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"PUMPING EFFECT"

—REPRODUCIBLE EXCESS HEAT IN A GAS-LOADING D/Pd SYSTEM—

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ABSTRACT

Excess heat in a gas-loading D/Pd system is detected using current-constant mode or temperature-constant mode. A reproducible **"pumping effect"** is observed for the D/Pd gas-loading system. This effect is induced when a mechanical pump increases pressure to several tens of pascals. Using this effect, the power density of "excess heat" (apparent excess energy) reaches 2 W/cc.

1. INTRODUCTION

Ten years ago, we started gas-loading experiments to detect energetic charged particles from the D/Pd system using CR-39 (solid state nuclear track detector)[1]. At that time we assumed that energetic charged particles should be necessary nuclear products, but not neutrons. The gas-loaded system was selected for its compatibility with CR-39. When we improved the gas-loading technique, the high-pressure, low-temperature loading system was switched to a low-pressure, high-temperature system. That made it feasible to combine the calorimetric measurement with the loading system. The distinction was evident between the H/Pd and D/Pd system in calorimetric behavior [2]. There was up to 2 W/cc of "excess heat" in the D/Pd system. The highest excess heat reached 100 W/cc in a burst [2]. To avoid uncertainties in heat transfer coefficient, a new scheme was developed to avoid any power input inside the D/Pd system. After careful calibration, we showed that the temperature of the D/Pd system might rise spontaneously while the temperature of the D/Pd system was higher than that of surrounding medium.[3] Gradually, we realized that with the high temperature gas-loading system, the loading ratio was no longer a unique criteria to generate excess heat. A pumping rate works effectively to trigger a sudden rise in the resistance of palladium wire. It might be interpreted as a sudden jump in the loading ratio, if the loading ratio is calculated in terms of resistance-loading curve [4]. A sudden jump in palladium temperature always accompanied this jump in resistance when the electrical current in palladium wire was kept constant. In order to analyze the cause of this resistance jump, we switched from the constant-current mode to the constant-temperature mode. The power input to the palladium wire was controlled by a computer to keep the temperature of the palladium wire constant. It was observed that the resistance jump remained in the temperature-constant mode as well; hence, it should be attributed to a jump in loading ratio. Moreover, the temperature-constant mode provides additional evidence of excess heat, because the reduction in power input is a direct measurement of the excess heat in the D/Pd system. This is true even if you do not know the exact value of heat transfer coefficient, as long as the heat transfer coefficient is assumed constant. We shall discuss this pumping effect first.

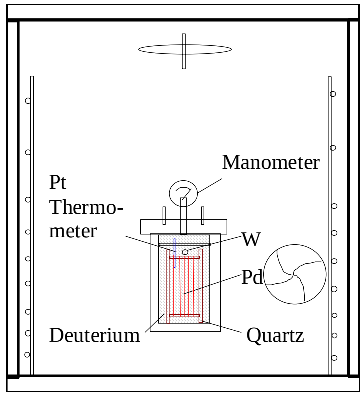

Fig. 1. Schematic of gas-loading system under low-pressure high-temperature

2. PUMPING EFFECT IN A GAS-LOADING D/PD SYSTEM

When we heat the palladium wire, we may anticipate that the loading ratio of D/Pd will drop if the pressure is kept constant. However, the experiments show this is not the case. Absorption occurs at the high temperature even if the pressure is lower than one atmosphere [5,6,7]. In our gas-loading experiments, a pumping effect was reproducible. We observe the pumping effect in the same experiment at different points on the loading curve, and we observed the same pumping effect in various experiments with different configurations (Pd wire, Pd tube, or Pd film). When the palladium wire was heated by electrical current through this wire in the deuterium gas, the resistance of the palladium wire was recorded to monitor the loading ratio. Fig. 1 shows a schematic of apparatus, the details of which were described in Ref. [2] and [3]. As indicated by an early experiment [8,9], the resistance of a palladium wire depends on both its loading ratio and its temperature. Figure 2 shows the resistance of the palladium wire, R(Pd), as a function of its temperature and loading ratio (x=atomic number ratio of D/Pd). Each dotted line shows the resistance as a function of its temperature (T_{Pd}) for a specific loading ratio (D/Pd). When we kept the electrical current, I(Pd), in the Pd wire constant and changed the temperature of Dewar wall (T_w), the Pd wire changed its temperature, T_{Pd}, to keep the thermal flow in balance with the electrical power input. The loading ratio was not changed when the T_{Pd} dropped from point 1 (180ºC) to point 2 (157ºC) and rose from point 2 to point 3 gradually. Turning on the pump at point 3 introduced a jump in loading ratio from 0.3 to 0.45 (point 3 to point 4). The time between two adjacent data points was 10 seconds only; hence, it was a quick jump. This jump was followed by a temperature rise due to the enhancement of the electrical power input at constant I(Pd) (point 4 to point 5).

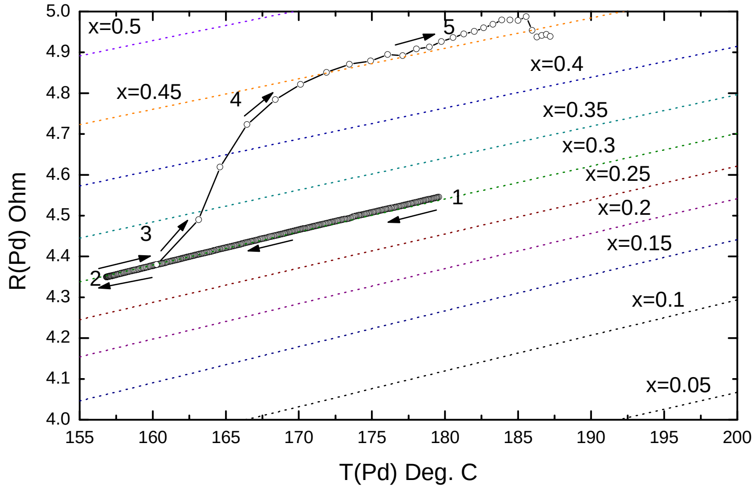

Fig. 2. Pumping at 160ºC induced a jump in loading ratio

This kind of behavior appeared once and once again every time the pump was started. It was thought that this jump in resistance was induced by a positive feed-back mechanism as follows. The pumping reduced the gas pressure; hence, the heat conductivity through gases was reduced. Consequently, the temperature of palladium wire (T_{Pd}) was enhanced because the heat transfer was reduced. The enhancement of T_{Pd} would cause the enhancement of resistance; hence, the electrical power input would be enhanced and it would cause the T_{Pd} to rise further. However, this kind of positive feed-back mechanism is not supported by the time behavior of the resistance of the Pd wire, because the resistance jumped up much faster than the temperature rose at the onset. The jump in the loading ratio came first. Nevertheless, what we were most interested in was whether any excess heat accompanied this jump in loading ratio.

3. CONSTANT-CURRENT MODE AND CONSTANT-TEMPERATURE MODE

When the electrical current in palladium wire, I_{Pd}, was kept constant by the power supply, the temperature rising after pumping may be caused by two factors: the jump in power supply and the reduction in heat transfer coefficient. Even if we may assume that the heat transfer coefficient does not change at the low pressure, we have to distinguish the heat from the electrical power input and the "excess heat " (if any). We may calculate the heat transfer coefficient, which is defined as:

$$k = \frac{I_{Pd}V_{Pd} + Q_{ex} - MC_p \dfrac{dT_{Pd}}{dt}}{(T_{Pd}+273)^4 - (T_w+273)^4} \tag{1}$$

Here, V_{Pd} is the voltage applied on the palladium wire; T_w is the temperature of Dewar wall; MC_p is the heat capacity of palladium wire; Q_{ex} is the excess heat if any. If T_{Pd} reaches its steady state, $\frac{dT_{Pd}}{dt} \approx 0$; then

$$k = \frac{I_{Pd}V_{Pd} + Q_{ex}}{(T_{Pd}+273)^4 - (T_w+273)^4} \tag{2}$$

If the value of k is known, we may use eq.(2) to calculate the excess heat, Q_{ex} , in terms of I_{Pd}, V_{Pd}, T_{Pd}, T_w and k. In fact, we do not know the exact value of k. However, if there is any excess heat in the D/Pd system, we expect to see a drop of the value k_4, every time the Q_{ex} increases. k_4 is defined as

$$k_4 = \frac{I_{pd} V_{pd}}{(T_{pd} + 273)^4 - (T_w + 273)^4} \quad (3)$$

This was observed at the onset of pumping. One might suspect that the sudden change in T_{Pd} might cause this jump in k_4; therefore, a further experiment was run in the constant-temperature mode.

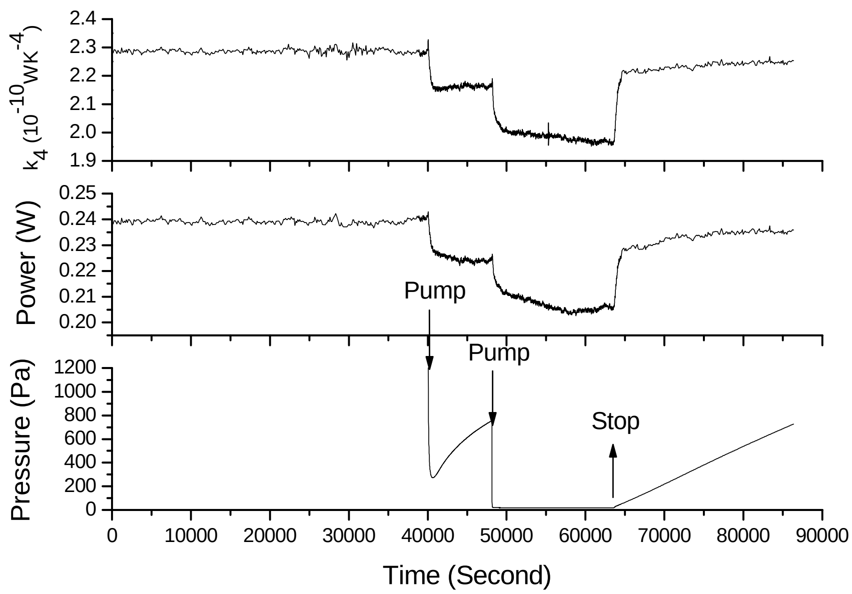

Fig. 3. Power is not a function of P(3), but directly related to pumping rate (990711-0.xls)

A computer controlled power supply was used to keep the temperature of the palladium wire, T_{Pd}, constant. A tiny Pt thermistor was attached on the palladium wire to closely monitor the temperature as a sensor for T_{Pd}. The T_{Pd} could be preset to a fixed value in the computer software. In this way, we eliminated the temperature effect during the pumping; however, we were still able to see this drop in k_4.

When we started pumping the deuterium Dewar at 40,000 sec. in Fig. 3, the power necessary to keep the constant T_{Pd} dropped quickly. One may suspect that the drop in deuterium gas pressure reduces the heat conductivity; hence, the necessary electrical power is reduced. This interpretation is not correct. When the pressure in the Dewar increased slowly from 200 Pa to 700 Pa. The k_4 did not increase with the pressure at all. When we increased the pumping rate again at 48,000 sec., k_4 dropped suddenly again. It is clearly shown that the k_4 is a function of pumping rate but not the function of pressure in the Dewar. Particularly, when we stopped the pumping at 63,000 sec., the k_4 jumped up quickly although the gas pressure was still very low in the Dewar. These data exclude the possibility of explaining the jump of k_4 as a jump in heat transfer coefficient. Indeed the jump in k_4 is possibly evidence of excess heat. Assuming a constant heat transfer, this jump of k_4 corresponds to excess heat of 0.035W, which is about 15% of the input power (0.24W). The volume of the Pd wire is about 0.237 cm^3 ; hence, it is on the order of 0.15 W/cc at the temperature of 50ºC. Based on the high temperature electrolysis experiments [7,10], We might anticipate that the excess heat would be enhanced at higher temperature. Fig. 4 showed the similar data at 95ºC and 100ºC. When the temperature of the Pd, T_{Pd}, was kept constant, the pumping at 69,000 sec. introduced a resistance jump and a power drop again. Since the T_{Pd} was kept constant, the change in resistance was attributed to loading, and the change in power was due to the excess heat. When the electrical power dropped from 2.28W to 1.84W, the temperature of Pd was still kept at 95±0.5ºC. If the heat transfer coefficient did not change during the pumping; then, the excess heat power was about 0.44W, which is 19% of the power input. When the pumping was stopped at 160,000 sec., the necessary power jumped back to 2.3W. This effect was reproduced in the next day, at 218,000 sec. the necessary power dropped to 1.84W due to the pumping again. There were two jumps in power at 250,000 sec. and 297,000 sec., respectively. They were different in nature. The first power jump at 250,000 sec. was due to the setting in computer. We required that T_{Pd} should jump from 95ºC to 100ºC at 250,000 sec.; then, the computer increased the power input to meet this requirement. However, at 297,000 sec. we stopped pumping, and the power jumped up instantly to keep T_{Pd} =100ºC. Fig. 4 shows that k_4 does not change at 250,000 sec., but k_4 jumps from $1.70\times10^{-10} \rightarrow 2.15\times10^{-10}$ W/K^4 at 297,000 sec. It shows clearly that pumping causes the change in k_4. In other word, the pumping may introduce a kind of excess heat in parallel to the jump in loading ratio. The power density for this excess heat near 95ºC is about 1.8 W/cc

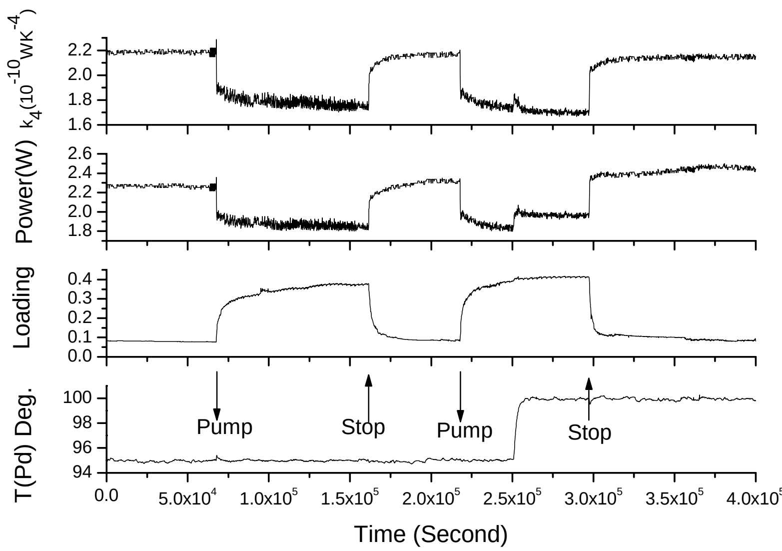

Fig. 4. Excess heat under constant T(Pd), 1998,12,13--17. (5_days7.xls)

We have extended this experiment to T_{Pd}=120ºC, and kept pumping as long as 20 days. The k_4 value was kept low until the pumping was stopped after 20 days. The corresponding excess heat power was 0.6W at 120ºC (greater than 2.5 W/cc).

4. DISCUSSION

Using the gas-loading method, we observed a power drop induced by pumping. This power drop may be related to excess heat on the order of 2 W/cc It is reproducible, and it can last as long as 20 days. If this is excess heat from the D/Pd system then it is of the order of 300 eV/atom. It is much greater than that from any conceivable chemical energy source. However, we have to do two more experiments to make it compelling. Firstly, we should put this whole gas loading system in a Seebeck calorimeter. We need an independent measurement of the heat flow, which does not rely on any heat transfer coefficient on the surface of palladium wire. Secondly, we should strive to reach a state which may keep the palladium wire warmer than the surrounding medium while the power input is entirely eliminated (i.e. a kind of “heat after death” effect).

With data from these two additional experiments in hand we will be able to state with confidence that the excess heat is reproducible and non-chemical origin.

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