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Use of Magnesium Hydride as Hydrogen Storage Material for Running Cars

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Abstract: ***The major energy source today are fossil fuels. But the over-consumption of these fossil fuels is leading to serious environmental issues. When fossil fuels are burnt they release carbon dioxide, sulphur dioxide, carbon monoxide etc.and have severe consequences on habitats. As they are non-renewable sources of energy they are depleting at a rapid rate and their sources are limited, therefore there is a supreme need of alternate fuel which is sustainable. Hydrogen is an alternative fuel that can be produced from various domestic resources and is abundant in our environment. It's stored in water (H_2O), hydrocarbons (such as methane, CH_4), and other organic matter. One of the challenges of using hydrogen as a fuel comes from being able to efficiently extract it from these compounds. Hydrogen can be produced by splitting water using alloy of Aluminum(with gallium, indium, thallium etc.).Since alloying materials are expensive and the storage of hydrogen according to this process is quite difficult so we found that MgH2 has high hydrogen storage capacity of 7.6 weight%. This research paper aims on the efficient use of hydrogen for running cars and analysis of its volume that can be stored in cars and also the power developed through it.***

Keywords: Magnesium hydride, Aluminium, Hydrogen and Cars

1. Introduction

In 1951 preparation from the elements was first reported involving direct hydrogenation of Mg metal at high pressure and temperature (200 atm, 500 deg. C) MgI2 catalyst: [6]

Mg + H2 = MgH2

On industrial scale MgH2 powder can be produced. The density of Mg is one third of Aluminum and it has been used as a lightweight structural material.[2] An ideal hydrogen storage material should have high hydrogen volumetric capacity, ambient reaction temperature for charging/discharging hydrogen and fast kinetics, excellent reversibility, low cost and low toxicity.[3] The problem of poor kinetics of MgH2 in hydrogen release has been solved by adding hydrolysis process, which can attain hydrogen production yield up to 15.2 mass % below 100 deg. C. Since Mg is stable in open atmosphere and has no adverse impact on human health [2]; thus it can be used as a storage material for hydrogen. Hydrogen can be also produced by splitting of water when brought in contact with Aluminium alloy.

2Al + 6H2O = 3H2 + 2Al(OH)3 [1]

Since, Aluminium is heavier than Magnesium and the fact of fabricating a different controllable unit for the reaction to produce hydrogen is inevitable.

Also, thermal decomposition reaction of diethyl magnesium MgEt2 (equation 1) and direct hydrogenation (equation 2) are used for the production of MgH2 [2];

MgEt2 = MgH2 + 2C2H4 ....(1)

Mg + H2 = MgH2 ....(2)

This gives us reactive MgH2 that makes handling difficult. Akiyama and co-workers have developed direct hydrogenation process by means of combustion synthesis [4] and hydrogen CVD [5].

Filament MgH2, and later, granule MgH2 were successfully synthesized using a hydrogen furnace shown in figure 1 [2]

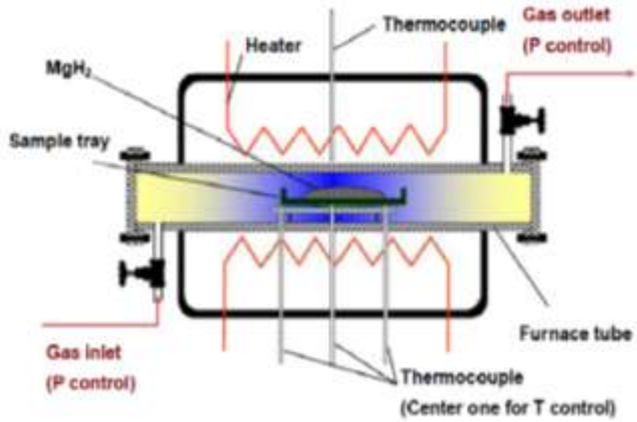

Figure 1: Hydrogen furnance

By decreasing the activation energy, we can enhance the kinetics. For this Nickel and Palladium are well known catalysts for molecular hydrogen dissociation can lower the hydrogenation and dehydrogenation temperature from 275 to 175 deg. C and from 350 to 275 deg. C, respectively [3]. Since, Magnesium Hydride is found to be a viable hydrogen storage material. Mg costs $3.7 per 100 grams and it is a onetime investment so we can use it to run the cars with hydrogen engine.

2. Literature Survey

In early 1780s Alessandro Volta built a toy electric pistol in which an electric spark exploded a mixture of air and hydrogen, firing a cork from the end of the gun.

After that in 1807 Swiss engineer François Isaac de Rivaz built an internal combustion engine powered by a hydrogen and oxygen mixture, and ignited by electric spark.

In 1860 Belgian Jean Joseph Etienne Lenoir (1822–1900) produced a gas-fired internal combustion engine similar in appearance to a horizontal double-acting steam engine, with cylinders, pistons, connecting rods, and flywheel in which the gas essentially took the place of the steam. This was the first internal combustion engine to be produced in numbers.

In 1892 Dr. Rudolf Diesel developed his Carnot heat engine type motor and in 1893 February 23 Rudolf Diesel received a patent for his compression ignition (diesel) engine.

In 1903 Egidius Elling builds a gas turbine using a centrifugal compressor which runs under its own power. By most definitions, this is the first working gas turbine.

In March, 1937 The Heinkel HeS 1 experimental hydrogen fueled centrifugal jet engine is tested at Hirth.

From 1991 to 2007 Mazda has developed Wankel engines that burn hydrogen.

In 2002 and 2007 BMW tested a supercar named the BMW Hydrogen 7, powered by a hydrogen ICE, which achieved 301 km/h (187 mph) in tests. At least two of these concepts have been manufactured.

Earlier the splitting of water is done by Electrolysis, Photo-electrochemical water splitting, Photo-electrocatalytic water splitting and Photo-biological water splitting.

As of 2016, there are 3 hydrogen cars publicly available in select markets; the Toyota Mirai, the Hyundai ix35 FCEV, and the Honda Clarity.

Pearl Hydrogen Power Sources of Shanghai, China, unveiled a hydrogen bicycle at the 9th China International Exhibition on Gas Technology, Equipment, and Applications in 2007.

3. Approach

We see that the problem of hydrogen storage can be solved by using MgH2 as hydrogen storage material instead of producing hydrogen on demand in vehicles.MgH2 readily reacts with water to form hy drogen gas

$$MgH2 + 2H2O = 2H2 + Mg(OH)2$$

At 287 deg. C it decomposes to produce H2 at 1 bar pressure [7].

We can use the hydrogen released to run the cars by filling the fuel tank of cars from filling stations. In normal diesel cars the capacity of fuel tanks ranges from 35 to 50 litres. And we can store 110 kg of hydrogen per metre cube.

- 1 metre cube = 110 kg of hydrogen
- 40 litres tank capacity = .04 metre cube
- 1 kg H2: 142 MJ = 39.4 KWh combustible energy
- 1 kg Mg can store 76 grams of hydrogen = 3.0126 KWh
- 1 gal (10 kg) MgH2 can store 0.76 kg of hydrogen
- 1 gal (10 kg) MgH2 makes 30.126 KWh as hydrogen
- 1 gal diesel makes 37.5 KWh

Further the kinetic can be enhanced by using shown in the table 1. [3]

Table 1: Magnesium hydrides for hydrogen storage

Material	Temperature (°C)		Max hydrogen Wt%	Reference
	T_{ads}	T_{des}		
MgH_2 + 10 wt% BCC ($Ti_{0.4}Cr_{0.1}$ $Mn_{0.22}V_{0.28}$) + 5 wt% MWCNTs	300	300	6	[1.]
71.5 wt% Mg-23.5 wt% Ni-5 wt% Fe	320	350	3.32(abs),2.42 (des)	[2.]
Mg-14 wt%Ni-2 wt%Fe-2 wt% Ti-2 wt% Mo	300	300	4.6	[2.]
Mg-10 wt%Ni-5 wt%Fe-5 wt% Ti	300	300	5.51(ads) 5.15(des)	[3.]
MgH_2 + 10 wt% TiF_3	300	280	6.27(abs) 5.98(des)	[4.]
MgH_2 + 10 wt% FeF_3	300	280	6.33(abs) 4.82(des)	[4.]
MgH_2 - 20 wt% AB_2 alloy	300	300	5.7	[5.]
MgH_2 - 40 wt% AB_2 alloy	300	300	4.1	[5.]
Mg-5wt%Ni-2.5wt%Fe-2.5wt%V	300	300	5.67 (ads) 4.91(des)	[6.]
Mg-23.5wt%Ni-2.5wt%Cu	300	300	4	[7.]
90Mg-6Ni-4C	100	250	5.23(abs) 3.74(des)	[8.]
Mg–14Ni–2Fe_2O_3–2Ti–2Fe	300	300	4.56 (ads) 3.32 (des)	[9]
Mg- 2 wt% MWCNTs	300	300	5(ads) 4(des)	[10]
Mg–15 wt% Ni –5 wt%Fe_2O_3	300	300	5.38 (ads), 5.28(des)	[11]
$Mg_xCu_6Ni_5Y_{1-x}$	300	200	4.2-4.5 (abs) 2.6 (des)	[12.]
Cat-MgH_2 (MgH_2- 5 wt% Nb_2O_5- 1 wt% Graphite) + 5 wt% Al	320	320	5.3	[13.]
Mg-10Ni-R (R=La,Nd,Sm)	150	250	3.5-4	[13.]
Mg-14Ni-6Fe_2O_3	300	300	3.28(ads) 3.37(des)	[14.]
Mg-10 wt % Fe_2O_3	300	320	4.37 (ads) 0.88 (des)	[15.]
Mg-14Ni-2Fe_2O_3-2Ti-2Fe	300	300	4.41(abs) 3.5(des)	[15.]
Mg-14Ni-3Fe_2O_3-3Ti	300	300	4.00(abs) 3.98 (des)	[15.]
Mg-23.5 wt% Ni -5 wt % Fe_2O_3	320	320	2.69 (ads) 2.27 (des)	[15.]
Material	Temperature (°C)		Max hydrogen Wt%	Reference
	T_{ads}	T_{des}		
Mg-15 wt% Ni- 5 wt % Fe_2O_3	300	350	3.73(ads) 3.32(des)	[16]
Mg-14Ni-6Fe_2O_3-2MWCNTs	300	300	2.92 (ads) 1.75 (des)	[17]
MgH_2+ 5 wt% Zr_8Ni_{21}	250	300	6.50	[17]
$Mg_{80}Ni_{15}Y_1Pd_4$	200	200	4.4	[18]
$Mg_{80}Ni_{15}Y_1Pd_4$	300	300	4.4	[19]
$Mg_{80}Ni_{15}La_1Pd_4$	200	200	4.2	[19]
$Mg_{80}Ni_{15}La_1Pd_4$	300	300	3.9	[19]
$Mg_{80}Ni_{15}Y_{2.5}Pd_{2.5}$	200	200	4.6	[19]
$Mg_{80}Ni_{15}La_{2.5}Pd_{2.5}$	300	300	4.3	[19]
$Mg_{80}Ni_{15}Y_{2.5}Pd_{2.5}$	200	200	4.5	[19]
$Mg_{80}Ni_{15}La_{2.5}Pd_{2.5}$	300	300	4.2	[19]
Mg-23.5Ni-2.5Cu	300	300	4.01(ads) 3.96(des)	[19]
88(87.5Mg-10Ni-2.5Cu)+5 wt% Nb_2O_5+7 wt% NbF_5	300	300	3.14(ads) 1.51(des)	[15]
MgH_2-10Ni-2$LiBH_4$-2Ti	300	300	4.44(ads) 1.97(des)	[16]
Mg_3Cd	300	300	2.8	[15]
MgH_2-10 wt% Nb_2O_5+5 wt% (ENG)	310	310	4.5(ads) 4.9(des)	[15]
MgH_2-10 wt% NiB	300	300	6	[15]
Ultrafine Mg-Ti particles	400	400	4.3	[15]
Mg (MgH_2)-based composites, using carbon nanotubes (CNTs) and with TCat	200	310	6	[16]

Theoretically, by using hydrolysis process Mg can store 15.2 mass % but practically it can store 6 to 7.6 mass % of hydrogen.

4. Result

1 gal (10 kg) of MgH2 can produce 30.126 KWh. This research paper suggests the use of hydrogen efficiently in vehicles and analyses the amount of hydrogen that can be stored in it and the amount of power that can be developed through it. Previous research performed only suggests use of hydrogen in vehicles but not about its storage and utilization.

5. Conclusion

The power produced by 1 gal of MgH2 is less than that produced by 1 gal diesel but the use of MgH2 is a step forward towards the use of sustainable resources. Also the use of hydrogen as a fuel does not have adverse effect on environment which fossil fuels have such as air-pollution. Using MgH2 as hydrogen storage material is economical and is viable and also for the betterment of our environment and upcoming generations, we can compromise with the slight lag in power.

6. Future Scope

This research paper suggests an alternative hydrogen storage material i.e., MgH2 for the running of cars without making very large modifications in the design. We have to just replace the diesel engine by hydrogen engine. This paper suggests that instead of using other means for hydrogen storage, we can use MgH2 and to utilize the hydrogen released in an efficient manner.In future, we may see this method of storage of hydrogen in various other transportation media and also in such machines where hydrogen can be used as a fuel.In this research paper, the analysis has been done by considering the storing capacity of 7.6 mass % but it may increase in future leading to greater storage amout of hydrogen and further leading to achievement of greater amount of power.

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