Excess Heat and Gamma Emission

An explanation of the experimental data showing excess heat and gamma emission which was obtained in a PdO/Pd/PdO/D(H) heterostructure

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Abstract

A cold fusion experiment generating various effects in PdO/Pd/PdO sample deuterated (hydrated) by the electrochemical method was analyzed using the TNCF model. The density of the trapped neutrons was determined by the amount of the excess heat, at most 2.0 x 10^{13} cm^{-3} cm. The gamma signals at energies of 3.8, 6.3 and 2.22 MeV observed in the experiment were identified as due to the neutron-nuclei fusion in the sample.

1. Introduction

The cold fusion phenomenon in various systems with hydrogen and/or deuterium has been widely and thoroughly investigated in these almost 8 years and the essential parts of the phenomenon has been confirmed.

In the experimental data of the cold fusion, gamma spectrum has recently been observed with high precision[1-4]. In the analysis of these data, we have given a consistent explanation[5] of gamma rays at $E_\gamma = 511$ keV and a nuclear transmutation of ^{39}K into ^{40}K. In a recent paper[4] showing the excess heat and gamma spectrum, there was observed an excess power of 1.5 to 2.5 W and clear gamma peaks in a range up to 7.5 MeV in Pd/D(H)/Li system. In the analysis of the data obtained in Pd/D/Li system[4], where a gamma spectrum in the energy range of 0.1 - 7.5 MeV was measured, we have confirmed fusion reactions between thermal neutrons and nuclei in the cathode[6]. In the report[7] of RCCFNT4 (4 th Russian Conference on Cold Fusion and Nuclear Transmutation), one of the authors (H.K.) had given a description of the fact and an explanation of the data[1] using the TNCF model.

In this paper we will give a consistent explanation of the excess heat and three gamma peaks obtained in the PdO heterostructure[2] in relation with nuclear reactions between nuclei in the sample and the trapped neutron, on the TNCF model. A possible explanation of the electrophysical processes observed in the experiment will be given.

2. Experimental Facts

1) Excess heat, 2) neutron emission, 3) gamma spectra and 4) electrophysical processes were measured in the heterostructure cathode saturated with D(H) by electrolysis of (I) D_2O+NaOD and (II) H_2O+KOH solution. Thickness of Pd sample was 50 μm and PdO coating was 500Å.

It was shown that Pd/PdO:D_x at $x \leq 10^{-3}$ possessed metallic conductivity in the temperature range of 4.2 - 300°K.

(1) Excess Heat

A strong heat flush with a duration of 2 - 7 s and energy density of 60 - 100 J/cm^2 was observed in the after-electrolysis period for a Pd/PdO:D(H) sample placed in air atmosphere. The thermal energy of each flash was approximately 2 - 5 times higher than the energy supplied to the sample during electrolysis. Neutron and γ-emissions accompanied the heat production.

(2) Neutron Emission

The neutron emission had a burst-like character (with intensity up to $I_n = 5 \times 10^2$ n/cm^2 in a time of 1 ms) and preceded the heat evolution.

(3) Gamma spectrum

The gamma emission was detected in the process of deuterium desorption from the sample with intensity maxima in the ranges of 3.8 ± 0.5, 6.3 ± 0.2 MeV as well as the sharp low intensity line of 2.22 MeV (width of about 10 keV).

(4) Electrophysical Processes

Electroconductivity and the variation of linear dimension of the sample were measured upon deuteration and desorption procedures, and the deuterium localization in cluster form at the Pd-PdO interface was established.

It was shown that Pd/PdO:D_x samples at $x \leq 10^{-3}$ possessed a metallic character of electric conductivity in the temperature region of 4.2 - 300°K.

3. Analysis of the Experimental Data

The number of events N_x in a time τ of the fusion reaction between the trapped neutron and the nucleus x is given by a following relation:

$$N_x = 0.35\, n_n v_n \rho_x V \sigma_{nx} \tau \xi. \qquad (1)$$

In this relation, $0.35 n_n v_n$ is the neutron flux per unit area and time, ρ_x is the density of the nucleus x in the volume V, σ_{nx} is the cross section of the fusion reaction. The adjustable factor ξ is introduced to take difference of the neutron stability in the sample into our consideration[5] suggested by an experimental data on the nuclear transmutation in the volume[3]. We will use values of $\xi = 0.01$ in the volume (PdD) and $\xi = 1$ in the surface layer (PdO/D and alkali metal layer if any) where the neutrons are less stable.

Considering abundance and fusion cross section of the nucleus, the effective reactions in the Pd/PdO:D cathode could be taken as follows:

$$n + p = d + \gamma(2.22 \text{ MeV}), \quad (2)$$
$$n + d = t + \gamma(6.25 \text{ MeV}), \quad (3)$$
$$n + {}^{18}O = {}^{19}O + \gamma(3.95 \text{ MeV}), \quad (4)$$
$$n + {}^{105}Pd = {}^{106}Pd + \gamma(9.6 \text{ MeV}), \quad (5)$$
$$n + {}^{108}Pd = {}^{109}Pd + \gamma(6.2 \text{ MeV}), \quad (6)$$

The natural abundance of the isotope ^{18}O is 0.204%, and the fusion cross sections of the reactions (2), (3) and (4) are 0.3, 5.5×10^{-4} and 2.1×10^{-4} barn at room temperature, respectively. The natural abundance of the isotopes appeared in the reactions (5) and (6) are 22.3 and 26.5%, respectively, and the cross sections of these reactions are 20.3 and 8.5 barn at 300°K, respectively.

Using the relation (1) for the number of events with $\xi = 0.01$ in the volume and = 1 in the surface layer(s), we obtain the density of the trapped neutron in the Pd film from the maximum and minimum excess heat data of 100 J/cm²/2 s = 75 W/cm² and 60 J/cm²/ 7 s = 8.6 W/cm² as $n_n = 2.0 \times 10^{13}$ and 2.3×10^{12} cm^{-3}, respectively, in the periods of events.

The gamma peaks at 3.8 ± 0.5, 6.3 ± 0.2, and 2.22 MeV should be attributed to the reactions (4), (3) and (2), respectively. It will be possible to give more quantitative analysis if we know the intensities of these peaks numerically using the value of n_n determined above as we did in the analysis of the data obtained in a porous Ni sample[5]. It is also noticed that the peaks at 2.2 and 6.3 MeV had been observed in another experiment[4] in the Pd/D/Li cathode.

The metallic electric conductivity of the sample used in this experiment can be explained as a result of the alkali metal layer supposed to be deposited on the surface of the sample in the electrochemical process of deuteron (proton) saturation.

4. Discussion

The gamma rays observed in this experiment[2] shows the unambiguous evidence of the fusion reactions between a neutron and nuclei in the system and also the existence of neutrons in the cold fusion materials. The neutrons could be considered as the trapped neutrons assumed in the TNCF model.

The density of the trapped neutrons 2.0×10^{13} cm^{-3} at most is determined by the maximum amount of the excess heat and is consistent with other values determined in different materials[8].

The experimental data of the neutron burst and heat evolution observed in this experiment shows that the nuclear events generating the neutrons is an origin of the excess heat generation not only by the amount but also by the time order.

There should be thin layers of alkali metal on the surface of the sample deposited in the process of the electrochemical saturation of the sample with deuterium (hydrogen). Then, fusion reactions of neutrons with nuclei of the alkali metal might give a large influence for the numerical value of n_n determined above taking into only Pd and PdO layers in the sample and lower its value.

We have to take into account a process of the photo-disintegration of deuterons to analyze numerically the experimental data of neutrons as a breeder of neutrons in the cold fusion process:

$$\gamma + d = p + n. \quad (7)$$

The threshold energy of this reaction is about 2.22 MeV and the cross section has a broad peak at about 4 MeV of 2.5 m barn[9]. The neutron burst observed in this and other experiments should be relevant with this neutron generating process.

More generally, it is necessary to consider photo-disintegration of a nucleus M with a mass number A though the cross section is small when the mass number A of the nucleus is large:

$$\gamma + {}^{A}M = {}^{A-1}M + n. \qquad (8)$$

This reaction will work as a neutron breeder and also as a mechanism to lower the mass number in NT (nuclear transmutation).

In conclusion, we could say that complex data obtained in the experiment[1,2] where the observed events in a sample with heterostructure have been explained consistently, at least partially, by using the TNCF model which assumes existence of the trapped neutron in the sample. The density of the trapped neutron determined from the experimental data of the excess heat is in the range between 2.3 and 20 x 10^{12} cm^{-3}, the same order of magnitude obtained in other samples in the cold fusion experiments.

References

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