Nuclear Physics Approach

Detection for Nuclear Products in Transport Experiments of Deuterium through Palladium Metals

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Abstract
To investigate the possibility of deuterium-deuterium nuclear fusion in a palladium metal, we carried out two kinds of experiments: low-energy deuterium ion bombardments with deuterated palladium, and deuterium transport through palladium. In the bombardment experiments, the cross sections for d(d,p)t reactions were measured to be less than 1.5×10^{-11} b at an ion energy of 2 keV. Measured branching ratios between d(d,p)t and d(d,n)^{3}He were unity in the ion energy range between 2 and 40 keV, even though the deuterium-deuterium nuclear fusion occurred in palladium. We also estimated the minimum detectable values for the charged-particle detection system, NE213 nuclear detector system, ^{3}He counter, and a quadrupole mass-spectroscope system used in both the experiments. In the deuterium transport experiments, we tried to detect nuclear fusion products by using these detector systems placed in a vacuum chamber which extracted deuterium from the sample palladium. Any extraordinary nuclear products, however, could not be observed in the experiments carried out under various temperature variations and for various modifications of palladium surfaces.

Introduction

Since Yamaguchi and Nishioka have reported that the nuclear product ^{4}He, which is direct evidence of nuclear fusion in deuterated palladium metals, was detected by using the "vacuuo method",[1] we have studied the dynamics of deuterium in palladium metals in order to reproduce and confirm the phenomenon. Because the processes by which a palladium metal is loaded with deuterium and the processes by which it is released from the deuterated palladium metals are important for understanding the deuterium dynamics in palladium metals, we measured the loading ratio, the electrical resistance, the surface temperature, and the deuterium pressure in a vacuum chamber.[2]

From the point of view of nuclear physics, on the other hand, as the d+d reactions in the palladium metals by the deuterons with the energy of a few keV are very important for understanding the generation and detection of ^{4}He in the vacuuo method, we have also studied the low-energy nuclear reactions of d+d in the palladium metals by colliding deuterium ions in a palladium metal. We found that above the deuterium ion energy of 5 keV, there was no enhancement of the cross sections of d(d, p)t and d(d, n)^{3}He and that the branching ratios between d(d, p)t and d(d, n)^{3}He were unity independent of the deuteron energy[3].

In this paper we report the two kinds of the experiments - the deuterium ion bombardments with ion energies less than 2 keV and the deuterium transports through the palladium disks - in order to clarify the reaction mechanisms and deuterium dynamics in a palladium metal. The cross sections of d(d, p)t reaction were evaluated in the bombardment experiments. From the results of the bombardment experiments, we also estimated the minimum detectable count-rates of the products due to nuclear fusion reactions. The deuterium transport is a release process of a constant amount of deuterium from palladium surface. In the transport experiments, we tried to detect nuclear products such as protons, toritons, ^{3}He, neutrons, and ^{4}He, in order to confirm the occurrence of nuclear fusion in a palladium metal using the detection systems.

Experiment

1) Evaluations of the detection limits

In the ion-bombardment and transport experiments, we tried to detect protons, toritons, and ^{3}He by the charged-particle system, neutrons by the NE213 system and the ^{3}He counter, and ^{4}He by the quadrupole mass-spectroscope (Q-mass) system, respectively.

The active areas of silicon surface detectors (SSD) were 450 mm^2. The sensitive depths of two detectors were 100 and 300 μm. A detector was covered with aluminum foil with a thickness of 7 μm or carbon foil with the density of 50 μg/cm^2 held by Ni meshes having 99% open area. Carbon foil was used when trying to detect ^{3}He.

The NE213 system and ^{3}He counter (Aloka Ltd:TPS-451S) were used to detect neutrons. The diameter of the active area of the NE213 detector was 20 inches. Comparing the counts-per-seconds (cps) of the systems for detecting charged particles and neutrons with the natural background cps, we evaluated the detection limits, the minimum detectable values of the systems. The detection limits of the charged-particle detection system were $2x10^{-4}$, $4x10^{-4}$, and $1x10^{-3}$ cps for protons, toritons, and ^{3}He, respectively. The limits of the NE213 system and ^{3}He counter (Aloka Ltd:TPS-451S) for neutron detection were 2 cps.

^{4}He was tried to detect by Q-mass with a cold trap system (Extrel:C50 Mass Spectrometer System). The temperature of the cold trap was 4.2 K to condense hydrogen and deuterium gas. The detection limit of ^{4}He was improved to be better than 1000 times of the limit without the trap. The ^{4}He detection limit of the Q-mass with the cold trap system was estimated to be $3x10^{11}$ cps using ^{4}He standard-leak of $1.3x10^{-7}$ atmcm^3.

2) Deuterium ion bombardment

We have already reported that we measured the cross sections and branching ratio between d(d, p)t and d(d, n)^{3}He as a function of deuterium ion energies (E_d) from 5 to 40 keV[3]. Figure 1 shows the results of the detection of charged particles at E_d=5 keV. The natural background is excluded in Fig. 1.

We tried to detect nuclear products in the deuterium ion bombardments with ion energies less than 2 keV by using the charged-particle, the NE213, the ^{3}He counter, and the Q-mass with a cold trap system. To obtain an ion current density as high as 10 mA/cm^2, an electron-cycrotron-resonance (ECR) ion source with an ion accelerating plate was used to generate the 2-keV deuterium ions. A 30x30x1-mm palladium plate with the loading ratio (D/Pd) of 0.65 was used as a target.

The count rate due to protons generated from d(d, p)t at 2 keV deuterium ion energy was less than that of the natural background. The cross section was estimated from the detection limit to be less than $1.5x10^{-11}$ b. The cross sections and branching ratios of d(d, p)t are shown in Fig. 2 as a function of the deuterium ion energy and good agreement with the theoretical results.[3) 4)] We could not detect ^{4}He in the bombardments of deuterium ion having the energies from 5 to 40 keV.

3) Deuterium Transport

To investigate the deuterium dynamics in the palladium metals and obtain evidence of nuclear fusion within the metals and/or at the metal surfaces, we tried to detect the nuclear products by the same detection systems as we used in the ion bombardment experiments.

The sample was a palladium disk of 21 mm in diameter and 0.5 mm thick. This size is the same as that of the gasket for ICF32-flange. The surface of the sample disks were cleaned chemically by acetone and aqua regia. Some samples were annealed or etched by ECR plasma sputtering. After cleaning the surface of a palladium disk, one side of the disk was coated with a thin film of MnO_x, SiO_2, LiF, Au, or Ag. The Experimental setup was shown in Fig. 3. The vacuum chamber was separated into two parts by the palladium disk. One side was filled with the deuterium at 200 kPa. The other side was evacuated. The deuterium was transported by diffusion through the palladium disk when the sample temperature was raised by a heater. We measured the temperature of the sample surface and the pressures of the deuterium-filled chamber and the vacuum chamber, and tried to detect the nuclear products by using the detection systems described above. All the detectors for nuclear products were placed at the side of the evacuated chamber.

We carried out the transport experiments under various conditions of temperature and deuterium pressure. The results of typical experiments with the deuterium transport through the palladium disk are shown in Fig. 4, where T is the temperature of the sample surface, and where P_1, P_2 and P_3 are respectively the pressures of the deuterium-filled chamber, the vacuum chamber, and the Q-mass. After 5-hour heating under a constant voltage to keep the temperature at 170℃, the deuterium was filled with the chamber. From 5 to 20 hours, P_1 was constant at 200 kPa. During the following 20 hours, we periodically changed the temperature of the palladium disk from 70℃ to 185℃ by adjusting the heater voltage. After 40 hours, the heater voltage was kept constant. The number of the deuterium molecules transported through the sample was estimated to be from 1.5×10^{17} to 3×10^{17} cps. The outputs of the neutron and ^{4}He detections are shown in Figs. 5 and 6. We could not any signals of the nuclear products during the deuterium transport experiments.

Conclusions

We tried to detect nuclear products in low-energy-ion bombardment experiments and in deuterium transport experiments by using the charged-particle detection system, the NE213 system, the ^{3}He counter, and the Q-mass system. In the ion bombardment experiments, the cross section of d(d, p)t was measured to be less than 1.5×10^{-11} b at the deuterium ion energy of 2 keV. It was found that we could not observe the distinguished enhancement of the cross section at the ion energy above 2 keV as the values of the measured cross section was good agreement with the calculated values from the theoretical results.[5)]

In deuterium transport experiments, we did not detect any fusion products within the detection limits and the accuracy of the systems. We thus obtained no evidence to confirm the extraordinary fusion phenomena in a palladium metal within our detection limits.

References

1) E. Yamaguchi and T. Nishioka, Frontiers of Cold Fusion (University Academy Press), (1993) 179.
3) K. Shikano, H. Shinojima and H. Kanbe, Proceedings of the 5th International Conference on Cold Fusion, (1995) 251.
4) H. Shinojima, T. Nishioka, K. Shikano and H. Kanbe, Proceedings of the 5th International Conference on Cold Fusion, (1995) 255.
5) A. Krauss, H. W. Becker, H. P. Trautvetter, C. Rolfs and K. Brand, Nucl. Phys., A465 (1987) 150.

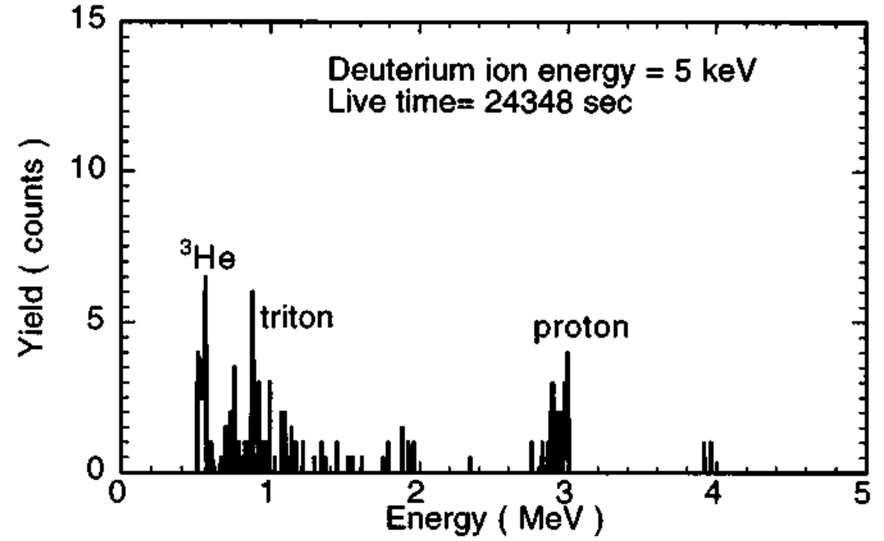

Figure 1. Energy spectrum of charged particles at E_d=5 keV.

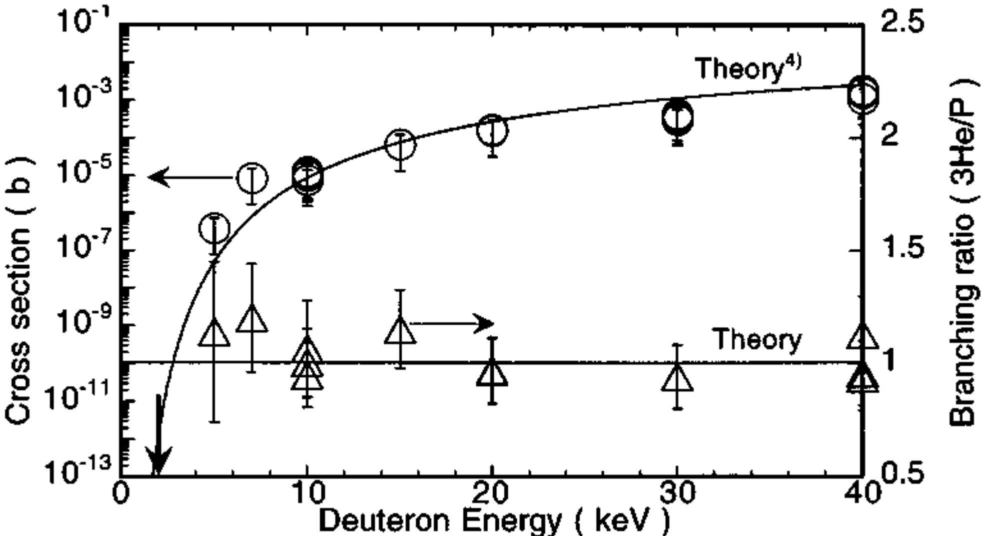

Figure 2. Cross sections of d(d,p)t as a function of deuterium ion energy[3)], adding the new result at E_d=2keV.

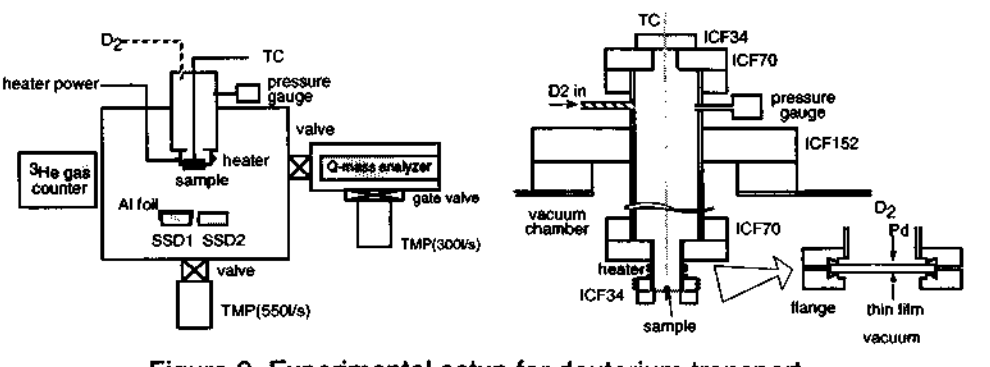

Figure 3. Experimental setup for deuterium transport.

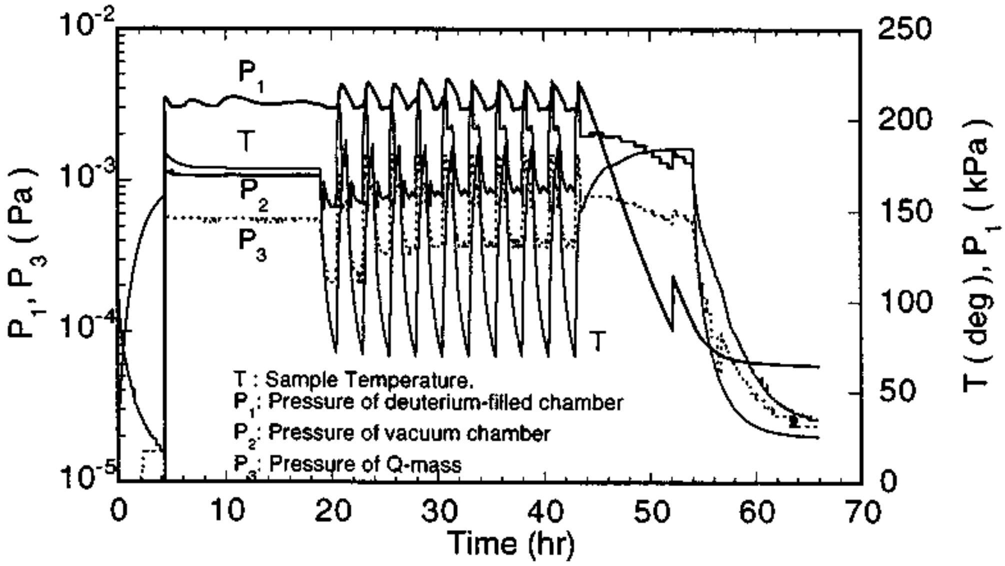

Figure 4. Temperature and pressure measurements.

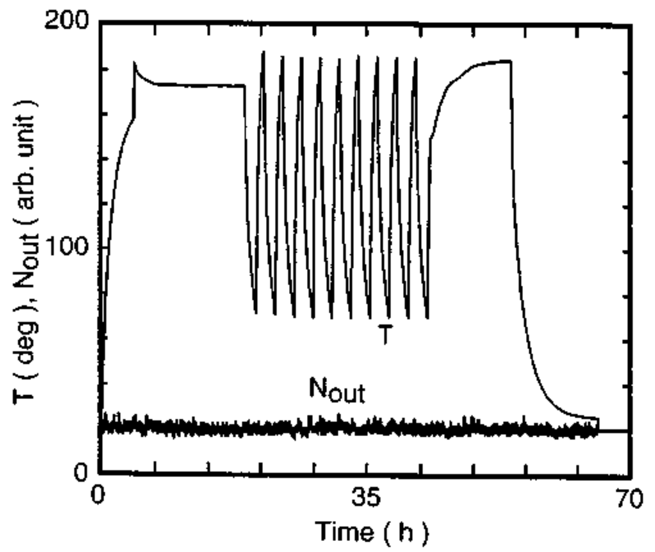

Figure5. Neutron detection by ^3He counter.
N_{out} is the output signal of the ^3He counter

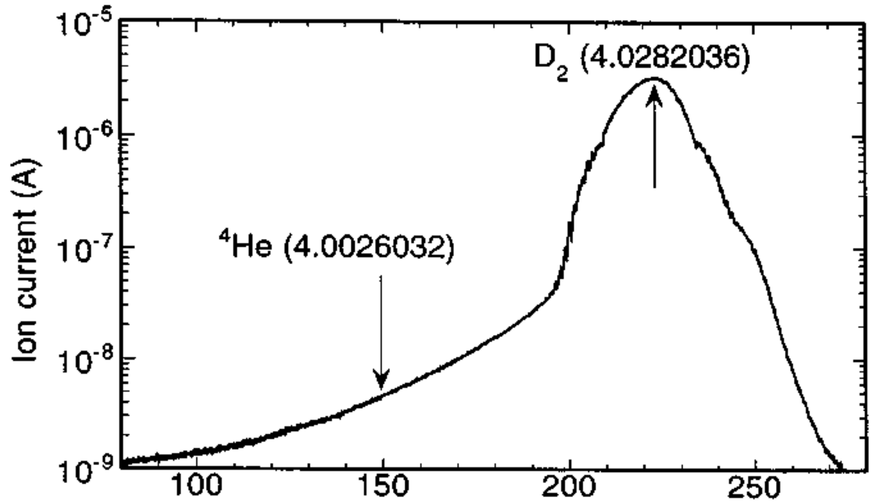

Figure 6. ^4He detection using Q-mass system.