

CASE REPORT

Features of Metal Hydrides for Hydrogen Storage

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Received: August 5, 2025;

Accepted: November 14, 2025;

Published: November 19, 2025.

Citation: Paizullakhanov MS, Parpiev O, Ruzimuradov O. Features of Metal Hydrides for Hydrogen Storage. *Chem Rep*, 2025, 6(1): 331-333. <https://doi.org/10.25082/CR.2025.01.004>

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Abstract: The aluminum–nickel alloy samples did not exhibit any hydrogenation under the tested conditions. Titanium powders absorbed hydrogen up to 3.8 wt.% at 12 atm and 700°C, which is slightly lower than the theoretical value of 4.04 wt.% for TiH₂. Lithium hydride (LiH) samples demonstrated high absorption capacity: at 700°C and 12 atm, the hydrogen content in lithium reached 12.5 wt.%. Therefore, achieving high absorption levels (> 6 wt.%) requires high temperatures (around 700°C) and elevated pressures (> 15 atm).

Keywords: hydrogen, battery, metal hydrides, reactor, hydrogen flow, aspect ratio

1 Introduction

The use of hydrogen as an energy carrier is limited by the challenges of its safe and efficient storage. Currently, the highest efficiency is achieved by compressing hydrogen to pressures of about 700 bar. To withstand such extreme pressures, storage tanks must be sufficiently strong and impermeable to hydrogen. However, such high pressures pose significant explosion risks. Therefore, research into alternative and safer hydrogen-storage methods is highly relevant. In this regard, the chemical binding of hydrogen in the form of metal hydrides is considered promising [1–4]. Metal-hydride storage enables the safe containment of high-purity hydrogen at low pressures (1–40 bar) with very high storage densities (up to 150 kg/m³, compared to 39 kg/m³ for hydrogen at 700 bar) in the form of reversible metal hydrides. In addition, metal-hydride systems provide a high volumetric hydrogen content relative to the metal volume (or mass) and can be easily regulated.

In addition, metal-hydride systems are characterized by a high volumetric hydrogen content relative to the volume (or mass) of the metal, as well as adjustable pressure and controllable rates of hydrogen absorption and release, allowing for multiple cycles of use.

2 Methods and Materials

In the hydrogenation experiments, metals such as aluminum, titanium, magnesium, and lithium were used in either bulk or powdered form. X-ray phase analysis was carried out using a PANalytical Empyrean diffractometer with Cu K_α radiation in Bragg–Brentano reflection geometry at $\lambda = 1.5418 \text{ \AA}$ and within the range $20^\circ \leq 2\theta \leq 60^\circ$ (where λ is the radiation wavelength and 2θ is the Bragg angle). Scanning electron microscopy was performed using JEOL JSM-6510 and HITACHI FLEXSEM 100 instruments.

3 Results

We carried out experiments on the hydrogenation of aluminum, titanium, magnesium and lithium metals. The metal hydrogenation process was carried out in a stainless steel reactor container with a high-temperature attachment. The samples were pre-dried at 200°C, then weighed on a balance, placed in the reactor (Figure 1).

Before heating, hydrogen was introduced into the reactor to purge the chamber of air. After purging, the valve was closed, and hydrogen was supplied at a pressure of 10–15 atm. Heating was then initiated according to the specified temperature program. The experiments were carried



Figure 1 Photo of the container – high-temperature reactor

out at temperatures ranging from 150 to 700°C. Cooling was performed either slowly in the switched-off furnace or rapidly, depending on the required conditions.

After cooling, the mass (m) of the sample was measured. The degree of metal hydrogenation was evaluated using the aspect ratio, defined as the ratio of the mass difference between the hydrogenated metal (M) and the initial metal (M_0) to the mass of the initial metal.

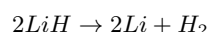
$$\alpha = \frac{M - M_0}{M_0} 100$$

In the case of porous nickel, the absorption was 0.7 wt.% at 15 atm and 300°C. Magnesium absorbed hydrogen up to 1.5 wt.%. The aluminum-nickel alloy samples did not show any hydrogenation under any conditions. Titanium powders absorbed hydrogen at a level of 3.8 wt.% at 12 atm and 700°C, which is slightly lower than the theoretical value of 4.04 wt%. TiH₂.

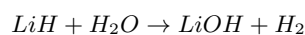
Lithium LiH samples showed high absorption values. At 700° C and a pressure of 12 atm, the amount of hydrogen in lithium metal was 12.5 wt.% , therefore, to obtain good absorption (> 6 wt.%) requires high temperatures (700°C) and high pressures (> 15 atm).

Metal hydrides are obtained by interaction of metals with hydrogen (as a rule, at a significant increase in pressure). The mechanism of formation of metal-like hydrides includes adsorption of molecular hydrogen on the surface of the metal, dissociation of H₂ into atoms and diffusion of H atoms into the crystal lattice of the metal.

It has been observed that LiH decomposes when heated to high temperatures (around 700°C) or when it reacts with water. Thermal decomposition results in the formation of lithium metal and hydrogen:



When lithium hydride comes into contact with water, it undergoes a vigorous reaction that produces lithium hydroxide and releases hydrogen:



Calculations show that 290 grams of hydrogen can be obtained from 1 kg of lithium hydride in water.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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