

A POSSIBLE ENHANCEMENT MECHANISM OF NUCLEAR FUSION

Takayasu Tanaka and Shun-ichi Himeno*

Faculty of Mechanical Engineering, Nippon Bunri University, Ichigi, Oita 870-0316, Japan

*Hanazono University, Nishinokyo Tubonouti 8-1, Nakagyouku, Kyoto 604-8456, Japan

ABSTRACT

An enhancing mechanism of nuclear fusions is presented, most part of which is within the framework of the traditional theories. In this mechanism, electron currents play an important role, which are induced by an externally applied field or counterstreams of free electrons which naturally exist inside, surface and outside of bulk metals. At places of electron currents, the electric potential becomes negative and there relevant nuclei gather and collide. Then, if electrons exist in close vicinities in addition, there the electric potential barriers are lowered further and the tunneling effects which bring about nuclear fusions drastically increase. Resultantly, the rate of nuclear fusions enhances as a whole. Then, if shape of the current can be sufficiently fine and strong the increase is more drastic. It is not clear that at present the mechanism can make enhance the fusion to any extent

1. INTRODUCTION

As is widely known, Fleischmann and Pons reported the "excess heat" in simple devices at room temperature in 1989, which is now called cold fusion (hereafter referred to as CF). After their experiment and many following ones, critical discussions appeared.^{2,3)} But, then succeeding various experiments were performed including re-examination by many other researchers. And the various abnormal results have been "confirmed" by them, though the degrees of the anomalies became smaller than ones at the initial stage.⁴⁾

The features now thought to be peculiar to "CF", which become gradually apparent by experiments, are as follows:

- 1) The phenomena are sporadic and lack of the reproducibility.
- 2) Excess heat release: That is, the heat is released and it is too much to be the heat due to the chemical reactions.
- 3) Heat-neutron anomaly: That is, the number of nuclear reaction emitting N_Q is far larger than the number of reaction as emitting neutrons N_n : $N_Q/N_n \sim 10^8$
- 4) Tritium anomaly: In other word, high t/n channeling ratio. That is, the number of nuclear reaction emitting tritium N_t is far larger than the number of reaction emitting neutrons N_n : $N_t/N_n \sim 10^7$.
- 5) Nuclear transmutation: In addition, recently, not a few nuclear transmutation phenomena are reported in CF experiments and other experiments.

To explain these, many theories were published. However unfortunately, no theory had been widely admitted to explain these queer results of experiments.

In this paper we propose a new mechanism which might be able to explain above features peculiar to "CF" to some extent, without making any particular assumption, which is made deviated from traditional theories. The essence of the assertion proposed in this paper is that the fine electron currents reduce the potential barrier between nucleon and as a result fusions take place.

Some similar attempts on this line have already been proposed. One kind of resemble attempts are due to the acceleration of deuterons by some mechanism. But the situation is different from them, that is, now not the electric field but the electric potential is important. Also there are some other attempts, which are discussed as shielding processes. Rabinowitz,⁵⁾ Rabinowitz and Worledge⁶⁾ showed that the shielding increase the Gamov factor astonishingly. Our mechanism is different from them on the point that the discreteness of electrons plays an important role and the electron

charge works more directly.

2. A NEW ENHANCEMENT MECHANISM

In this section, the present authors propose a new mechanism. This mechanism assumes electron currents of microscopic scale. They are induced not only by an externally applied field but also they naturally exist as counterstreams of free electrons. They exist inside and/or outside of bulk metals. Such electron currents make regions where the electric potential is negative. And nuclei gather there and mutually collide. The fusions in low energy region take place only through tunneling effect but the tunneling heavily depends on the potential barriers. If then an electron exists in close vicinity in addition, the potential is lowered and as a result of it, the rate of nuclear fusions drastically increases. The difference with that of Rabinowitz et al. is that they considered the screening effects but it is not so effective and for short range interaction it does not work well, whereas we consider a bare electron and the effect is far stronger. Now the discreteness of electrons is very important! This is the scenario of nuclear fusion, which we should like to insist.

The situations we study in this paper may be various:

A) Place There are cases of inside and /or outside solid: i) Crack parts in solid, which is not connected to the outside of solid. ii) Crack parts in solid, which is not connected to the surface of solid. iii) Surface Layer iv) On surface of solid. v) Over surface of solid. vi) Far from surface of solid.

B) Current Next, each case can further be classified into finer ones according to the applied current: i) External current is applied. ii) Not applied.

C) Surrounding Each case can further be classified depending on what the current is surrounded by: i) Vacuum. ii) Solution (or plasma).

Depending on the combination of above situations A⊗B⊗C conditions, the situation becomes completely and qualitatively different ones but the fundamental situation is same. So for a while, we will proceed without restricting the situation and later we will study the different parts briefly.

We assume that the current and ionization of one or both of the collision nuclei. This is a natural assumption, because this can easily be realized inside solids or in electrolytes or in plasmas outside the solid. In fact, in electrolytes or plasmas, atoms can easily be ionized, as the ionization energies deduce due to shielding effects of surrounding media.

3. NUCLEAR REACTION RATE

It is known that collisions of two particles, whose densities of first kind particles and that of the second kind are n_1, n_2 and the cross section is σ , then the rate of nuclear reaction is

$$r = n_1 n_2 \sigma v .$$

Now the situation is considered where electrons play significant role, we must simply remedy this as

$$r' = n_1 n_2 \sigma'(n_e(r, t), v_e) v .$$

Here, σ' is modified cross section due to the presence of electrons whose velocity is v_e at distance r . Using a numerical factor,

As is well known, the cross section of reaction through channel α is obtained by WKB⁷⁾ method as

$$\sigma_r(\alpha) = \sum_{l=0}^{\infty} (2l+1) \pi \lambda^2 T_l(\alpha) \cong \sum_{l=0}^{\infty} (2l+1) \pi \lambda^2 \frac{4k}{K} v_l, \quad (k \ll K)$$

where $T_l(\alpha)$ the transmission coefficient. Here, k is the wavenumber of the incident nucleus; $k = MV/\hbar$ where M and v are the reduced mass of the incident and target nuclei, and the relative velocity of relevant particles. The K is the wavenumber just inside the nucleus of the target particle; $K^2 = K_0^2 + k^2$ and K_0 is the same one when $\epsilon = 0$ and $\lambda = 1/k$. The v_l is the penetration factor and is

$$v_l = \sqrt{\frac{U_l(R) - \varepsilon}{\varepsilon}} \exp(-2G), \quad G \equiv \int_r^{r_0} \sqrt{\frac{2M}{\hbar^2} [U_l(r) - \varepsilon]} dr, \quad (U_l > \varepsilon = \frac{\hbar^2 k^2}{2M})$$

where U_l is an effective potential, $U_l = V_l + \hbar^2/2 \cdot l(l+1)/r^2$, and r_0 is an outer radius satisfying $U_l = \varepsilon$, and $V(r)$ the Coulomb potential.

Since we are now studying the case of the low energy level and then $l=0$ is most important, we study collisions of $l=0$, in the presence of electron charges. Then, U_l becomes the true potential V . The V is an addition of the potential between a proton and a neutron of a deuteron, U_{p-n} and the potential between a deuterons and a nearby electron, U_{d-e} :

$$V = U_{p-n} + U_{d-e}.$$

The reaction rate, when the catalyzing electrons are absent, is already obtained. The real reaction rate is obtained by multiplying r by the distribution function of the deuteron-deuteron relative velocity and integrating it.

Now, the situation is more complicated, as we must take into account catalyzed by electrons in addition. We now focus our attention to deuteron -deuteron reaction. As the distance of nucleons in deuteron is over 2 \AA , if the distance from the center of mass of two deuterons is $1 \sim 2 \text{ \AA}$, the electric field of the catalyzing electron works well, and the nuclear fusion will relatively easily be performed. So we estimate to what extent often such a situation will be realized, without thinking too much the detailed situation. In solid or solution, 1 \AA^3 cube of solid contains about one electron in it. So in order to realize an encounter of such two deuterons and one electron (three bodies), the electron encounters only one time among $(10^{10}/10^{15})^3 = 10^{15}$ times. This gives a small parameter. In addition, the movement of catalyzing electrons reduces the reaction rate. The thermal velocity of electron become about 100 times or more compared with that of ions due to quantum effect. The number of electrons near deuterons throughout the time interval of collision is $1/(10^2)^3 = 10^{-6}$. So a small factor $10^{-15} \times 10^{-6} = 10^{-21}$ appears. But then instead the Gamov factor G becomes small.

4. EFFECTS OF QUANTUM MECHANICS

Due to the Dirac equation, an electron oscillates rapidly in time with frequency, $2pc/\hbar \approx 1.55 \times 10^{21}/s$ (zitterbewegung). And as a result of it, an electron is thought to be a particle of order of Compton length of the electron, $\hbar/m_e c = 3.86 \times 10^{-13}/m$. On the other side, the largeness of an atom is characterized by the Bohr radius, $a_0 = 4\pi\epsilon_0 \hbar^2/m_e e^2 = 5.29 \times 10^{-11} m$. The radius of an electron due to the is small 10^2 times compared with the Bohr radius but 10^3 times larger than the radius of a proton and/or a neutron, which are of order of $10^{-15} m$. But the zitterbewegung is a phenomenon when we "continue" to "observe" the electrons and it is fundamental problem in physics how we should consider when we do not "observe" it. The mass of a proton and/or a neutron compared with that of an electron is about 1800 times heavier and hence the zitterbewegung effect of nucleon is much smaller than that of an electron. Hence the spread of nucleon can be neglected in the following discussion.

Rather the wavefunction of the electron is thought to spread far wider than these spreads. The de Broglie wavelengths ($\lambda_c = h/mv$) for a electron and a proton are $7.1 \times 10^9 m$ (300K), $1.2 \times 10^9 m$ (1eV) and $1.7 \times 10^{10} m$ (300K), $2.9 \times 10^{11} m$ (1eV). So quantum effects are important for both of them.

5. NEW ENHANCEMENT MECHANISMS

We now study new other enhancing mechanisms.

- i) First, if there is a structure as accompanying string shaped electron current, then ions gather there and neutralize the potential, and further current can flow, without hindered by the negative potential. As a result, large current can flow in a narrow string. This increases the chance of collisions of concern.
- ii) Second, in deuteron, nucleons change from neutron to proton and vice versa rapidly catalyzed by pions and each nucleon should rather be thought to be the mix of two states. But if it is permitted that those proton and neutron are more or less static and independent of each other within the time interval of interaction, and further that neutrons of two deuterons exist nearer sites accidentally or by Coulomb repulsive force, then the real distance of two charges becomes larger and becomes nearly $4 \times 10^{-15} m$ ($> 2 \times 10^{-15} m$) and the restrictive condition for fusion becomes weaker.

iii) Third, when the two deuterons access nearer, the bond length itself of each deuteron might become longer and the fusion might become easier. And then the exchanges of pions between nucleons probably become slower and the independency of nucleon will increase and the above effect becomes more effectively. Of course the discussion in ii) and iii) are effectual for other combination of nuclei.

Probably whether these discussions are right or not will easily be ascertained.

6. DISCUSSION

Hitherto, we discussed the possibility of enhanced nuclear fusions. Our discussion heavily depends on the string currents. But the state of the currents near surface severely depends on the shape of surface. To make good condition for our purpose we must make the surface skillfully. Recently, the progress of nano-technology is remarkable and hence we can construct the microscopic structure at surface of solid as we like. On surface, there are many walking atoms and these atoms will destroy the structure of surface. These will bring about the sporadic feature.

On the line hitherto discussed, we can now propose a new interpretation of the result of experiment done by M. Mackubre, et al.⁸⁾ and other reports, that when the ratio D/Pd becomes 0.9, then excess power appears. When D is loaded into Pd, in the Pd many places where stresses work appear and many cracks appear in the electrode. Then inner of the electrode many spots appear as the mechanism here proposed work well there. And, also outer of the electrode many spots suitable for nuclear fusion might naturally appear after the elapse of long time under an externally applied electric field in the electrochemical system.

We have discussed on sporadic feature of our mechanism but have not on other features. Now, we do not intend to explain all queer phenomena hitherto found but rather should proceed further without doing it. On the remaining points, our system of discussion is on of many body and we anticipate some of the queer features might be understand from it.

We eventually anticipate the possibility of fusions of other kind of light nuclei. We also anticipate nuclear fusions take place not only at surface of solid but also in solid and in solution likewise, as the most mechanisms here discussed work as well.

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