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## Excess Energy and Nuclear Products

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### **“Fine Tuning” Mechanism for Resonance Tunneling in D/Pd Systems**

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#### Abstract

A “Fine Tuning” parameter is introduced to describe how an extremely narrow energy level in the nuclear potential well is able to keep itself in resonance with the energy level in the lattice potential well. The good agreement between theoretical expectation and the experimental observation provides an additional evidence for the “resonance penetration of Coulomb barrier via lattice confined deuterons”, and suggests the key to enhance the reproducibility of “excess heat”.

#### 1. Introduction

The assumption of a narrow nuclear energy level solves the puzzle of “excess heat” without commensurate neutron and Gamma radiation<sup>[1]</sup>. This assumption is supported by the “heat after death” and “heat after life” experiments; however, a question remains, i.e. how an extremely narrow energy level is able to be in resonance with the narrow energy level of a lattice confined ion. A “fine tuning” mechanism in terms of “self-lock” is proposed to solve this remaining problem.

#### 2. Theoretical Expectation —“Fine Tuning” parameter.

The characteristic time in “heat after death” experiments ( $10^4$  seconds), and the fact of “excess heat without commensurate neutron radiation” have revealed a low energy resonance d-d state with an energy width of  $10^{-19}$  eV. On the other hand, the lattice confined deuterons are distributed on the energy band in the palladium lattice potential well. If the density of state in that energy band is greater than  $\rho_c(E) \approx 10^{19}/\text{eV}$ ; then, the resonance penetration of Coulomb barrier would be more probable since the energy band width in the palladium lattice may be greater than 1 meV. This requirement on density of state turns out to be a requirement on the grain size in the Pd crystal: i.e. the grain size should be greater than 50 ~100 microns.

However, the dynamics of resonance requires more than a grain size. The extremely narrow energy level may resonance with one of the energy levels in the lattice energy band, but the heat released in this resonance may quickly push themselves away from the resonance due to the thermal expansion which shifts the energy band. If we would like to keep them in resonance, there has to be a

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restoring force to pull them back. The variation of the density of state,  $\rho(E)$ , may provide such a restoring force, if  $\frac{d\rho(E)}{dE} < 0$ . ( $E$  is the energy of the relative motion of d-d state). In Fig.1 it shows schematically an energy band with a negative derivative of density of state. When the thermal expansion lowers the energy band, the resonance nuclear energy level,  $E_N$ , will see a higher energy level in that energy band; hence, see a less density of state. This difference in the density of state in an energy band will reduce the heat released by the resonance, and reduce the thermal expansion. In other words, the negative derivative,  $\frac{d\rho(E)}{dE} < 0$ , will provide a negative feed-back to pull back the energy band and restore the resonance between the nuclear energy level,  $E_N$ , and the lattice energy level,  $E_L$ . It is very similar to the "self-lock" phenomenon in "fine tuning" mechanism of a radio receiver.

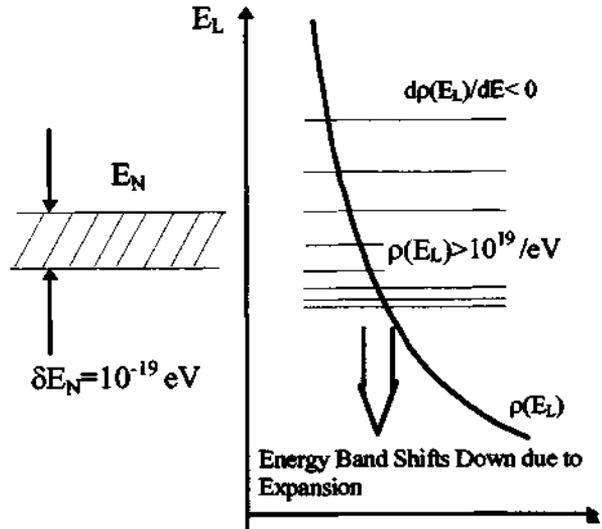


Fig.1 Energy Band Structure in Pd Crystal

There is a critical derivative of the density of state,  $\left(\frac{d\rho}{dE}\right)_c$ , in order to make this "fine tuning" work. Any power perturbation inside the calorimeter,  $\Delta\tilde{p}$ , will result a thermal expansion,  $\frac{\Delta\lambda_L}{\lambda_L} = \frac{\Delta\tilde{p}}{k_c} \cdot \alpha$ . Here,  $\lambda_L$  is the lattice constant  $k_c$  is the heat transfer coefficient of the D/Pd system (0.1 ~ 0.7 W/K for most of "excess heat" experiments);  $\alpha$  is the linear expansion coefficient ( $\approx 11.8 \times 10^{-6} \text{ K}^{-1}$  for palladium). The shift of the energy band due to this expansion is about  $\Delta E_L = 2 \frac{\Delta\lambda_L}{\lambda_L} E_L$ . The energy band shift  $\Delta E_L$  will change the number of resonance states from  $\rho(E_L)\Delta E_N$  to  $\rho(E_L + \Delta E_L)\Delta E_N$ . Here,  $\Delta E_N$  is the width of the nuclear energy level. This change will reduce the "excess heating" power by an amount of  $\Delta E_N \left(\frac{d\rho}{dE}\right)_{E_L} \cdot \Delta E_L \cdot \frac{E_F}{\tau_{ex}}$ . Here,  $E_F$  is the "fusion energy" released by a pair of d-d resonance state during their life-time  $\tau_{ex}$ .  $E_F \approx 23.8 \text{ MeV}$  and  $\tau_{ex} \approx 10^4$  seconds. Thus the restoring power is

$$\left| \frac{\Delta\tilde{p}}{k_c} \cdot \alpha \cdot 2E_L \cdot \Delta E_N \cdot \left(\frac{d\rho}{dE}\right)_{E_L} \cdot \frac{E_F}{\tau_{ex}} \right| > |\Delta\tilde{p}|$$

This restoring power has to be greater than the initial power perturbation,  $\Delta\tilde{p}$ , in absolute value but opposite in their signs in order to keep this resonance. In other words, the derivative of the density of the state has to be negative but its absolute value has to be greater than a critical value:

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$$\left| \frac{d\rho}{dE} \right| > \frac{k_c \cdot \tau_{ex}}{\alpha \cdot 2E_L \cdot \Delta E_N \cdot E_F}$$

Since the density of the state in a Pd sample is proportional to its volume,  $V_{Pd}$ ; it is evident that the ratio of  $V_{Pd}$  to  $k_c$  will determine the restoring force for the fine tuning mechanism. We may define

$\left(\frac{V_{Pd}}{k_c}\right)$  as a "fine tuning" parameter

$$F \equiv \left(\frac{V_{Pd}}{k_c}\right)$$

The greater the "fine tuning" parameter,  $F$ , is, the more stable the resonance between the nuclear energy level and the lattice energy band, provided that the derivative of the density of the state less than zero, i.e.

$$\frac{d\rho(E)}{dE} < 0$$

### 3. Experimental Observation

The experiments have verified the first requirement ( $\rho_c(E) > 10^{19} eV^{-1}$ ) by the metallography of the annealed Pd samples<sup>[2][3]</sup> and the positive annealing fact<sup>[4]</sup>. Now we examine the "fine tuning" parameter in various experiments. Table 1 lists some of these early positive "excess heat" experiments, and the recent negative experiment completed by Quickenden et al.<sup>[5]</sup>

Table 1 "Fine Tuning" Parameter in Various Experiments

	Heat Transfer Coefficient (W/°C)	Volume of Palladium (cm <sup>3</sup> )	"Fine Tuning" Parameter (cm <sup>3</sup> · °C /W)
Quickenden[5]	0.71	0.0251	0.0354
Mckubre[6]	0.46	0.353	0.767
Kunimatsu [7]	0.2	0.232	1.16
Miles [8]	0.14	0.343	2.45
Fleischmann & Pons [9]	0.0648	0.0392	0.605
Xing Z.Li [2]	0.1	0.234	2.34
Lewis [10]	0.0714	0.073	1.02

It is noticed that in that negative experiment their "fine tuning" parameter is much less than those of all other positive experiments. Particularly, it is interesting to notice that the "fine tuning" parameter in the early "negative" experiment of Lewis is relatively large, there should have been "excess heat" as pointed out by Dr. Miles in 1994. However, it was reported as a negative one.

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An important test on this “fine tuning” mechanism is the sign of the derivative,  $\frac{d\rho}{dE}$ . Although it is difficult to calculate its exact number, it is possible to determine its sign according to the shape of the lattice potential well. The quantum mechanics gives the qualitative conclusion that the derivative of the density of state will be

$$\frac{d\rho}{dE} \begin{cases} < 0 & \text{(square - well)} \\ = 0 & \text{(harmonic well)} \\ > 0 & \text{(Trumpet - like well)} \end{cases}$$

as schematically shown in Fig.2. The inelastic neutron scattering experiment showed that the lattice potential well in Pd is a square-well-like one because its anharmonicity parameter is positive (see Fukai [11]).

Our gas-loading experiment provides an additional evidence on this “fine tuning” mechanism. In Fig.3, the upper line shows the temperature difference between the twin D/Pd and H/Pd systems and the lower curve shows the derivative of the temperature of the D/Pd system with respect to the time (in an enlarged scale). When the heating power through the tungsten wire is shut off, the temperatures of the twin systems are changing with the room temperature, but the temperature of the D/Pd system ( $T(D)$ ) is always higher than that of H/Pd system due to the possible “excess heat” source in the D/Pd system. It is interesting to observe that this “excess heat” source changes in day and night also. The maximum of  $[T(D)-T(H)]$  appears at the point where the  $T(D)$  drops quickest, and the minimum of  $[T(D)-T(H)]$  appears at the point where  $T(D)$  rises quickest. This behavior implies a heat source in D/Pd system, which is proportional to  $(-dT(D)/dt)$ . A possible explanation of this behavior is just that the density of state in the resonance energy band decreases with the energy, i.e.  $\frac{d\rho}{dE} < 0$ . When the  $T(D)$  is dropping, the D/Pd system will see a higher density of state in resonance. This is equivalent to adding an additional “heat source” into the D/Pd system. The quicker the  $T(D)$  drops, the stronger this additional “heat source”, which enlarges the temperature difference between the D/Pd and H/Pd systems.

#### 4. Conclusion.

The “fine tuning” mechanism supports the theory of penetration of the Coulomb barrier via lattice confined ions, and the experiments support this “fine tuning” mechanism by three facts:

$$\rho(E) > \rho_c(E), \quad \frac{d\rho}{dE} < 0, \quad \text{and} \quad \frac{V_{pd}}{k_c} > F_c.$$

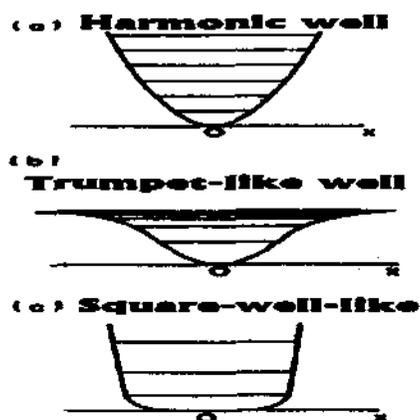


Fig.2 Three types of well with different sign of  $d\rho/dE$

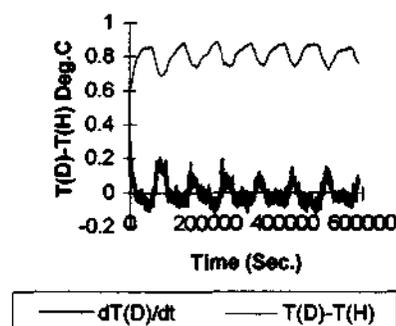


Fig.3  $T(D)-T(H)$  &  $dT(D)/dt$

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A critical "fine tuning" parameter,  $F_c$ , is introduced to qualitatively describe this negative feed-back for the "fine tuning" mechanism. In order to make the "excess heat" reproducible, it is important to use large Pd sample (large  $V_{pd}$ ), good insulation of calorimeter (less  $k_c$ ), suitable annealing to increase the  $\rho(E)$ , keep the square-well-like potential field in the Pd ( $\frac{d\rho}{dE} < 0$ ), and keep the high population on that resonance energy level.

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