AN EXTENDED MICRO HOT FUSION MODEL FOR BURST ACTIVITY IN DEUTERATED SOLIDS

NUCLEAR REACTIONS
IN SOLIDS

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An extended micro hot fusion scenario attempts to explain the burst processes of cold fusion reports and unsuccessful experiments. A heuristic model requires only 10 m^3 of palladium deuteride to release a power of 1 GW for a long time. This might facilitate future commercial use of cold fusion.

To explain cold fusion, several authors have proposed the idea of micro hot fusion¹⁻⁶ (MHF). In this paper, we suggest an extended MHF picture that attempts to explain also the reported high tritium-to-neutron ratios, kilowatt heat bursts, and tritium-containing hot spots.

When deuterons saturate in metals, they can form bubbles around impurities and dislocation nuclei.¹ These bubbles grow preferentially where current, pressure, or temperature are changed.¹ References 4 and 6 indicate that such nonstationary conditions are essential to reproduce cold fusion, which explains why so many experimentalists have failed to reproduce cold fusion.⁴ During their growth, bubbles will deform the metal lattice and give rise to cracks that propagate through the lattice.¹ The crack growth rate reaches its maximum at temperatures $-100, \dots, 0^\circ\text{C}$ (Ref. 6). In fact, several teams⁷⁻⁹ observed neutron bursts preferentially at these temperatures.

Hydrogen and palladium have different electronegativities. Therefore, the hydrogen is charged by $+0.45e$ per nucleus,² and the palladium is negatively charged. Moreover, the absorption of hydrogen gives rise to a deformation and expansion of the metal lattice. This expansion enhances the formation of larger metal ions (anions). As the chemical binding energy is typically of the order of electron volts, the attractive force on an electron by the metal lattice should be

$F_m = 1 \text{ eV}/1 \text{ \AA} = 10^8 \text{ eV/cm}$. This means that electric fields of $E_c = F_m/e = 10^8 \text{ V/cm}$ have to arise between the bubble and the metal lattice, which exist until and while the cracks are formed. As these cracks are flat capacitors¹ of diameter $d_c = 1 \text{ }\mu\text{m}$ and length $l_c = 10 \text{ }\mu\text{m}$ (Ref. 2), deuterons can be accelerated up to energies of $W_d = eE_c d_c = 10 \text{ keV}$. Note that kilo-electron-volt ions¹⁰ and electrons¹¹⁻¹⁴ have just been detected. These cracks should be formed each within some microsecond,¹⁵ where their formation should be accompanied by radio and acoustical emissions.² Indeed, this has been verified.^{7,16,17}

The energy within each crack is $W_c = \epsilon_0 E_c^2 d_c l_c^2 = 10^{-7} \text{ J}$. By considering that $V_c = 10\%$ of the electrode volume is filled with cracks,² we obtain a heat output of $W_h = V_c W_c d_c^{-1} l_c^{-2} = 100 \text{ J/cm}^3$. According to Segre et al.,¹ $W_d = 10 \text{ keV}$ allows a neutron production of $n_d = 10^4/\text{cm}^3$ of cathode material. Since each $d(d,n)^3\text{He}$ reaction yields $E_f = 3.3 \text{ MeV}$ of energy, this yields $W_n = n_d E_f = 10^{-8} \text{ J/cm}^3$; hence, $W_h/W_n = 10^{10}$. This explains the many reports of high heat-to-neutron ratios (for a list of these experiments see Ref. 5). We should note that the formation of bubbles, cracks, and electric fields is independent of the choice of the hydrogen isotope, which might explain Yamaguchi and Nishioka's^{18,19} observation of excess heat in palladium loaded with ordinary hydrogen.

Moreover, within one electrode, the formation time of cracks is determined by the deuteriding time and the fracture time [10^4 s (Ref. 2)], which might explain the reported emissions lasting for several hours.^{7,20-23}

We have seen that cracks can be formed, which allows the production of kilo-electron-volt deuterons. These deuterons will rapidly lose their energies by collisions with the atoms of the metal lattice. The mean path will be $d_s = 0.1 \text{ }\mu\text{m}$; therefore, small hot spots of the volume $V_s = d_s l_c^2 = 10^{-11} \text{ cm}^3$ will arise. As a metal lattice can store heat, each atom in the hot spot will receive the energy $W_a = W_c V_s^{-1} n_a^{-1} \sim 1 \text{ eV}$, where $n_a = 6 \times 10^{22}/\text{cm}^3$ is the number density of the atoms in the

lattice. According to Collins et al.,²⁴ this energy is able to allow an Oppenheimer-Phillips mechanism catalyzed by the metal lattice. Opposite from conventional fusion reactions, the metal lattice will obtain most of the energy that arises from the reaction $d(d, p)t$, so that the fusion products do not have enough energy to leave the metal lattice but have enough to start a further fusion reaction. This might explain the many reports on high tritium-to-neutron ratios (for lists of these experiments see Refs. 5, 25, and 26).

Because of their high inner pressure of $p_i = W_c V_s^{-1} = 10^{10}$ Pa, these small areas will explode, and these explosions might give rise to further cracks and therefore kilo-electron-volt deuterons and small hot spots. This means that a chain reaction might occur where these hot spots can grow to large hot spots. Autoradiographs showing tritium-containing hot spots of diameter $d_H = 10 \mu\text{m}$ and size $l_H = 1 \text{ mm}$ were performed by Rout et al.,¹⁴ Srinivasan,²⁷ and Srinivasan et al.²⁸ (see also Ref. 25). These hot spots contained $^{28}n_t = 10^{12}$ tritons.

Interestingly, Gozzi et al.²⁹ recorded 10^{11} tritium atoms in a cell, which produced heat evolution and a neutron burst that lasted 4 min. So, one can speculate that Srinivasan's hot spots may have been formed within a similar period of time. The correctness of this would explain the reports on bursts that lasted $t_b \sim 10 \text{ min}$ (Refs. 30 through 33). In this case, the released power per volume is $P_H = n_t E_f d_H^{-1} l_H^{-2} t_b^{-1} = 100 \text{ W/cm}^3 = 100 \text{ MW/m}^3$. To avoid misunderstandings, we should note that the power P_H and the tritium rates n_t concern the fusion reactions within the large hot spots, whereas the energy W_h and the neutron rates n_d concern the reactions caused by the kilo-electron-volt deuterons that have arisen by the electric fields of the cracks.

Assume that such hot spots have been formed. In this case, the metal lattice will be heated up and plastically deformed, so that its inner pressure will press the deuterium (and also the tritium) out of the electrode. Interestingly, there exist reports^{34,35} on strong deuterium emissions. If the temperature is high enough (locally up to $W_d \sim 1 \text{ eV}$, thus 10^4 K , should be possible), parts of the electrode will melt, so that the cracks will disappear. When the deuterium is reloaded, crack and hot spot formation will occur again and allow neutron, tritium, and kilo-electron-volt ion production (see Ref. 14). Interestingly, Arata and Zhang³⁴ observed neutron emissions for periods of 30 min to 40 h while breathing of the palladium, i.e., strong absorption and emission of deuterium.

Note that the power estimated earlier was observed by experimentalists. Oriani et al.³⁶ reported heat evolution of more than 60 W/cm^3 , Takahashi et al.³⁷ reported heat evolution of up to 100 W/cm^3 , Karabut et al.³⁸ reported heat evolution of up to 300 W/cm^3 , and Fleischmann et al. recently announced that they recorded bursts of heat that yielded³⁹ 3.7 kW/cm^3 for 11 min, thus more than 2000 kJ/cm^3 of palladium.

Might this heat have arisen by chemical reactions?

The catalytic recombination $2\text{D}_2 + \text{O}_2 \rightarrow 2\text{D}_2\text{O}$ yields 147.3 kJ/mol of D_2 , and the absorption of deuterium by the palladium $n\text{D}_2 + \text{Pd} \rightarrow \text{Pd}, \dots, \text{D}_{2n}$ yields 18.4 kJ/mol of D_2 . If we assume 0.1 mol of deuterium to be within each cubic centimetre of PdD_x , we obtain, therefore, an energy of 7.5 and 0.9 kJ/cm^3 , respectively, so these bursts cannot be explained by these processes. And, "even if the electric power supplied to keep the cell working was absorbed, it would be negligible compared with the heat energy liberated."³⁹

Because of the great success in explaining the burst processes of cold fusion reports, the extended MHF picture seems to be worth checking further. To verify whether cold fusion might become a means of producing commercial energy, we suggest that in future experiments, experimentalists use electrodes of kilogram rather than gram weight.

We must note that large deuterided electrodes might become extremely dangerous because the energy released by chemical and eventual fusion reactions can become very large. One researcher was killed in a disastrous explosion that occurred in January 1992. While the energy release mechanism does not appear to have been directly related to phenomena of the type discussed here,⁴⁰ the possibility of explosive energy releases from larger cells is clearly illustrated.

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