"EXCESS HEAT" INDUCED BY DEUTERIUM FLUX IN PALLADIUM FILM

BIN LIU, XING Z. LI, AND QING M. WEI
Department of Physics, Tsinghua University, Beijing 100084, China
E-mail: lxz-dmp@tsinghua.edu.cn

N. MUELLER, P. SCHOCH, AND H. OEHRE
Inficon Limited, Alte Landstrasse 6, LI-9496 Balzers
Principality of Liechtenstein

An early work at NASA, USA has repeated at INFICON Balzers, Liechtenstein in 2005. It is a confirmation of the correlation between excess heat and deuterium flux permeating through the Pd film. The maximum excess power density is of the order of 100 W/cm^3(Pd).

1. Introduction

Early in 1989, G. C. Fralick *et al.,* of NASA, USA conducted an important experiment to search for the neutron radiation using gas-loading method in a D/Pd system instead of electrolysis.[1] They could not find any evidences for the neutron radiation in a D/Pd system; however, they discovered unexpectedly the "excess heat" in a D/Pd system. Thanks to J. P. Biberian, we became aware of this NASA work after ICCF-11. This NASA experiment was very similar to our gas-loading experiments, which have been conducted at Tsinghua University since 1989.[2−4] The excess heat appeared in both our experiments and in NASA experiments whenever deuterium gas was pumped out from the Pd samples. In our early work,[2] we used palladium wire only and heated Pd wire using the electrical current through it. G. C. Fralick *et al.* utilized the Pd-alloy tube in a hydrogen purifier, and heated this tube using an external electrical heater from outside of tube. Nevertheless, in W. Wu and X. Z. Li's work,[3] we utilized Pd tube also, but we heated the Pd tube using electrical current through Pd tube. This is different from Fralick's heating from external heater. On the other hand, X. Z. Li and J. Tian[4] were using an external heater, but the pumping was done only at one side of the Pd tube. However, G. C. Fralick *et al.* pumped deuterium gas from both sides of the Pd-alloy tube. We now use a Pd disk heated by an external heater, and pump down from both sides of the Pd film (Fig. 1). Although the configuration varied in various experiments, the results are all similar, i.e., the "excess heat" appears while a deuterium flux leaving palladium is created.

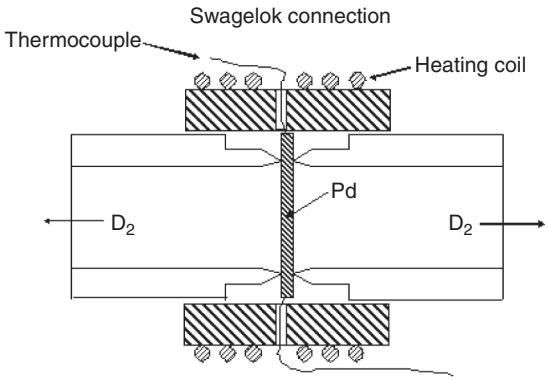

Figure 1. A thin palladium film is sealed between two tubes using a Swaglok connection structure. There are two small holes on the nut. Thermocouples are inserted into holes in order to measure the temperature of the edge of the Pd film. The heating coil winding is wrapped around the nut to heat the Pd film.

2. NASA's Early Gas-loading Experiment

In a hydrogen purifier (HP-25, commercial available through Johnson & Matthey Inc., Fig. 2), 13.8 atm. deuterium gas was fed into the palladium tube from both the inner side and outer side. It was heated electrically to 383°C. When the deuterium gas was pumped out using the mechanical pump, the temperature of the palladium tube increased suddenly from 383°C to 400°C in 15 s. It was not caused by the reduction of heat conductivity, because there was no such temperature variation when hydrogen gas was fed instead of deuterium gas. It was further confirmed by switching off the electrical power before starting the pump. In this case, the temperature dropped from 374°C to 370°C and then slowly increased back up to 375°C, again indicating the heating as the deuterium was removed from the palladium. As before, no neutrons were registered by either detector during the time the heating occurred.

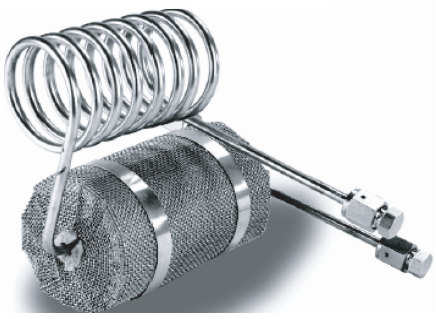

Figure 2. Hydrogen purifier is utilized as a palladium tube-deuterium system with heating element wrapped in the insulator. The helical stainless tube on the top is for cooling the purified gas.

With the assistance of INFICON R&D Laboratory, this NASA experiment was repeated and the gas sample was analyzed using high-resolution quadruple mass spectrometer. This paper would report the result of excess heat first. The result of quadruple mass spectrometer analysis would be reported in another paper.[5]

3. Tsinghua–INFICON Collaboration

Early in 1989, the hydrogen purifier was an existing equipment for NASA scientists to study the D/Pd system; however, it was not easily accessible for us in 2005. With the assistance from IERA,[6] we had experience in running Swagelok connection like that in Fig. 1. The advantage of this configuration was that it was easy to utilize the high-resolution quadruple mass spectrometer in the INFICON R&D Laboratory in order to identify the nuclear products from the D/Pd system. A Pd film with high purity (99.98%) was cut to be fit into the Swagelok connection. It was about 20 mm in diameter and 0.1 mm in thickness. The Pd film might be heated to 330°C using the electrical heater wrapped around the nut. The temperature of the Pd film might be monitored by the thermocouples inserted into the holes on the nut. The system was pumped to 10^{-6} mbar. Then the deuterium gas was filled into the system to 999 mbar. The electrical heater was turned on to heat the system from 25.3°C to 330.2°C in 1.5 h using ∼113 W heating power while the room temperature is about 23.6–25.0°C. During the heating the deuterium pressure dropped first because of the strong absorption of the Pd film. The pressure was down to 996 mbar first; then, it increased slowly due to the heating. When we started pumping, the pressure was 1004 mbar. The Pd temperature started increasing when we started pumping as that seen in Fig. 3. When pressure was down to 0.1 mbar, the decreasing rate of pressure slowed down. An additional turbo-molecular pump was turned on at that time. The pressure was further down to 10^{-4} mbar. A very clear temperature rising was observed in this period. The temperature reached the highest point (339.8°C) after 70 min; then, it started decreasing even if the pumping continued to pump the pressure down to 10^{-5} mbar. This behavior was very important in order to exclude the effect of the heat conductivity. Usually, we might worry about that the heat conductivity might drop while the gas pressure dropped. Indeed, this last period just showed that the effect of heat conductivity in this temperature rising was not important. The electrical heating power was provided by a VARIAC power supply. It showed a stable voltage about 221.2 V(AC). We might worry about the room temperature fluctuation. It was monitored by a thermocouple and a mercury thermometer. The lowest was 23.1°C, and the highest was 25.0°C.

4. Discussion

The absorption of deuterium gas into palladium is an exothermic process. Hence, the degassing of deuterium from the palladium is supposed to be an endothermic process. We were supposed to observe the temperature drop when we started pumping. This was true, when the data acquisition system was able to catch that

short temperature drop just after the starting point of pumping. It was caused by both the endothermic degassing and the adiabatic expansion. However, this short drop in temperature was always followed by a temperature rising which was corresponding to the correlation between heat and deuterium flux. This phenomenon was discovered in the study of gas-loading in palladium wire,[2] and was named as "pumping effect". The careful study using high precision calorimetry confirmed this phenomenon, and called it as correlation between heat flow and abnormal deuterium flux.[3,4] The early NASA gas-loading experiment provided a strong evidence to this phenomenon unexpectedly.[1] The collaboration with INFICON R&D laboratory has made us even more confident about this phenomenon.

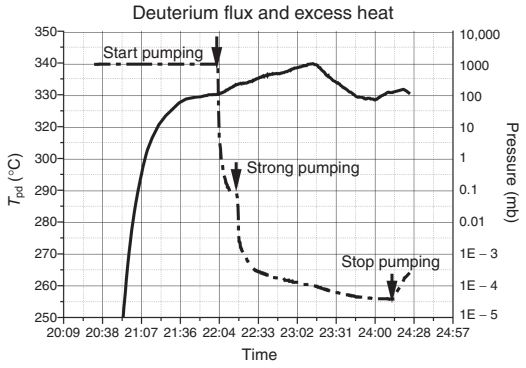

Figure 3. Solid line shows the temperature at the edge of the Pd film. Dash-dotted line shows the pressure around the Pd film. The temperature started increasing when pumping was started. However, temperature dropped later even if the pumping was continuing.

We may estimate the excess power in this pumping period. The resistance of the heater was 433 Ω at 330°C, it provides an effective heating power of 113 W at 221.2 V. This heating power was able to maintain a temperature difference of (330.2–24.0) = 306.2°C. Hence, the temperature difference of (339.8–330.2) = 9.6°C might imply an "excess power" of 3.5 W. The volume of the Pd film was about 0.031 cm^3; hence, the power density for the palladium was about 114 W/cm^3. It is about the power density in a modern nuclear fission reactor.

Acknowledgments

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