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STORING HYDROGEN

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ABSTRACT OF THE DISCLOSURE

A method for storing hydrogen whereby gaseous hydrogen is adsorbed by nickel-magnesium alloys at temperatures above 250° C. and pressures above 18 pounds per square inch.

The invention described herein was made in the course of, or under a contract with the U.S. Atomic Energy Commission.

Prior art

Hydrogen is conventionally stored in pressure vessels which are dangerous both from fire and explosion hazards. Others in the art have tried to form stable metal hydrides in order to eliminate the hazards arising from containment of hydrogen in pressurized containers. The metals and alloys previously employed by those skilled in the art have been too expensive to allow their widespread use in conventional processes such as rockets and fuel cells.

It is an object of this invention to provide those skilled in the art with a simple, economical, safe method of storing hydrogen.

Description of the invention

We have discovered a novel method for storing hydrogen by forming a hydrogen metal alloy complex, wherein hydrogen gas is absorbed into a metal alloy, comprising contacting gaseous hydrogen with a solid nickel-magnesium alloy, said alloy containing from about 40 weight percent to about 80 weight percent nickel based upon the total weight of the nickel-magnesium alloy and from about 20 weight to about 60 weight percent magnesium based upon the total weight of the nickel-magnesium alloy, while maintaining said hydrogen and said alloy at a pressure of at least about 18 pounds per square inch and at a temperature of at least about 250° C. until said alloy has absorbed up to about 5 weight percent hydrogen based upon the total weight of the nickel-magnesium alloy. The product formed by our method is a hydrogen-nickel-magnesium complex, whose exact physical and chemical structure is not known at this time.

The hydrogen-nickel-magnesium complexes produced by the practice of our invention are stable at temperatures below 250° C. and the complexes need not be stored in pressure vessels. Thus, hydrogen can be readily stored by forming the complex in accordance with the method disclosed by our invention and thereafter cooling the complexes and maintaining them at normal atmospheric pressures until it is desired to release the hydrogen contained therein. To release the hydrogen from the complex, all that is required to be done is to heat the hydrogen containing complex to a temperature above 250° C. and to allow the hydrogen to escape.

A unique feature of our novel complexes is the fact that hydrogen is released at a constant rate from a complex when the complex is maintained at a specific temperature at or above 250° C. until the complex contains less than one weight percent of hydrogen based on the total weight of nickel-magnesium alloy contained in the complex. For example, a hydrogen-nickel-magnesium complex containing 5 weight percent hydrogen based upon the weight of the nickel-magnesium alloy upon being heated at a constant temperature of 250° C. will maintain a constant hydrogen pressure of 18 lbs. per square inch above the alloy until about one weight percent of hydrogen remains in the complex. This feature provides those skilled in the art with a simple hydrogen source in which the rate of release can be carefully controlled by simply controlling the temperature of the complex during the release. Thus, it will be apparent to those skilled in the art that our invention can be readily adapted to conventional techniques to provide a safe dependable source of hydrogen for a multitude of uses such as rockets, fuel cells, etc.

In the preferred embodiment of our invention, the nickel-magnesium alloy contains 53 weight percent nickel and 47 weight percent magnesium based on the total weight of the alloy. The alloys found useable in our invention can be produced by any conventional alloying technique. They can be produced by simply heating the proper amounts of nickel and magnesium under an inert or hydrogen atmosphere with an induction heater until a melt is formed, intimately mixing the ingredients of the melt and thereafter cooling the melt until a solid alloy is formed. Liquid metal alloys are not desirable for use in the practice of our invention because the pressure requirements required to form the desired hydrogen-alloy complex would be too great. The presence of oxygen in the nickel-magnesium alloy is to be avoided as oxygen tends to inhibit the rate of formation of the complex. We have found it preferable to use a powdered nickel-magnesium alloy in the practice of our invention because the increased surface area provided by the powder increases the rate of absorpition of the hydrogen by the alloy. However, our invention is not limited to any particular physical shape of the alloy and blocks and meshes of the alloy can be employed and indeed in certain applications such shapes may be desirable. Conventional pressure vessels and heating devices may be employed in the practice of our invention.

In the preferred embodiment of our invention the hydrogen and the nickel-magnesium alloy are heated to a temperature of 300° C. and maintained under a pressure of 120 pounds per square inch absolute. The pressure can be maintained by adding additional increments of hydrogen to the system to counterbalance the increments taken up by the alloy during the absorption phase of the process.

We have found that one atom of hydrogen will be adsorbed per atom of metal contained in the alloy. One mol of an alloy having the formula Mg_2Ni will absorb up to 4.5 mols of hydrogen during the practice of our invention. Thus the alloys found useable in our invention will absorb roughly 5 weight percent hydrogen based on the total alloy weight.

Example I

Apparatus.—An upright reactor vessel consisting of a stainless steel tube flanged on both ends and having an inside diameter of ¾ inch and a length of about 13 inches was fitted with a thermocouple well through the top flanged end of the vessel and extended therein for about 7 inches. A small crucible made of aluminum oxide was attached to the bottom of the thermocuple to hold the samples to be treated at about the middle of the vessel. The bottom end of the vessel was sealed and a connection was fitted to the side of the vessel to permit gas to be withdrawn and introduced in the vessel. The vessel was inserted into an electrically heated furnace.

Procedure

A 2 gm. sample of an alloy consisting of 45% by weight Mg and 55% by weight Ni (Mg_2Ni) was weighed

out in a dry box. The sample was pulverized so that it could through a 25 mesh screen, reweighed and introduced into the Alundum crucible. The sample was immersed in acetone so that it was not exposed to air as the crucible was removed from the dry box and introduced into the reactor. The reactor was sealed, evacuated and the sample heated in vacuo for about 2 hours at a temperature of 275° C. H_2 was admitted to the reactor until a pressure of 125 p.s.i.a. was reached at which point the vessel was sealed. The reactor vessel was then heated to about 300° C. The rate at which the sample absorbed H_2 could be determined by the pressure decrease in the system over a period of time. When absorption was essentially complete, the reactor was cooled to room temperature and gaseous H_2 was vented from the system until a predetermined pressure of 30 p.s.i.a. was reached. The sample was reheated to about 300° C. and allowed to come to equilibrium and the pressure recorded. At equilibrium some gaseous H_2 was removed from the system after which a new equilibrium was reached. When no further H_2 evolved from the sample upon removing gaseous H_2, the entire cycle was repeated by readmitting H_2 into the system and reabsorbing H_2 in the alloy.

Results

A hydrogen content of over 4 wt. percent has been repeatedly obtained by absorption in an alloy with the starting composition of 45 wt. percent Mg, 55 wt. percent Ni (Mg_2Ni). The fact that the sorption-desorption cycle can be repeated indefinitely is of practical significance for it allows for economic use of the alloys to effectuate H_2 storage.

We have also prepared samples of the alloy which were cooled to room temperature after they had sorbed about 4 weight percent hydrogen based upon the weight of the nickel-magnesium alloy. These samples did not lose their hydrogen upon exposure to the atmospheric conditions found in our laboratory. Further, they were not damaged when they were recycled through the procedure described in this example.

We claim:

1. The method of storing hydrogen comprising contacting gaseous hydrogen with a solid nickel-magnesium alloy, said alloy being composed of from about 40 weight percent to about 80 weight percent nickel based on the total weight of the nickel-magnesium alloy and from about 20 weight percent to about 60 weight percent magnesium based upon the total weight of the nickel-magnesium alloy, while maintaining said hydrogen and said alloy at a pressure of at least about 18 pounds per square inch and at a temperature of at least about 250° C. until said alloy has absorbed up to about 5 weight percent hydrogen based on the total weight of the nickel-magnesium alloy.

2. The method of claim 1 wherein said alloy contains 53 weight percent nickel and 47 weight percent magnesium based upon the total weight of the nickel-magnesium alloy.

3. The method of claim 2 wherein said alloy and the hydrogen are maintained at a temperature of about 300° C.

4. The method of claim 3 wherein said alloy and the hydrogen are maintained at a pressure of about 120 pounds per square inch.

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