Study on waste heat measurement and composition change of Pd conductor after laser stimulation in H$_2$ gas-loading system

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Abstract: This study mainly involves that palladium hydride with different gas-loading ratio is stimulated by YAG frequency doubling laser ($\lambda$=532nm) in H/Pd gas-loading system to produce excess heat. The range of hydrogen loading ratio of palladium hydride is 0 to 0.8. The results show that the waste heat is produced in the experiment stimulated by laser. When the hydrogen loading ratio in Pd is 0.3±0.01, the maximum waste heat produced by the system within 1 hour is about 120.91±0.47 J. Some new elements are produced on the surface of Pd samples, including Si, Al, Ca and some others, these elements were found in local locations by scanning electron microscopy and energy spectrum analysis. This suggests that some reactions may have taken place in the experiment.

1. Introduction

At present, in the study of CMNS, the common methods to trigger the excess heat produced by condensed phase materials (hydrogen palladium, deuterium palladium, hydrogen and nickel, etc.) are laser stimulation, current stimulation, magnetic field stimulation, pressure stimulation, temperature stimulation and so on. Among them, the laser stimulation method has been applied in the field of CMNS research early because of the characteristics of the laser itself. In 2003, D.Letts [1] et al used He-Ne laser to trigger the deuterium-containing palladium cathode in heavy water, and obtained a maximum thermal power output of about 1W when the laser input power 30mW, and the experimental repeatability was good. In 2005, V.Violante [2] made appropriate modifications to the above experiments, and the experiments were also successful. In 2006, K.Sinha [3] also modified and repeated the experiment. Because deuterium is charged to the palladium cathode by electrolysis, it is difficult to quantitatively study the effect of hydrogen content of palladium on "abnormal heating". In addition, hydrogen and deuterium are isotopes with similar properties, hydrogen is more abundant than deuterium, so hydrogen is chosen as the experimental object in this study. In the gaseous system, the external temperature of the constant experimental system, by measuring the thermal effect of pure palladium and hydrogen-containing palladium irradiated by YAG frequency doubling laser, the effects of laser power, hydrogen content of palladium ($x=[H]/[Pd]$) and temperature on abnormal heating were studied quantitatively. According to the previous experimental basis [4] and the existing experimental conditions, We use subatmospheric pressure, hydrogen is filled into palladium wire by gaseous hydrogen charging, stimulate palladium hydride with different hydrogen content ($x=0$, 0.2, 0.3,
0.4, 0.8) with a wavelength of 532 nm Nd: YAG frequency doubled laser. After laser stimulation, the surface morphology of the sample was observed with a SEM, and elemental analysis was performed with an EDS.

2. Experimental

2.1. Material and equipment

The system and Pd materials used in the experiment are the same as those studied earlier by our research team [5]. Nd: YAG frequency doubling laser (Changchun Zhongji Optical Electronic Company) wavelength was 532 nm after doubling frequency, pulse frequency was 15 S⁻¹, input power is 30, 40, 50mW. The surface morphology and micro element composition of palladium wire before and after laser irradiation were analyzed by SEM and EDS.

2.2. Heating coefficient (k) calculation

Before the experiment of palladium with different hydrogen content triggered by laser, the heating equilibrium constant (k) of the system should be determined, which is a blank experiment. That is, the internal retaining vacuum level (~2.0 Pa) is maintained in the internal reaction system, using a series of different power YAG multiplier laser irradiation pure PD wires (x = 0), the time is 1 h, and the temperature increased from the palladium wire and the irradiation laser power on the palladium wire degrade the system equilibrium constant K: $k = \Delta T / \Delta P (°C/W)$. Wherein, $\Delta T$ is a temperature increase of the PD wire after the laser irradiation, and $\Delta P$ is a laser power change that is irradiated onto the PD wire. This is the input laser power.

2.3. Laser trigger experiment

The laser beam is switched repeatedly at the same point of the same Pd wire for the same time (1 hour), but it is considered that the loading ratio of hydrogen in palladium is about 0.2, 0.3, 0.4 and 0.8. After different power laser irradiation, the relationship between hydrogen loading ratios (x) and palladium wire temperature and the corresponding heating coefficient (k) is shown in Fig. 1.
2.4. SEM and EDS analysis

The original Pd samples and laser-stimulated Pd samples were analyzed by SEM and EDS, together with the Pd line used as the control of as reception. The sample is not cleaned before each inspection. The morphology and microscopic element composition of Pd line before and after laser stimulation are shown in Fig. 2 and Fig. 3. After laser stimulation, unexpected elements and new geomorphological features appeared on the surface of Pd samples.
3. Analysis and discussion

3.1. The change of waste heat caused by the difference of laser power and hydrogen content in Pd

Changes in excessive heat as load ratios were studied when the laser excited H / PD was studied. It can be seen from figure 2 that when the loading ratio is between 0.2 and 0.4, the exothermic behavior sometimes occurs when the Pd line is irradiated by YAG laser. When the hydrogen content in palladium is 0.8, there is no exothermic behavior triggered by different laser input power. This shows that in the H/Pd system we have established, the higher the load ratio, the easier the exothermic behavior occurs. When the Pd load ratio is 0.3±0.01 (p < 0.01), the maximum waste heat effect of the system within 1 hour is about 120.91±0.47J.

3.2. Estimation of waste heat

When the laser is triggered with hydrogen-containing palladium, the palladium wires illuminated by the laser include only 1/5 (9 mm) of the entire wire, and the number of PD atoms contained in this portion is about $1.0 \times 10^{20}$. It is assumed that these PD atoms are combined with the H atom to form a palladium hydride, and the formation of about 6.4 joules will be released, and each PDH is released by $6.4 \times 10^{-20}$ joules. As an example of our experiment, when the load ratio is 0.3, the number of hydrogen-containing atoms containing the palladium wire in the laser is about $3 \times 10^{19}$, that is, when these hydrogen atoms are combined with palladium, they will release about 1.9 Joules. But in fact, the heat released by our measured experiment is $120.91\pm 0.47$Joules, and each Pd atom releases about $3.77\times 10^{-18}$ joules of heat of formation. Obviously, this is about 60 times higher than the heat of formation of PdHx compounds.

3.3. Changes of Surface Morphology of Pd before and after Laser trigger

The Pd surface was analyzed by SEM and EDS before and after laser trigger. Selected several areas and points for testing, all the results show that the content of Pd in the sample is close to 100% (Fig. 2). After laser stimulation, it can be seen from Fig. 2 and Fig. 3 that the surface characteristics of Pd samples before and after laser stimulation are obviously different, and the surface becomes rougher.
than that before aeration. When hydrogen is absorbed into the palladium lattice, holes and cracks are formed, this makes it easier for hydrogen to be loaded into palladium later. In addition, it can be seen from the EDS diagram that Si, Al, Ca and other new elements appear in some local parts, such as dark pits, dark cracks, while the content of Pd decreases accordingly.

4. Conclusions

It can be seen that in this Pd/H gas loading system, low-energy laser can trigger palladium with low hydrogen content to produce waste heat. Through the SEM and EDS analysis of Pd surface before and after laser trigger, it is found that there are some new elements on the surface of Pd wire in addition to Pd, which means that some reactions may have taken place in the experiment, which may be an explanation for the generation of excess heat. The specific reason needs to be demonstrated by further experiments.

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