TNCF Analysis of Neutron Emission from TiD_x Film Excited by an Electric Current

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Synopsis

Experimental data of neutron measurement obtained in TiD_x film (x ~ 1.5) were analyzed using the TNCF model. An apparent difficulty in interpretation of the data, detection of neutrons above background level but inconsistent between two kinds of detectors, was resolved by the model and the arbitrary parameter in the model - the density n_n of the trapped neutron - was determined as ~ 5.4 x 10^{11} cm^{-3} in the case of neutron emission of 102 /s observed by one of two detectors.

1. Introduction

The TNCF model for the cold fusion (CF) phenomenon has been used to explain the events of CF phenomenon, i.e. the excess heat, tritium, ^4He and neutron generation, in materials containing hydrogen isotopes[1-3]. The experimental fact of large ratios of numbers of events N_t/N_n and N_Q/N_n (t, n and Q stand for tritium, neutron and the excess heat, respectively) had been unsolved riddles from the conventional point of view, based only on the two-body reactions of deutrons. This, in addition to the poor reproducibility of the phenomenon, has been a cause of prevailing bias against the acceptance of the cold fusion phenomenon.

The TNCF model has been able to explain these characteristics of the cold fusion phenomenon quantitatively, or at least qualitatively, with only one adjustable parameter n_n, the density of the trapped thermal neutron in solids, with some additional assumptions related with cross sections of nuclear reactions in and on the solids[1-3].

In the present paper, we analyze experimental data[4,5] of neutron generation in TiD_x films ($x \simeq 1.5 \sim 2.0$) on tungsten substrates with several patterns of electric voltage upon them.

2. Experimental results

To check the occurence of the nuclear reaction between two deuterons considered as a candidate of the cold fusion reaction in solids, measurements of neutrons with an energy of 2.45 MeV were performed with a titanium film in following experimental conditions; 1) the employment of a metal matrix with suitable chemical and physical properties, 2) the achievement of a high deuterium loading in the matrix and 3) the imposition of non-equilibrium perturbations in the deuterium-metal system.

The sample was prepared from an iodide-titanium film deposited uniformly over an electrically self-heated tungsten filament (the size of which is $4.0 \times 2 \times 0.025\ mm^3$). The titanium film was deuterated to a composition D/Ti ~ 1.5.

To provoke non-equilibrium conditions, two methods were used; a) Through the Ti film, different electric current patterns were passed, b) phase transitions were induced by thermal cycles.

Two liquid scintillation counters, NE213 and BC501, were used to measure 2.45 MeV neutron expected from one of possible direct reactions between two deuterons:

$$d + d = {}^3He\ (0.82\ MeV) + n\ (2.45\ MeV). \quad (1)$$

With the performance of the detectors having been checked, they concluded that the above reaction (1) did not occur in a confidence level of 99.9% though some anomalous events were monitored in one of neutron detectors when multiple electric current cycles up to high values were performed in the samples.

3. Analysis of the Data by the TNCF Model

First, we have to admit the conclusion[4,5] that there was no $d + d$ reaction (1) in the sample TiD_x ($x \sim 1.5$) used in the experiment. This conclusion is not consistent with the TNCF model which assumes a trigger reaction between the trapped thermal neutron and nuclei (deuteron in this case) in and on the sample:

$$n + d = t\ (6.98\ keV) + \gamma (6.25\ MeV). \quad (2)$$

The cross section of this reaction is 5.5×10^{-4} barn.

The triton with 6.98 keV genrated in this trigger reaction can induce a succeeding breeding reaction with a deuteron, the cross section of which is 3.0×10^{-6} barn in a path of a length ~ 1 μm:

$$t + d = {}^4He\ (3.5\ MeV) + n\ (14.1\ MeV). \quad (3)$$

The photon with an energy 6.25 MeV generated in this reaction; can induce photodisintegration of a deuteron (the threshold energy ~ 2.2 MeV) giving the neutron an energy about 2 MeV:

$$\gamma (6.25\ MeV) + d = n + p. \quad (4)$$

The cross section of this reaction is about 2 mbarn (2×10^{-3} barn) and the neutron generated in this reaction has an energy of ~ 2 MeV.

The neutron with 14.1 MeV generated in the reaction (3) can accelerate or dissociate deuterons to generate neutrons:

$$n\ (14.1\ MeV) + d = n' + d', \quad (5)$$
$$n\ (14.1\ MeV) + d = n + p + n. \quad (6)$$

The cross sections of the elastic collision (5) and the disintegration (6) are 0.62 and 0.18 barn, respectively.

The accelerated deuteron up to an energy e (the maximum is 12.5 MeV) in the reaction (5) can induce direct d-d reactions: (7)

$$d\ (e\ MeV) + d = {}^3He + n\ (2.45\ MeV) + e,$$
$$= t + p. \quad (8)$$

The cross sections of the reactions

(7) and (8) for a deuteron with 12.5 MeV are 8.9×10^{-3} and 3.1×10^{-3} barn, respectively.

Thus, the neutron with energies of ~ 2 MeV can be generated in several reactions in the chain from (2) to (7) in the TNCF model. From our point of view, therefore, to confirm nuclear reactions in solids (NRS denoted by Cuevas et al.[4]), it is desirable to detect the photon with energy 6.25 MeV (reaction (2)) as done by Lipson et al.[6] and Oya et al.[7] or to detect the neutron with an energy 14.1 MeV (reaction (3)) which has not been done yet by anyone.

The rather low probability of the reaction (7) in TiD_x makes it difficult to detect 2.45 MeV neutrons than in electrolytic system with ^6Li where a high energy triton with 2.7 MeV is expected by the reaction: (9)

$$n + {}^6Li = {}^4He\ (2.1\ MeV) + t\ (2.7\ MeV).$$

The triton has larger cross section of ~ 10^3 barn for the reaction (3) than the one generated in the reaction (2).

The lack of time correlation between the significant signals in two detectors in the experiment[4] might be the effect due to low values of the neutron counts above background level. In addition to this difficulty, there might be another cause for the inconsistency that the sensitivities of the detectors for lower energies than 2.45 MeV expected from the reaction (6).

Therefore, we can take their anomalous events observed by one of two detectors as meaningful to calculate the adjustable parameter n_n in the TNCF model.

The most anomalous result detected in their Exp1[4] is 16 counts/20 s by BC501 which corresponds 102 n/s. Assuming this neutrons were generated in the reaction (6) finally starting from the reaction (2) in the TiD_x (x ~ 1.5) sample containing the trapped thermal neutrons with a density n_n, we can determine n_n as follows:

$$n_n \sim 5 \times 10^{11}\ cm^{-3}.$$

4. Conclusion

The analysis given above shows that the cold fusion phenomenon is a probe of nuclear reactions occurring in solids, especially with hydrogen isotopes, as explained by us[1~3]. The individual experimental data of the cold fusion phenomenon are generally incomplete because of the difficulty of measuring the events occurring there. Therefore, it is necessary to supplement the lack of data by physical imagination; it is more reasonable to assume a common cause for the whole events rather than to assume a different cause for each event if the common cause can consistently explain the data. This is the point of view used to establish the TNCF model.

The success of explanation of data obtained in various cold fusion experiments by the TNCF model shows the TNCF point of view is effective to understand the contradicting each other events scientifically. We hope more efforts in experiment and theory will be in the direction to check the idea of the TNCF model for scientific understanding of the cold fusion phenomenon.

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Prof. Kozima Answers Jones

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Regarding the e-mail message of S.E. Jones' "Experimental Test of Claims of Reduction of Radioactivity in Electrolytic Cells" (cited in *Elemental Energy* (*Cold Fusion*) **22**, 79 (1997)).

In the message, Jones reported a series of experiments at BYU searching for variations in levels of radioactivity in electrolytic cells containing radioactive thorium (Th) salts. He observed that the apparent radioactivity of the entire cell dramatically decreased and also that Th plated out onto the cathode. He has concluded that it is necessary to treat not only electrolytic solution but also cathode itself to show the reduction of radioactivity in electrolytic cells as done on Good Morning America 6/11/97 by CETI's Patterson Power Cell.

I'd like to point out that Jones' discussion of the Th surface layer onto the cathode is consistent with production of metal electrolyte layer on the cathode surface which is an important presumptions in the TNCF model.

It is also common sense, as noticed by Jones, that radioactive wastes are transmuted partially in a nuclear reactor by effects of neutrons in it ("Nuclear Wastes: Technologies for Separation and Transmutation," National Academy Press, 1996).

As we have shown by analyses of many experimental results obtained in cold fusion experiments, there is a possibility of the quasi-stable existence of thermal neutrons trapped in materials with some characteristics. The neutron