Australian Mines Limited
ABN 68 073 914 191
ASX | AUZ

Level 34, 1 Eagle Street,
Brisbane, Queensland 4000

T: + 61 7 3184 9184
E: info@australianmines.com.au
W: australianmines.com.au

AUSTRALIAN MINES LIMITED

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Australian Securities Exchange
20 Bridge Street
Sydney NSW 2000

ASX RELEASE

Patent Submissions - Solid State Hydrogen Storage Update

Australian Mines Limited ("**Australian Mines**" or "**the Company**") is pleased to provide an update on its metal hydride solid state hydrogen storage research and development program ("Program").

Metal hydrides serve as a promising potential solution for safe, efficient, and high-density hydrogen storage. The purpose of the Program is to reduce the metal hydride's operating temperature and increase the absorption and desorption rates while maximising energy density. Modifications of AUZ's MH-Oct22 metal hydride (ASX, 10 October 2022), has resulted in a new metal hydride, hereafter called MH-May24. Tests undertaken by Australian Mines development partner, Amrita Centre for Research and Development on MH-May24 demonstrates significant improvement in the absorption and desorption rates of hydrogen at lower temperatures. Subject to the risk factors and discussion below, the energy density of MH-May24 may allow the development of hydrogen storage systems that exceed the energy storage capabilities of both hydrogen compressed to 700bar and liquid hydrogen.

Highlights

- Under isothermal conditions and at a pressure of 38 bar MH-May24 absorbs hydrogen as follows:
    - Absorbs 5.2wt% hydrogen at 200°C.

- Absorbs 4.2wt% hydrogen at 200ºC in less than 4 minutes.
- Absorbs up to **4.7wt% hydrogen at 100ºC**.
- **Absorbs hydrogen at room temperature** whereas MH-Oct22 did not absorb any hydrogen at temperatures below 250ºC; and

- Previously, temperatures of at least 350ºC were required to achieve **desorption** rates within minutes whereas MH-Oct22 shows similar results at 300ºC.
- Under isothermal conditions of 250ºC and at vacuum[1] MH-May24 **desorbs 5wt% Hydrogen in approximately 3.3 hours**. Practical applications generally require hydrogen desorption kinetics over several hours.
- Both MH-Oct22 and MH-May24 were prepared using a production process that the Company considers may be applicable for **industrial scale manufacturing**.
- The Company has strategies it intends to implement that may further improve the reaction kinetics and operating temperatures and pressures of MH-May24.
- The Company has **submitted applicable applications to patent** both MH-Oct 22 and MH-May24

AUZ's CEO, Andrew Nesbitt commented *"We are very happy with the new metal hydride as we achieved similar performance to the earlier metal hydride, but at significantly lower temperatures. Subject to the risk factors discussed below, we believe the energy density of this metal hydride is competitive and importantly shows high absorption and desorption kinetics at potentially practical pressures and temperatures. With this improved performance, patent applications in place and a plan for further improvements, we consider now is the right time to partner with hydrogen industry players to consider the technology's practical application to hydrogen storage for transport."*

Hydrogen Economy Background

Development of practical, safe, cost-effective and efficient storage of a large amount of hydrogen in a small volume remains one of the fundamental challenges of the hydrogen economy[2].

Currently, the two most common techniques used to store hydrogen are to compress it to a high pressure or to liquify it (liquefaction). These storage methods require tanks

[1] In this announcement where the term vacuum is used the pressure was less than 0.5 bar.
[2] https://www.hymarc.org

and/or cooling equipment, which are bulky and heavy and are not expected to achieve the desired gravimetric and volumetric densities required to be competitive with current Electric Vehicles ("EVs"). Solid-state hydrogen storage is considered to have the potential to be competitive with current EVs.

Metal Hydrides and Australian Mines R&D Program

High-capacity metal hydrides are expected to be very important for storage applications in the future hydrogen economy due to their exceptional attributes. The high gravimetric capacity of metal hydrides for hydrogen storage is one of the main advantages they have over the conventional mature compressed gas and liquid hydrogen storage methods. MgH_2, for example, has a gravimetric capacity of up to 7.6wt% hydrogen. However, in practice it has not been possible to utilise the high gravimetric capacity of MgH_2 for practical hydrogen storage technologies due to two major problems:

1. the kinetics of hydrogen absorption and desorption in MgH_2 is extremely slow occurring over the timescale of hours; and
2. thermal stability of MgH_2 is too high, requiring very high temperatures to release hydrogen.

To overcome these issues various researchers have focused on modifying metal hydrides systems to improve hydrogen absorption and desorption properties, reaction rate kinetics and operating temperature. While some success has been achieved with alloying and nano-crystallisation of MgH_2 systems, results have been highly process dependant and have used processes that are difficult to apply to industrial scale manufacturing.

It is Australian Mines' collaborative research and development (R&D) partnership with Amrita Centre for Research and Development, which is focused on both modifying metal hydride systems and using manufacturing process that are likely to be scalable that has led to the development of MH-Oct22 and MH-May24 metal hydrides

Results & Discussion

Table 1 provides a comparison of the hydrogen absorption and desorption capacities of MH-Oct22 and MH-May24 under isothermal[3] conditions at temperatures up to 350ºC. Improvements in the performance of MH-May24 over MH-Oct22 down to room temperature are observed.

Figure 1 shows the hydrogen absorption kinetics of MH-May24 under isothermal conditions at 200ºC, 100ºC and room temperature. It can be observed that at 200ºC MH-May24 absorbs 4.2 wt% hydrogen within minutes. Although the absorption of hydrogen at room temperature is slower, it should be noted that absorption of hydrogen by the metal hydride is exothermic, and in a practical system, which would not be held at isothermal conditions, the heat generated by the hydrogenation process could increase the temperature and may increase the hydrogenation rate.

Figure 2 shows MH-May24 hydrogen desorption kinetics under isothermal conditions at 300ºC and 250ºC. The desorption rate at 300ºC is faster than is likely required for a practical system. The rate of desorption of hydrogen at 250ºC may be suitable for a practical system. We note that although MH-May24 dehydrogenation was not observed at room temperature, this may not be an impediment within a practical system coupled with a starter and a Proton Exchange Membrane (PEM) fuel cell. A significant amount of heat is generated by operating PEM fuel cells that is equivalent[4] to 45 to 60% of the total energy content of hydrogen entering the cells. This heat may be used to heat the metal hydride as it must be removed from the PEM fuel cell to prolong its lifetime and maintain performance.

		350ºC	300ºC	250ºC	200ºC	100ºC	RT
MH-Oct 22	Absorption wt.% @38 bar (time for max absorption)	5.2 (35 min)	4.8 (35 min)	4.8 (1 hour)	0	0	0
	Desorption wt.% @vacuum (time)	5.0 (4 min)	4.3 (6 hours)	4.6 (8 hours)	0	0	0
MH-May24	Absorption wt.% @ 38 bar (time for max absorption)	5.0 (28min)	5.0 (26 min)	5.2 (1 hour)	5.1 (1 hour)	4.7 (3 hours)	2 (4 hours)
	Desorption wt.% @ vacuum (time)	4.9 (5 min)	5.0 (10 min)	5.0 (3.3 hours)	0	0	0

Table 1: Comparison showing improved temperature performance of MH-May24 over MH-Oct22.

[3] An isothermal process is a type of thermodynamic process in which the temperature of a system remains constant.
[4] Nguyen, H. Q., & Shabani, B. (2020). Proton exchange membrane fuel cells heat recovery opportunities for combined heating/cooling and power applications. Energy Conversion and Management, 204, 112328.

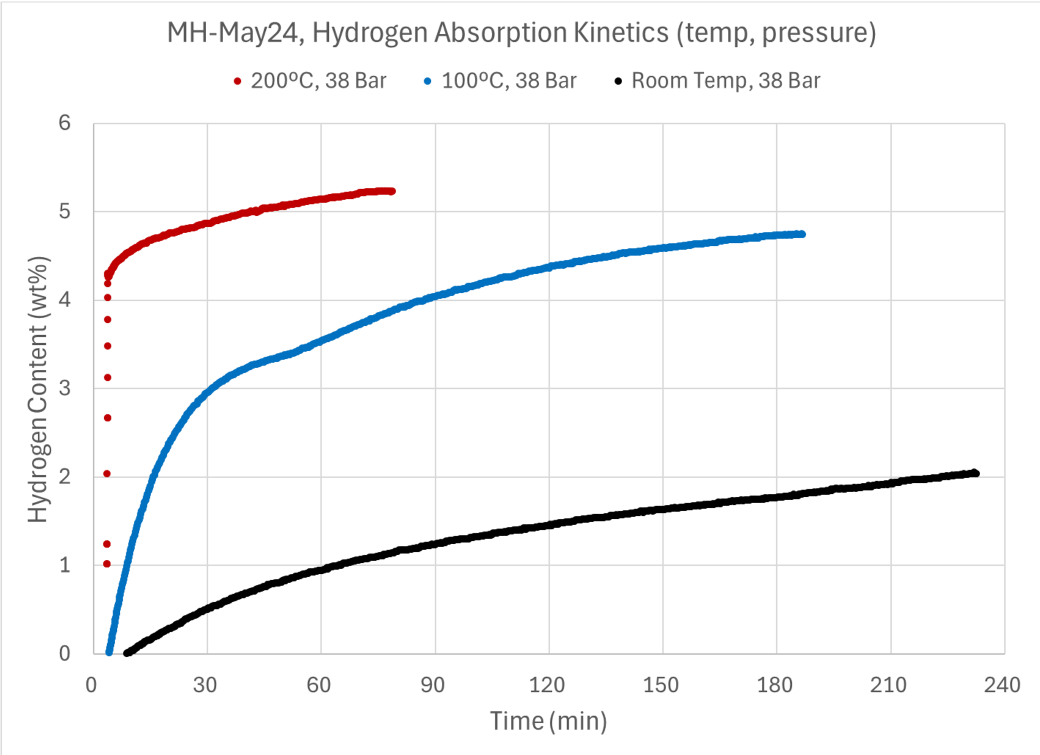

Figure 1: MH-May24 hydrogen absorption kinetics under isothermal conditions at 200ºC, 100ºC and room temperature.

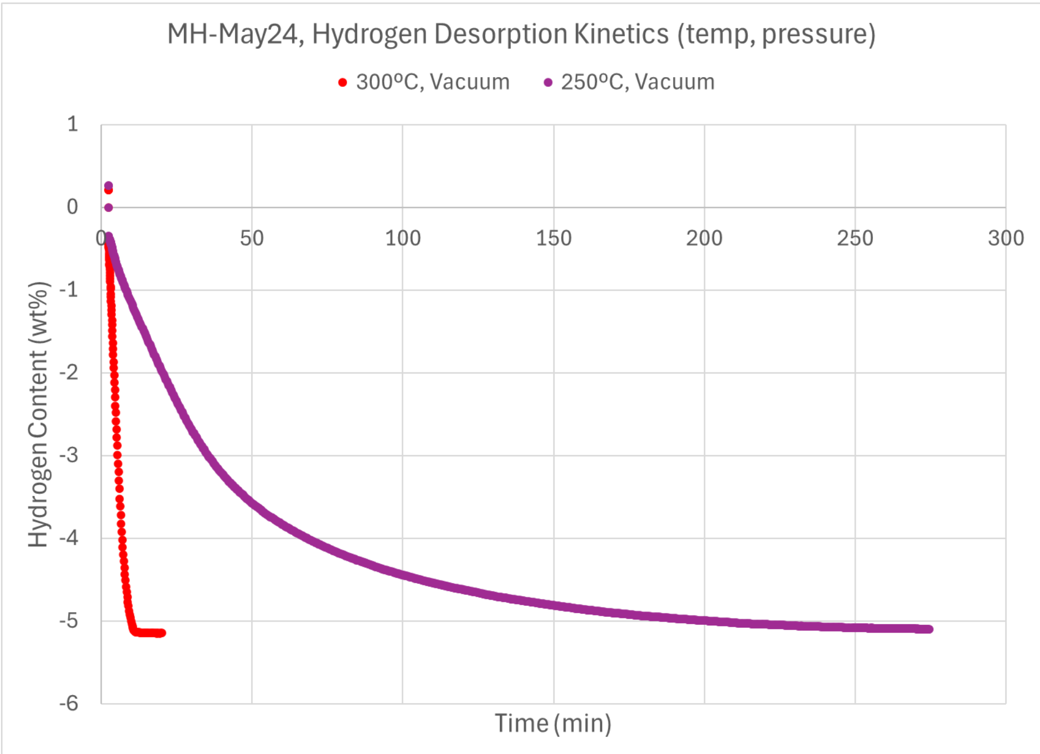

Figure 2: MH-May24 hydrogen desorption kinetics under isothermal conditions at 300ºC and 250ºC

Storage Capacity and Energy Densities of different hydrogen storage technologies

Positioning MH-May24 against competing hydrogen storage technologies is important to understand its potential commercial applications. Figure 3 provides a comparison based on volumetric and gravimetric energy densities of storage systems adapted from “A Review on metal hydride material for hydrogen storage”[5]. As the figure is based on a ‘system’ the authors applied an assumed penalty of 50% weight increase on metal hydride materials and a 100% volume increase. Applying this same penalty to the 5.2% hydrogen content (w%) obtained for MH-May24 at 200 °C results in a possible theoretical system Gravimetric Energy Density of 1.15 kWh/kg and Volumetric Energy Density of 1.78 kWh/dm^3, as indicated with the red ✖ in Figure 3. The positioning indicates a potential for considerable improvement over compressed hydrogen at 700bar (CGH2). Please note that although the authors have shown MgH_2, $LiBH_4$, and $NaAlH_4$ in Figure 3, all face challenges in practical applications due to their high decomposition temperatures and the need for high pressure to hydrogenate. LH2 in the figure represents liquid hydrogen, which has limited applications as it requires cryogenic temperatures.

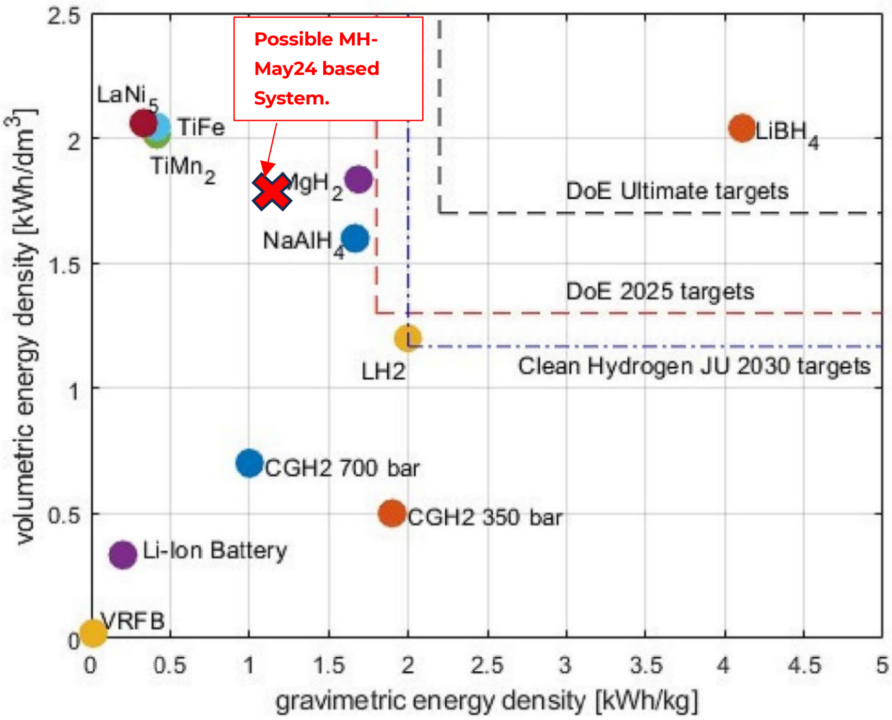

Figure 3: Adapted from “A review on metal hydride materials for hydrogen storage”[6] The densities are presented as theoretical “system” densities by applying an assumed penalty of 50% extra weight and 100% extra volume to metal hydride materials.[7]

[5] Klop, N., Grimmer, I., Winkler, F., Sartory, M., & Trattner, A. (2023). A review on metal hydride materials for hydrogen storage. Journal of Energy Storage, 72, 108456.

[6] Klop, N., Grimmer, I., Winkler, F., Sartory, M., & Trattner, A. (2023). A review on metal hydride materials for hydrogen storage. Journal of Energy Storage, 72, 108456.

[7] MH-May24: the weight has been increased by 50% and the volume has been increased by 100%, to allow for a comparable plot.

Strategy

Now Australian Mines has patent applications in place and has demonstrated its ability to improve reaction kinetics and operating temperatures and pressures, its strategy is twofold:

1. Seek to partner with hydrogen industry players to consider the technology's practical application to hydrogen storage for transport;
2. Undertake further developments of MH-May24 to seek to further improve hydrogen storage reaction kinetics and operating temperatures and pressures. Although improvements have already been made the company has several untested strategies that may further improve reaction kinetics and operating temperatures and pressures.

The final objective is to develop a metal hydride that is a hydrogen storage material that is:

1. Is capable of practical use in a hydrogen fuel cell electric vehicle ("FCEV")
2. Amenable to industrial scale manufacture; and economically attractive
3. Suitable for development and deployment with an industry partner.

Intellectual Property

As previously mentioned, Australian Mines has commenced a program of intellectual property protection in relation to its metal hydride program. The Company has filed Provisional Patent Applications for the specifications and synthesis of MH-Oct22 and MH-May24 metal hydrides.

Risks

There are several risks that could affect Australian Mines' ability to advance the development of metal hydrides to produce a commercially viable solid state hydrogen storage material. These risks include, but are not limited to, experimental uncertainties, the technology may not achieve hydrogen storage capacities at practical temperatures and pressures, the material if used in a system may have inadequate system gravimetric capacity, system volumetric capacity, system storage costs, system durability and operability, charging and discharging rates, fuel quality or dormancy.

For more information, please contact:

Andrew Nesbitt
Chief Executive Officer
Australian Mines Limited
+61 8 9481 5811
investorrelations@australianmines.com.au

Authorised for release by the Board of Directors of Australian Mines Limited

Australian Mines Limited supports the vision of a world where the mining industry respects the human rights and aspirations of affected communities, provides safe, healthy, and supportive workplaces, minimises harm to the environment, and leaves positive legacies.