Deuterium (Hydrogen) Flux Permeating through Palladium and Condensed Matter Nuclear Science

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Abstract

Deuterium (hydrogen) flux permeating palladium has been analyzed using mass spectroscopy (SRS RGA200) in a new apparatus. The "mass 6" component has been confirmed again. It is found that Langevin rate of D_3^+ generation in the mass spectrometer plays an important role. However, "mass 6" component cannot be attributed to D_3^+ only. The palladium plays an important role as well. The mixture of deuterium and hydrogen gas has been used to test the prediction of resonant tunneling theory as well.

1. INTRODUCTION

Deuterium (and hydrogen) flux and condensed matter nuclear science has been an interesting subject since ICCF-9 (Beijing, China, May 2002) [1,2,3]. During ICCF-10, (Cambridge, MA, USA, August 2003) the correlation between the deuterium flux and the heat flow was reported [4]. After ICCF-10, a deuterium flux experiment was conducted at Institute of Engineering Application Research, USA (IEAR) to detect the heat and the nuclear products. The preliminary experimental results were reported at The 5th Asti Workshop on Anomalies in Hydrogen / Deuterium Loaded Metals [5] (March 2004). It was reported that the temperature gradient in the radial direction of Pd disk was reversed when the deuterium flux was permeating through a thin palladium disk. The mass spectroscopy data showed that a "mass 6" component appeared in the deuterium gas permeating through the thin palladium disk. It is desirable to confirm this "mass 6" component and analyze this component. Particularly, the tritium production would be a test of the selective resonant tunneling theory, because the selective resonant tunneling theory predicts more tritium production if the mixture of deuterium and hydrogen gas were used instead of pure deuterium gas.

2. CONFIRMATION OF "MASS 6" COMPONENT

The mass spectrometer at IEAR was sensitive enough to detect the "mass 6" component in the deuterium gas passing through the thin palladium disk; however, that mass spectrometer worked only before and after the operation of the apparatus. An advanced mass spectrometer (SRS RGA200) was applied in this new apparatus at Institute of Plasma Physics, Hefei, CHINA. This mass spectrometer was able to measure the "mass 6" component on-line along with other mass numbers.

The new apparatus used a long thin palladium tube (ϕ 3 × 0.08 × 140mm) instead of the thin palladium disk used at IERA (ϕ 20 × 0.1 mm) in order to increase the Pd surface area. An electrical heater was installed at one end of the Pd tube, and the other end of the thin Pd tube was blocked

(Figure 1). When deuterium gas was fed into the Pd tube, the deuterium flux permeating through the thin Pd wall was analyzed by a mass spectrometer (SRS RGA200) when the Turbo-molecular pump kept the pressure lower than 10^{-2} Pa.

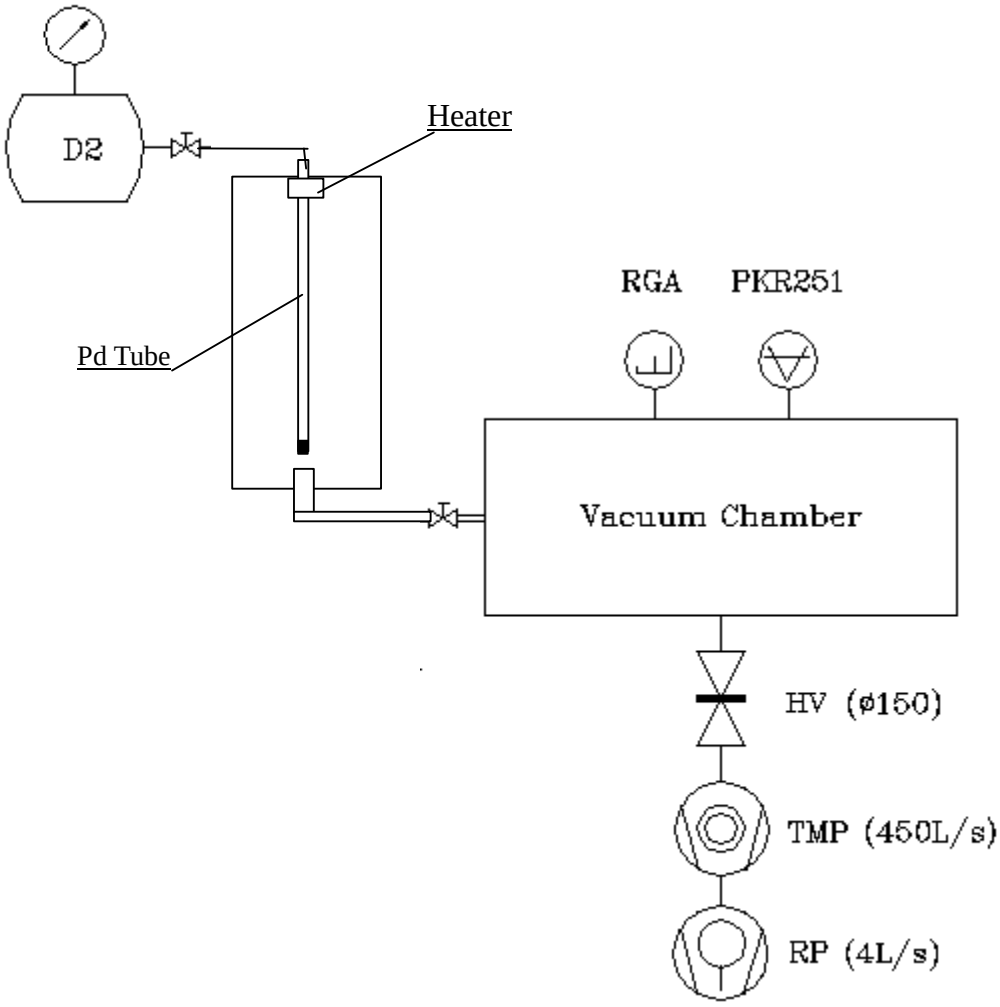

Fig.1. Schematic of new apparatus

Figure 2 shows clearly that "mass 6" component is one of the components growing with the deuterium flux. The upper line represents the "mass 4"component. It increased in steps because the heating power in the electrical heater increased in steps. The highest temperature near the heater was about 140ºC. The occurrence of a "mass 6" component in the IEAR experiment was again confirmed in this experiment. In addition, this on-line measurement shows clearly that the "mass 6" component increases much faster than any of the other components (masses 1,2,3,4,5,7). The mass 7 component stays very low; hence, we can eliminate the possibility of lithium contamination here (the natural abundance ratio for Li-7 to Li-6 is more than 12). We have to distinguish the contribution from the D_3^+ ion to the "mass 6" component from a possible T_2^+ ion contribution in order to find the signal we are searching for.

3. LANGEVIN RATE IN MASS SPECTROMETER

It is well known that the D_3 neutral molecule is unstable; hence, there is no way to ionize the D_3 neutral molecule inside the mass spectrometer to produce D_3^+. However there was another process to produce the signal of D_3^+. Early in 1905, Langevin [6] found that there was a large generation rate of

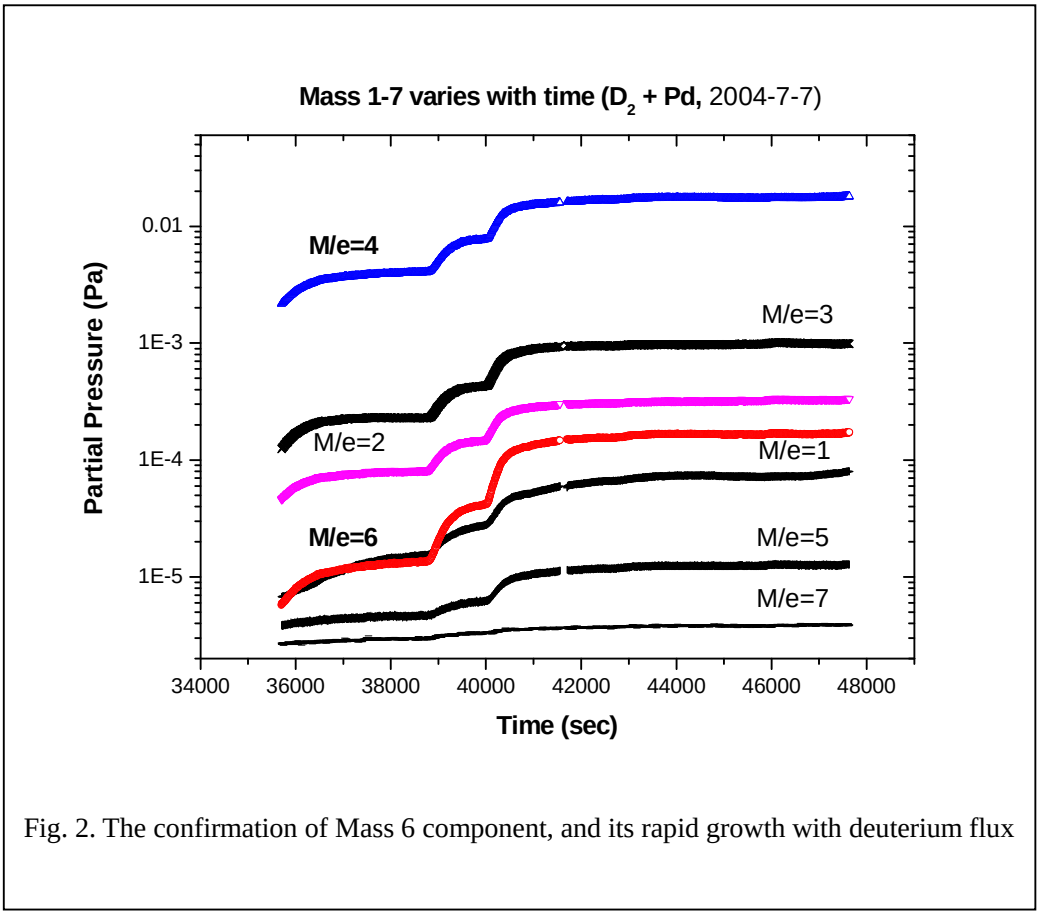

Fig. 2. The confirmation of Mass 6 component, and its rapid growth with deuterium flux

D_3^+ through the reaction [7,8,9]:

$$D_2^+ + D_2 \rightarrow D_3^+ + D + 1.7eV \qquad (1)$$

the D_2^+ ion inside the mass spectrometer may polarize the neutral D_2 molecule and dissociate it. As a result, D_3^+ was generated as a secondary process inside the mass spectrometer. Since it is an exothermic process, the cross-section of reaction (1) might be much greater than that of the collision between two neutral molecules by a factor of 10 to 100. This Langevin rate explains observed "mass 6" component here and in early IEAR experiments, because the ionized D_2 molecule might trap another neutral D_2 molecule easier when the density of D_2 molecule is getting higher and higher.

This Langevin rate may be confirmed by two facts:

(1) The "mass 6" persists while using the D_2 gas without Pd tube;

(2) The quadratic dependence of "mass 6" on "mass 4".

When D_2 gas was fed directly into the mass spectrometer without permeation through a Pd tube, the partial pressure of various components decreased with time due to the pumping in the line of spectrometer. Fig 3 shows the changes of "mass 4, 2, and 6", respectively. The steps in figure 3 was caused by an interruption near 43000 seconds when the spectrometer was switched to another mode in order to measure the whole mass range (mass 1-200). Fig. 3 shows that even if there is no Pd tube, the

"mass 6" component might be as high as 10% of the "mass 4"component when "mass 4" is more than 0.03 Pa. Thus "mass 6" cannot be attributed to the occurrence of T_2^+ as expected.

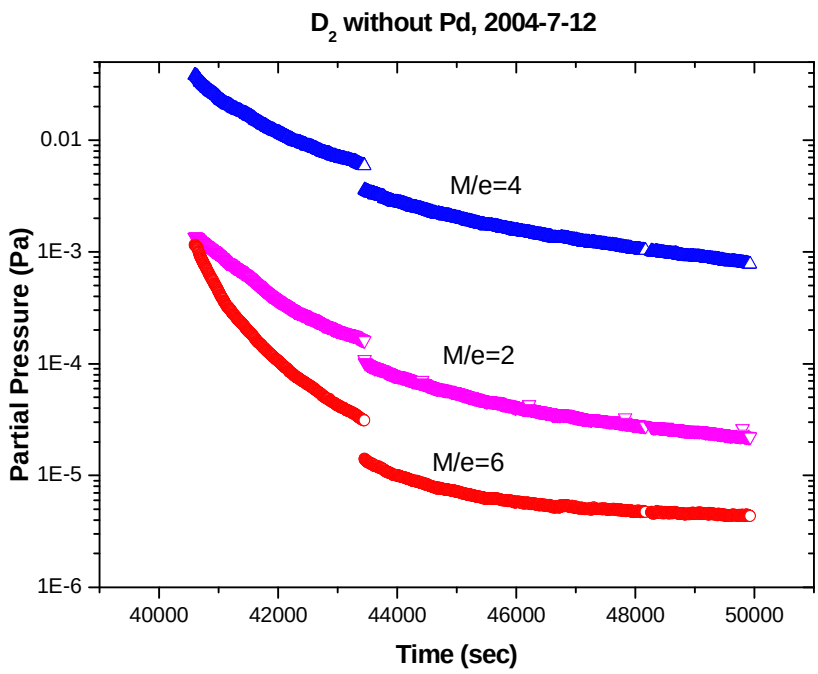

Fig. 3. Mass 6 appeared in mass spectrometer even if the deuterium gas has not been permeating through a thin wall of Pd tube.

Figures 4 and 5 shows the dependence of "mass 6" on "mass 4"for the cases of using Pd tube and without Pd tube, respectively. A similar quadratic dependence on "mass 4" was observed in both cases. This implies that the "mass 6" component was mainly generated inside the mass spectrometer in terms of Langevin rate.

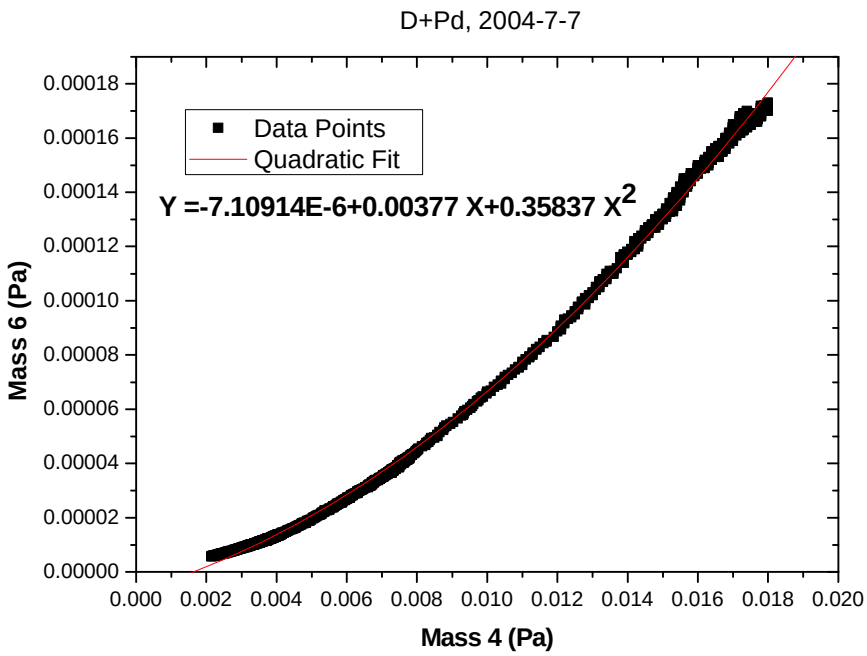

Fig. 4. Mass 6 varies with Mass 4 quadratically as Langevin rate

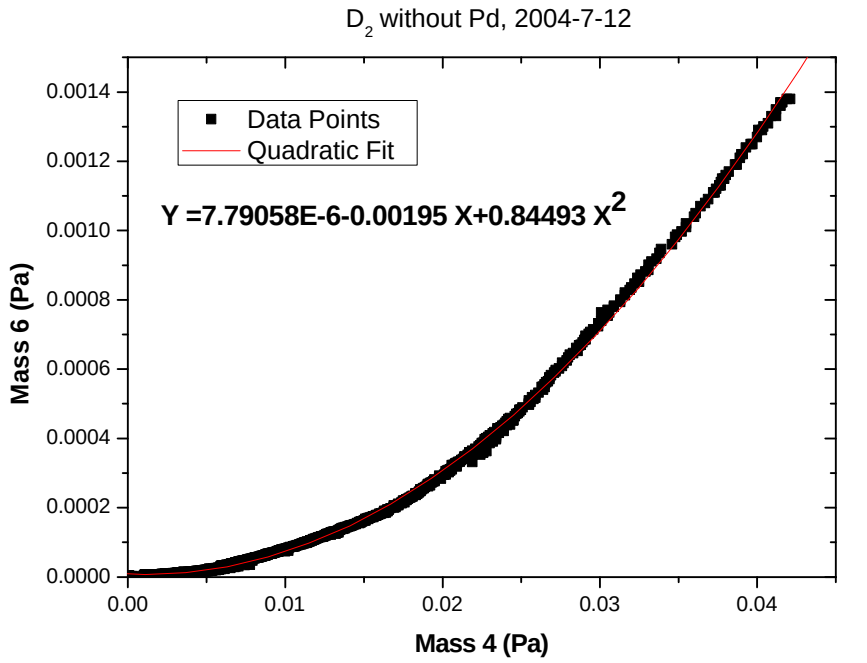

Fig. 5. Mass 6 dependence on Mass 4 in the case of having no Pd

THE ROLE OF Pd

In order to eliminate the Langevin rate of D_3^+ generation, we might search the low "mass 4" region where the quadratic dependence might suppress the Langevin rate. Fig.6 shows the results when the mixture of H_2 and D_2 gases was fed into the Pd tube. At 33720 seconds, the heater was turned on, Masses 1, 2, 3, 4 were all increasing with time due to the enhanced flux permeating through the thin wall of Pd tube, but Masses 5, 6 were decreasing first. This "mass 6" dependence on "mass 4" is very different from the quadratic Langevin rate. This dependence appeared only when the mixture of H_2 and D_2 gases was fed into the Pd tube. We did not observe such dependence when the mixture of H_2 and D_2 gases was fed directly into the mass spectrometer, or when the D_2 was fed into the Pd tube. Although it is not easy to judge what the "mass 6" component is, we can be sure this "mass 6" was not generated inside the mass spectrometer. The Pd tube played important role here, and H_2 gas played important role here as well. A plausible explanation based on the selective resonant tunneling model [10-15] is that:

$$p + d \xrightarrow[RESONANT\ \ TUNNELING]{} {}^3He^* + e_k \xrightarrow[K-ELECTRON\ CAPTURE]{} T + \nu_e \qquad (2)$$

As a result of resonant tunneling, the He-3 excited state was formed as an intermediate state first; then, the K-electron capture would turn He-3 into tritium [16]. The tritium ion, T_2^+, formed a part of the "mass 6" component in mass spectroscopy.

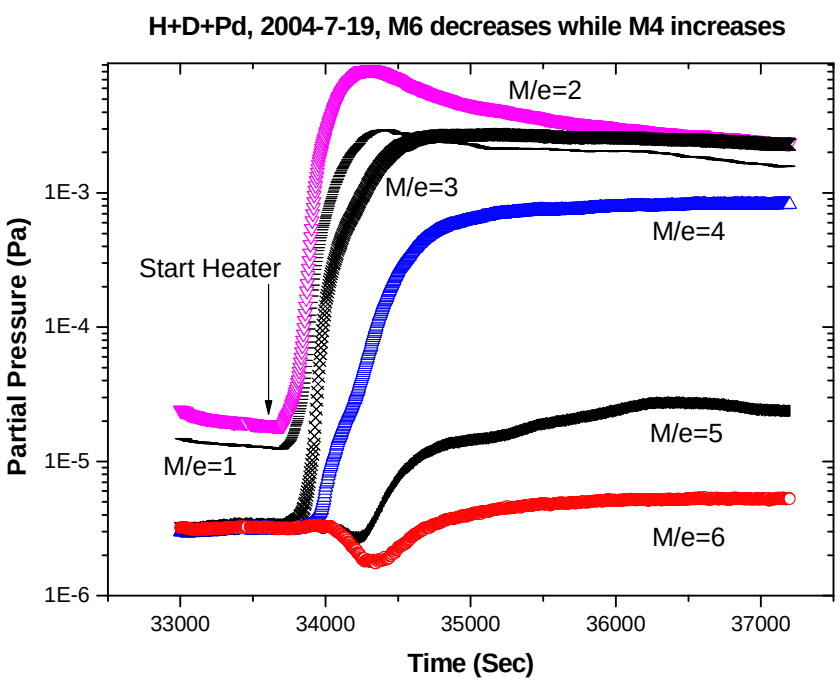

Fig. 6. When the mixture of H_2 and D_2 gas was fed into the Pd tube, Mass 6 decreased at low Mass 4 region when Mass 4 increased

4. DETECTION LIMIT

It is important to discuss the detection limit, if the triton was formed in process (2). The pumping rate of the turbo-molecular pump is 450 litres/second. Having considered the conductance of the system, the effective pumping rate is about 250 litres/second. The detection limit of this mass spectrometer is about 10^{-7} Pa; hence, the detection limit of the generation rate of "mass 6" is about 2.5×10^{-5} Pa·Litres/second which is about 10^{11} triton/second. This is a rather high rate of triton generation in usual condensed matter nuclear science experiments. (F. Will's early electrolytic experiment [17] generated tritons at an average rate of 2×10^{5} triton/(sec·cm^2)). In order to enhance the rate of triton generation, we might enhance the deuterium flux. However, the Mass spectrometer was not able to work when the pressure was higher than 10^{-2} Pa; hence, the maximum D_2 flux was limited to 2.5 Pa·Litres/second. Consequently, we have to develop a new apparatus which is able to detect much lower triton generation rate under a heavy deuteron back ground, or circulate the gas in the system in order to accumulate the number of tritons.

5. FUTURE EXPERIMENT

A new mass spectrometer has been developed in the department of physics at Tsinghua University. It combined the time-of-flight mass spectrometer with a laser stimulated fluorescence spectrometer. Hence, not only is the sensitivity greatly enhanced, but also the light emission would provide a new criterion to distinguish the T_2^+ from D_3^+. Hopefully, this new system would produce the evidence of the correlation between deuterium flux, excess heat, and the nuclear products.

ACKNOWLEDGEMENTS

This work is supported by The Ministry of Science and Technology (Fundamental Division), Natural Science Foundation of China (#10145004) and Tsinghua University (Basic Research Fund (985-I)). We are grateful to The Institute of Plasma Physics for providing enssential assistance during this experiment.

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