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Research Article

Modification of Pd–H_2 and Pd–D_2 Thin Films Processed by He–Ne Laser

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Abstract

In this work, we performed experiments of absorption of hydrogen and deuterium gas by Pd thin films, and we compared the behavior of these samples to unprocessed films. We also employed a continuous wave He–Ne laser to irradiate the samples inside the chamber during the treatment, in order to increase the gas absorption. Using a scanning electron microscope (SEM) and an electron probe micro-analyzer (EDX), we observed structures like spots on the surface of the treated samples. Inside the spots, elements other than Pd were found. Based on these results, we determined that gas loading is an effective way to transmute elements, and the laser action has been a very effective way to increase morphological changes in the treated samples.

Keywords: Cold fusion, Laser, Palladium thin film, Silicon, Transmutation

1. Introduction

In March 1989, Fleischmann and Pons [1] reported a large amount of excess enthalpy, and a weak level of radioactivity, from electrolytic cells with Pd cathodes during the electrolysis of D_2O. The effect only occurred when a critical threshold of the stoichiometric ratio $x = [D]/[Pd]$ of deuterium in palladium is achieved. The main point at issue was that the claimed excesses of enthalpy were consistent only with a nuclear process (deuterium fusion) and that such a process at ambient temperature and without the emission of a commensurate number of neutrons was considered to be inconsistent with modern nuclear science.

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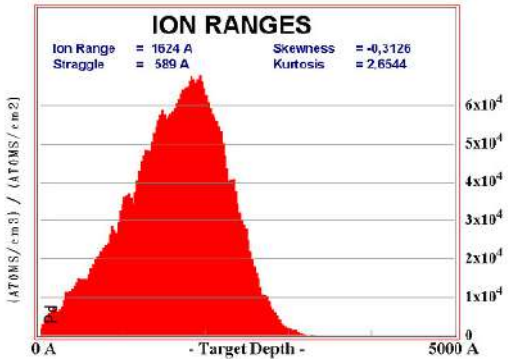

Figure 1. Boron ion distribution vs. target depth.

In the years following the announcement, many replications of excess heat and helium have been published [2,3], and many new methods to improve the stoichiometric ratio x have been studied [4]. Possible theoretical explanations of the reported phenomena were proposed [5,6] but they are still far from explaining all results.

Recently the gas loading method became a very effective tool to obtain high absorption of D or H gases inside Pd metallic lattice, while at the same time keeping the level of contamination low [7]. Important results were achieved by this method and particular attention has been paid to reproducing transmutation effects [8].

In this work, our attention was devoted to the transmutation phenomenon utilizing Pd film samples treated by gas loading. We also implanted B in these samples in order control the nuclear processes the way Iwamura et al. have done. The treatment of the samples was combined with a continuous wave He–Ne laser light to enhance gas loading inside Pd thin films, as in previous studies [9].

2. Experimental Set-up and Results

Using the thermal evaporation technique, we fabricated Pd thin films of 500 nm thickness deposited on Si wafers of about 1 cm^2 surface area. A 50 nm Ti layer was used to improve the adhesion between the substrate and the Pd layer.

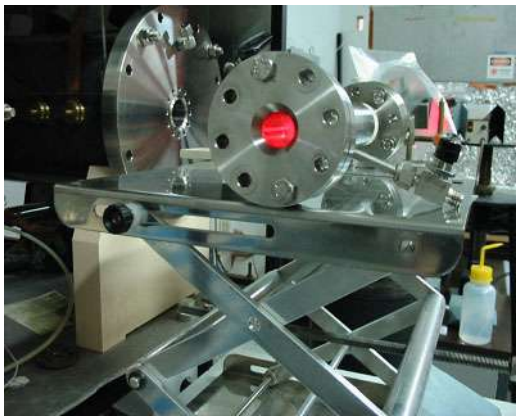

Figure 2. Photo of experimental set-up showing the irradiated chamber.

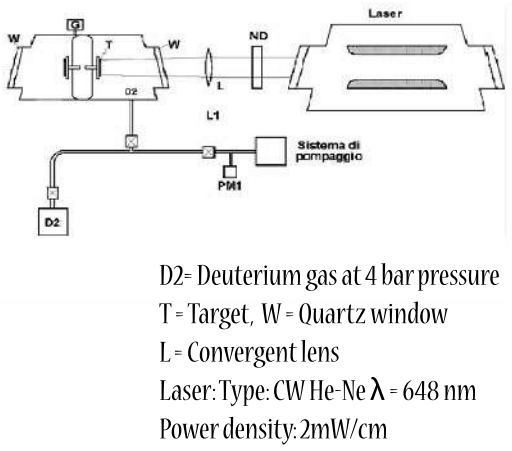

Figure 3. Schematic drawing of the experimental set-up. D_2: Deuterium gas at 4 bar pressure; T: Target; W: Quartz window; L:Convergent lens; Laser: CW He–Ne $\lambda = 648$ nm and Power density = 2 mW/cm^2.

These samples were implanted with B ions; a 150 keV accelerating voltage produced a maximum ion concentration at 158 nm depth in the palladium layer. Figure 1 shows the distribution of B ions versus target depth.

The thin film samples were placed in cylindrical stainless steel chambers of about 250 cm^3 in volume. Figure 2 shows a photo of the experimental set-up.

The chambers were equipped with at least one quartz window to allow the laser beam to irradiate the samples. To avoid contamination, the chambers were carefully cleaned with acetone and dried in nitrogen flux before the experiment. Subsequently a pair of Pd/Si samples has been placed inside the chambers filled with H_2 or D_2 gas to a maximum pressure of 4 bar. In Fig. 3, we have a schematic drawing of a chamber.

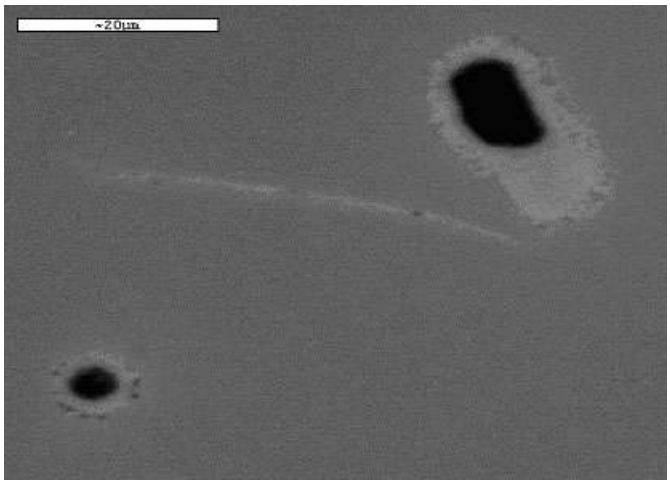

Figure 4. Spots on the surface of a sample with 76 days of treatment (by D_2 gas only).

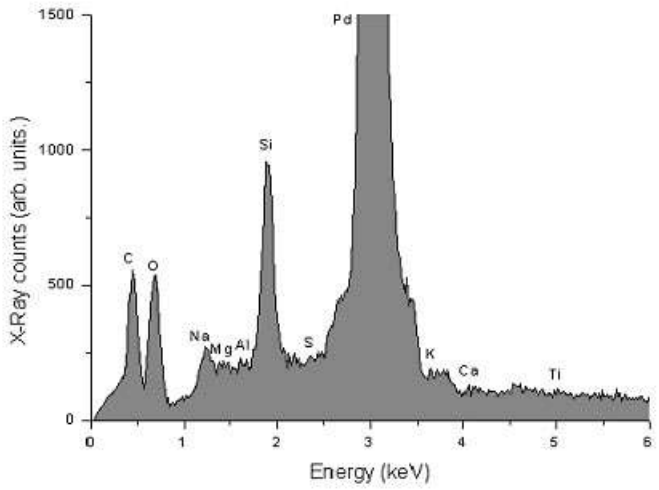

Figure 5. EDX spectrum of a sample with 76 days of treatment (by D_2 gas only). We can observe the presence of the following elements: C, O, Ca, Al, S, Mg, K, Na.

The samples were gas loaded, and one sample for each chamber was irradiated by a CW He–Ne laser ($\lambda = 648$ nm) from 16 July to 29 September 2004, at a laser power density of about 2 mW/cm^2.

After the treatment ending, the samples were analyzed by a Scanning Electron Microscope (SEM) and an EDX micro-analyzer. Different behaviors were revealed for samples kept in air, laser treated and without laser treatment. With the samples kept in air, the film surface was smooth, with a mirror-finish. The

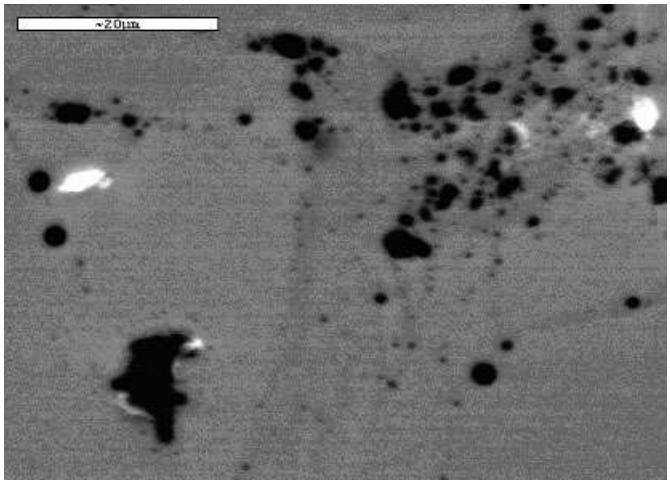

Figure 6. Spots on the surface of a sample with 76 days of treatment (by H_2 gas and by He–Ne laser action).

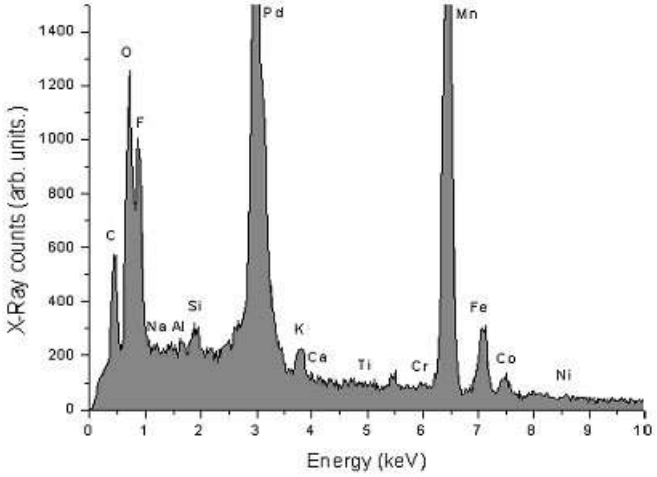

Figure 7. EDX spectrum of a sample with 76 days of treatment (by H_2 gas and He–Ne laser). We can observe the presence of the following elements: C, O, Ca, Fe, Al, S, Mg, K, Na, F, Cr, Mn, Co, Ni.

samples placed in deuterium gas but not treated with lasers showed morphological modifications of the Pd-film due to the gas absorption. Those treated with lasers showed even more morphological modifications. The modifications consisted of the formation of spots with dimension of 1–50 μm after gas loading. Figure 4 shows an example of spots on the surface of a sample of palladium implanted with boron, loaded by D_2 gas, but not laser irradiated.

Table 1. The principal detected elements in every experiment.

H_2		D_2	
Laser	No-laser	Laser	No-laser
Si	Si	Si	Si
Pd	Pd	Pd	Pd
Ti	Ti	Ti	Ti
C		C	C
O		O	O
Ca		Ca	Ca
K		K	K
Na		Na	Na
Al		Al	Al
Cr		Mg	Mg
Fe			S
CO			
Ni			
Mn			
S			
F			

By EDX analyser, we investigated inside the spots and found the presence of new elements such as C, O, Ca, Fe, Al, S, Mg, K and Na. In Fig. 5, an example of the EDX spectrum of a Pd sample with 76 days of treatment is shown. It is possible to observe the presence of many "new" elements which were not present before the treatment.

In addition, by He–Ne laser action, we found a larger number of spots and a larger number of new elements. Figure 6 shows a SEM micrograph of a sample processed by H_2 gas and laser; Fig. 7 shows EDX spectrum obtained from one spots of the sample: the new elements were: C, O, Ca, Fe, Al, S, Mg, K, Na, F, Cr, Mn, Fe, Co, and Ni.

Table 1 shows the new elements reported in the experiments. We observe that the combination between H_2 gas loading and laser action on the treatment of the samples is an effective method of producing many transmutation elements. The results with D_2 gas loading alone, without laser irradiation, also produce new elements, and there are no evident differences between the number and type of elements produced with and without the laser. The laser action increases the spot density on the surface of the treated samples, but it does not change the nature of the reaction. All new elements were found inside the spots. None of them seems to be generated from a particular nuclear reaction between B and D_2 and H_2. These experiments confirm the reproducibility of the transmutation phenomenon but we are still far from clarifying the mechanism inside the crystalline lattice of Pd samples that causes the transmutations.

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