## Nuclear Physics Approach

# Observation of Nuclear Products in Gas Release Experiments with Electrochemically Deuterated Palladium

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Abstract

Gas release experiments have been performed using electrochemically deuterated palladium. We developed a gas storage system to store gas released from a deuterated palladium. Using the system, we analyzed the released gas and investigated effects of hydrogen concentration on mass number 5 gas. As a result, mass number 5 gas cannot be explained by hydrogen concentration and we conclude that DT gas is produced in the gas release experiments.

## 1. Introduction

Since Fleichmann and Pons reported on "cold fusion" phenomena in 1989, much research has been carried out and many reports indicated that nuclear reactions occurred in deuterated palladium. From those reports and our research[1,2,3], it is necessary for inducing anomalous nuclear effects to make deuterium atoms diffuse in palladium metals under high D/Pd condition. In order to clarify this point, we have performed gas release experiments to release absorbed gas by heating electrochemically deuterated palladium metals in a vacuum chamber and reported on anomalous nuclear effects(neutron emission, X-ray emission, DT gas breeding)[1,2].

We demonstrated that mass number 5 gas increased during heating in previous paper[1,2]. Mass number 5 gas measured by Q-Mass is composed of DT and $DDH^+$. $DDH^+$ ions are formed of deuterium and hydrogen. Deuterium derives from samples and hydrogen is contained in samples and a vacuum chamber. In previous paper, we estimated mass number 5 gas without taking account of effects of hydrogen contained in samples. In this paper, therefore, in order to confirm that DT gas is released in our experiments, we analyze the sample gas and investigate effects of hydrogen concentration on mass number 5 gas using two kinds of method as follows.

(1)monitoring mass number 5 gas and hydrogen simultaneously during experiments with two quadrupole mass spectrometers.

(2)estimating of hydrogen concentration of the released gas from the sample using a gas storage system described in this paper.

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2. Method

An experimental procedure is as follows. Palladium metals($\phi$3 × 25mm : Tanaka Kikinzoku Kogyo K.K.) are annealed at 900°C in a vacuum chamber(<$10^{-7}$ torr) for 10 hours and are washed with heavy aqua regia. The palladium samples are loaded with deuterium in $D_2O$-LiOD electrochemical cell and are electroplated with Cu in a $CuSO_4$-$D_2O$ electrochemical cell to maintain high deuterium loading ratio. After that, the sample is heated up to 180°C to release absorbed gas in a vacuum chamber. As described in ICCF-5 proceedings[2], the vacuum chamber is equipped with nuclear measurement apparatus(He-3, SSB, CdTe, NaI, Q-Mass) in order to observe anomalous nuclear effects. As for Q-Mass, we use two quadrupole mass spectrometers (one is high resolution and the other is normal resolution). All these devices are located in a clean-room where temperature and humidity are always controlled at constant levels(23°C±1°C, 40%±5%) in order to prevent contamination and false counts induced by humidity in the air.

We, furthermore, developed a gas storage system connected with the vacuum chamber to store and to analyze the released gas from the sample. Figure 1 shows a scheme of the system. This system is composed of a gas storage chamber and a dry pump to hold backing vacuum of a turbo-molecular pump and to compress the sample gas into a gas storage chamber. Using this system, we store released gas from the sample during experiments. After experiments, the gas is analyzed by a mass spectrometer.

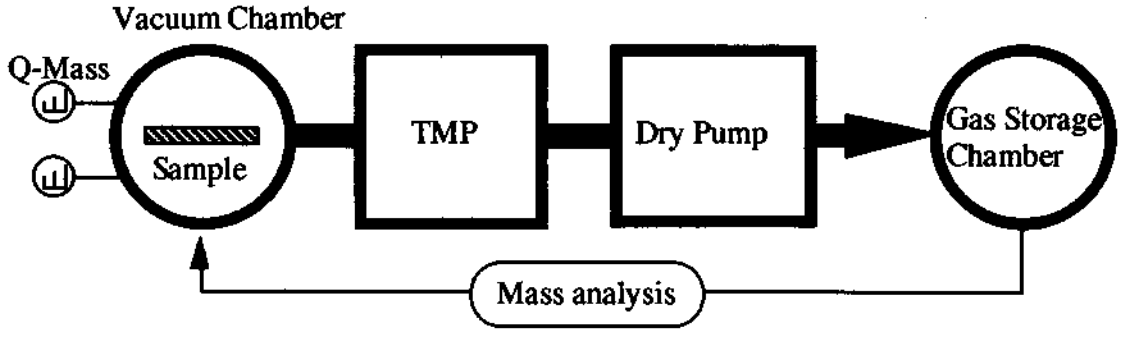


Figure 1. A scheme of gas storage system

3. Results and Discussion

We simultaneously monitored mass number 5 gas and mass number 1 gas($H^+$) using two quadrupole mass spectrometers during experiments. Figure 2 shows the result of time evolution of mass number 1 signals and mass number 5 signals during heating. Mass number 1 signal is proportional to hydrogen concentration. The figure indicates that mass number 5 gas increases while hydrogen decrease. Therefore, time variation of mass number 5 gas does not correspond with $DDH^+$ time evolution. It is considered that mass number 5 gas is not composed of $DDH^+$ alone.

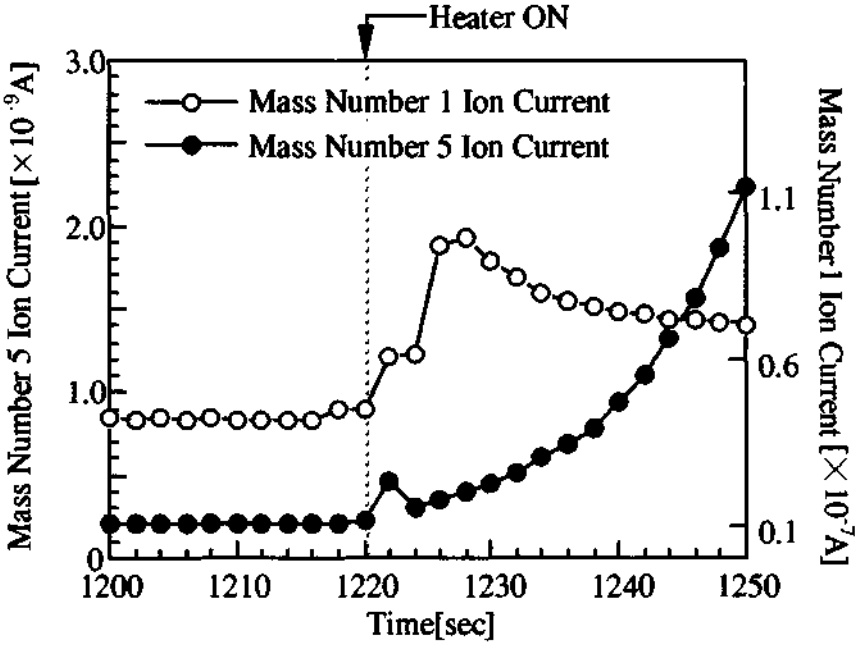


Figure 2. Time evolution of mass number 1 ion current and mass number 5 ion current

We stored released gas from the sample in order to analyze hydrogen concentration with a mass spectrometer. Figure 3 shows mass spectrum of the released gas. Comparing mass number 3(HD) ion current intensity with mass number 4($D_2$) ion current intensity, hydrogen concentration is estimated 3.4% (deuterium is 96.6%). Since the released gas contains hydrogen, it is important for analyzing mass number 5 gas to take account of $DDH^+$ formation depending on hydrogen concentration.

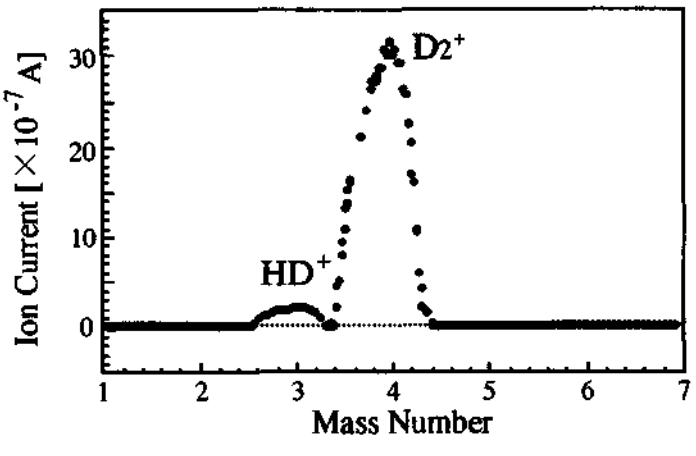


Figure 3. Hydrogen concentration in released gas

Figure 4 shows effects of hydrogen on $DDH^+$ formation. $DDH^+$ ion current is measured by introducing mixing gas of deuterium and hydrogen into the chamber. The figure indicates that $DDH^+$ ion current intensity increase with increasing hydrogen concentration. Threfore, $DDH^+$ formation depends on hydrogen concentration. In a previous report[2], however, we evaluated DT gas breeding ratio without considering effects of hydrogen and defined DT gas breeding ratio as

equation(1) using $DDH^+$ ion intensity of standard gas of $D_2$ cylinder (D: 99.6%, H: 0.4%).

$$\text{DT Gas Breeding Ratio} = \frac{\text{Mass 5 Ion Current}}{DDH^+ \text{ Ion Current}} \qquad (1)$$

In this paper, we estimate hydrogen concentration of samples and determine $DDH^+$ background intensity using figure 4. Introducing the $DDH^+$ background intensity into equation(1), we evaluate DT gas breeding ratio. If DT gas breeding ratio is larger than 1.0, DT gas is released from deuterated palladium.

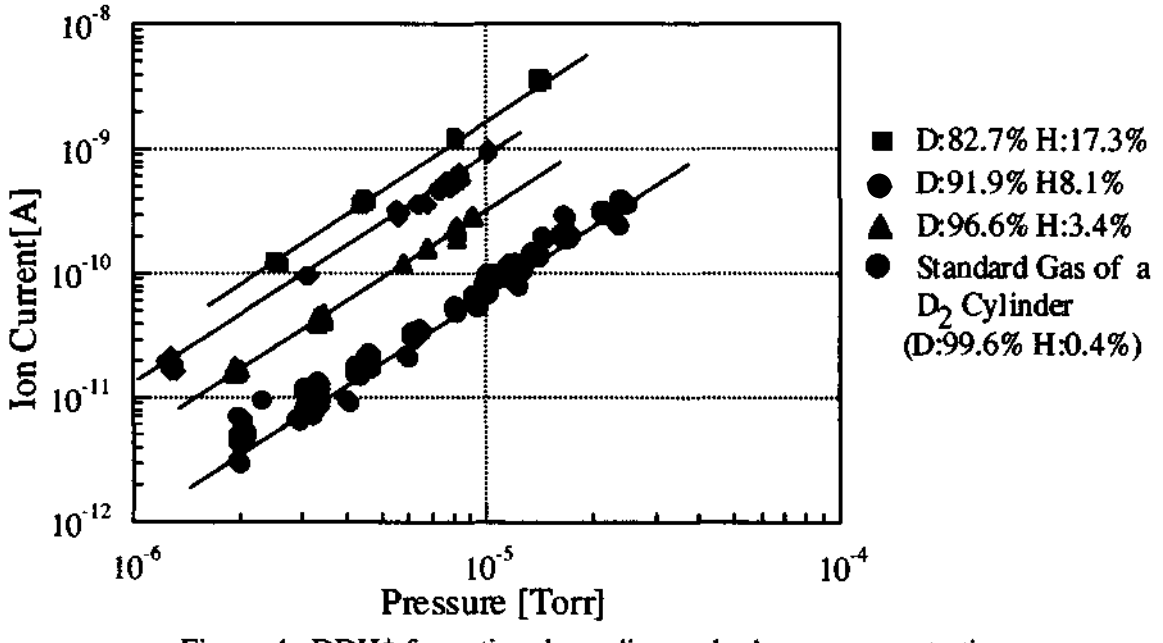


Figure 4. $DDH^+$ formation depending on hydrogen concentration

Figure 5-(a), 5-(b) shows time evolution of mass number 1 ion current, total pressure and DT gas Breeding ratio analyzed using this procedure. Mass number 1 signals correspond with hydrogen concentration and total pressure is proportional to deuterium density. Hydrogen concentration is 5.7% in this experiment. In figure 5, DT gas breeding ratio is larger than 1.0 during heating. It is considered that DT gas is released from the sample. Furthermore, in figure 5-(b), DT gas breeding ratio changes rapidly, though mass number 1 signals(hydrogen concentration) and total pressure(deuterium density) do not change. This indicates that time variation of DT gas breeding ratio does not correspond with time evolution of $DDH^+$. Therefore, DT gas breeding ratio cannot be explained by $DDH^+$ formation.

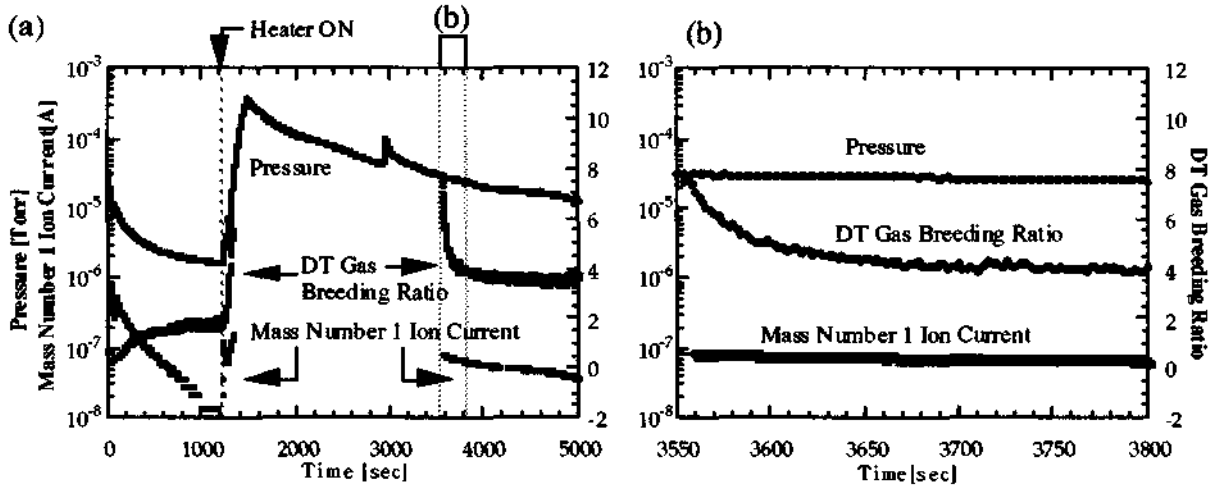


Figure 5. DT gas breeding ratio time evolution

4. Conclusion

DT gas breeding ratio analysis with taking account of $DDH^+$ formation depending on hydrogen concentration has been performed. As a result, DT gas breeding ratio is higher than 1.0 and time evolution of DT gas breeding ratio does not correspond with hydrogen time evolution. Therefore, mass number 5 gas cannot be explained by the formation of $DDH^+$ and we conclude that DT gas is contained in mass number 5 gas in gas release experiments.

Reference

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