Theoretical Study of the Phenomenon of Cold Fusion within Condensed Matter and Analisys of Phases (α, β, γ) Theoretical Model Between Low Energies of Deuterium Nuclei Cold Fusion

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Abstract: The aim of this work is to explain the deuteron-deuteron reactions within palladium lattice by means of the coherence theory of nuclear and condensed matter. The coherence model of condensed matter affirms that within a deuteron-loaded palladium lattice there are three different plasmas: electrons, ions and deuterons plasma.
Then, according to the loading percentage x=D/Pd, the deuterium ions can take place on the octahedrical sites or in the tetrahedral on the (1,0,0)-plane. Further, the present work is concentrated on Palladium because, when subjected to thermodynamic stress, this metal has been seen to give results which are interesting from both the theoretical and experimental points of view. Moreover in Pd lattice we can correlate the deuterium loading with D-Pd system phases (i.e. □,□ and □) by means of theory of Condensed Matter. Further, This paper seek to demonstrate that, at room temperature, the deformation of the crystalline lattice can influence the process of interaction of deuterons introduced within it. Calculations of this probability, in fact, showed an increase of at least 2-3 orders of magnitude with respect to the probability of fusion on the surface of the lattice. These phenomena open the way to the theoretical hypothesis of a kind of chain reaction, as a result of the deuterium loading and catalysed by micro-cracks formed in the structure by micro-explosions, can favour the process. In the second section we will discuss the problem of interaction of Deuteron-Plamon.

Key words: condensed matter, Dislocations of the ions within the metal, Coherence Theory, low energy nuclear reactions (LENR)

I. Introduction

The Coherence Theory of Condensed Matter is a general theoretical framework, which is widely accepted by most scientists working on cold fusion phenomena. According to this coherence theory of condensed matter [5], it is assumed that the electromagnetic (e.m.) field due to elementary constituents of matter (i.e. ions and electrons) plays a very important role on system dynamics. Considering a coupling between e.m. equations due to charged matter and the Scrödinger equation of field matter operator, it is indeed possible to demonstrate that in proximity of an e.m. frequency ω_0, the matter system features a coherent dynamics. Thus it is possible to define coherence domains, whose length is about $\lambda_{CD} = 2\pi/\omega_0$. Obviously, the simplest model of matter with a coherence domain is a plasma system. In the common plasma theory, a plasma frequency ω_p must be considered, as well as the Debye length measuring the Coulomb force extension, i.e. the coherence domain length. For a system with N charge Q of m mass within a V volume, the plasma frequency can be written as:

$$\omega_p = \frac{Q}{\sqrt{m}}\sqrt{\frac{N}{V}} \qquad (1)$$

In this present work, the "nuclear environment" has been studied, which supposedly exists within a D_2-loaded palladium lattice at room temperature, as in accordance with the Coherence Theory. Traces of nuclear reactions have been observed in a palladium lattice when this is loaded with deuterium gas [1, 2, 3]. For this reason, Low Energy Reaction Nuclear (LERN) has been defined by many physicists. More robust experiments have shown that in the case of D_2-loaded palladium the following nuclear reactions are more frequent [3, 4]:

$$D + D \rightarrow {}^3H + p + 4.03 MeV \quad (1)$$

$$D + D \rightarrow {}^4He + 23.85 MeV \quad (2)$$

In this present work, a 'coherence' model is also proposed, by means of which the occurrence of reactions 1 and 2 can be explained in accordance with more reliable experiments, as well as their probability. Firstly, an analysis of the environment has been carried out through the coherence theory of matter, i.e. of plasmas which are present within palladium (d-electrons, s-electrons, Pd-ions and D-ions); then, the potential reported in ref. [6, 7] has been considered, adding the role of lattice perturbations. Thus, a D-D tunneling probability has been computed.

2. Plasmas within non loaded palladium

According to the Coherence Theory of Condensed Matter, electron shells are in a coherent regime within a coherent domain in a Pd crystal at room temperature. Indeed, they oscillate in tune with a coherent e.m. field trapped in coherent domains. For this reason, plasmas of *s*-electrons and *d*-electrons must be taken into account in order to describe the lattice environment.

2.A. Plasmas of d-electrons

They are formed by electrons of palladium d-shell. Computing:

$$\omega_d = \frac{e}{\sqrt{m}} \sqrt{\frac{n_d N}{V}} \quad (3)$$

d-electrons plasma frequency is obtained. But according to the coherence theory of matter, this plasma frequency must be adjusted of a factor 1.38. This correction can be easily understood by observing that formula (3) is obtained assuming a uniform d-electrons charge distribution. But of course the d-electron plasma is localized in a shell of R radius (that is about 1Å), so the geometrical contribution is

$$\sqrt{\frac{6}{\pi}} = 1.38 \quad (4)$$

Labeling a *renormalized* d-electron plasma frequency with ω_{de} [5],

$$\omega_{de} = 41.5 eV / \hbar \quad (5)$$

and the maximum oscillation amplitude ξ_d is about 0.5 Å.

2.B. Plasmas of delocalized s-electrons

The s-electrons are those neutralizing the adsorbed deuterons ions in a lattice. They are delocalized and their plasma frequency depends on loading ratio (D/Pd percentage), by means of the following formula [5]:

$$\omega_{se} = \frac{e}{\sqrt{m}} \sqrt{\frac{N}{V}} \cdot \sqrt{\frac{x}{\lambda_a}} \quad (6)$$

where

$$\lambda_a = \left[1 - \frac{N}{V} V_{pd} \right] \quad (7)$$

and V_{pd} is the volume actually occupied by the Pd-atom. As reported in reference [5],

$$\omega_{se} \approx x^{1/2} 15.2 eV / \hbar \quad (8)$$

As an example, for $x=0.5$, $\omega_{se} \sim 10.7\ eV/\hbar$.

2.C. Plasmas of Pd ions

Finally, plasmas created by Palladium ions forming the lattice structure must be considered. In this case, frequency can be demonstrated as being [5]

$$\omega_{pd} = 0.1 eV \quad (9)$$

3. Plasmas Within D2-Loaded Palladium

It is known that deuterium is adsorbed when placed near to a palladium surface. This loading can be enhanced using electrolytic cells or vacuum chambers working at appropriate pressure [8, 9]. By means of the Theory of Condensed Matter by Preparata, it is assumed that three phases exist concerning the D_2-Pd system, according to a $x=D/Pd$ ratio:

1)	phase α	for	$x<0.1$
2)	phase β	for	$0.1<x<0.7$
3)	phase γ	for	$x > 0.7$

In the α – phase, D_2 is in a disordered and non coherent state (D_2 is not charged!). Concerning the other phases, the following ionization reaction takes place on the surface, due to lattice e.m.:

$$D_{lattice} \rightarrow D^+ + e^- \quad (10)$$

According to the $x=D/Pd$ loading percentage, deuterium ions can take position on octahedral sites (fig.1) or in the tetrahedral ones (fig.2) in the (1,0,0)-plane. According to the coherence theory, a deuterons plasma in an octahedral site is defined as β-plasma, whereas a deuterons plasma in a tetrahedral one is defined as a γ-plasma.

It is possible to state that frequency of a β-plasma is given by [5]:

$$\omega_\beta = \omega_{\beta 0}(x+0.05)^{1/2} \quad (11)$$

where

$$\omega_{\beta 0} = \frac{e}{\sqrt{m_D}}\left(\frac{N}{V}\right)^{1/2}\frac{1}{\lambda_a^{1/2}} = \frac{0.15}{\lambda_a^{1/2}} eV/\hbar \quad (12)$$

As an example, for $\lambda_a=0.4$ and $x=0.5$, $\omega_\beta=0.168\ eV/\hbar$.

In tetrahedral sites, D^+ can occupy the thin disk encompassing two sites (fig 3), thus forming a barrier to D^+ ions. Notice that the electrons of the d-shell oscillate past an equilibrium distance y_0 (about 1.4 Å), thus embedding ions in a static cloud of negative charge which can screen the Coulomb barrier. As reported in [5],

$$\omega_\gamma = \sqrt{\frac{4Z_{eff}\alpha}{m_D y_0^2}} \approx 0.65 eV/\hbar \quad (13)$$

This frequency obviously depends also on the chemical conditions of palladium (impurities, temperature etc…). Due to a large plasma oscillation of d-electrons, a high density negative charge condenses in the disk-like tetrahedral region where the γ-phase D^+ are located, giving rise to a screening potential *W(t)* whose profile is reported in fig. 4. It must be highlighted that the γ-phase depend on the *x* value and that this new phase has been experimentally observed [11].

The new phase γ is a very important one in LERN investigation. In fact, many cold fusion scientist claim that the main point of *cold fusion protocol* is that the D/Pd loading ratio must be higher than 0.7, i.e. that deuterium must take position in tetrahedral sites.

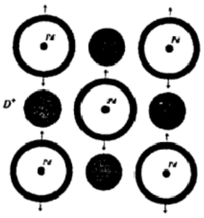

Fig. 1. The octahedral sites of a Pd lattice where deuterons take position

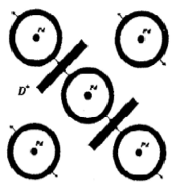

Fig. 2. The thin disks of tetrahedral sites of a Pd lattice where deuterons take place

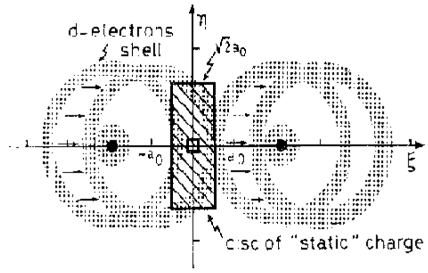

Fig. 3. Possible d-electron plasma oscillation in a Pd lattice

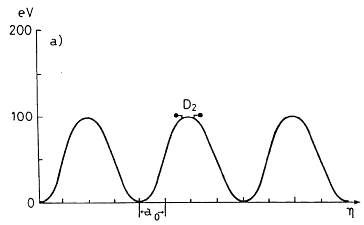

Fig.4. The profile of the electrostatic potential in a arbitrarily direction η

4. D-D potential

As shown in reference [6], the phenomena of fusion between nuclei of deuterium in a crystalline lattice of a metal is conditioned by structural features, by the dynamic conditions of the system, and also by the concentration of impurities which are present in the examined metal.

A study has been held of the curves of the interaction potential between deuterons (including a deuteron-plasmon contribution) in the case of three typical metals (Pd, Pt and Ti). A three-dimensional model showed that the height of the Coulomb barrier decreases on varying the total energy and the concentration of impurities which are present in the examined metal.

A potential accounting for both the role of temperature and impurities is given by the following expression [6]:

$$V(r) = k_0 \frac{q^2}{r} \cdot M_d \left(V(r)_M - \frac{J\ kT\ R}{r} \right) \quad (14)$$

In (14), the $V(r)_M$ Morse potential is given by:

$$V(r)_M = (J/\zeta)\left\{\exp(-2\varphi(r-r_0)) - 2\exp(-\varphi(r-r_0))\right\} \quad (15)$$

Here parameters φ and r_0 depend on the dynamic conditions of the system, ζ is a parameter depending on the structural features of the lattice, i.e. number of "d" band electrons and type of lattice symmetry, varying between 0.015 and 0.025.

Obviously the Morse potential is used in an interval including an inner turning point r_a and continuing towards

$r=0$, where it approaches the Coulomb potential (fig 5).
In reference [6], a fusion probability is obtained by means of the following formula (α is the zero crossing r-value of potential):

$$|P|^2 = \exp\left(-2\int_0^{\alpha} K(r)dr\right) \tag{16}$$

where:

$$K(r) = \sqrt{2\mu\left[E - V(r)\right]/\hbar^2} \tag{17}$$

This fusion probability is obtained using the reasonable value of 10^{21} min^{-1} for the nuclear rate, and it is normalized to a number of events per minute of 10^{-25} for $\alpha=0.34Å$, $E=250$ eV, $T=300K$ and $J=0.75$ (high impurities case). Many experiments confirmed these fusion rate values concerning reactions 1 and 2 [10].
In this present work, the role of potential (14) is studied in accordance with the coherence theory of condensed matter, in the three different phases α, β and γ.

In this theoretical framework, two key points need a clarification:
1) what KT is.
2) what the role of electrons and ions plasmas is.
Concerning the first point and according to different deuteron-lattice configurations, KT can be:
i) the lattice temperature if we consider deuterons in the α-phase.
ii) ω_β if we consider deuterons the in β-phase.
iii) ω_γ if we consider deuterons in the γ-phase

The second point is a more controversial issue. In fact, the lattice environment is a mixture of coherent plasmas (Pd ions, electrons and deuterons plasmas) at different temperatures, due to different masses. Thus, describing an emerging potential is a very hard task. The method proposed in this present work is that of considering the total contribution of lattice environment at D-D interaction (i.e. V_{tot}) as a random potential $Q(t)$. In accordance with this model,

$$V_{tot}(t) = V(r) + Q(t) \tag{18}$$

obviously assuming that:

$$\left\langle V_{tot}(t)\right\rangle_t \neq 0 \tag{19}$$

That is, a second order potential contribution $Q(t)$ is supposed to be a periodic potential whose frequency will be labeled by ω_Q, oscillating between the maximum value Q_{max} and 0.
The role of potential $Q(t)$ is that of increasing or decreasing the barrier. The plot of potential V_{tot} for two different value of $Q(t)$ is reported in figure 6.
This means that the following main cases may occur in accordance with ω_Q and with the energy of incoming particles to the barrier:
1) the particle crosses the barrier in the point α
2) the particle crosses the barrier in the point α'

Scenario 2) can be regarded as a worst case to obtain a high tunneling probability, and scenario 1) as a best case.
To determine the model parameters, some hypothesis must be suggested on $Q(t)$ and ω_Q. In this present work, an approximation is made of $Q(t)$ as equivalent to a screening potential $W(t)$ due to d-electrons, as reported in fig 5. This means that $\omega_Q \sim \omega_d$. Obviously, there is a strong dependence between the scenario and the deuteron phase, since $Q(t)$ is only the d-electrons screening potential, at first order. To resume, the following cases may occur in a palladium lattice according to the loading ratio:
i) α-phase
In the α phase, deuterons are in a molecular state and thermal motion is about:
$0.02\ eV < \hbar\omega_\alpha < 0.2\ eV$
This phase takes places when x is lower than 0.1. Since $W(t)$ is zero, the D-D potential is:

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\alpha R}{r}\right) \tag{20}$$

The expression (20) has been partially evaluated in a previous paper [6], only focusing on the dependence of a tunneling probability on impurities which are present within the lattice. In this present work, a correlation is made between potential features and loading ratio. Numerical results are shown in paragraph 6.
ii) β-phase
When x is higher than 0.1 but lower than 0.7, phase β happens. The interaction takes place between deuteron ions oscillating by the following energy values:
$0.1\ eV < \hbar\omega_\beta < 0.2\ eV$
In this case $W(t)$ is zero, so the potential is given by expression (21):

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\beta R}{r}\right) \tag{21}$$

Comparing expressions 20 and 21, it seems very clear that the weight of impurities is more important in the β-phase. This conclusion is obviously in accordance with previous papers [6, 7], where the role played by temperature in the tunneling effect was studied.
iii) γ-phase
Finally, the deuteron-palladium system is in the γ phase when the loading ratio is higher than 0.7. According to a synchronism between phase oscillations of deuteron and d-electrons plasmas, the following two cases must be considered:
Case 1: Q(t)=0
In this case, the potential is a natural extension of formula (14), and can be written as:

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\gamma R}{r}\right) \tag{22}$$

Case 2: Q(t)≠0
This is the more interesting case. It happens when ω_γ is about ω_Q and obviously when the respective oscillations are in phase. Deuterons undergo a screening due to the d-

electrons shell, so a supposition is made that D-D potential must be computed assuming a disappearance of the well which is present in potential (14), due to Morse contribution. Indeed, using a classical plasma model where D^+ ions are the positive charge and d-electrons are the negative one, it is extremely reasonable to suppose that the following potential must be used:

$$V(r,t) = const\frac{q^2}{r}\cdot M_d\left(\frac{\alpha}{|\vec{r}|}e^{-\frac{|\vec{r}|}{\lambda_D}} - \frac{J\hbar\omega_\gamma R}{r}\right) + Q(t) \quad (23)$$

where

$$V_C(\vec{r}) = \frac{\alpha}{|\vec{r}|}e^{-\frac{|\vec{r}|}{\lambda_D}} \quad (24)$$

and λ_D is the Debye length of this classical plasma. Notice that *Q(t)* is an unknown perturbative potential. About this, it can only be stated that:

$$\langle Q(t)\rangle_t \approx \frac{W_{\max}}{\sqrt{2}} \quad (25)$$

As previously said, this is supposed to be a screening potential due to d-electrons and its role is supposed to be that of reducing the repulsive barrier.

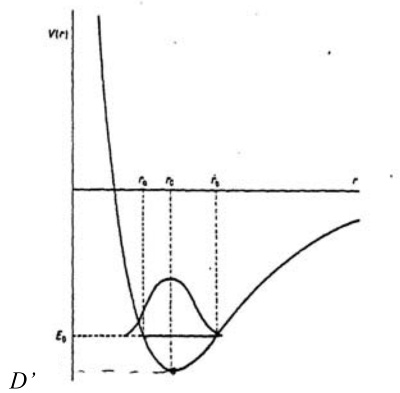

Fig. 5. D-D potential features using a Morse potential

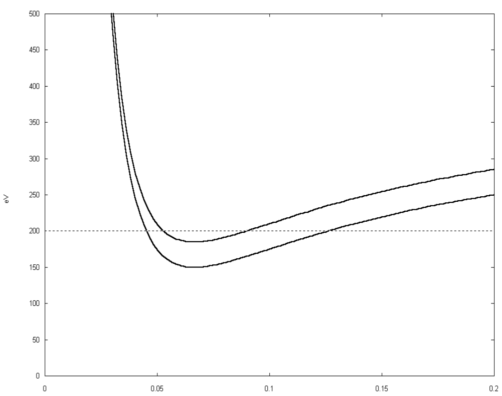

Fig. 6. Potential features for two different arbitrary values of *Q(t)*.

5. The barrier crossing treatment

A discussion follows on how to handle the crossing of the barrier in the γ-phase and when *Q(t)* is different from zero. The starting point in any case is the Schrödinger equation:

$$\frac{\hbar^2}{2\mu}\Psi''(r)\left[E - V_{tot}(r,t)\right]\Psi(r) = 0 \quad (26)$$

Nevertheless, this is a difficult problem to solve. To handle this topic in a simple way, it can be observed that using $V_{tot}(r,t)=V(r)+W_{max}/\sqrt{2}$, this problem concerns four main energy values E_1, E_2, E_3 and E_4 (check fig. 7). This problem is equivalent to the treating of a double barrier case. From reference [12],

$$E_1 = \text{a few eV}; \quad (27)$$

$$E_2 = -D\left(1 - \frac{\gamma\hbar}{\sqrt{2\mu D}}\left(\mu + \frac{1}{2}\right)\right)^2 \quad (28)$$

$$E_3 \sim \left(\frac{m_e}{M_N}\right)E_1 \sim \frac{1}{1000}eV \quad (29)$$

$$E_4 = D' \quad (30)$$

γ is the constant of metal anharmonicity and ν is the vibrational constant. Another important quantity is *D'*, which is the depth of the potential well. According to the Morse potential (15), this is J/ζ . Now building an energy tensor E_{ij} :

$E_{11}=E_1$
$E_{22}=E_2$
$E_{33}=E_3$
$E_{44}=E_4$
$E_{ij}=E_i-E_j$
$E_{ij}=-E_{ji}$

a square quadratic energy value can be defined:

$$\langle E\rangle = \sqrt{\frac{trE_{ij}E^{ij}}{4}} \quad (31)$$

and a dispersion:

$$\sigma = \sqrt{\frac{\sum_{i\neq j}E_{ij}E^{ij}}{4}} \quad (32)$$

If we neglect the term *Q(t)* and consider only the random feature of deuteron energy, the following could be a reasonable value for *K(r)*:

$$K(r) = \frac{1}{\hbar}\sqrt{2\mu\left[V(r) - \left(\sqrt{\frac{TrE_{ij}E^{ji}}{4}} \pm \sigma\right)\right]} \quad (33)$$

And finally:

$$P(\alpha) = \exp\left(-2\int_0^\alpha K(r)dr\right) \quad (34)$$

But according to statistical treatment,

$$P = P(\alpha, \langle E \rangle, \sigma) \quad (35)$$

where

$$\alpha = \alpha[Q(t)] \quad (36)$$

as already seen concerning the γ phase. Since the greater contribution to $Q(t)$ is supposedly due to a screening effect of d-electrons in the γ-phase (i.e. of random potential), any other case can be neglected and only the following two cases must be considered (i.e. featuring a double barrier approximation):

1) Q(t) =0 → α = 0.34 Å.
2) Q(t) ≠0 → α =0.16 Å

Of course, case 2) is the more advantageous to obtain a high tunneling probability.

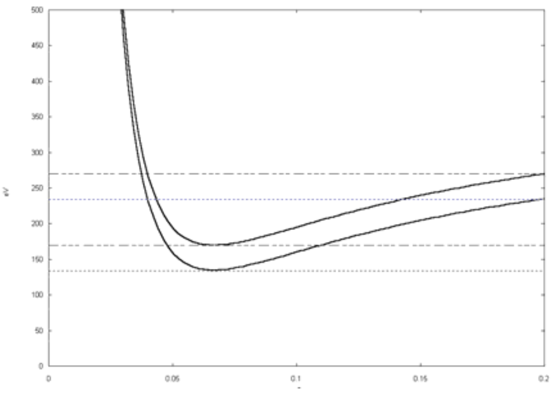

Fig. 7. Features of $V(r)$ and $V(r)+W_{max}/\sqrt{2}$

6. Results and discussion

A presentation follows of the D-D fusion probability normalized to number of events per minute concerning D-D interaction in all different phases. More exactly, fusion probability in phases α, β and γ are compared, using a reasonable square average value of 200 eV and a σ value of 50 eV, in order to cross potential (14) in all four points E_1, E_2, E_3 and E_4 . The role of d-electron screening is also considered as a perturbative lattice potential. This treatment only concerns the case when $Q(t)$ is different from zero, and implies changing the time-dependent problem of a tunneling effect into a double barrier problem. To resume, the emerging of a double barrier in the γ-phase is a new 'physics fact'. Notice that cold fusion scientists built up their expectations about a new γ phase, because screening enhances the fusion probability. From an experimental point of view, it is possible to state that three typologies of experiments exist in the phenomenology of cold fusion [13]:

1) those that have given negative results.
2) those that have given some results (little signs of detection with respect to background, fusion probability of about 10^{-25}), using a very high loading ratio.
3) those that have given clear positive results, like Fleischmann and Pons experiments.

Nevertheless, our opinion is that the experiment like in point 3) are lacking in accuracy from an experimental point of view. For this reason, we believe that this theoretical model of the controversial phenomenon of cold fusion must only explain the experiments like in point 1) and 2). In this case, the role of loading ratio must be considered in the experimental results.

Results about the α-phase are shown in Table 1. In this case, it can be observed that the theoretical fusion probability is lower than 10^{-74}, which is very small. It is possible to state that if the deuterium is loaded with a $x < 0.2$ percentage, no fusion event is observed! The same absence of nuclear phenomenon is compatible with a loading ratio of about 0.7 (Table 2), since the predicted fusion probability is less than 10^{-42} in this case. These predictions are obviously in agreement with the experimental results. But for $x>0.7$, a full range of valid experiments on cold fusion has reported some background spikes (check reference [10] as an example). A remarkable result of our model is shown in Table 3: some background fluctuations can be observed in the γ-phase, since we predict a fusion probability about 10^{-25} due to a very high loading ratio. This represents a new result with respect to references [6, 7], since in those cases the fusion probability was independent of loading ratio. In order to predict a very noteworthy nuclear evidence (about 10^{-17}), ω_γ must be comparable with ω_Q (Table 4). Only under this condition can the screening potential enhance the tunneling probability and the D-D interaction become a like-Debye potential. The condition allowing this equivalence result of ω_γ to ω_Q will be discussed in another paper. Here, we only underline that it is a very unlikely condition.

TABLE I

Fusion probability has been computed for "impure" Pd ($J \approx 0.75\%$), using a α-potential (potential 20), and normalized to a number of event/min for different values of energy (σ =±50 eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200eV$

$\omega_\alpha \approx 0.05$ eV	$\omega_\alpha \approx 0.1$ eV	$\omega_\alpha \approx 0.15$ eV	$\omega_\alpha \approx 0.2$ eV
$\sigma\approx$-50 P $\approx10^{-100}$	$\sigma\approx$-50 P$\approx10^{-103}$	$\sigma\approx$-50 P$\approx10^{-100}$	$\sigma\approx$ -50 P$\approx10^{-99}$
$\sigma\approx$-40 P $\approx10^{-99}$	$\sigma\approx$ -40 P$\approx10^{-101}$	$\sigma\approx$-40 P $\approx10^{-98}$	$\sigma\approx$ -40 P$\approx10^{-97}$
$\sigma\approx$-30 P $\approx10^{-97}$	$\sigma\approx$-30 P$\approx10^{-100}$	$\sigma\approx$-30 P $\approx10^{-96}$	$\sigma\approx$ -30 P$\approx10^{-96}$
$\sigma\approx$-20 P$\approx$ 10^{-95}	$\sigma\approx$-20 P $\approx10^{-99}$	$\sigma\approx$-20 P $\approx10^{-94}$	$\sigma\approx$ -20 P$\approx10^{-93}$
$\sigma\approx$-10 P$\approx$ 10^{-94}	$\sigma\approx$ -10 P$\approx10^{-97}$	$\sigma\approx$-10 P $\approx10^{-91}$	$\sigma\approx$ -10 P$\approx10^{-90}$
$\sigma\approx$0 P $\approx10^{-92}$	$\sigma\approx$ 0 P $\approx10^{-96}$	$\sigma\approx$ 0 P $\approx$ 10^{-90}	$\sigma\approx$ 0 P $\approx10^{-86}$
$\sigma\approx$10 P $\approx10^{-91}$	$\sigma\approx$ 10 P $\approx10^{-94}$	$\sigma\approx$10 P $\approx10^{-87}$	$\sigma\approx$ 10 P $\approx10^{-83}$
$\sigma\approx$20 P $\approx10^{-90}$	$\sigma\approx$ 20 P $\approx10^{-92}$	$\sigma\approx$20 P $\approx10^{-85}$	$\sigma\approx$ 20 P $\approx10^{-80}$
$\sigma\approx$30 P $\approx10^{-89}$	$\sigma\approx$ 30 P $\approx10^{-90}$	$\sigma\approx$30 P $\approx$ 10^{-82}	$\sigma\approx$ 30 P $\approx10^{-78}$
$\sigma\approx$40 P $\approx10^{-86}$	$\sigma\approx$ 40 P $\approx10^{-89}$	$\sigma\approx$40 P $\approx10^{-80}$	$\sigma\approx$ 40 P $\approx10^{-74}$
$\sigma\approx$50 P $\approx10^{-84}$	$\sigma\approx$ 50 P $\approx10^{-87}$	$\sigma\approx$50 P $\approx10^{-79}$	$\sigma\approx$ 50 P $\approx10^{-71}$

TABLE II

Fusion probability has been computed for "impure" Pd ($J \approx 0.75\%$), using a β-potential (potential 21), and normalized to a number of event/min for different values of energy ($\sigma = \pm 50$ eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200 eV$

$\omega_\beta \approx 0.33$ Å	$\omega_\beta \approx 0.68$ Å	$\omega_\beta \approx 1.03$ Å	$\omega_\beta \approx 1.38$ Å
$\sigma\approx-50\ P\approx10^{-83}$	$\sigma\approx-50\ P\approx10^{-88}$	$\sigma\approx-50\ P\approx10^{-86}$	$\sigma\approx-50\ P\approx10^{-81}$
$\sigma\approx-40\ P\approx10^{-81}$	$\sigma\approx-40\ P\approx10^{-87}$	$\sigma\approx-40\ P\approx10^{-85}$	$\sigma\approx-40\ P\approx10^{-75}$
$\sigma\approx-30\ P\approx10^{-80}$	$\sigma\approx-30\ P\approx10^{-86}$	$\sigma\approx-30\ P\approx10^{-83}$	$\sigma\approx-30\ P\approx10^{-73}$
$\sigma\approx-20\ P\approx10^{-79}$	$\sigma\approx-20\ P\approx10^{-85}$	$\sigma\approx-20\ P\approx10^{-80}$	$\sigma\approx-20\ P\approx10^{-70}$
$\sigma\approx-10\ P\approx10^{-78}$	$\sigma\approx-10\ P\approx10^{-84}$	$\sigma\approx-10\ P\approx10^{-74}$	$\sigma\approx-10\ P\approx10^{-68}$
$\sigma\approx0\ P\approx10^{-76}$	$\sigma\approx0\ P\approx10^{-82}$	$\sigma\approx0\ P\approx10^{-73}$	$\sigma\approx0\ P\approx10^{-62}$
$\sigma\approx10\ P\approx10^{-75}$	$\sigma\approx10\ P\approx10^{-81}$	$\sigma\approx10\ P\approx10^{-72}$	$\sigma\approx10\ P\approx10^{-60}$
$\sigma\approx20\ P\approx10^{-74}$	$\sigma\approx20\ P\approx10^{-79}$	$\sigma\approx20\ P\approx10^{-71}$	$\sigma\approx20\ P\approx10^{-54}$
$\sigma\approx30\ P\approx10^{-73}$	$\sigma\approx30\ P\approx10^{-76}$	$\sigma\approx30\ P\approx10^{-70}$	$\sigma\approx30\ P\approx10^{-50}$
$\sigma\approx40\ P\approx10^{-72}$	$\sigma\approx40\ P\approx10^{-75}$	$\sigma\approx40\ P\approx10^{-69}$	$\sigma\approx40\ P\approx10^{-45}$
$\sigma\approx50\ P\approx10^{-71}$	$\sigma\approx50\ P\approx10^{-70}$	$\sigma\approx50\ P\approx10^{-65}$	$\sigma\approx50\ P\approx10^{-42}$

TABLE III

Fusion probability has been computed for "impure" Pd ($J \approx 0.75\%$), using γ-potential with *Q(t) =0* (potential 22), and normalized to a number of event/min for different values of energy ($\sigma = \pm 50$ eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200 eV$

$\omega_\gamma \approx 0.6$ eV	$\omega_\gamma \approx 0.65$ eV	$\omega_\gamma \approx 0.7$ eV	$\omega_\gamma \approx 0.75$ eV
$\sigma\approx150\ P\approx10^{-75}$	$\sigma\approx150\ P\approx10^{-55}$	$\sigma\approx150\ P\approx10^{-58}$	$\sigma\approx150\ P\approx10^{-65}$
$\sigma\approx160\ P\approx10^{-74}$	$\sigma\approx160\ P\approx10^{-52}$	$\sigma\approx160\ P\approx10^{-57}$	$\sigma\approx160\ P\approx10^{-62}$
$\sigma\approx170\ P\approx10^{-73}$	$\sigma\approx170\ P\approx10^{-47}$	$\sigma\approx170\ P\approx10^{-53}$	$\sigma\approx170\ P\approx10^{-59}$
$\sigma\approx180\ P\approx10^{-70}$	$\sigma\approx180\ P\approx10^{-45}$	$\sigma\approx180\ P\approx10^{-48}$	$\sigma\approx180\ P\approx10^{-55}$
$\sigma\approx190\ P\approx10^{-69}$	$\sigma\approx190\ P\approx10^{-43}$	$\sigma\approx190\ P\approx10^{-44}$	$\sigma\approx190\ P\approx10^{-50}$
$\sigma\approx200\ P\approx10^{-68}$	$\sigma\approx200\ P\approx10^{-42}$	$\sigma\approx200\ P\approx10^{-54}$	$\sigma\approx200\ P\approx10^{-44}$
$\sigma\approx210\ P\approx10^{-66}$	$\sigma\approx210\ P\approx10^{-41}$	$\sigma\approx210\ P\approx10^{-46}$	$\sigma\approx210\ P\approx10^{-38}$
$\sigma\approx220\ P\approx10^{-64}$	$\sigma\approx220\ P\approx10^{-40}$	$\sigma\approx220\ P\approx10^{-42}$	$\sigma\approx220\ P\approx10^{-35}$
$\sigma\approx230\ P\approx10^{-63}$	$\sigma\approx230\ P\approx10^{-39}$	$\sigma\approx230\ P\approx10^{-35}$	$\sigma\approx230\ P\approx10^{-31}$
$\sigma\approx240\ P\approx10^{-61}$	$\sigma\approx240\ P\approx10^{-37}$	$\sigma\approx240\ P\approx10^{-34}$	$\sigma\approx240\ P\approx10^{-28}$
$\sigma\approx250\ P\approx10^{-60}$	$\sigma\approx250\ P\approx10^{-35}$	$\sigma\approx250\ P\approx10^{-31}$	$\sigma\approx250\ P\approx10^{-25}$

TABLE IV

Fusion probability has been computed for "impure" Pd ($J \approx 0.75\%$), using a Debye potential (potential 24), and normalized to a number of event/min for different values of energy ($\sigma = \pm 50$ eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200 eV$

$\lambda_D \approx 0.3175$ Å	$\lambda_D \approx 0.635$ Å	$\lambda_D \approx 0.9525$ Å	$\lambda_D \approx 1.27$ Hz Å
$\sigma\approx-50\ P\approx10^{-65}$	$\sigma\approx-50\ P\approx10^{-62}$	$\sigma\approx-50\ P\approx10^{-53}$	$\sigma\approx-50\ P\approx10^{-53}$
$\sigma\approx-40\ P\approx10^{-62}$	$\sigma\approx-40\ P\approx10^{-58}$	$\sigma\approx-40\ P\approx10^{-50}$	$\sigma\approx-40\ P\approx10^{-52}$
$\sigma\approx-30\ P\approx10^{-60}$	$\sigma\approx-30\ P\approx10^{-56}$	$\sigma\approx-30\ P\approx10^{-46}$	$\sigma\approx-30\ P\approx10^{-50}$
$\sigma\approx-20\ P\approx10^{-55}$	$\sigma\approx-20\ P\approx10^{-55}$	$\sigma\approx-20\ P\approx10^{-42}$	$\sigma\approx-20\ P\approx10^{-46}$
$\sigma\approx-10\ P\approx10^{-53}$	$\sigma\approx-10\ P\approx10^{-53}$	$\sigma\approx-10\ P\approx10^{-40}$	$\sigma\approx-10\ P\approx10^{-43}$
$\sigma\approx0\ P\approx10^{-52}$	$\sigma\approx0\ P\approx10^{-51}$	$\sigma\approx0\ P\approx10^{-36}$	$\sigma\approx0\ P\approx10^{-37}$
$\sigma\approx10\ P\approx10^{-51}$	$\sigma\approx10\ P\approx10^{-50}$	$\sigma\approx10\ P\approx10^{-35}$	$\sigma\approx10\ P\approx10^{-33}$
$\sigma\approx20\ P\approx10^{-50}$	$\sigma\approx20\ P\approx10^{-49}$	$\sigma\approx20\ P\approx10^{-32}$	$\sigma\approx20\ P\approx10^{-28}$
$\sigma\approx30\ P\approx10^{-49}$	$\sigma\approx30\ P\approx10^{-46}$	$\sigma\approx30\ P\approx10^{-31}$	$\sigma\approx30\ P\approx10^{-25}$
$\sigma\approx40\ P\approx10^{-47}$	$\sigma\approx40\ P\approx10^{-43}$	$\sigma\approx40\ P\approx10^{-30}$	$\sigma\approx40\ P\approx10^{-20}$
$\sigma\approx50\ P\approx10^{-45}$	$\sigma\approx50\ P\approx10^{-40}$	$\sigma\approx50\ P\approx10^{-29}$	$\sigma\approx50\ P\approx10^{-17}$

The principal theoretical objective of this section is that of demonstrating whether there is a relationship between low energies, if lattice deformation Ψ at room temperature can influence the process of fusion.
In particular, the probability of fusion within a microcrack was calculated to evidence a possible "enhancement of the tunneling effect".
Further, the aim is to evaluate theoretically the influence of the concentration of impurities using the trend of the curve of potential. A very high barrier is found within the pure lattice (J=0.25% approx.). While for the impure metal (J=0.75% approx.), maintaining the same thermodynamic conditions for the system, there may be a higher probability of fusion, with a lower total potential energy so that the tunneling effect is enhanced.

7. Deformation

This communication reports an analysis of the influence of variations in the thermodynamic conditions which could, as a result of deformation, produce dislocations in the lattice and microcracks which may be able to concentrate in their vicinity a significant fraction of the deuterons present in the metal, catalysing a chain reaction which could favour the process. Further, the study researches a relation between low energies to confirm the hypothesis regarding microcracks by means of theoretical quantitative estimations of the coefficient of structural deformation[1] Ψ of the perturbed crystalline lattice, independent of time. More precisely, the probability of fusion within a microcrack was calculated and compared with that calculated on the surface, to evidence a possible enhancing effect, also taking into consideration the vibrational states of the deuterons. Theoretical indications which we consider interesting.
In agreement with the hypothesis of "chain reaction" proposed in reference[1], it was found that the appearance of microcracks, in effect, increases the rate of deuteron fusion within the lattice.
We also analyse the trend of the curve of potential of deuteron-plasmon interaction within the Palladium lattice, from which it can be deduced that the thickness of the Coulomb barrier is reduced on varying the total energy and the percentage of impurities present in the metal. The tunneling effect was again calculated in order to evidence any possible enhancement of this effect within the microcrack.

8. The three-dimensional model

This section considers whether, and within what limits, the number of fusions within a generic cubic lattice could be

conditioned or influenced by both extensive lattice defects and other characteristics and thermodynamic conditions. In fact, in the case of internal perturbation, the interaction between the impurities present and the dislocations which are produced in the metal during deformation can significantly modify the electrical properties of the material.
Possible deformations produced in the crystalline lattice by variations in the temperature are also considered.
Further, under conditions far from saturation, the rate of fusion within the metal depends on the number of deuterium nuclei absorbed per unit of time, and also this could depend on the deformation of the lattice.
If this effectively occurs, it is not difficult to hypothesise that the energy produced by the micro-explosions within the microcracks present could favour the formation of new microcracks, which in turn would capture further deuterons by the same mechanism.
In a three-dimensional model, the probability of fusion between deuterium nuclei (where no microcrack exists, that is in a zone on the surface of the crystalline lattice), is equal to the probability of penetration in a Coulomb potential barrier $V(r)$, given by:

$$|P|^2_{sur} = \exp\left(-2\int_0^\alpha \left[\frac{1}{\hbar}\sqrt{\mu\left(E - V_{eff}(r)\right)}\right]_{sur} dr\right) \quad (34)$$

α is approximately 0.11 Å , E is the total initial energy in eV, principally thermal in nature, $\hbar$ is Planck's constant, and μ is the reduced mass of the deuterons. The process of fusion within crystalline lattices can be schematised supposing that the electrical charge is uniformly distributed on a thin spherical shell and is equal to the range of effective interaction between the nucleons, which can be described in terms of an effective Coulomb potential:

$$V_{eff}(r) \approx \frac{q^2}{r} - const \quad (35)$$

where q is the deuteron charge.
It is known that in the presence of interactions between deuterium nuclei and collective phonic excitation in the metal, the number of fusions λ_f in a gas consisting of λ deuterons with density ρ is given by:

$$\lambda = \lambda_f \frac{4\pi\rho\hbar}{\mu_d} \left\langle \frac{1}{p} \right\rangle \quad (36)$$

where μ_d is the reduced mass of the deuterium nuclei, p is their impulse, and where the parentheses $\langle\ \rangle$ represent the thermal mean. Examining, for convenience, a CFC lattice structure subjected to deformation, it is possible to calculate the probability of fusion, Ψ, within a microcrack, on varying the temperature.
Denoting the volume of a single cell by $d\Omega$, the deformation of the entire lattice is given by:

$$\Psi \simeq \left(\iiint_\Omega \eta J \xi_{(r)} \frac{\sigma_i bhL}{a^2 kT} D_k \exp\left(-\frac{2F_k}{kTJ}\right)\right) d\Omega \quad (37)$$

J is the concentration of impurities, η is a parameter which depends on the lattice and electronic structure of the metal under consideration, , $\xi_{(r)}$ is the number of dislocations; $\sigma_i\, bhL$ represents the independence of the internal stress from the external conditions and the hypothesis, valid in this approximation, is that the energy of the barrier in different states of near equilibrium of nuclei within the lattice, which includes the stress under conditions of non-equilibrium, is very small if not almost zero. σ_i refers to the stress within the lattice; bh are two parameters which depend on the dislocations; L is the length of the dislocation; a^2 is the position of equilibrium of the dislocation core, separated along a "split" in the crystalline lattice with symmetry, in this case, of CFC; kT is the thermal energy to which the metal is submitted, which at room temperature is approximately 0.025eV); $2F_k$ is the Helmholtz free energy; D_k represents the point of minimum approach, within a microcrack, between the deuterium nuclei with energy kT; J is the concentration of impurities around a dislocation.
We have already suggested that a greater number of events could occur within a microcrack, under appropriate conditions the possible consequence of a dislocation, than on the lattice surface. To demonstrate this, approximate calculations were made, taking into account the lattice deformation and the depth of the microcrack. Taking the centre of mass as the reference system, the probability of fusion can be written as [1] :

$$|P|^2_{\text{int}} = \exp\left(-2\int_0^\alpha K(r)_{\text{int}}\, dr\right) \quad (38)$$

where α is approximately 0.11Å, $K(r)_{\text{int}}$ is given by:

$$K(r)_{\text{int}} = \sqrt{2\mu\left[E - V(r)\right]/\hbar^2} \quad (39)$$

E is the total initial energy in eV, principally thermal in nature, $\hbar$ is Planck's constant, μ is the reduced deuteron mass. Equations (38) - (39) refer to the process of fusion within a microcrack. The Coulomb potential $V(r)$, containing the temperature contribution, is given by the expression:

$$V(r) = k_0 \frac{q^2}{r} \cdot M_d \left(V(r)_M - \frac{J\ kT\ R}{r} \right) \quad (40)$$

In (41), $V(r)_M$ is the Morse potential, given by:

$$V(r)_M = (J/\zeta)\left[\exp\left(-2\varphi\left(r - r_0\right)\right) - 2\exp\left(-\varphi\left(r - r_0\right)\right)\right] \quad (41)$$

J indicates the concentration of impurities present in the metal, while the parameters φ, r_0 depend on the dynamic conditions of the system.

ζ is a parameter which depends on the structural characteristics of the lattice, the number of “d” band electrons and the type of lattice symmetry, varying between 0.015 and 0.025.

If (38) is divided by (36) and multiplied by (37), it follows that:

$$\Gamma \approx \frac{\exp\left(-2\int_0^{\varepsilon} \mathrm{K}(r)_{\text{int}}\ dr\right)}{\lambda_f \cdot \dfrac{4\pi\ \rho\ \hbar}{\mu_d} \cdot \langle \dfrac{1}{p} \rangle} \cdot \Psi \qquad (42)$$

Expression (42) represents the probability of fusion of deuterons within a microcrack: this is inversely proportional to the number of nuclei absorbed by the metal. In the context of the approximations applied, the probability of fusion so calculated is equal to the coefficient of deformation of the corners per unit of total deformation of the entire lattice.

Using (42) and adopting both the Morse and effective potentials, the probability of fusion, normalised to the number of events per minute, was calculated using a simulation programme.

$$V(r) = \left(k\ \ q^2\right)\left(V_{eff}(r) - \frac{K\,T}{J\varepsilon\ \ R}\right) \qquad (43)$$

where $\mathrm{K\,T}$ is the mean kinetic of the gas, and ε is the vibrational energy, typically of the order of some eV for the quantum states considered.

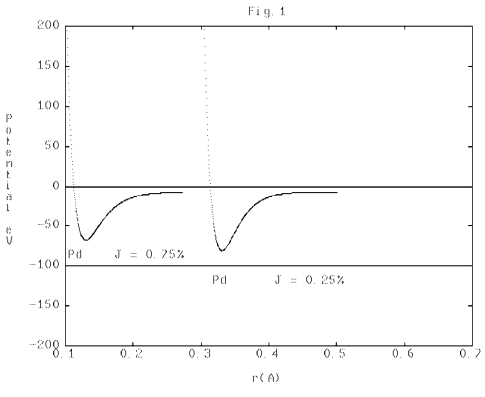

Fig. 1**.** Comparison between the potentials (41) and (43), for $J \approx 0.75\%$ and $J \approx 0.25\%$, respectively, at temperature T = 280 K. In the first case. both the height and thickness of the potential barrier are reduced.

9. Conclusions

As a conclusion, we have shown that the model proposed in this present paper can explain some anomalous nuclear traces in solids, but definitely jeopardizes any hope about the possibility of controlled fusion reactions in matter.

In the first part of the work we cosiderato various parameters type the potential function of time, the number of d electrons, the depth D of the Coulomb 'barrier, the various energy levels and their tensors. The effective interaction between the deuterons inside the metal: it in fact shows that the coupling between plasmons and deuterons, in the presence of impurities, is able not only to decrease the thickness, but also to lower the height of the barrier Coulomb K in various types of deuterated lattices.

We also assumed that instead of a static Coulomb barrier are two together that oscillate and for this reason that the phenomenon of cold fusion is open to any road both theoretical and experimental.

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