Nuclear Physics Approach

On the Existence of the Trapped Thermal Neutron in Cold Fusion Materials

KOZIMA Hideo

Department of Physics, Faculty of Science, Shizuoka University
836 Oya, Shizuoka 422, JAPAN
Tel. +81-54-238-4738, Fax. +81-54-238-0993, E-mail. sphkoji@sci.shizuoka.ac.jp

Abstract

The stable existence of the thermal neutron assumed in the TNCF model has been discussed in this paper on the basis of the interaction of the neutron and the nuclei on the lattice points in the crystal. If an optimum shape of a boundary is formed stochastically, neutrons could be trapped in a crystal region surrounded by the boundary. The trapped neutron can form the neutron Cooper pair lowering its energy interacting each other through the phonon. The stabilized neutron, then, will not decay spontaneously and also not be captured by one of the lattice nuclei. To specify the stability of a neutron in a crystal, a new concept "neutron affinity of a nucleus" was introduced. Trapped neutron destabilized by a large perturbation can induce a trigger and succeeding breeding reactions resulting in the cold fusion phenomenon.

1. Introduction

In 1989, Fleischmann et al.[1] published a paper showing the discovery of the so-called Cold Fusion. After the discovery of the cold fusion, it has been recognized that the cold fusion phenomenon includes not only the generation of the excess heat, small nuclei, neutron and the photon but also the nuclear transmutation including the heavy nuclei in metals occluding hydrogen isotopes (D and H) and compounds including them. The cold fusion is used as such in this paper.

To explain the cold fusion phenomenon, the first proposal[2] of a phenomenological model was made in the November 1993 on an assumption of the trapped thermal neutron catalyzing fusion reactions in crystals (TNCF model).

The model has been developed [3~7] in this three years to fit the various phases of the phenomenon. The electrolytic experiments including the first one by Fleischmann et al.[1] were analyzed[7] with success: The questions solved by the model included the poor reproducibility of the events, large N_t/N_n ($\equiv t/n$) ratio, large N_Q/N_n ratio and also the large value of N_{He} comparable to N_Q where N_t, N_n, N_Q and N_{He} are the number of events generating tritium, neutron, the excess heat and ^{4}He, respectively. $N_{trigger}$ is also used as a number of trigger reaction.

In the next section, we will give the basic postulates of the model and the result of the analyses of the experimental data by the model. In the section 3, we will discuss the existence

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Table 1: Neutron Density n_n and Relations between the Numbers N_x of Event x Obtained by Theoretical Analysis of Experimental Data on TNCF Model ($(N_Q)_{exp} \equiv Q$(MeV)/5 (MeV), $(N_Q)_{theo} \equiv N_{trig}$)

Authors	System	Measured Quantities	n_n (cm^{-3})	Other Theoretical Results (Remarks)
M.Fleischmann et al.[1]	Pd/D/Li	Q, t, n $N_t/N_n \sim 10^7$ $N_Q/N_t \sim 5.5$	$\sim 10^{10}$	$N_t/N_n = 1.1 \times 10^6$ $N_Q/N_t = 1$
A.Takahashi et al.[8]	Pd/D/Li	t, n $N_t/N_n \sim 8.7 \times 10^4$	10^3	$N_t/N_n \sim 1.1 \times 10^6$
M.H.Miles et al.[10]	Pd/D/Li	Q, ^{4}He (N_Q/N_{He}=1$\sim$ 10)	$10^9 \sim 10^{10}$	$N_Q/N_{He} = 1$
R.Bush et al.[11]	Ni/H/Rb	NT (^{85}Rb$\rightarrow$ ^{86}Sr) $N_Q/N_{NT} \sim 3$	1.6×10^7	$N_Q/N_{NT} = 1$
M.Okamoto et al.[13]	Pd/D/Li	Q, NT(^{27}Al $\rightarrow$ ^{28}Si)	$\sim 10^{10}$	$N_Q/N_{NT} \sim 1.4$
Y.Arata et al.[15]	Pd/D/Li	Q ^{4}He($10^{20} \sim 10^{21}$ cm^{-3}) $N_Q/N_{He} \sim 6$	$\sim 10^{12}$	(Assume t channeling in cathode wall) $N_Q/N_{He} = 1$
M.C.H.McKubre[17]	Pd/D/Li	Q (Formula)	$10^9 \sim 10^{10}$	Qualit. explanation
D.Cravens (P.P.C.)[19]	Pd/H/Li	Q (Q_{out}/Q_{in}=3.8)	8.5×10^9	(If PdD exists)
J.O'M.Bockris et al.[22]	Pd/D/Li	t ($\sim 3.8 \times 10^7$/cm^{2}s)	1.1×10^6	$N_t/N_{He} \sim 1$
A.G.Lipson et al.[26]	Pd/PdO/D,Na	γ (E_γ=6.25 MeV)	4×10^5	(If efficiency = 1 %)
V.Romodanov et al.[24]	Mo/D_2	t ($\sim 10^7$ /s)	1.8×10^7	(If sample is MoD)
I.Savvatimova[23]	Pd/D_2	NT (^{106}Pd$\rightarrow$ ^{107}Ag)	9×10^{10}	
O.Reifenschweiler[27]	$TiT_{0.0035}$	Reduction of β decay	1.1×10^9	($T = 0 \sim 450$ °C)
J.Dufour[29] (SS is for Stainless Steel)	Pd,SS/D_2 Pd,SS/H_2	Q, t, n	9.2×10^{11} 4.0×10^9	(D(H)/Pd $\sim$ 1 is assumed)
T.N.Claytor et al.[30]	Pd/D_2	t (0.15 nCi/h)	1.4×10^7	(If D/Pd $\sim$ 1.)
F.G.Will et al.[31]	Pd/D_2SO_4	t ($\sim 1.8 \times 10^5$/cm^{2}s)	3.5×10^7	(If $\ell_0 \sim 10$ μm)
M.Srinivasan et al.[32]	Ti/D_2	t ($t/d \sim 10^{-5}$)	1.9×10^8	
A.DeNinno et al.[33]	Ti/D_2	t (5.4 Bq/g D_2)	1.2×10^6	(D/Ti=1,τ =1 week)
S.Focardi et al.[34]	Ni/H_2	Q	3.0×10^{12}	($N_p = 10^{21}$ was used)

of the stable trapped neutrons in the cold fusion materials in terms of the verification of the postulates.

2. Result of the Analyses of Typical Quantitative Experimental Data by the TNCF Model

The TNCF model stands on the four basic postulates:

1) Trapping of thermal neutrons in a specific region of a crystal,

2) Stabilization of the trapped neutron in a crystal made of nulei having positive "neutron affinities" against β decay and also against a fusion reaction with a nucleus in the crystal,

3) Destabilization of the trapped neutron by a perturbation due to foreign atoms at boundaries and in crystal to induce the trigger reactions generating energetic particles.

4) Breeding reactions induced by the energetic particles born in the trigger reaction generate cold fusion products (the excess heat, nuclear products and transmuted nuclei).

Using these postulates, typical experimental data in the cold fusion phenomenon have been analyzed[8~36] and the result is recited here in Table 1 with some modification.

Nuclear reactions used in the calculation were usual ones between the trapped neutron and nuclei in the material and some examples were written down as follows:

$$n + {}^6\mathrm{Li} = {}^4\mathrm{He}\ (2.1\ \mathrm{MeV}) + t\ (2.7\ \mathrm{MeV}), \quad (1)$$

$$t\ (2.7\ \mathrm{MeV}) + d = {}^4\mathrm{He}\ (3.5\ \mathrm{MeV}) + n\ (14.1\ \mathrm{MeV}) + 2.7\ \mathrm{MeV}, \quad (2)$$

$$n\ (14.1\ \mathrm{MeV}) + d = n'\ (\varepsilon) + d'\ (\varepsilon'), \quad (3)$$

$$n\ (14.1\ \mathrm{MeV}) + d = n'\ (\varepsilon) + p\ (\varepsilon') + d'\ (\varepsilon''), \quad (4)$$

$$n + d = t + \gamma + 6.25\ \mathrm{MeV}, \quad (5)$$

$$n + p = d + \gamma + 2.2\ \mathrm{MeV}, \quad (6)$$

$$n + {}^7\mathrm{Li} = {}^8\mathrm{Be} = 2\,{}^4\mathrm{He} + e^- + \bar{\nu}_e + 16.2\ \mathrm{MeV}, \quad (7)$$

$$d\ (\varepsilon) + d = t\ (1.01\ \mathrm{MeV}) + p\ (3.02\ \mathrm{MeV}) + \varepsilon, \quad (8)$$

$$= {}^3\mathrm{He}\ (0.82\ \mathrm{MeV}) + n\ (2.45\ \mathrm{MeV}) + \varepsilon, \quad (9)$$

$$n + {}^A\mathrm{M} = {}^{A+1}\mathrm{M}' + e^- + \bar{\nu}_e. \quad (10)$$

In the last equation, M and M' are symbols of nuclei with mass number A and $A+1$, respectively, relevant with the nuclear transmutation.

3. Existence of the Trapped Thermal Neutrons in the Cold Fusion Materials

The success of the explanation of the cold fusion phenomenon by the TNCF model illustrated in the preceding section has shown the reality of the basic postulates of the TNCF model in which is the stable existence of the trapped thermal neutrons in the cold fusion materials.

Therefore, the supposed existence of the trapped thermal neutron should be investigated on the knowledge of solid state and nuclear physics. A preliminary treatment of this problem was given in the previous paper[4)] and the essential points are explained as follows:

1) Trapping.

There are several causes to reflect a thermal neutron to trap it in a crystal; the difference of the neutron band structure (band effect), the Bragg reflection and the total reflection at a boundary. The difference of the neutron band structure seems effective in massive samples with a thick surface layer and the total reflection in the case of special samples with such an appropriate geometry as the Patterson's beads and Arata's Pd-black.

2) Stabilization.

The trapped thermal neutron behaves as a Bloch wave in the crystal and it is possible to become stable through the interactions with the lattice nuclei having a positive neutron affinity against the beta decay and also against a fusion with one of lattice nuclei[4)]. Formation of the neutron Cooper pair enforces the stability of the trapped neutrons in an optimum situation.

3) Destabilization and Trigger Reaction.

The trapped thermal neutron, though, can fuse with a nucleus as a trigger reaction in the surface layer or in the volume of the crystal if a perturbation is strong enough to destroy the stability of the neutron. From the results of the analyses, we can say that it occurs usually near the surface of the sample where the neutron is reflected, i.e. where it stays long in the classical sense. Otherwise, when the temperature of the sample is fairly high, it occurs even in the volume of the sample.

4) Breeding Reaction.

The fusion reaction between the neutron and nuclei becomes as a trigger reaction inducing successive reactions breeding the excess heat and nuclear products. The particles generated by a trigger reaction such as the reaction (1), (2) and (6) react with particles and nuclei in the sample. The triton reacts with a deuteron to generate ^{4}He and a neutron; the neutron with an energy 14.1 MeV can accelerate several deuterons (protons) to energies enough to fuse with another deuteron (and nucleus) with a large probability. These breeding reactions can occur successively and then generate gigantic amount of heat and particles in optimum situations. These processes would be the causes of some experimental data showing such an extraordinary result as explosion and neutron bursts. This phase of the cold fusion phenomenon was not fully analyzed yet though some possibilities were shown with model calculations[43,44].

The variety of numerical values n_n of the trapped thermal neutron n_n from 10^3 to 10^{12} cm^{-3} determined from experimental data shows variety of the trapping ability of materials used hitherto in the cold fusion experiments. Also, the variety of events from the excess heat and several nuclear products, such as from tritium t , helium 4 ^4He, neutron n and gamma γ , to the transmuted nuclei shows how the TNCF model is universally applicable in nuclear processes occurring in cold solids.

There were many experiences showing the effect of the aging of samples to realize the cold fusion phenomenon like that shown in the experiment analyzed before[32]. The present author had a similar experience in which Pd plate bought many years ago gave a positive result[45] while a newly bought one did not (which was not written in the paper). Such experiences are explained by the TNCF model if the aged Pd samples had the surface layer by oxidation in the air to trap the thermal neutron and kept much neutrons in them.

The conditions to facilitate the existence of the trapped thermal neutron explain the poor reproducibility of the phenomenon; The trapping conditions can be formed by stochastic processes such as the atomic diffusion in crystals or crystal growth on the solid surface and are not reproducible quantitatively by its nature. The cold fusion phenomenon induced by the trapped thermal neutron, therefore, has qualitative reproducibility but not quantitative.

4. Conclusion

The phenomenological analysis of typical experimental data obtained hitherto in the cold fusion experiments with electrolysis or discharge gave us a unified consistent concept of physics of the cold fusion. The reliable data showed clearly several facets of truth in the solid state - nuclear physics. The facets united by a paste have formed a whole figure of the physics of particles in a crystal with the trapped thermal neutron.

The postualtes of the existence of the stable thermal neutron in crystal itself has a theoretical verification[4,5] based on the neutron - lattice nuclei interaction with a new concept "neutron affinity of lattice nuclei".

The success in the analysis of the cold fusion phenomenon on the TNCF model shows in reverse the reality of the trapped thermal neutron. This feature of the analysis will open a new science of the low energy neutron in solid interacting with lattice nuclei through the nuclear force. The existence of the trapped neutron in appropriate systems as Pd-black and the Patterson bead will be checked by the neutron magnetic resonance (nMR) like NMR or ESR used in the solid state physics and in the physical chemistry.

Other systems than the electrolytic and discharge ones have also shown the characteristic cold fusion phenomenon not even more exciting than the latter. It will be fascinating program to analyze various experimental data in various systems on the TNCF model as done above. If we have a hint to get rid of obstacles disturbing our route to a goal, it is easy then to find out paths to reach the goal. Exploration of the cold fusion phenomenon as answering to the energy crisis will be accelerated by the new idea to unify the abundant separate facts obtained hitherto in experiments.

The other three reports[46~48] to be presented in this Conference by us will supplement the description given in this report.

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