Deuteron Fusion Experiment with Ti and Pd Foils Implanted with Deuteron Beams

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ABSTRACT

In order to examine the "cold" deuteron fusion reaction, we have tried making deuteron implantation experiments on Ti and Pd foils. A 20 cmΦ x 24 cm cylinder-type vacuum chamber was installed at the end section of a 240 keV deuteron accelerator. In the center of the chamber, a Ti or Pd foil sample was set to face toward 3 nsec pulsed deuteron beams collimated with a 3 mmΦ aperture. A Si-SSD was placed behind the foil sample for the measurement of high energy charged particles emitted from the foil by the supposed deuteron fusion reactions.

During the deuteron implantation for a 19 μm thick Pd foil, almost all signals came from the well-known D-D reaction but an unusual peak was measured around 5 MeV after the implantation, i.e., without deuteron beams. Also an inexplicable 8 MeV helium peak was measured during the deuteron implantation for 20 μm thick Ti foils with aluminum-oxide layer on their surface. These 5 and 8 MeV peaks seem to suggest the following three-body fusion reaction which A. Takahashi proposed as a hypothetical explanation of the mechanism of the cold fusion phenomena : 3D $\rightarrow$ d(15.9 MeV) + α (7.9 MeV), t (4.75 MeV) + ^{3}He (4.75 MeV). Further implantation experiments on characterized foil samples and more detailed measurements for the identification of the 5 MeV particles and for the precise detection of the 15.9 MeV deuteron correlated with the 7.9 MeV α and others are needed to prove the 3D fusion reaction.

1. Introduction

Since M. Fleischman and S. Pons[1] and S. Jones[2] announced on the cold nuclear fusion, many scientists in the world have made every effort[3][4] to reproduce and explain the amazing phenomena. A. Takahashi proposed a bold multibody fusion model[5][6] for explaining the large excess-heat produced in the D_2O/Pd electrolysis experiments[1][7][8]. And in order to directly detect more energetic particles from the multibody fusion reactions, A. Takahashi and his group have tried making deuteron implantation experiments besides electrolysis experiments by modifying a deuteron accelerator OKTAVIAN[9], which has been used to produce D–T neutrons. Vacuum environment in the beam experiments is suited for the identification of nuclear reactions in Ti and Pd foil samples, or for the exact measurement of the type and energy of the nuclear charged particles emitted from the foils.

The purpose of the present deuteron implantation experiments is to find out energetic charged particles except those from normal D–D and related secondary D–T and D–^{3}He reactions. At first this paper describes the experimental method and apparatus and then shows some preliminary results obtained for Ti and Pd foil samples implanted with 240 keV deuteron beams.

2. Experiment

A 20 cmΦ x 24 cm cylinder-type vacuum chamber was installed at the end section of the deuteron accelerator. In the center of the chamber, a Ti or Pd foil was set to face toward the deuteron beam collimated with a 3 mmΦ aperture. The configuration of the experimental apparatus is shown in Fig.1. The central portion of a foil sample was implanted with 3 nsec pulsed deuteron beams, whose repetition frequency was 2 MHz. The average beam current was 2–10 μA. To examine the nuclear charged particles from the foil, a silicon semiconductor detector (Si-SSD) was set behind the foil, which was for the avoidance of a large number of backscattered deuterons. Therefore, the thickness of sample foils was controlled to be penetrated by not deuteron beams but more energetic nuclear particles. In such a foil sample, 240 keV deuterons are perfectly decelerated and many low energy deuterons should be between lattice atoms excited by the repeated pulsed-beams. The Si-SSD was commercially available, had the effective window area of about 35 mm^2 and the depletion layer depth of about 150 μm and analyzed energy till about 15 MeV for α-rays and about 4 MeV for protons. The distance between the foil sample and the Si-SSD was 15–30 mm. Also to examine the type of the energetic charged particles, another Ti foil was occasionally placed between the sample foil and the Si-SSD. Discrimination between hydrogen, helium and others can be made from the difference in their energy loss rate in the screen foil.

Samples for the deuteron implantation were 5–20 μm thick Ti (99.5%) and 5–25 μm thick Pd (99.95%) foils. As for some of the sample foils, moreover, we formed about 1000Å thick aluminum-oxide layer on their surface by an evaporation process. The preparation of these foils was based on the suggestion by

E. Yamaguchi[10][11], A. Takahashi[12] and others; a thin metal oxide layer on Pd plate may play an important role in enhancing the excess–heat production. Three types of Ti and two types of Pd foil samples were prepared to examine the aluminum–oxide layer effect. They were a 20 μm thick unprocessed Ti foil, the same foil whose surface was covered with 0.1 μm thick aluminum–oxide layer, the same foil with one sided aluminum–oxide layer, a 12.5 μm thick bare Pd foil and the same Pd foil with both sided aluminum–oxide layer. The formation of the aluminum–oxide layer on the surface of the samples was made at the same time by an evaporation process. Therefore, the constitution of the aluminum–oxide layers should hardly differ between the samples. A series of the deuteron implantation experiments on these samples was carried out under the same conditions of deuteron beams, the measuring system and others.

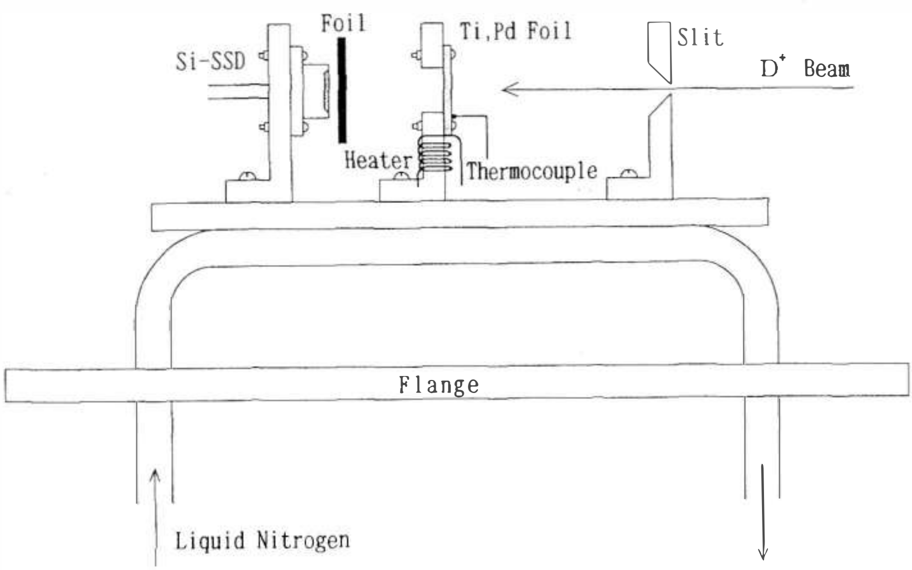

Figure 1. Configuration of experimental apparatus

3. Result and Discussion

It is about a year since we began the deuteron implantation experiments and so far (before using the foil samples with aluminum–oxide layer) we have obtained some unusual data showing a few but significant counts in the energy region over the highest energy of protons from the normal D–D reaction. However, statistics of the data were too low to discuss the relation to the nuclear particles expected from the multibody fusion model.

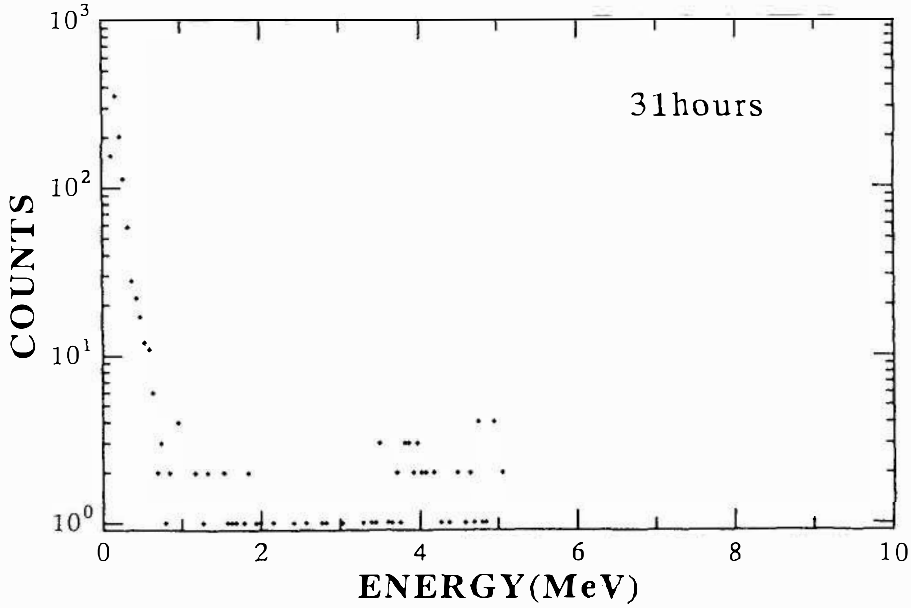

Figure 2. Typical example of inexplicable energy spectra of charged particles measured for 19 μm Pd foil in deuteron implantation experiments

Figure 2 shows a typical example of inexplicable energy spectra of charged particles measured for a 19 μm Pd foil. In the spectrum counts were stored for 31 hours after finishing a five-hour deuteron implantation. During the deuteron implantation, almost all signals came from the well-known D-D reaction but a weak peak was measured around 5 MeV after the implantation, i.e., without deuteron beams, and it may have something to do with the 4.75 MeV T and ^{3}He which are expected from the following three-body fusion reaction(5)(6): 3D $\rightarrow$ d(15.9 MeV) + α (7.9 MeV), t (4.75 MeV) + ^{3}He (4.75 MeV). This uncommon but interesting result also seems to be similar to experimental results which G.Chambers et al.(13) obtained by 350 eV deuterium bombardment of a 1 μm thick Ti film evaporated onto 500 nm Au on a 3.8 μm thick Ni foil, although the peak in Fig.2 is not so clear as that by G.Chambers et al. They have described that the particle in the 5 MeV peak looks like the triton.

In accordance with Takahashi's suggestion, we quite recently made similar deuteron beam experiments using sample foils with aluminum-oxide layer on their surface. Figure 3 shows a typical energy spectrum of charged particles measured for the 20 μm thick Ti foil with 0.1 μm thick aluminum-oxide layer bombarded by 240 keV deuteron beams. Besides the normal proton peak from the well-known D-D reaction, some small peaks were measured in the energy region higher than the proton peak. And in the similar measurements with the screen foil in front of the Si-SSD, we observed that the 22 μm Ti screen foil caused large energy reduction and broadening of the 8 MeV peak in Fig.3 and moreover that the 40 μm

Ti screen foil removed almost all 8 MeV signals. It is simply given from the well-known Bethe formula that 8 MeV hydrogen can easily penetrate the 40 μm thick Ti foil but 8 MeV helium suffers large energy loss in the 22 μm Ti foil and can not penetrate the 40 μm foil. From these measurements, the particle of the 8 MeV peak looks like helium, which may be 7.9 MeV α expected from the 3D fusion reaction. The 15.9 MeV deuteron correlated with the α can not be analyzed with the Si-SSD with thin depletion layer depth (150 μm). As for the peaks in the energy range of 3–5 MeV, the type of the particles could not be identified because the peaks with low statistics were too near the proton peak from the D-D reaction. Therefore, the interpretation on the 3–5 MeV peaks is unsatisfactory.

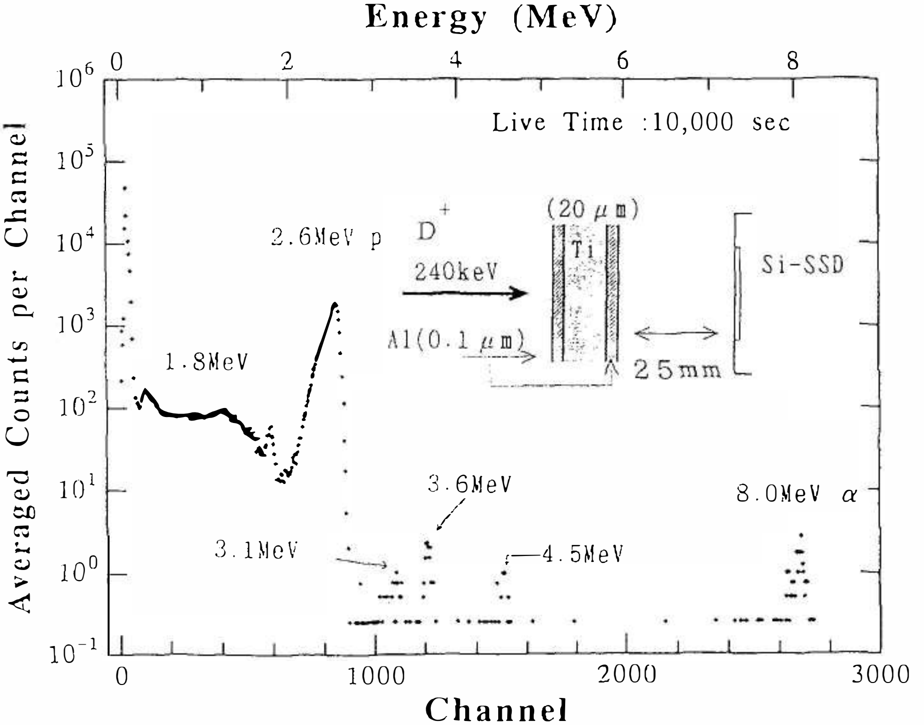

Figure 3. Typical energy spectrum of charged particles measured for the 20 μm thick Ti foil with 0.1 μm thick aluminum-oxide layer bombarded by 240 keV deuteron beams

Table 1 summarizes results of the series of the experiments on the foils with the aluminum-oxide layer. As for the three cases (1),(2) and (3) concerning the Ti foils with aluminum-oxide layer on their surface, the similar unusual 8 MeV and some 3-5 MeV peaks were measured and their spectral figures were on the whole the same, although the counting rate of the peaks fairly differed. On the other hand, these peaks were not observed for the bare Ti and Pd foils [case(4),(6)]. In addition the similar 8 MeV peak was measured for the Pd foil with aluminum-oxide layer [case(5)]. It is clear from these results that the aluminum-oxide layer should have something to do with the unusual 8 and 3-5 MeV peaks. Also in the case (3) the similar uncommon spectrum was measured for the foil with one-sided aluminum-oxide layer behind the deuteron beams, which means that the direct reaction between deuteron beams and aluminum-oxide layer or impurities in it is low possibly related to the unusual peaks.

Table 1. Unusual peaks of charged particles measured for Ti and Pd foils in deuteron implantation experiments

Case	Foil type	Aluminum-oxide layer	3-5 MeV peaks	8 MeV peak
(1)	Ti (20μm)	Both-sided	Three clear	Clear
(2)	Ti (20μm)	One-sided*	Two clear	Clear
(3)	Ti (20μm)	One-sided**	One clear	Clear
(4)	Ti (20μm)	None	None	None
(5)	Pd (12.5μm)	Both-sided	One weak	Weak
(6)	Pd (12.5μm)	None	None	None

* : facing toward beams, ** : behind beams

4. Conclusion

In order to examine the "cold" deutron fusion reaction, Ti and Pd foils were implanted with 240 keV, 3 nsec pulsed deuteron beams. The energetic charged particles from the foils were measured with the Si-SSD which was placed behind the foil.

During the deuteron implantation for a 19 μm thick Pd foil, almost all sig nals came from the well-known D-D reaction but an unusual peak was measured around 5 MeV after the implantation (i.e., under beam off). Also an inexplicable 8 MeV helium and some weak 3-5 MeV peaks were measured during the deuteron implantation for 20 μm thick foils with aluminum-oxide layer on their surface. These 5 and 8 MeV peaks seem to suggest the following three-body fusion reaction which A.Takahashi proposed as hypothetical explanation of the mechanism of the cold fusion phenomena : 3D $\rightarrow$ d(15.9 MeV) + α (7.9 MeV), t (4.75 MeV) + ^{3}He (4.75 MeV). The present experiments have been preliminarily started and have given rather qualitative data. Further implantation experiments on foil samples characterized with appropriate surface analyzers and more elaborate measurements with enough statistics for the identification of the 5 MeV particles and for the precise detection of the 15.9 MeV deuteron correlated with the 7.9 MeV α and others are needed to prove the 3D fusion reaction or to explain the unusual spectra. Moreover, such a simple experiment is incapable of explaining the process leading to the fusion reaction and the aluminum-oxide layer effect on the reaction. We have many problems to be solved.

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