A Mechanism for Cold Nuclear Fusion: Barrier Reduction by Screening under Transient Coherent Flow of Deuterium

Noriaki MATSUNAMI
Crystalline Materials Science, School of Engineering,
Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-01,
Japan

ABSTRACT

A mechanism for the cold nuclear fusion is suggested, based on reduction of the barrier penetration factor λ due to screening by enhanced electron density around deuterium at excited/ionic states under transient coherent flow of d in metals. For D^- state, $\lambda \approx 70$ or the rate of ~1 fusion/s•cm^3 is obtained. The effective region and probability of the transient coherent D^- state are discussed.

1. Introduction

The cold fusion reported in 1989 by Fleischmann and Pons[1] and Jones et. al.[2] has been investigated extensively[3-6]. Many of the mechanisms suggested for enhancement over the standard theory (see,e.g., ref.[7]), which fails to explain the anomalous cold fusion rate, are summarized in refs.[3,6]. At present, however, none of these mechanisms is readily satisfactory. Among all, the most striking of the cold fusion phenomena is irreproducibility. This would strongly suggest that the cold fusion involves extreme transient or fluctuating processes as discussed below.

In this paper, a mechanism is suggested based on reduction of the barrier due to screening by enhanced electron density around d at excited and/or ionic states under transient coherent flow of deuterium. The effective region and probability are discussed with emphasis on the irreproducibility and the fusion rate is derived.

FRONTIERS OF COLD FUSION

2. Barrier Reduction by Screening at Transient States

The present model follows that the d-d fusion rate is proportional to the square of the overlap of two deuterium wavefunctions. During electrolysis of D_2O or discharge after charge of d under high pressure or by implantation, the d concentration would be near saturation and hence the coherent (fluid-like) movement of d is expected, unless otherwise no space is available[8,9]. Under these movements, deuterium would pass through the transient,i.e., excited and/or ionic states, at which the electron density around d might be enhanced due to the charge transfer from metal atom to d, like non- and anti-bonding states, and thus reducing the barrier factor. The cohesive energy of the ionic states is comparable with that of metal-hydrides as discussed later. Since there is little information on the transient states, the following potential is used in this study;

$$V(x)=(1-z)/x + (z/x)\exp(-x/b) \quad , \qquad (1)$$

where b is the screening parameter and z is the effective number of electrons around d (z=1 and 2 correspond to D^0 and D^- states, respectively). Herein atomic units(au) are used unless specified. In the coherent movement of d, the relative energy ε would be close to zero and the turning point x_0 satisfying $V(x_0)=\varepsilon=0$ is given by;

$$x_0=b\log\{z/(z-1)\} \quad . \qquad (2)$$

The barrier factors calculated using the WKB method are given in Table 1 for various b and z, including λ obtained with an approximate formula(error<10%);

$$\lambda=(2\pi k)^{1/2}\{(1/\pi x_0)^2+(1/8b)^2\}^{-1/4} - \log(8kx_0) \, , \qquad (3)$$

where $k=m_r/m_e$ is the reduced mass m_r of d-d system divided by the electron mass m_e. For z=1(D^0), $x_0=0.5$ is employed.

Table 1. The barrier factor λ for the screening parameter b (au) and the effective number of electrons z(z=1,2 correspond to D^0,D^-). The values in the parenthesis are obtained with eq.(3).

b	0.05	0.1	0.2	0.3
z=1	59(58)	83(82)	105(105)	113(114)
z=1.5	34(36)	51(53)	74(77)	92(96)
z=2	27(29)	40(42)	59(62)	74(77)
z=3	20(21)	30(32)	45(47)	57(59)

A small contribution from the log term in eq.(3) and WKB formula which should be eliminated to match the Gamow factor for the Coulomb potential($V(x)=1/x$) will not change λ significantly. One sees that λ is close to 70 for z=2 or D^- state with the screening parameter b=0.3, this b value being close to that in free H_2 molecule[10,11] and the ground state of H in Pd[12].

3. Fusion Rate

Let the probability and fractional volume being at the transient states be f_t and f_v, the fusion rate Y is given by

$$Y(/s\cdot cm^3)=AN\lambda exp(-\lambda)/a_0^3(f_t f_v)\ , \qquad (4)$$

here $a_0=0.529\times10^{-8}$ *cm is the Bohr radius,* $A=1.5\times10^{-16}$ cm^3/s is the reaction constant[13,14] and N is the d-d pair concentration. For $\lambda=74$(e.g.,b=0.3,z=2) with $f_t f_v=1$ and $N=10^{22}/cm^3$, $Y\approx5/s\cdot cm^3$ is obtained. The factors f_t and f_v, which depend on d/metal atom ratio, defect densities and etc, would have values much less than unity and large fluctuations. The parameter b and z may also have fluctuation as contrast to that at the ground state. These would result in "irreproducibility" of the cold fusion.

The cohesive energy E_c for an ionic lattice of MH is given by E_c=(Madelung energy)-(Ionization energy of M)+(Electron affinity of H), neglecting a repulsive contribution. Suppose a hypothetical ionic states of Pd^+H^- (H^- at tetrahedral sites of the fcc Pd lattice), this is equivalent to ZnS structure with d_{nn}=0.17 nm, where d_{nn} is the nearest neighbor distance between metal ion and H^-, and one gets E_c=6.4 eV[15,16]. Similarly, one finds E_c=8 eV for $Ti^{2+}H_2^{2-}$ (H^- at the mid points of the 2nd nearest neighbors of the fcc Ti lattice, equivalent to NaCl structure with d_{nn}=0.28 nm). These values are comparable with E_c of metal hydrides, 6.7 and 10 ev for PdH[12] and TiH_2, respectively. The repulsive contribution is small unless d_{nn} is too small and E_c is relatively insensitive to the structure. Thus high probability being at the ionic states is expected for the transient states, if the activation energy into these states is smaller than that of diffusion. The present model does not require contraction of two d nuclei nor acceleration of deuterium. The details will be described elsewhere.

4. Conclusion

The fusion rate is derived based on the reduction of the barrier penetration factor due to screening by enhanced electron density around d at excited ionic states under transient coherent flow of d in metals. The fusion rate can reach to ~ 1/s•cm^3 and critically depends on the effective time and region of the transient states, resulting in the "irreproducibility" of the cold fusion. More investigations on the transient states would be fruitful.

References

1. M. Fleischmann and S. Pons, J. Electroanal. Chem. 261(1989)301.
2. S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne, S. F. Tayler & J. Rafelski, Nature 338(1989)737.
3. J. O'M. Bockris, G. H. Lin and N. J. C. Packham, Fusion Technol. 18(1990)11.
4. E. Storms, Fusion Technol. 20(1991)433.
5. V. A. Tsarev and D. H. Worledge, Fusion Technol. 20(1991)484.
6. G. Preparata, Fusion Technol. 20(1991)82.
7. C. D. Van. Siclen and S. E. Jones, J. Phys. G12(1986)213.
8. G. Alefeld and J. Völkl, "Hydrogen in Metals I And II", (Springer-Verlag,1987).
9. Y. Fukai, Adv. in Phys. 34(1985)263.
10. T. E. Sharp, Atomic Data 2(1971)119.
11. N. Matsunami, Rad. Effects and Defects in Solids 112(1990)181.
12. Z. Sun and D. Tomanek, Phys. Rev. Lett. 63(1989)59.
13. N. Jarmie and R. E. Brown, Nucl. Instrum. & Methods B10/11(1985)405.
14. A. Krauss, H. W. Becker, H. P. Trautvetter, C. Rolfs and K. Brand, Nucl. Phys. A465(1987)150.
15. C. Kittel,"Introduction to Solid State Physics",(Wiley,1976).
16. W. A. Harrison,"Electronic Structure and The Properties of Solids",(Dover,1989)