Possibility of Nuclear Fusion in Solid

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ABSTRACT

General mechanism of nuclear fusion is briefly reviewed. The cross section of fusion for a pair of nuclei is very small at low temperature but local high density concentration of nuclei due to supersaturation of hydrogen absorbed in the solid texture is possible to excite nuclear fusion with enough reaction speed to be detected.

Reaction rate

The possibility of excitation of nuclear fusion at low temperature of deuterium are discussed by many authors and various interpretations of experimental results which suggest the nuclear fusion of high reaction rate have been proposed but they are rather almost negative for the experiment.

Generally, the reaction rate of nuclear fusion, that is, the reaction speed N is expressed by the multiplication of the average reaction rate of a pair of nuclei f, the number of pair nuclei in a unit volume and total volume of the nuclear systems V. The number of pair nuclei in a unit volume with number density n is calculated to be $n(n-1)/2 \simeq n^2/2$ when n is large number. Then;

$$N = \frac{1}{2} f n^2 V \quad ----- (1)$$

The reaction rate of a pair of nuclei f is the averages over the distribution of thermal velocities for the multiplication of cross sections of fusion of reaction and collision velocities v of the pair nuclei.

$$f = \langle \sigma v \rangle \quad -------- (2)$$

The fusion cross section of a pair nuclei σ is expressed by G. Gamow formula as a function of collision energy E,

$$\sigma = S(E)\frac{1}{E}\exp - \frac{A}{\sqrt{E}} \quad ---------- (3)$$

S(E) is a factor of fusion rate in the fields of nuclear force very close to the nucleus which is so called "astrospectroscopic factor".[1] It means the fusion rate of a pair of bear nuclei without Coulomb repulsion force. The empirical values have been measured for ^2H-^2H fusion down to the energy E = 10 KeV.[2]

The other part of the formula corresponds to the factor of rate of permeation of nuclei through the Coulomb potential barrier by the tunnelling effect. In order to surmount the Coulomb potential barrier between the nuclei, collision energy of 300 KeV or temperature of 3×10^9 degree Kelvin is needed for a pair of nuclei. This energy is not so often realized naturally in the universe, even the temperature of the sun, the energy source of which is mainly nuclear fusion of hydrogen, is 1.5×10^7 degree K.[3] Under the temperatures lower than the threshold energy for surmounting the Coulomb potential, the fusion of a pair of nuclei is accomplished by tunnelling Fig. 1. A is the factor of integrated Coulomb potential to permeate through by tunnelling which is proportional to the charge of each nucleus of the pair.

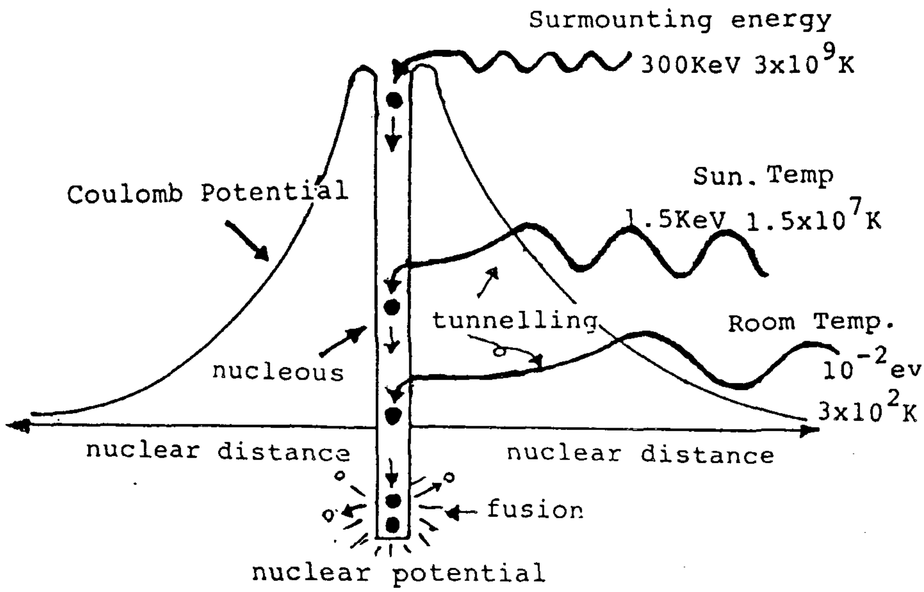

Fig. 1 Barrier potential and nuclear potential between a pair of nuclei and tunnelling effect.

Assuming the values of S(E) is constant for ^2H-^2H reaction. The value of σ increases almost exponentially as collision energy or temperature increases higher up to 300 KeV.

So far as concerned with the fusion cross section σ of a pair of nuclei, the possibility of the fusion with large reaction speed N is hardly expected in the low energy region of collision, that is, at room temperature, except that the factor S(E) would be altered drastically in the lower-energy region than 10 KeV by some reason.

Number density of nuclei

However, the reaction speed N is also the function of number density of nuclei and the volume of the system as shown in formula (1). The reaction rate of nuclear fusion through tunnelling is generally so small that these factors play the important roles in the observed net reaction speed N. The reaction rate of fusion of a pair of hydrogen in the sun is once in ten billion years, the enormous energy radiation of the sun is to be maintained by its giantly large volume V in formula (1)[3)]

For the fusion in the laboratory scale, the number density of the nuclei is the most important as well as the temperature, but it is difficult to satisfy both conditions together, because the high pressure of the high density gas is much more promoted by the temperature.

The compromise between the temperature and density of constituent nuclei is mainly the technical problem, that is, high temperature and low density is the category of the conventional high temperature plasma nuclear fusion and low temperature and high density of nuclei is that of low temperature nuclear fusion. So the main technical problem for low temperature nuclear fusion is to realize the state of super-high number density of nuclei.

A rough estimation of high density needed for the realization of reaction speed of 10^{10} event/cm^3.S. is to be 10^{40} nuclei/cm^3. The pressure of gas with that density is to be ~ 10^{20} atm. at room temperature This value seems to be practically impossible to be realized artificially.

Metals Pd, Ti and others, and alloys absorb the large amounts of hydrogen or its isotopes in their texture, that is, Pd absorbs hydrogen gas with the volume 10^3 times larger than itself's of 1 atm. at room temperature. This means the hydrogen gas of 10^3 atom is to be reserved in a palladium metal at 1 atm. and the reserved density of hydrogen nuclei is almost 10^{23} nuclei/cm^3. It is quite high value of density but still not enough to realize the above reaction speed. But the higher density of nuclei is possible to be realized locally in the metal which is filled with hydrogen, making the metal in the supersaturation state by heating, electrical bombardment or mechanical impact. The excess hydrogen created by supersaturation are to be deposited as many small babbles in the metal texture through the mechanism of spinodal decomposition of solid solution of hydrogen[4], when the high density of hydrogen nuclei are to be concentrated around the babbles. Fig. 2

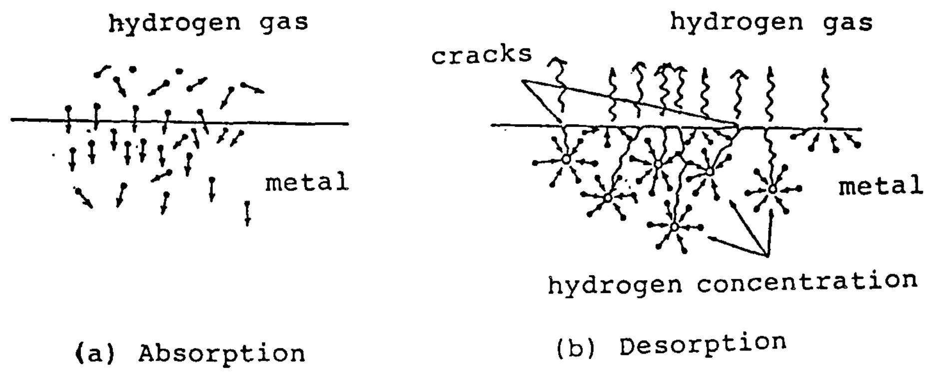

Fig. 2 Schematic illustration of hydrogen absorption and desorption of metal

The babbles (void) deposited in the metal make distraction of the metal texture that is called "Hydrogen embrittlement".[5] The smaller is the size of a deposited bubble, the higher is the density of nuclei which is to be concentrated around the bubble before it breaks the texture. The motive force for the concentration of nuclei is the excess free energy created by the supersaturation of absorbed hydrogen in the texture.[6][7]

The supersaturation is to be accomplished by-stimulating the well hydrided metals with methods of heating, electrical bombardment or mechanical shock.

The densities of hydrogen concentrated around the bubbles are to be sensitive to the structure of the metal texture that is, the size and numbers of lattice defects, impurity atoms, strain and etc.

Even the characters of absorption and desorption properties for the hydrogen is structure sensitive to the materials which absorb hydrogen. It is the reason that the experiment of the solid fusion is often difficult to reproduce.

The problem is not possibility but efficiency of nuclear fusion at low temperature. The efficiency is possible to be promoted by "Solid Nuclear Fusion".

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