

Production of Helium and Energy in the “Solid Fusion”

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Abstract: In this paper, a new type “Solid Fusion Reactor” has been developed to test the existence of solid state nuclear fusion (“Solid Fusion”): reproducible experiments have been made at room temperature and without external power input. (Both of the energy and helium generation affected by the reactor structure, gas flow rate, powder weight, and cooling condition were studied.) Deuterium gas loading processes of two types of nano material (ZrO_2Pd_{35} and $ZrO_2Ni_{30}Pd_5$) were studied respectively in this paper. The results showed the energy produced in ZrNiPd powder is higher than in ZrPd powder. Helium as an important evidence of solid-state fusion was detected by mass analyzer “QMS”. As results, “Solid Fusion” has been confirmed by the helium existence.

1. Introduction

Though enormous reports [1-3] have been published on the deuterium nuclear fusion reactions, and scientists have hoped that “cold fusion” finally will solve the world’s energy problems. “Cold fusion”, however, has not been generally accepted due to the lack of experimental evidences on the stable and/or continuous generation of large amount of excess heat or nuclear reaction products [4]. It is well known that excess heat and Helium (or Tritium) have been considered the Solid Fusion Reaction’s products in Pd/D system [5].

It was studied that many factors having effects on the reaction heat in solid-state fusion, for instance: the gas flow rate, vessel structure and size, and cooling condition. Helium as an important evidence of solid-state fusion was detected by mass analyzer “QMS” in this paper.

Two kinds of powder were investigated under the same conditions in this paper: one is nano powder ZrO_2Pd_{35} (: ZrPd alloy), and the other is $ZrO_2 Ni_{30}Pd_5$ (: ZrNiPd alloy).

As shown in Fig.1, X-ray diffraction analysis was carried out for both of the nano powder ZrPd and ZrNiPd. From Fig.1 [A], we can see that almost all of the palladium elements exist as the palladium oxide (PdO) in the original nano powder (ZrPd). Based on these X-ray analysis results, to remove the Oxygen from the original ZrPd powder, a “deoxidization treatment” is very important for the nano powder ZrPd before the general pressurization of the powder with D_2 gas.

The process of “deoxidization treat” is as follows:

- (1) Firstly, the nano powder ZrPd was sealed inside the stainless vessel and then vacuumed at room temperature until the vacuum up to about 5×10^{-5} [torr]. Then the vessel (with the sample powder inside) was baked and vacuumed at $150[^\circ C]$, kept for 6 hours, then was cooled down to the room temperature. The vacuum degree of vessel was finally about 5×10^{-6} [torr] at room temperature;
- (2) Secondly, D_2 gas was loaded into the high vacuumed vessel with a fixed flow rate 20 [cc]/[min]. The total gas volume was decided by the sample weight (16.5 to 18 [cc]/ [g]). As results, this process made the PdO transmute into Pd, and D_2 gas into D_2O ;
- (3) Finally, exhausting the D_2O from the vessel: the reaction vessel was vacuumed at room temperature until the vacuum up to about 5×10^{-5} [torr], then baked and vacuumed at $150 [^\circ C]$ until the vacuum up to 2×10^{-6} [torr], kept for over 6 hours. Then the vessel was cooled down to room temperature.

Fig.1 [B] shows the X-ray analysis result of powder after “deoxidization treat”. The intensity of PdO got a big fall, but little PdO still exists in the powder. And Fig.1[C] is the X-ray analysis result of powder after fusion reaction (after D_2 gas loading), the intensity of PdO is about the same as the Fig.1 [B]’s. Accordingly, even if much more D_2 gas loaded, the PdO cannot be removed completely. This residual intensity of PdO in Fig. 1 [B] and [C] may be the limit contents of ZrPd powder.

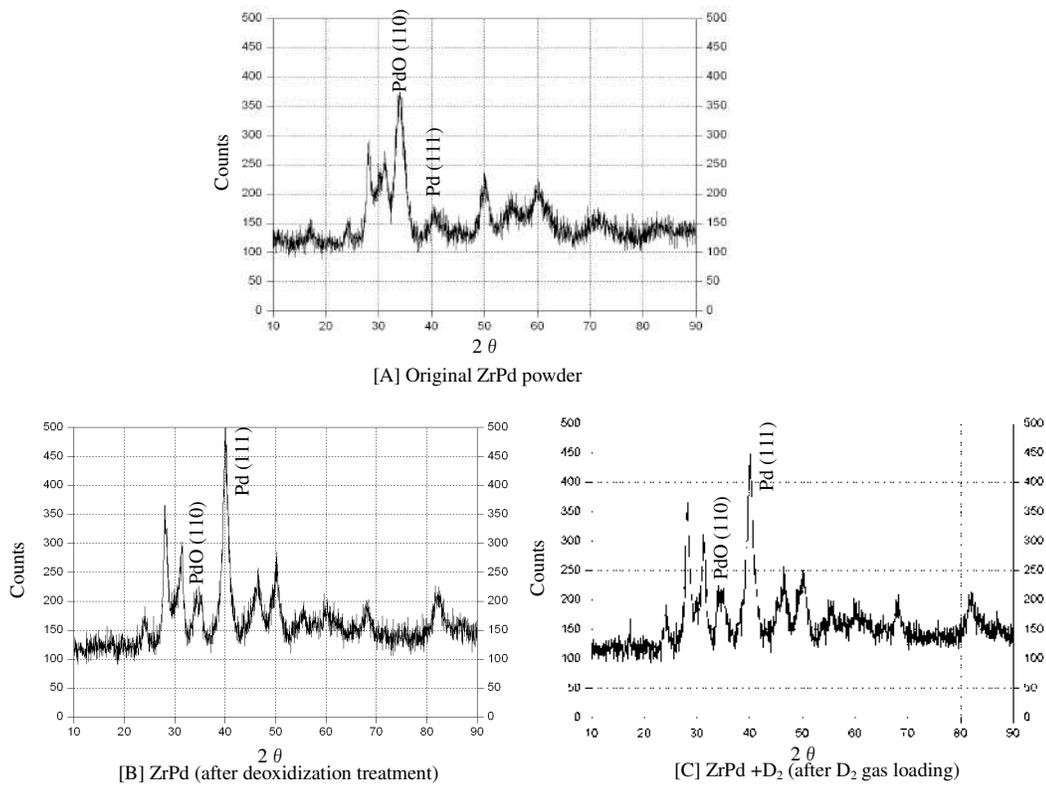


Fig.1 - X-ray diffraction analysis of ZrPd powder

Note: Based on the X-ray analysis results, the process of “deoxidization treat” is unnecessary for ZrNiPd powder. So only process (1) mentioned above is necessary when ZrNiPd powder is adopted.

2. Experiments and results

We used two kinds of material: nano powder (ZrPd) and powder (ZrNiPd) to investigate the process of D₂ gas loading at the same conditions: the stainless vessel; the weight of powder (16 [g]); the final pressure inside the vessel (P_{in}) is 10-16 [atm].

To make the powder's surface contact with D₂ gas as much as possible, we developed a small new plate shape device inside the reactor, as shown in Fig. 2. Powders are put in every plate with equal weight, and then the experiment is carried out according to the process as mentioned above, namely, process (1-3) and process (3) for nano powder (ZrPd) and powder (ZrNiPd) respectively. Within Fig.2, T_{in} is powder temperature, T_s (T_{surface}=(T_{surface1}+T_{surface2})/2) is the temperature of vessel surface and T_f (T_{flange}) is the temperature of the vessel flange and lid.

2.1 Experiment 1 (Energy generation):

Firstly, the above mentioned process (1)-(3) for ZrPd powder and process (1) for ZrNiPd powder was carried out; after that, pure D₂ gas was loaded into the closed vessel with a fixed flow rate (v_G=20,50,70cc/min, respectively) until the inner pressure (P_{in}) reaches at the range of 10-16[atm].

Fig. 3 [A] and [B] show the survey data of the temperature change with time applying nano powder (ZrPd) and the powder (ZrNiPd) respectively, using the above mentioned reactor vessel, as shown in

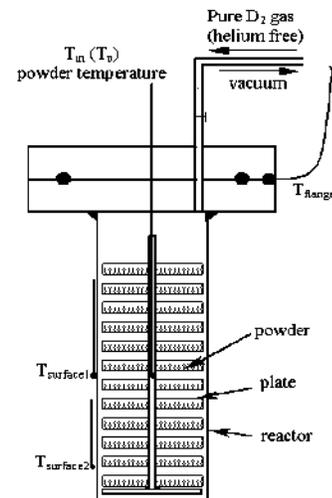


Fig.2 - Fusion reactor

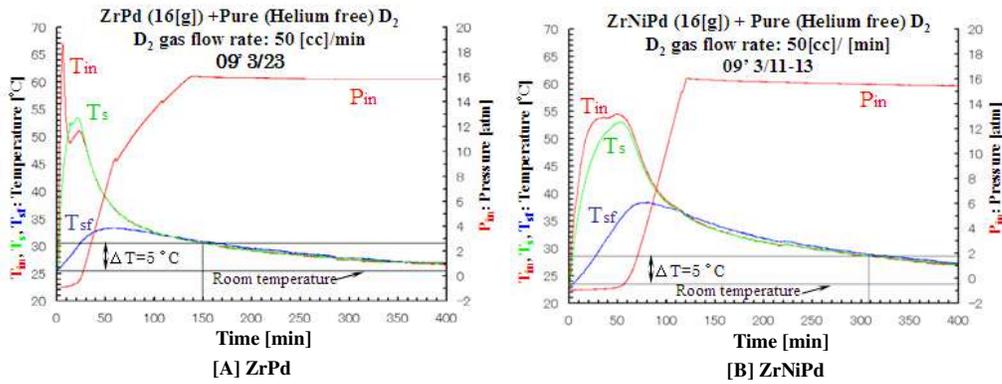


Fig.3 - Distribution of temperature and inner gas pressure

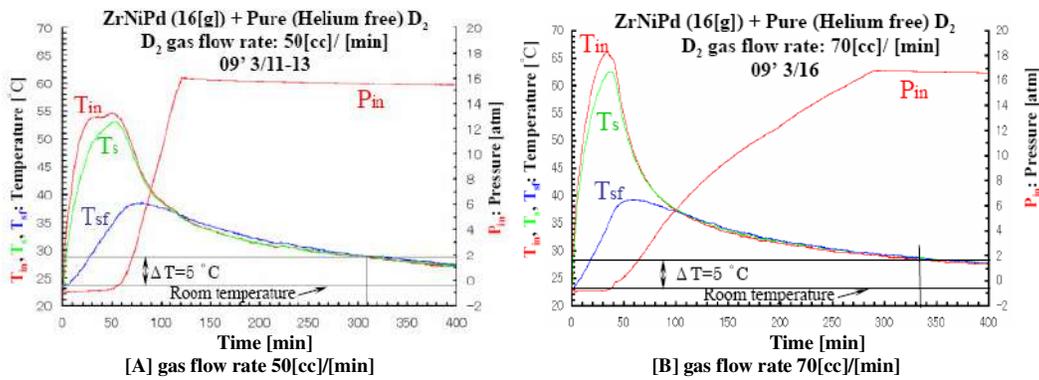


Fig.4 - Distribution of temperature and inner gas pressure

Fig.2. The reactor vessel is cooled in air with shelter during D_2 gas loading. Within Fig.3, T_{in} is powder temperature, T_s ($T_{surface}=(T_{surface1}+T_{surface2})/2$) is the temperature of vessel surface and T_f (T_{flange}) is the temperature of the vessel flange and lid, P_{in} is the pressure inside the reactor vessel.

As for a time interval of 5 [°C] of T_{in} , T_s and T_f above room temperature, Fig.3 [A] (nano powder (ZrPd)) lasts about 150 [min]; Fig.3 [B] lasts about 308 [min]. Namely, the heat that ZrNiPd powder generated is much more than nano powder ZrPd.

Fig. 4[A] and [B] are using the same powder (ZrNiPd (16 [g])), at the same conditions except D_2 gas flow rate. D_2 gas flow rate in Fig. 4[A] and [B] are 50 [cc]/[min] and 70 [cc]/[min] respectively. Comparing the time interval of 5 [°C] above room temperature between [A] and [B], the [B] lasts about 335 [min], it is longer than [A] (about 308 [min]).

Applying this cooling type, we can know the temperature change process of the powder (T_{in}) and the reactor vessel (T_s) during D_2 gas loading. However, the reaction temperature of powder cannot be controlled, so the reaction rate of powder is unable to be kept in a high range. Accordingly, the excess energy cannot be put into practice.

Therefore, to obtain a quantitative excess energy in solid fusion, three cooling type were applied. The sketch of these three cooling type is shown in Fig. 5.

Type-1, the reactor vessel is cooled down in air with shelter; the reaction energy was calculated on the basis of the data of the temperature change of T_{in} , T_s and T_f ;

Type-2, the reactor vessel was put in a water bath with a constant water volume at room temperature, and the energy was calculated on the basis of the temperature change of the cooling water. This type makes to get excess energy easily but cannot be controlled for a stable output;

Type-3, the reactor vessel was enclosed by the copper tube, which was welded on the surface of the reactor vessel. During the D_2 gas loading, the reactor was cooled down by the water flowing through the copper tube with the constant water flow rate (40[cc] / [min]); the water was from a water chiller. And then the energy was calculated by the temperature difference between the outlet and inlet of cooling water.

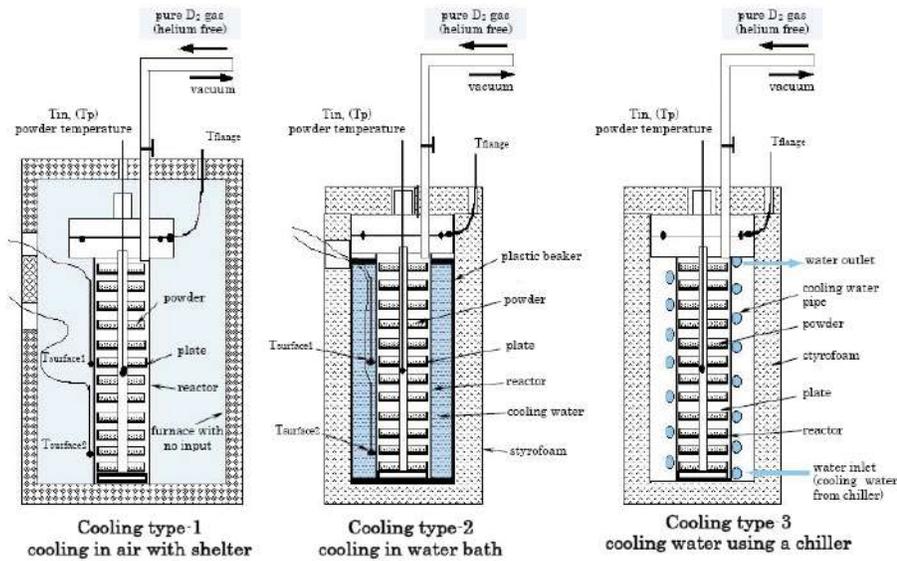


Fig.5 - Three kinds of cooling type during D₂ gas loading

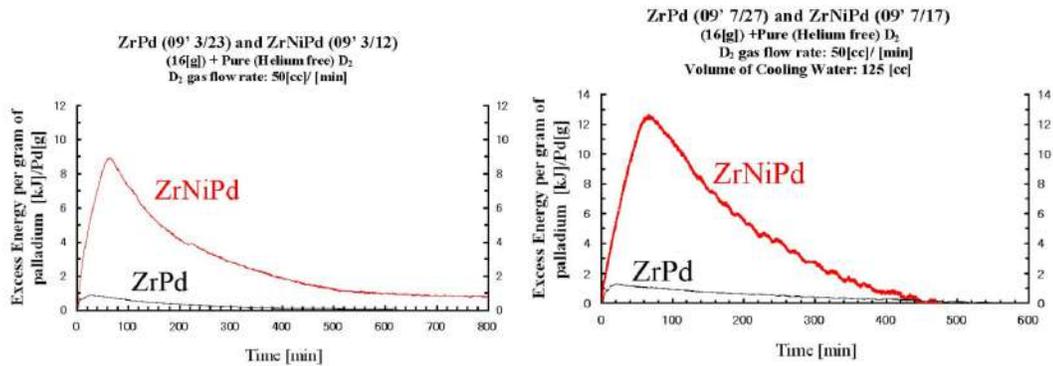


Fig.6 - Excess Energy change with time (cooling type-1)

Fig.7 - Excess Energy change with time (cooling type-2)

Among the three types, the cooling type-3 is the most useful one to get a stable excess power output.

Fig. 6 is one example of using the cooling type-1, which shows the distribution of reaction energy of both the ZrNiPd powder and ZrPd powder. Comparing the excess energy per one-gram palladium between the ZrNiPd powder (red line) and the ZrPd powder (black line), it can be found very clearly that the energy of ZrNiPd powder is larger than that of the ZrPd powder. Also, the same result was obtained by using cooling type-2 as shown in Fig. 7.

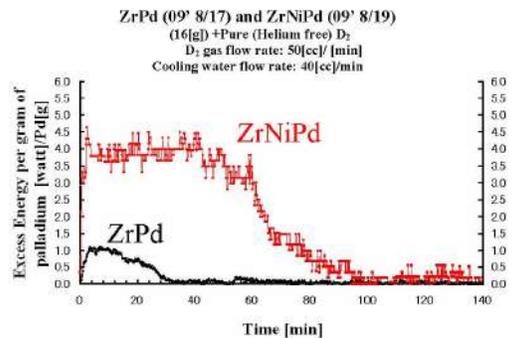


Fig.8 - Excess Energy change with time (cooling type-3)

To obtain the output power change with time precisely, we applied the cooling type-3 for both of ZrNiPd powder and ZrPd powder. The sample weight was 16 [g], cooling water flow rate was 40 [cc] / [min]. Fig. 8 is an example showing the reaction power (per one gram palladium) change with time. In the case of ZrNiPd powder (red line), the generated power is 4 [watt] lasting 60 minutes, then the power dropped gradually with the time last. The total lasting time is about 100 minutes. For the case of ZrPd powder (black line), the generated power is only 1 [watt] lasting only 10 minutes, and the total lasting time is about 32 minutes.

Fig. 9 and Fig. 10 are the comparison of the measuring data among three cooling types. The two

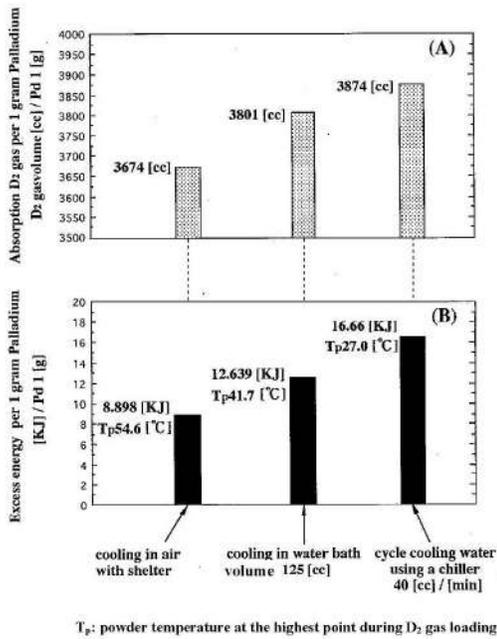


Fig.9 - Absorption volume of D₂ gas and excess energy of the ZrNiPd powder (16[g]) during the pure D₂ gas loading under the same conditions except for the cooling condition.

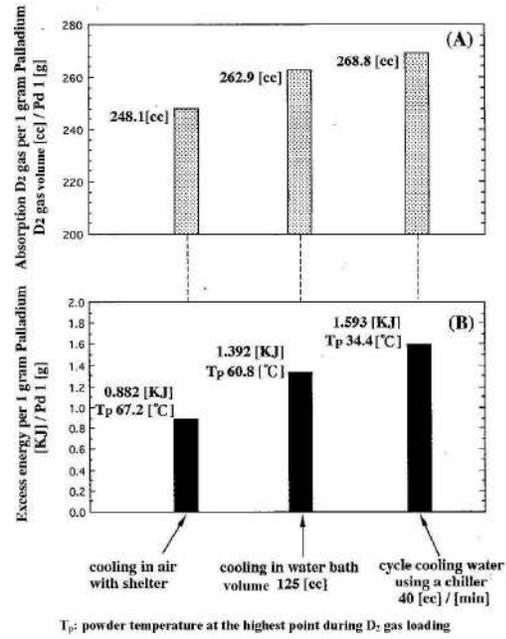


Fig.10 - Absorption volume of D₂ gas and excess energy of the ZrPd₃₅ powder (16[g]) during the pure D₂ gas loading under the same conditions except for the cooling condition.

figures show that the absorption volume of D₂ gas and excess energy changed with the different cooling conditions. Both of the powders, either ZrNiPd or ZrPd, when applying the cooling type-3, the absorption volume of D₂ gas and excess energy are higher while the powder's temperature is lower than other two cooling types during the D₂ gas loading.

Furthermore, the two powder's absorption capacity of D₂ gas and excess energy (per 1 gram palladium) are compared, as shown in Fig 11. Both of the powders, ZrNiPd and ZrPd, are tested with the same conditions and applying two kinds of D₂ gas flow rate. In Fig. 11, we can see, on the case of ZrNiPd powder, the absorption capacity of D₂ gas is fifteen times higher than that of the ZrPd applying the gas flow rate of both 50 [cc]/[min] and 70 [cc]/[min]. Also its excess energy is ten times higher than that of the ZrPd powder.

In the case of the cooling type-1, the reactor was cooled in air with shelter and the powder temperature rose up with the increase of the absorption volume of D₂ gas. The powder temperature cannot be controlled. While using the cooling type-3, the powder temperature can be stably controlled around 25 [°C] as shown in Fig.12.

As we known, the normal palladium absorption capacity of D₂ gas decreases with the rise of temperature. When using the cooling condition of type-1, the powder's temperature is higher than other two, so the absorption capacity of D₂ gas and excess energy is lower than other two types.

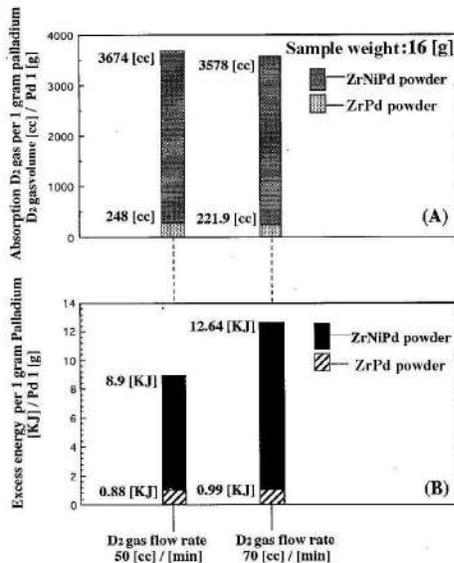


Fig.11 - Comparison of the absorbed D₂ gas volume and excess energy between ZrNiPd powder and ZrPd₃₅ powder under different gas flow rate.

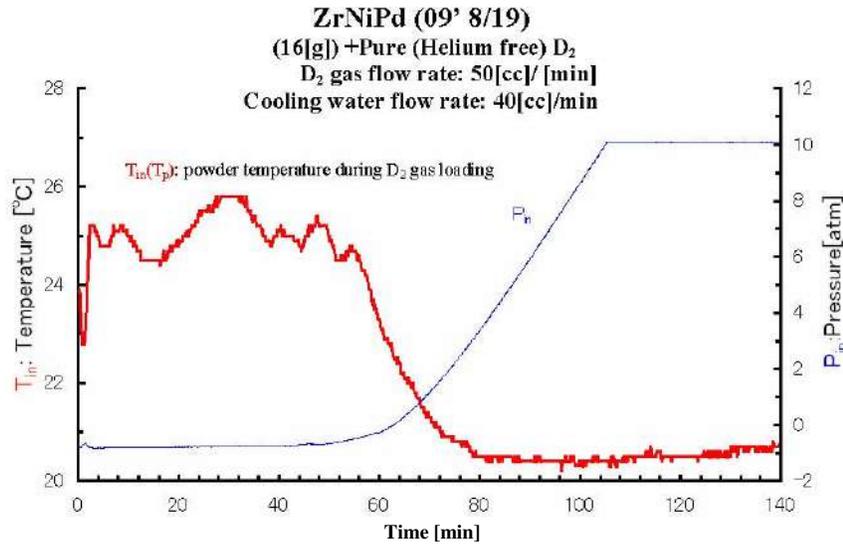


Fig.12 - Powder temperature change with time using the cooling type-3

Therefore, the change of the cooling condition not only decreases the energy losses, but also increases the powder's absorption capacity, which is in favor of increasing the solid fusion reaction rate.

However, it must be confirmed by the fusion reaction products of helium.

2.2 Experiment 2 (Helium generation):

By using quadrupole mass spectrometer -"QMS", the helium can be detected for reacted powders and gas [6]. The helium has been detected many times for reacted powders and gas by using "QMS", as shown in Fig. 13. The "QMS" have two functions: normal resolution and high-resolution test. Both of the gas and powder can be analyzed by the "QMS". The helium can be identified by three kinds of analysis

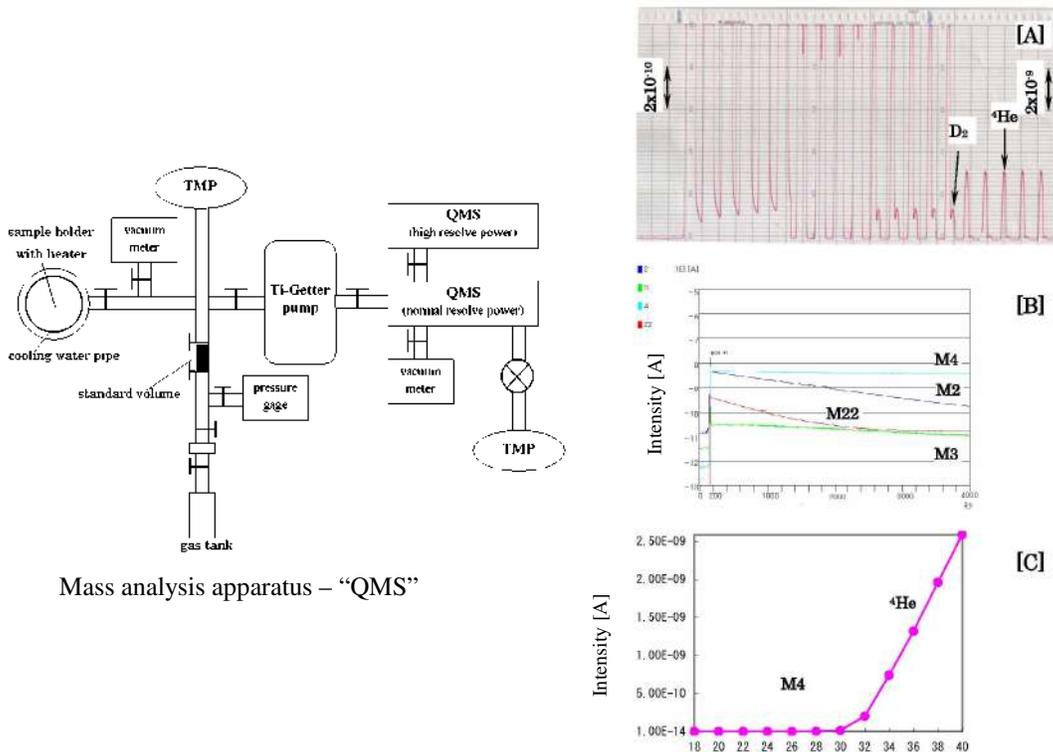


Fig.13 - QMS analysis principle and characteristic

methods. The first one is the normal resolution analysis; the second one is using the high-resolution test to separate the spectrum peak of helium from that of deuterium. During the analysis of gas, both functions of normal and high resolution were applied at the same time. At the right side of Fig. 13, an example of high resolution results is shown (Fig. 13 [A]), the helium ($He4$) and D_2 were separated clearly; Fig.13 [B] shows the normal resolution analysis result, many mass of element can be detected, because the Ti-getter has the absorption function of hydrogen system gas, but it can not absorb the helium. If the helium exists in the sample gas, the line of mass 4 will finally become parallel after most of D_2 gas absorbed.

The third one, Fig. [C] shows the result of measuring the ionization voltage of the main mass number 4 (helium, deuterium) and number 22 (neon- $Ne22$) by using ionization mechanism. The ionization voltage of hydrogen system is from 22 [volt] and that of $He4$ and $Ne22$ is about 28 ~ 30 [volt]. It can be confirmed whether the $He4$ or $Ne22$ exists or not, and the intensity of that element. As we know, the ratio of $He4$ per $Ne22$ is near 3 in the case of air gas. According to the measuring results of above mentioned three methods, the existence of helium can be confirmed clearly, and it also can be identified that helium is generated by solid fusion reaction not from air by calculated the element ratio of Helium / Neon 22.

But some people still have a prejudice, doubting it is true or not.

Recently, to make everyone understand clearly at a glance, we performed an interesting experiment: the concentration of helium from the fusion reacted gas. The apparatus's schematic diagram is shown in Fig. 14.

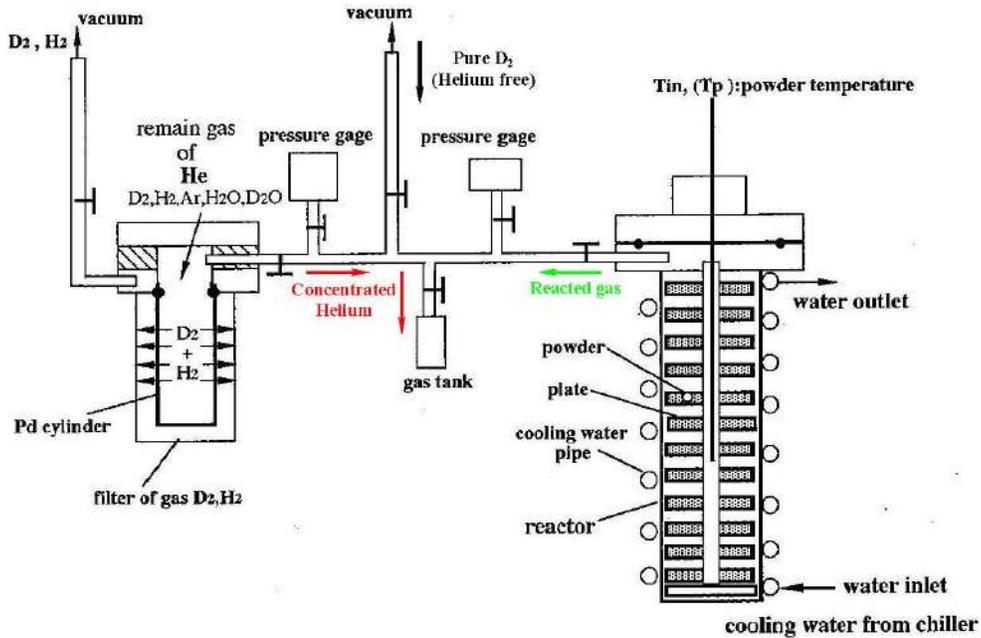


Fig.14 - Concentration apparatus of Helium from reacted gas and powders

By using the palladium filter, the D_2 and H_2 gas were removed from the fusion reacted gas. As results, if helium exists in the reacted gas, it will be concentrated, and we can control the concentration times of the gas easily by controlling the gas pressure.

Fig 15 [A] and [B] shows one example of the mass analysis of the fusion reacted gas of $ZrNiPd$ powder and $ZrPd$ powder (sample weight: 16 [g]). The measuring gas volume is 2.5 [torrcc]; the spectrum peak of Helium and D_2 gas analysis using high resolution mass analysis, the left one shows the reacted gas before concentration, and the right one shows the concentrated gas. You can see helium intensity of the concentrated gas of $ZrNiPd$ is much higher than that of the $ZrPd$ powder.

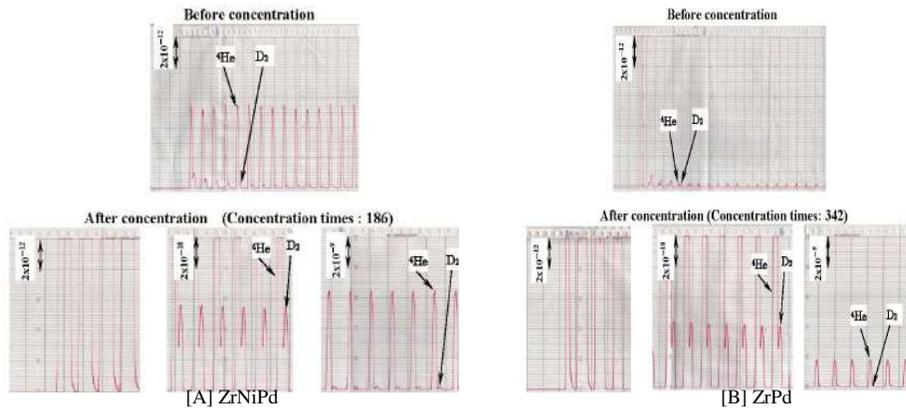


Fig.15 - Spectrum of reaction products by high resolution of mass analysis Helium intensity and the intensity ratio of Helium per Neon22 detected from reacted gas of ZrNiPd powder using "QMS" were shown in Fig.15[C].

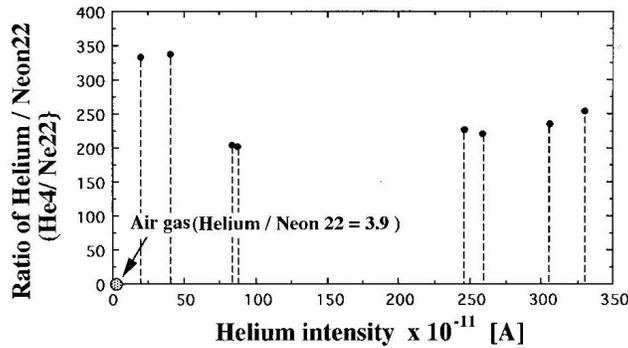


Fig.15[C] - Helium intensity and the intensity ratio of Helium per Neon22 detected from reacted gas of ZrNiPd powder using "QMS"

Fig 16 [A] and [B] is the graph of the mass analysis results of the fusion reacted gas of ZrNiPd powder and ZrPd powder respectively. Sample weight: 16 [g]), the measuring gas volume is 2.5 [torrcc].

Fig. 16 [A] shows the helium intensity relates to the concentration times of the ZrNiPd powder with D₂ gas loading. The helium intensity increases with the increase of the concentration times of the reacted gas. The highest helium intensity is up to 330x10⁻¹¹ [A] after 189 times concentration, which is 654 times of the gas before concentration

And Fig. 16 [B] is the results of ZrPd powder. Like the ZrNiPd powder, the helium intensity also increases with the increase of the concentration times of the reacted gas. The highest helium intensity is 116 x10⁻¹¹ [A] after 331 times concentrated.

Comparing Fig.16 [A] and [B], we can see that the highest helium intensity of the concentrated gas of ZrNiPd is much higher than that of the ZrPd powder, even if the concentration time of the former is less than the latter.

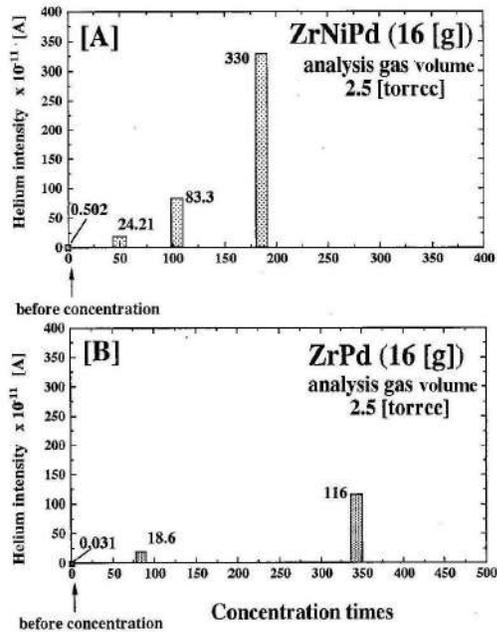


Fig.16 - Helium intensity relation to concentration Times with D₂ loading using cooling type-3

The comparison of the helium intensity of reacted gas with excess energy is shown in Fig. 17. It is the helium intensity per one gram palladium related to the excess energy per one-gram palladium, concentration times is also shown in this figure. We can see ZrNiPd powder generated not only the higher energy but also larger numbers of helium than the ZrPd powder. It indicated the helium intensity increases with the increase of the excess energy.

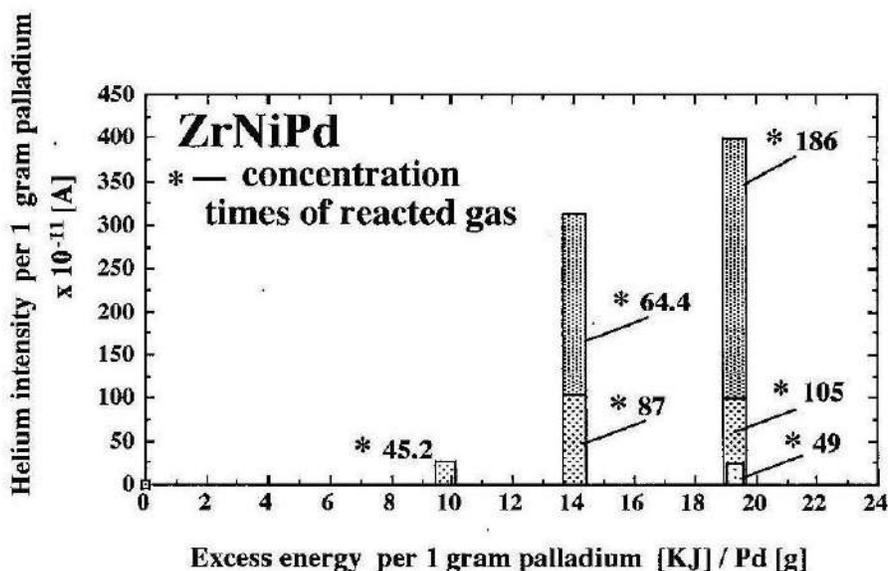


Fig.17 - Comparison of the helium intensity of solid fusion reacted gas with excess energy

3. Conclusions

(1) Both powder of ZrNiPd and ZrPd were used in solid fusion which generated the excess energy and the helium as products of fusion reaction, and the helium were measured many times by using mass analysis apparatus "QMS". As results, as for either excess energy or helium, the ZrNiPd powder is always about ten times higher than the ZrPd powder;

(2) Using the weight 16 [g] of the ZrNiPd powder, the excess power 4 [watt] continued stably for about one hour, and only consumed the palladium less than one gram, its cost is lower than the ZrPd powder and the experiment operation is easy with good reappearance, it is very useful of practical use, so we choose the ZrNiPd powder as a good material for the solid fusion at now;

(3) The concentration of helium was very successful; these results hint that the reacted gas of "solid nuclear fusion" will be a helium source as a helium production. However the powder is made in the ambient atmosphere, accordingly the original powder contains a little other composition like as air gas. Even if after the powder was baked at 150 [°C] for 16 ~20 hours to remove these gases before D₂ gas loading;

Though a trace of the gases still remain in the powder and these remained gases have a higher mass number than mass four, it maybe removed by a centrifugal separator. Of course it's not so easy, and these problems will be solved by a factory, but not by us in laboratory.

4. References

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