STORING HYDROGEN - THE FUTURE CLEAN ENERGY NANO-CHOCOLATE VS METAL HYDRIDE

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INTRODUCTION

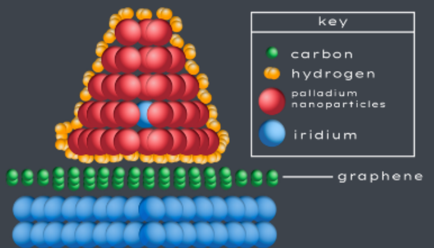
Hydrogen is an abundant element that can be extracted from water using electrolysis and is considered a climate friendly, carbon-free energy carrier for the future. When hydrogen is consumed in a fuel cell and producing electricity, its byproduct are simply heat and water and doesn't generate greenhouse gas emissions like fossil fuel sources, perfect for future zero carbon needs. Hydrogen's broad application ranges across all sectors, from transportation, commercial and industrial to residential and portable, like providing auxiliary power for trucks, aircraft, rail, ships, cars, trucks and buses.

TRADITIONAL METHODS

Storing hydrogen is costly: either the gas has to be kept in pressurised tanks, at up to 700 bar, or it must be cooled down to minus 253 degrees Celsius to liquify. Both procedures consume additional electrical energy during storage process, making hydrogen inconvenient to store and extract and a not-so-clean and unappealing alternative to fossil fuel.

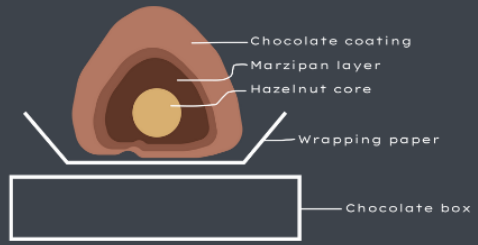
#1. GRAPHENE SUPPORTED PD NANOCLUSTERS

Palladium has been known for the capability to absorb large amount of hydrogen up to 900 times its own volume in the space between its atoms at room temperature to form palladium hydride. However, extracting hydrogen after storage has been a problem due to hysteresis. DESY's Andreas Stierle and his team's newest research tries to solve this problem by storing hydrogen in graphene supported palladium nanoclusters.



Each Pd nanoparticles with diameter of 1.2 nm are attached to an iridium core, and all of them are attached to the graphene layer at intervals of 2.5 nm, forming a periodic structure. The iridium helps order the nanoparticles on the superlattice and therefore increases thermal stability. The Pd nanoparticles provide storage of atomic hydrogen, which then migrates to the graphene layer due to hydrogen spillover to achieve high-density hydrogen storage. The researches found that the hydrogen molecules only binds to the surface of the palladium nanoparticles and can be easily extracted by slightly increasing the temperature.

An analogy of the nanoparticles. Chocolate version.



PROS OF METHOD #1

√ Large surface area for hydrogen chemisorption
√ Requires only 10 mbars at room temp. to extract hydrogen
√ Convenient, lightweight and possibly cheaper alternative

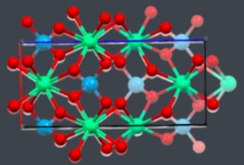
CONS OF METHOD #1

X Use of precious and rare metal

#2. SODIUM ALANATE SYSTEM

Sodium alanate is a complex hydrides of sodium and aluminium with the chemical formula $NaAlH_4$ or Na_3AlH_6 that can absorb and release hydrogen in the following 2-step reaction:

$$3NaAlH_4 \rightleftharpoons + 2Al + 3H_2$$
$$Na_3AlH_6 \rightleftharpoons 3NaH + Al + 1.5H_2$$



Aluminium is in excess of the stoichiometric aluminium content of sodium aluminium tetrahydride, and upon heating, the excess aluminium is chemically bonded with hydrogen. However, sodium alanate hydride cannot be adopted in its pure from because only a small amount of hydrogen is released upon reaching the melting point of 183 degrees celsius at which it starts to decompose. To solve this problem, the reaction kinetics can be improved by the addition of catalysts and make the system recyclable. For example:

1. Titanium-doped $NaAlH_4$
2. Scandium-doped $NaAlH_4$
3. Addition of CeAl2 which transforms into CeAl4 after prolonged cycling to further facilitate hydrogenation
4. Addition of carbon

Another way researchers have investigated is producing nanostructure of sodium alanate with particle sizes down to 150 nm through ball milling (a kind of mechanical grinding) to decrease energy required for hydrogen absorption.

PROS OF METHOD #2

√ Inexpensive
√ Abundant in nature
√ Lightweight
√ Large gravimetric and volumetric capacity for hydrogen storage per unit weight

CONS OF METHOD #2

X Rehydrogenation rate starts to decrease after recycling after few hundred times
X Requires higher hydrogen pressure when compared to method 1

CONS OF USING HYDROGEN AS FUEL

X Leaks may cause explosion as hydrogen is a flammable gas
X Electrolysis requires electricity which unless generated from renewable sources are not environmentally friendly / carbon neutral

THE FUTURE & CONCLUSION

More research has to be done before practical application. Research includes:

- How other carbon structures like carbon sponge might be a more suitable carrier than graphene to hold more nanoparticle units.
- How catalysts can be modified to further reduce energy required for sodium alanate system to be applicable in PEM fuel cells in vehicles.
- How to sustain hydrogen absorption capacity after long period of recycling.

Graphene supported palladium nano-clusters or successfully modified metal doped sodium alanate system can potentially be applied in PEM fuel cells in vehicles to generate and carry electricity in a climate friendly way. Applications are endless. These researches help us create A FUTURE with AFFORDABLE AND CLEAN ENERGY.

REFERENCES

- Li, L., Xu, C., Chen, C., Wang, Y., Jiao, L., & Yuan, H. (2013). Sodium alanate system for efficient hydrogen storage. International journal of hydrogen energy, 38(21), 8798-8812.
- Franz, D., Schröder, U., Shayduk, R., Arndt, B., Noei, H., Vonk, V., ... & Stierle, A. (2021). Hydrogen Solubility and Atomic Structure of Graphene Supported Pd Nanoclusters. *ACS nano*, *15*(10), 15771-15780.
- Palladium hydride. (2012, September 6). In WikiDoc. https://wikidoc.org/index.php/Palladium_hydride