

Probability of Deuteron-Plasmon Fusion at Room Temperature within Micro-cracks of Crystalline Lattices with Deuterium Loading

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Abstract: This communication seeks 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.

Key words: Deuteron-plasmon, micro-cracks, lattice defects.

1. Introduction

This communication presents a study of the influence of temperature on the phenomenon of deuteron fusion within crystalline lattices with a FCC structure. We hypothesise that a kind of chain reaction, catalysed by the micro-cracks [1] which arise in the structure as the result of variations in the thermodynamic conditions or other causes, can favour the process. Here we aim to confirm the hypothesis regarding micro-cracks through quantitative theoretical estimations of the coefficient of structural deformation of the disturbed metal lattice, independent of time, obtained for different temperature values in the range 100-300 K. Thus, the length and depth of the micro-cracks, induced by micro-explosions and by lattice deformation on varying the temperature in the range 100-300 K, are analysed in Section 2, and an attempt is made to evaluate their influence on deuteron fusion in impure lattices on varying the energy of the

deuterons.

2. Deformation in Cubic Lattices

This section considers whether, and within what limits, the rate of fusion within a generic cubic lattice can be conditioned or influenced, not only by local lattice defects and other thermodynamic characteristics and conditions, but also by any “deformations” arising in the crystalline lattice as the result of varying the temperature. If this effectively occurs, it is not difficult to hypothesise that the energy produced by the micro-explosions within the micro-cracks could favour the creation of new micro-cracks which, in turn, would capture further deuterons by the same mechanism and thus trigger a kind of chain reaction. On the other hand, the formation of micro-cracks, provoked by the energy released during long periods of electrolysis with Deuterium, has already been observed experimentally in Palladium electrodes [2], but has until now been considered only a consequence of nuclear fusion. Our hypothesis is rather than that this phenomenon could favour the process, enhancing the probability of fusion of the deuterons absorbed by the metal lattice. We wish

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to analyse the internal perturbations “independence of time” which can occur following D₂ loading, and the consequent alteration in the properties of the metal. In fact, the loading does not simply produce an increase in the percentage of deuterium present, with a consequent disequilibrium in the “d” band; according to our hypothesis, this type of procedure also produces lattice deformations followed by dislocations which would cause micro-cracks in the structure. In the case of internal perturbation, in fact, it can happen that the interaction between the impurities present and the dislocations produced in the metal during a deformation significantly alters the electrical properties of the material. Then, as a result of the different arrangement of the atoms with respect to the non-perturbed lattice, certain special reactions can occur and incorporate the impurities in the nucleus of the dislocations [1]. An important effect on the reaction is represented by electronic screening due to the metal lattice. This effect, already studied by Rabinowitz [3], can be accounted for by means of a model in which the negative charge is distributed in the nucleons, and can be represented schematically supposing that q^- is uniformly distributed within a thin spherical shell which radius, $R \geq r_1$, is equal to the effective range of the interaction between the nucleons, describable in terms of a shifted Coulomb potential [3]:

$$V = (kq^2) [1/r - 1/R], \quad r_1 \leq r \leq R \quad (1)$$

In Eq. (1), q is the deuteron charge, r_1 is the semi-classical point of inversion, $k = 1/4\pi\epsilon_0$, and R is the nuclear radius. Then, $V = 0$ for $r > R$. The solution for the semi-classical tunnelling factor Λ is [3]:

$$\Lambda = D \exp \left[- 2 \gamma (r_1) \right] \quad (2)$$

$$\gamma(r_1) = \left(\pi / 2\hbar \right) \left[\left(2q^2 / 4\pi \epsilon_0 \right) \mu r_2 \right]^{1/2} \quad (2')$$

In Eqs. (2) and (2'), D is a numerical constant of the order of unity, μ is the reduced effective mass of the deuteron, r_2 is the classical point of inversion, and \hbar is the reduced Planck constant. To take account of the

effect of impurities present in the metal, the constant D is modified in Eq. (2), substituting the product $J\eta$, where J is the concentration of impurities and $\eta \cong 1$. The numerical calculation was performed using a programme which takes account of the temperature contributions through the deuteron interaction potential $V(r)$, which in this case can be expressed as:

$$V(r) = k_0 \frac{q^2}{r} \cdot M_d \left(V(r)_M - \frac{J k T R}{r} \right) \quad (3)$$

where, $V(r)_M$ is the Morse potential, $k = 1/4\pi \epsilon_0$, q is the charge of the deuteron, M_d the reduced mass of the deuterium nuclei, T the absolute temperature at which the metal is held experimentally, J the concentration of impurities in the crystalline lattice [4], and R is the nuclear radius. It is known that in the presence of interactions between deuterium nuclei and collective [2] phonic excitations in the metal, the number of fusions λ_f in a gas consisting of λ deuterons with density ρ is given by:

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

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. We can now consider, for convenience, a cubic lattice structure subjected to deformations and calculate the probability of fusion within a microcrack, Γ , on varying the temperature. Indicating the volume of a single cell by $d\Omega$, the deformation of the whole lattice is given by:

$$A_V = \left[\left(\iiint_{\Omega} \eta \left(\xi(r) \left(\frac{1}{V} \right) \left(\frac{\partial V}{\partial T} \right)_P \right) d\Omega \right) \frac{1}{L} \int_0^L J c(r,t) dr \right] \quad (5)$$

where, $\left(\frac{1}{V} \right) \left(\frac{\partial V}{\partial T} \right)_P$ represents the volume deformation coefficient of the crystalline lattice, maintaining the pressure constant and varying the temperature and time of exposure to the deuteron gas, in function of the micro-explosions within the microcrack; η is a parameter which depends on the lattice and electronic structure of the metal under consideration; m depends on the cubic symmetry [5, 6] of the lattice, which is 1/3.

Integrating on the upper limit L , which is the length of the Pd sample, gives the medium loading level; $c(r, t)$ is the local concentration of d^+ ions in the Palladium at time t , in the three directions; and J the concentration of impurities.

Finally, $\xi_{(r)}$ is the number of dislocation. We are interested in the deformations of CFC type which occur in metals such as Pd at room temperature. We will try to evaluate the dislocation of ions in the crystalline lattice induced by the deformation in order to determine the effect of this phenomenon on deuteron fusion. We have already suggested that within a microcrack, the possible consequence of a dislocation under appropriate conditions, there could occur a greater number of events than on the surface. Setting the reference system as that of the centre of mass, the probability of fusion in a zone of the metal in which there is no microcrack, for example on the surface, can be written as Ref. [1]:

$$|P_{sur}^2 = \exp\left(-2 \int_0^\alpha \left(\sqrt{2[E-V(r)]/\hbar^2}\right)_{sur} dr\right) \quad (6)$$

where, α is approximately 0.19\AA , E is the total initial energy, substantially thermal in nature. Eq. (6) refers to the process of fusion on the surface of the crystalline lattice. The Coulomb potential $V(r)$, containing the temperature contribution, is given by the Eq. (1):

$$V(r) = k_0 \frac{q^2}{r} M_d \left(V(r)_M - \frac{JkTR}{r} \right) \quad (7)$$

The same symbolism is adopted in this equation as that of Eq. (3). In Eq. (8), $V(r)_M$ is the Morse potential, given by:

$$V(r)_M = (J/\zeta) \left[e^{-2\varphi(r-r_0)} - 2e^{-\varphi(r-r_0)} \right] \quad (8)$$

J indicates the concentration of impurities present in the metal, while the parameters φ and r_0 depend on the dynamic conditions of the system, ζ is a parameter, variable between 0.015 and 0.025, which depends on the structural characteristics of the lattice, the number of “d” band electrons and the type of lattice

symmetry. If we divide Eq. (6) by Eq. (4) and multiply by Eq. (5), it follows that:

$$|T|_{wm}^2 \sim \frac{\exp\left(-2 \int_0^\alpha \left(\sqrt{2[E-V(r)]/\hbar^2}\right)_{wm} dr\right)}{\lambda \cdot \frac{4\pi\rho\hbar}{\mu_d} \cdot \left\langle \frac{1}{p} \right\rangle} \cdot \Lambda_V \quad (9)$$

Eq. (9) represents the probability of fusion of the deuterons within the microcrack. This is inversely proportional to the number of nuclei absorbed by the metal. In the context of the approximations made, the probability of fusion calculated is equal to the coefficient of corner deformation per unit of total deformation of the entire lattice. Using Eq. (9), and adopting the Morse potential, the probability of fusion within the microcrack, normalised to the number of events per minute, was calculated using a numerical simulation programme which employs the “WKB” method. The potential Eq. (8) with a “shell” potential of the type Eq. (1) modified as follows:

$$V = (kq^2) \left((1/r) - \frac{KT}{J\epsilon R} \right), r_1 \leq r \leq R \quad (10)$$

where, KT is the mean kinetic energy of the gas, ϵ is the vibrational energy which is typically of the order of some eV for the quantum states under consideration, and q is the deuteron charge. Using Eq. (6), the probability of fusion on the surface was calculated to confirm, qualitatively, the enhancing effect. Using Eq. (9), the probability of fusion was calculated within a microcrack with loading, i.e. $J = 0.8\%$. This means that as well as breaking the equilibrium of the “d” band, this procedure can also enhance the tunnelling effect within the microcrack.

3. Conclusions

The principal objective of this communication was that of demonstrating if and how the deformation of the crystalline lattice, at room temperature, can influence the process of fusion. In particular, we calculated the probability of fusion within a microcrack, comparing it with that calculated on the surface to evidence a possible enhancing effect.

With this aim, we have identified the probability of fusion within a microcrack with the deformation coefficient Γ , and performed a numerical simulation using the WKB method in the case of a model with cubic structure. The result is that, in effect, the presence of lattice deformation enhances the probability of fusion by at least 2-3 orders of magnitude compared with case of non-deformed lattices.

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