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Ceramic Porous Absorber for Hydrogen Storage

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Abstract: The study is devoted to the processes of hydrogen absorption in porous ceramic materials and the study of the main approaches to solving the problem of hydrogen storage. Various modern methods for storing hydrogen in various states of aggregation are described, including storage in a liquefied form at low temperatures and in chemically bound forms such as metal hydrides. The results include the synthesis of porous materials for hydrogen absorbers, suggesting various types of hydrogen absorbers in the form of porous materials. The study shows the dependence of the degree of hydrogen absorption on the composition of the absorber and the temperature of hydrogen sorption. A ceramic porous material with a zeolite composition of sodium aluminosilicate (AlSiNaO) has been developed, exhibiting a high hydrogen absorption coefficient (13.2 wt.%).

Kye words: hydrogen, production, storage, hydrides, absorbers, porous ceramics, zeolites, aspect number.

Introduction

Hydrogen, which has a unique set of physical and chemical properties, is widely used in various technological processes. High specific energy intensity (142 MJ/kg or 39 kWh/kg, which is three times more than traditional liquid hydrocarbons), the absence of harmful products from the oxidation of hydrogen with oxygen and the possibility of using it in fuel cells with an efficiency of more than 50% - all this contributes to rapid growth of research in the field of hydrogen energy technologies. However, one of the main problems preventing the practical use of hydrogen in many areas is the low efficiency of its storage and transportation.

Fuel cell power plants demonstrate the highest efficiency to date - up to 80%, and the average annual productivity of a fuel cell is 19710 kWh at a cost of 0.0766 $/kWh [1]. Despite the fact that this cost exceeds the price of electrical energy supplied from the city power grid, the approach under consideration is of interest in conditions of shortage of electrical energy and natural gas.

It is important to note that determining the effectiveness of hydrogen absorber materials is based on several criteria: the ability to retain large quantities of hydrogen at room temperature, rapid release at moderate temperatures, resistance to cyclic use, and cost-effectiveness. To date, there is no material that would fully satisfy all these requirements. The search for new materials and various proposed solutions to this problem are actively discussed in recent review articles [1-5].

As part of our materials synthesis research, many compositions have been tested to produce porous ceramics. The goal of the work was the idea of a United States absorber based on an inexpensive porous material of a zeolite composition.

Methodology

The technology for producing porous ceramics included the following operations;

- preparation of a charge of a given composition;
- wet grinding in a ball mill;
- drying at 200oC;

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- molding into tablets with a diameter of 20 mm;
- firing at a temperature of 1150oC for 2 hours;
- slow cooling in the oven.

Results and discussing

The resulting materials of aluminosilicate composition, synthesized from raw materials melted in a solar furnace, had the following indicators

- density 375–550 kg/m3;
- specific surface 2500 cm2/g;
- exhibit compressive strength of 3.7–4.9 MPa.

Such materials can be used as hydrogen absorbers for the physical binding of hydrogen in pores by van der Wals forces at high (30–50 atm) pressures.

These data, taking into account the hydrogen density value of 0.09 kg/m3 under normal conditions (300K, 1 atm), make it possible to calculate the aspect number for a porous material under normal conditions.

The porosity of materials is a priori related to the property of water absorption. For materials of this composition, water absorption ranged from 10 to 23%, which indicates the corresponding porosity of the material. Thus, the higher the porosity, the more hydrogen the material absorbs.

As can be seen from table. 1, the main components in the ceramic material are aluminum oxide 67 wt%, silicon oxide 25.2 wt%, and sodium oxide 6.9 wt%.

Table 1. Chemical composition of the initial state of the raw material

Composition	Al_2O_3	P_2O_5	SiO_2	Na_2O	Fe_2O_3	SO_3
Content, mass%	67.12	0.21	25.21	6.88	0.02	0.56

Figure 1 shows an X-ray diffraction pattern of the synthesized material based on aluminum oxide.

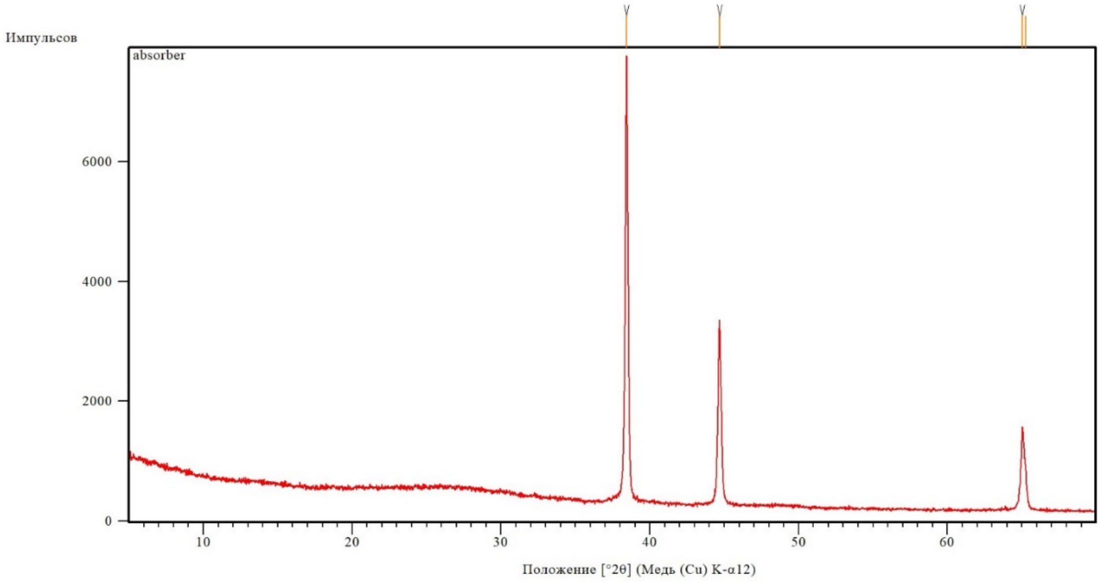

Fig.1. X-ray diffraction pattern of the synthesized material based on aluminum oxide.

Analysis of the X-ray diffraction pattern shows that the material is single-phase and has a zeolite structure of sodium aluminosilicate AlSiNaO with a lattice parameter a = 4.056 nm, space group Fm3m (it is not possible to obtain such data from the presented X-ray diffraction pattern).

Figure 2 shows the dependence of the aspect number on the temperature of hydrogen absorption.

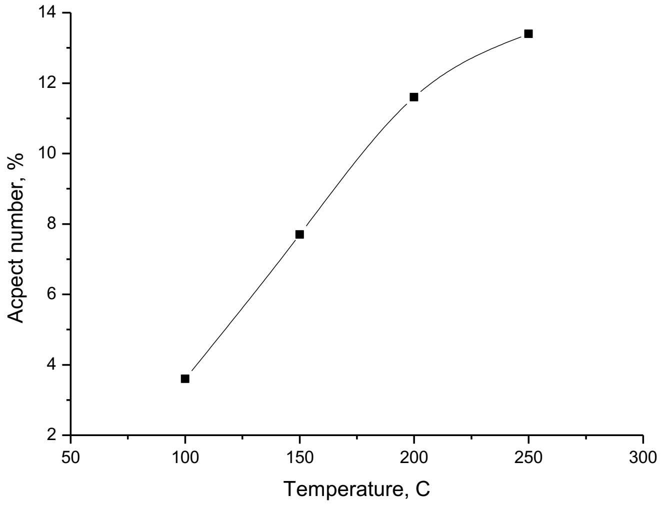

Fig.2. The dependence of the aspect number on the temperature of hydrogen absorption.

An increase in the value of the aspect number with increasing temperature is observed: from 3.5 wt.% at 100°C to 13 wt.% at 190°C. (does not correspond to the graph) (also at the top you write that at 200 C 4.3 wt.%) was obtained

This material is a good hydrogen absorber at a temperature of 190°C and the aspect number for it was 13.24 wt.%.

Now it is possible to evaluate the effectiveness of using ceramic porous absorbers in steel reactors. Let's say a cylindrical steel reactor with a height of 400 mm and a diameter of 300 mm has an internal volume of 0.028 m3.

At a given density of porous ceramics - 450 kg/m3, the mass of porous ceramics placed in the reactor: 0.028×450 = 12.6 kg.

This volume contains 450 x 0.028 = 12.6 kg of porous ceramics. If you saturate it with hydrogen at a pressure of 100 atm, then you can introduce up to (12.6 x 13.24)/100 = 1.67 kg of hydrogen into it. If you use a steel cylinder as a container for storing hydrogen, then at a pressure of 80 atm you can introduce 9 x 0.028 = 0.25 kg of hydrogen into it.

Conclusion.

Thus, a porous material based on sodium aluminosilicate AlSiNaO with a lattice parameter a=4.056 nm is a good hydrogen absorber. With an increase in the temperature of the sorption process from 100°C to 190°C, the value of the aspect number increases from 3 wt.% to 13 wt.%

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