events in the production of cold fusion in palladium electrodes via the tight cluster mechanism: (1) electrode preparation: cleaning, purging, and annealing, (2) deuterium transfer to Pd surface: electrolysis, (3) electron delocalization from deuterons: chemisorption, (4) flow of deuterons into Pd lattice: electric field-driven diffusion associated with tunneling, (5) termination of deuteron flow and saturation of electrode: impenetrable surface barriers, (6) cluster growth: symmetry force catalyzed boson condensation, (7) deuteron fusion $d^2 + d^2 \rightarrow He^{4*}$: nuclear tunneling of coulombic barrier, (8) energy release $He^{4*} \rightarrow He^4 +$ heat: compound nucleus–deuteron cluster interaction, and (9) disruption of cluster and localized lattice meltdown: thermal dissipation of 24 MeV excitation energy.

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3. DISCUSSION OF EVENTS AND PROCESSES

3.1. Electrode Preparation

The electrode must be cleansed of impurities that could prevent deuterium atoms from chemically bonding to the palladium crystal surface. H^1 isotopes must be purged from the electrode interior in order to permit deuteron saturation of the electrode. Application of a reverse electric field and annealing may be used in this electrode-purging process. Annealing can also serve to reduce lattice imperfections. These imperfections act to reduce the flow of deuterons into the electrodes and thereby increase the time required for the initiation of energy production.

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3.2. Deuterium Transfer to Electrode Surface

The process whereby deuterium atoms are transferred from the heavy water electrolyte to the electrode surface via electrolysis will not be discussed here. However, it should be noted that because of palladium's unique electron configuration and crystalline structure it is a likely candidate for cluster formations. This is associated with the fact that the majority of the Pd covalent electrons are in tightly bound 4d orbitals. This serves to provide for larger octahedral sites wherein deuterons can aggregate.

3.3. Electron Delocalization from Deuterons

This occurs at the surface of a palladium electrode in the following manner: palladium has a $4d^{10}$ electron configuration[2] which by itself would suggest that palladium would be an electrical nonconductor since the d levels are filled. However, the fact that palladium is an electrical conductor implies that the 4d electronic energy states overlap the 5s levels.[3] This results in the formation of an unfilled conduction band. As a deuterium atom approaches a palladium surface its electron merges into one of the unoccupied lower lying energy levels of the palladium conduction band. As a consequence, the deuterium atom's electronic wave function becomes delocalized and spreads throughout the electrode.[4] This process is known as chemisorption.[5]

3.4. Flow of Deuterons into the Palladium Lattice

This is facilitated by the electric field, within the palladium lattice, which is associated with the electrolysis process. It should be noted that, as deuterons flow through the crystalline lattice, charge neutrality is maintained through the attraction of conduction electrons. There are two mechanisms by which this flow can proceed: tunneling[6] and classical diffusion. In this process, deuterons tunnel directly through palladium covalent bonds that separate adjacent octahedral sites. Classical diffusion is associated with the flow of deuterons around the covalent bonds. This can be a much slower process than electric field-driven tunneling. It should be noted that the probability for tunneling is expected to be a maximum when the electric field orientation relative to the crystalline lattice is along a <1,1,0> direction. For all crystallites wherein the electric field is oriented along a <1,1,1> direction, the tunneling probability is expected to be a minimum. Thus, the deuteron flow into crystallites with this relative orientation is expected to be somewhat slower.

3.5. Termination of Deuteron Flow and Saturation of Electrode

Ordinarily the coulombic repulsive force between deuterons is sufficient to prevent multiple deuteron occupancy of octahedral sites. However, if the deuterons enter a region which is confined by an impenetrable barrier, such as an electrode surface which is covered by solder or some other impenetrable conducting material (see Fig. 1), then the deuteron electric field-driven flow will stop. This will eventually produce a static saturation of the octahedral sites. Under the influence of an electric field all available octahedral sites are expected to fill most rapidly in those crystallites wherein the electric field is along the preferred <1,1,0> direction as shown in Fig. 1.

3.6. Cluster Growth

With all neighboring octahedral sites filled a few deuterons, under the pressure of an electric field,[2] im-

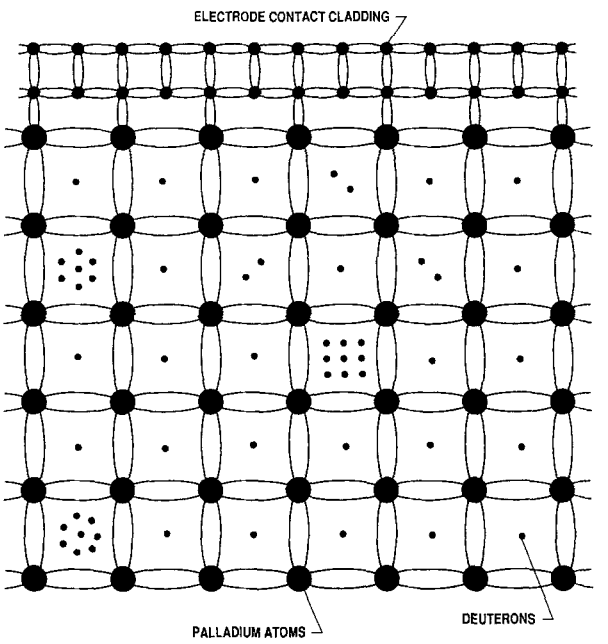

Fig. 1. Electrode interface between palladium and an electrical contact material with a perpendicular electric field along a<1, 1,0> direction.

[2] It is anticipated that the macroscopic electric field will have a rather significant effect on the deuterons should their wave functions overlap to produce long-range energy bands.

pacted by lattice vibrations, and having no way of escape, will start to crowd into common sites. At first, the boson symmetry interaction force will be small but, as more deuterons collect into a given octahedral site, the symmetry force will increase. This force increases as "*N*" the number of deuterons within the cluster. This will cause the deuterons to draw closer together. After a sufficient number have gathered into a common site, the separation distance between the innermost deuterons will become sufficiently small to permit a relatively large probability of their fusing. Also, as the deuterons gather in a common site, they will cause a greater concentration of the conduction electron wave function in and around the cluster. Since the electron wave function is delocalized from the deuterons it is not expected that these electrons will be able to produce a very large repulsive exclusion symmetry force such as occurs when two isolated deuterium atoms approach each other. Looked at in another way, the electron Fermi level within the cluster will be higher than that of the palladium conduction band. This will result in a flow of electrons out of the cluster into the surrounding lattice until the local Fermi energies become equal.

3.7. Deuteron Fusion, Energy Release, and Local Meltdown

As deuterons collect within an octahedral site there is an increasing probability that two will fuse to form a He^4 compound nucleus with an excitation energy for 24 MeV. This corresponds to a He^4 giant resonance energy level. There is a relatively high probability that this He^4 nucleus will interact, via its electromagnetic field, with the surrounding deuterons in the cluster. As the 24 MeV of energy is transferred to the deuterons in the cluster, they will move out through the lattice creating a plasma that initially has a temperature on the order of 10^{11}K. Since the energy required to break the palladium chemical bonds is about 4ev[7] this suggests that about 6×10^6 atoms will have their bonds ruptured. In effect this produces a localized meltdown out to a distance of about 70 lattice sites (270 A) from the fusion center. This plasma would in turn serve to attenuate any high-energy electromagnetic radiation (x-rays) that would normally accompany such a reaction. If the fusion were to occur near the periphery of a large cluster, or within a small cluster, there is a greater probability that it will yield tritium via the Oppenheimer–Phillips process. Subsequent to tritium formation will be neutron production via the reaction T + d −> He^4 + n.

4. EXPERIMENTAL DESIGN CONSIDERATIONS

The foregoing observations suggest the following experimental design features:

1. All palladium electrode surfaces which are not (1) immersed within the electrolyte and (2) also not exposed to the electric field must be sealed by some electrode contact cladding or a poison which is capable of terminating deuteron flow and confining them at high concentrations. Two possible methods for achieving this are shown in Figs. 2a and b. Figure 3 illustrates what might occur if these diffusion barriers are not present.

2. Cluster formation is expected to take place in those regions where deuteron flow ceases. Since deuterons can diffuse past grain boundaries and dislocations it is expected that the most likely location for the initial cluster formation will be internally near the electrode cladding. It should be noted that grain boundaries and dislocations are among those factors that may be responsible for the delay in electrode excess power production.

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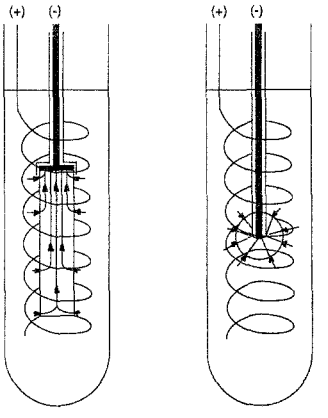

Fig. 2. Two possible modified palladium electrode designs which provide surface diffusion barriers to achieve a greater deuteron stoichiometry.

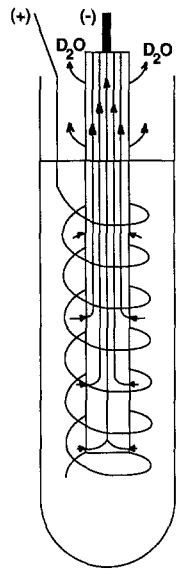

Fig. 3. A palladium electrode design that indicates how deuterons can escape in the absence of a diffusion barrier.

REFERENCES

1. R. Bush and R. Eagleton (1989). Cold Nuclear Fusion: A Hypothetical Model to Probe an Elusive Phenomenon. Paper presented at the Workshop on Cold Fusion Phenomena sponsored by the Los Alamos National Laboratory, May 1989.
2. C. E. Moore (1949). *Atomic Energy Levels* (National Bureau of Standards, Circular no. 467; Waber and Cromer (1965). *J. Chem. Phys.*, **42**, 4116.
3. G. Alefeld and J. Völkl (1978). *Hydrogen in Metals II* (Springer-Verlag, New York), p. 76.
4. G. Alefeld and J. Völkl (1978). *Hydrogen in Metals I* (Springer-Verlag, New York), p. 108.
5. P. W. Atkins (1978). *Physical Chemistry* (W. H. Freeman and Co., San Francisco), p. 380.
6. R. P. Bell (1980). *The Tunnel Effect in Chemistry* (Chapman and Hall, New York).
7. C. Kittel (1986). *Solid State Physics* (6th Ed.) (John Wiley and Sons, New York), p. 55.