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Energy Storage using Palladium and Titanium Targets

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Abstract

Background/Objectives: The paper provides the structure of titanium and palladium tablets saturated with deuterium and intended for increasing the energy of deuterons. **Methods/Statistical analysis:** The tablets have a double-sided oxide layer on the surface of deuterated palladium and titanium. The target is heated in the oxygen environment up to a temperature of 1200 0C. Heating during free oxygen access on the both sides of the tablet leads to the fact that the tablet is oxidized to form TiOx and PdOy oxides. The thickness of the oxide layer is varied from 0.02 to 0.05 microns. The energy of deuterons increases by more than two orders of magnitude during irradiation of tablets by an electron beam with an energy of 30 keV on the both sides as compared to the thermal energy. The proposed method allows us to obtain a greater number of deuterons with an energy exceeding the energy released during one-sided irradiation. **Findings:** The high kinetic energy of atoms (D) can be achieved due to acceleration in a strong electric field formed during electron irradiation. The effective acceleration energy can be estimated as follows $W_D^{eff} = \square + eE(TiO_2)h(TiO_2)$, where $\square$ = 3 eV is the average primary energy of the ion in the target caused by the generation of plasmons; $E(TiO_2) \approx 3.10^7\ V/cm$ is the electric field intensity in the target; $h(TiO_2) = 1.5 \cdot 10^{-5}\ cm$ is the thickness of the oxide layer on the target surface. Estimations provide the maximum acceleration energy of deuterons $W_D^{eff} \square 500\, eV$. **Applications/Improvements:** This paper presents the study of structural characteristics of the tablets made of titanium and palladium and intended for the increase in energy of deuterons during electron irradiation of deuterated metals.

Keywords: Electron Irradiation, Energy Storage, Kinetic Energy of Atoms, Palladium and Titanium Target

1. Introduction

Hydrogenation of metals is known[1-4] to lead to formation of a hydrogen subsystem that can store energy under exposure to electrons. The main characteristics of the hydrogen subsystem are the energy and a special electron state that was found in the study of the electronic metal spectra and desorption of hydrogen[3,5,6]. The study of deuteron desorption from a combined system of Pd/PdO saturated with deuterium to form Pd/PdO: D_x and irradiated by electrons has shown that the energy of deuterons increases by more than two orders of magnitude compared to the thermal one[1,3,4].

Further study of this phenomenon led to the need for the development and creation of devices in the form of tablets which would increase the energy of deuterons and provide their production in a controlled manner. Earlier, the tablets with a one-sided layer of oxide were studied on the surface[2] of deuterated palladium. The thickness of the oxide film was 20 nm (see Table). Excitement by an electron beam on the one side was not very effective, since there was no total oscillation of the electron density for the deuterium subsystem of a metal.

This paper presents the study of structural characteristics of the tablets made of titanium and palladium and intended for the increase in energy of deuterons during electron irradiation of deuterated metals.

2. Materials and Methods

2.1 Experimental Procedure

In the study, the surface layer of palladium oxide is applied

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simultaneously on both sides of the palladium plate, the oxidized plate is saturated with deuterium, and the tablet is irradiated by an electron beam simultaneously from the two opposite sides.

Increasing the energy and number of deuterons occurs for the following reason. In the previous work[3-4], the tablet was provided with a layer of palladium oxide on the one side. According to the hypothesis[2,3,5], the main role belongs to the effect of resonance formation of plasmons which provide deuterons with energy. Plasmons are formation of amplified oscillations of the electron density in the medium, for example in metal.

In the case when palladium oxide layers are on the both sides, and the tablet is irradiated by colliding beams, there is an effect of multiple and interference amplification of oscillations of the electron density in the deuterium subsystem of the tablet. More plasmons are formed in comparison to a tablet with a one-sided oxide layer. The internal energy of deuterons can theoretically increase by 4 times after non-elastic collision. The proposed method allows deuterons to be obtained in a greater number with energies exceeding the energy for the one-sided oxide layer. At the same time, it is necessary to eliminate desorption of deuterium, the effectiveness of which can be rather high[6].

The tablets made of titanium were prepared by the procedure[7]. Here is a specific example of producing the tablet from palladium. The 300 mm^2 tablet is cut of the palladium plate 50 microns in thickness. The plate is then heated in the air or oxygen atmosphere up to a temperature of 1200 ^{0}C. The tablet is oxidized and forms PdO_y oxide during heating with free oxygen access to the both sides of the tablet. The thickness of the oxide layer is varied from 0.02 to 0.05 microns and depends on the mode of oxidation and time. After oxidation the tablet is placed in an electrolysis unit equipped with two platinum anodes and filled with a solution of LiOD. Two platinum anodes allow the tablet to be uniformly and identically saturated with deuterium from the both sides. The saturation time was selected in such a way that the bulk concentration of deuterium was 73 - 78% in palladium. The titanium tablets were saturated using the Sieverts' method[8]. After saturation with deuterium, the tablet was irradiated by colliding and identical electron beams.

Figure 1 shows a scheme of irradiation, where there are the tablet (1), the detectors (1,2) for measuring the energy of deuterons, the double-sided layers of metal oxide (3 and 4), the electron beams (6) irradiating a tablet, the manipulator (5) for fixation and movement of the tablet, the base of the installation (7). The cross section of the beams is equal to 48 mm^2. The beam energy is 30 keV. During electron irradiation of the tablet, the beam current of positively charged deuterons from the surface of the tablet is 0.73 mA/cm^2, which exceeds the value of current during one-sided irradiation by about 1.5 times. At the same time, the amount of excited deuterium atoms exceeds the amount obtained by simple increasing (doubling) the area of the tablet (see Table 1).

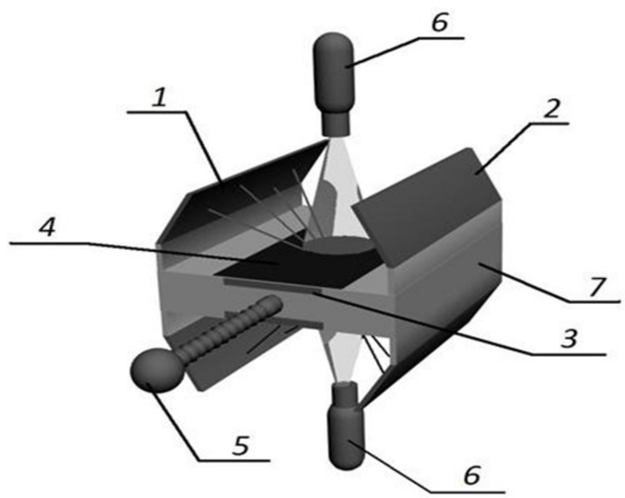

Figure 1. Scheme for electron irradiation of the tablet (titanium and palladium).

3. Results

Table 1 provides the experimental parameters. Columns 1-4 show the results of experiments for one-sided electron irradiation. Column 5 shows the parameters of the tablet with the increased area of irradiation. These data prove that a new effect is not determined by the quantitative increase in area of his tablet. Column 6 provides the parameters of the tablet and experiment for double-sided irradiation. As seen from Column 6, the energy of deuteron during opposing irradiation exceeds the energy by 40%-45% in a tablet with one-sided irradiation for the smaller area of the tablet. This fact qualitatively and quantitatively shows a new positive effect.

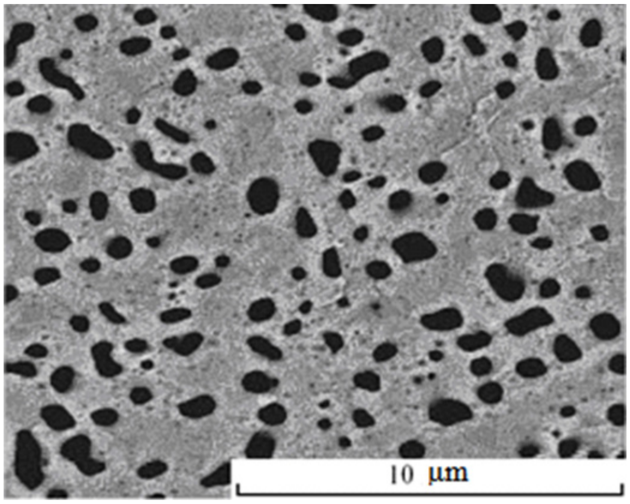

Figure 2. Electron microscope images of the Pd/PdO: Dx sample surfaces after electron irradiation.

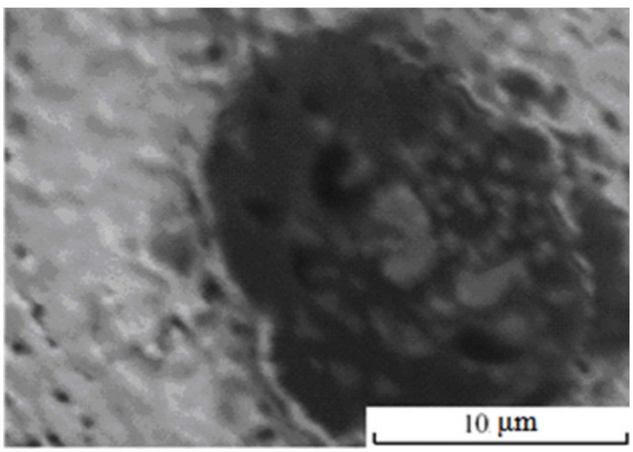

Figure 3. Electron microscope images of a crater on the Pd/PdO:Dx surface.

In addition, the method for obtaining and using the new tablet leads to the increase in velocity and number of deuterons desorbed, which is an important factor for using, for example in the ITER reactor for atomic fusion and higher energy. To obtain the titanium tablets, it was used information from[6-7] (Figure 5).

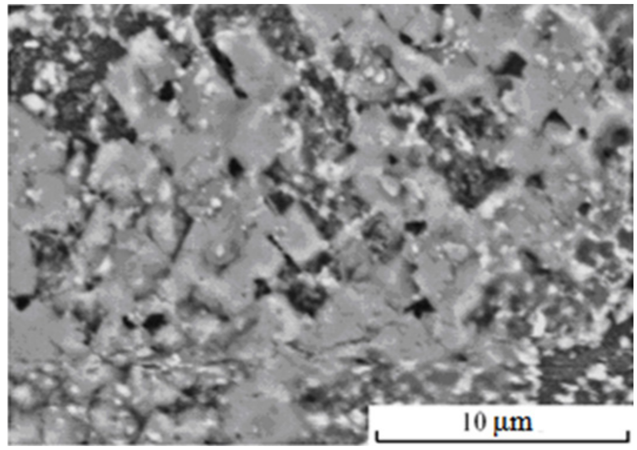

Figure 4. Electron microscope images of the Ti/TiO: Dx sample surfaces after electron irradiation.

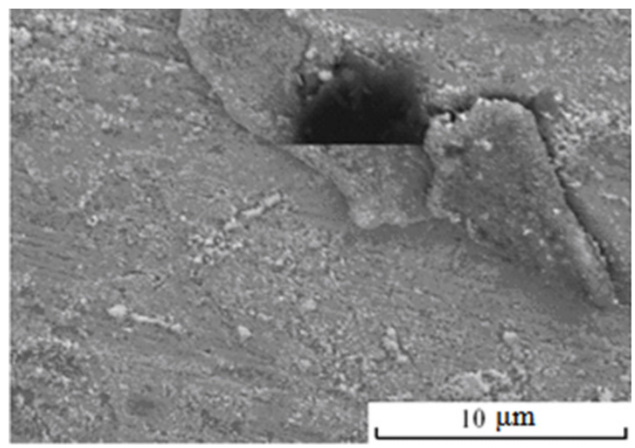

Figure 5. Electron microscope images of a crater on the Ti/TiO:Dx surface.

Table 1. Parameters of the targets for obtaining of energetic deuterons

Parameters of the tablet No. of experiment	**1**	**2**	**3**	**4**	**5 Increased irradiation area**	**6**
Area of the tablet, S, mm^2	200	50	300	100	300	300
Area of electron beams, mm^2	7.0	28	60	60	76	48
Desorption rate, D/c.cm^2	1.8 10^{14}	1.3 10^{14}	2.3 10^{14}	2.3 10^{14}	2.4 10^{14}	4.8 10^{15}
Energy of electrons, keV	50	6	30	50	30	30
Average energy of deuterons, eV	0.26	0.20	0.28	0.40	3,6	5.2
Thickness of the PdO_y oxide layer, micron	0.00	0.00	0.01	0.02	0.02	0.02
Degree of tablet saturation with deuterium	0.6	0.6	0.6	0.6	0.73	0.73
Energy of colliding electron beams, keV	no	no	no	no	no	30

It should be noted that the increase in oxide layer on the metal surface up to 100 nm leads to the considerable change in the gas release of deuterium from metal. It is observed a step change in the rate of deuterium yield, which allows us to make a preliminary conclusion either about the participation of deuterium in the formation of clusters on dislocations[3], or about abnormal collective electron-beam excitation of the internal hydrogen atmosphere in metals.

4. Discussion

Figures 2-4 show the comparative images of the tablet surfaces irradiated by electrons. After target saturation with deuterium and electron irradiation, numerous pores 100-2000 nm in diameter (Figure 1) are formed on the surface. Also, craters 1-20 nm in diameter (Figure 2) are found on the surface. In some experiments, palladium is replaced by titanium (Figure 3). Pores are not formed in the titanium target in contrast to the palladium one. However, craters of the same diameter (Figure 4) are also formed. The presence of a thin metal oxide layer on the surface of the target plays a dual role. The layer delays "premature" removal of deuterium and increases the chance of multiple scattering of plasmons[9].

At the same time, the presence of a thin oxide layer does not provide a significant acceleration of deuterium atoms, since the palladium oxide is a semi-metal with a high conductivity with the lack of polarization. The large amount of pores (about 50 nm in length) allows the atom energy of deuterium to be increased due to channeling. The oxide layer reaches 150 nm in the titanium target[7,8]. The formation of craters on the surface of the target indicates a high concentration of energy in these areas. The formation of vacancy defects in titanium[10-11], where deuterium is accumulated, can influence on the increase in energy of the particles capable of nuclear fusion.

5. Conclusion

The high kinetic energy of atoms (D) can be achieved due to acceleration in a strong electric field formed during electron irradiation. The effective acceleration energy can be estimated as follows $W_D^{eff} = \square + eE(TiO_2)h(TiO_2)$, where $\square$ = 3 eV is the average primary energy of the D^+ ion in the target caused by the generation of plasmons; $E(TiO_2) \approx 3.10^7$ *V/cm* is the electric field intensity in the target; $h(TiO_2) = 1.5 \cdot 10^{-5}$ *cm* is the thickness of the oxide layer on the target surface. Estimations provide the maximum acceleration energy of deuterons $W_D^{eff} \square 500\, eV$.

The task of further research is to develop the structure of tablets which amplifies the multiple scattering of plasmons exciting a hydrogen subsystem of palladium or titanium, which leads to the increased energy of deuterons. The prospect of the use of targets in power engineering depends on the structure of the target, the nature and degree of excitation, which allows the number of high-energy deuterons to be increased.

6. Acknowledgements

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