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Effect of activated alloys on hydrogen discharge kinetics of MgH_2 nanocrystals

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Abstract

Activated alloys synthesized by arc-melting were examined as catalysts for improving the hydrogen sorption characteristics of nanostructured magnesium hydride, proposed as a reversible hydrogen storage material. The MgH_2 -catalyst absorbing materials were prepared by ball milling of pure MgH_2 with hydrided $\text{Zr}_{47}\text{Ni}_{53}$, $\text{Zr}_9\text{Ni}_{11}$, and other investigated alloys. The nanostructured MgH_2 -intermetallic systems were tested at 250 °C and catalyst addition of eutectoid $\text{Zr}_{47}\text{Ni}_{53}$ resulted in the fastest desorption time and highest initial desorption rate. Also, the catalyzed Mg -hydride with activated $\text{Zr}_9\text{Ni}_{11}$ and $\text{Zr}_7\text{Ni}_{10}$ phases showed fast desorption kinetics. Moreover, the results demonstrated that the composition of dispersed Zr_xNi_y catalysts has a strong influence on the amount of accumulated hydrogen and desorption rate of Mg -nanocomposite.

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Keywords: Hydrogen storage materials; Intermetallics; Nanostructures; High-energy ball milling; X-ray diffraction

1. Introduction

Improving reversible hydrogen sorption rates of solid-state stores at moderate temperature are of great technological importance for the adoption of hydrogen for transportation and stationary applications. Among the different metal hydrides types (Fig. 1) developed previously [1], magnesium-based hydrides are of particular interest for hydrogen storage due to the high energy density they can provide (7.6 H-wt.%). From large number of studies available, currently emerges a general perspective that optimum sorption hydrogen storage characteristics may be reached only in catalytically enhanced systems [1,2].

Improved sorption characteristics of nanocrystalline MgH_2 by doping with transition metals and oxides were previously reported. Recent papers by Oelerich et al. [3], Hanada et al. [5] and Skripnyuk et al. [4] give an overview of catalyzed MgH_2 nanocomposites prepared by mechanical milling for the hydrogen storage applications. A storage capacity of 6.5 wt.% after doping MgH_2 with nanosized-Ni in a temperature range

of 150–250 °C was reported by Hanada et al. [5]. Moreover, a remarkable improvement in desorption kinetics was also observed by the same group [6] by using 1 mol% Nb_2O_5 -doped nanostructured MgH_2 at 160 °C under helium flow. More recently, Kojima et al. [7] reported that nano-Ni/ Al_2O_3 /C catalyst composites have a significant effect in enhancing the sorption kinetics of ball milled MgH_2 at 200 °C under vacuum condition.

While such catalysts give substantial rise to the sorption rates, further increase in the kinetic and thermodynamic properties of nanostructured Mg -hydride could be possible by using new activated phases of alloys. The aim of this work is to explore the ability of different binary and ternary metal alloys as catalysts to increase the hydrogen sorption properties of nanostructured magnesium hydride.

2. Experimental details

2.1. Synthesis of the nanocomposite materials

The synthesis of the nanocrystalline Mg -based compounds was accomplished by milling a mixture of elemental magnesium hydride (98% pure, from Th. Goldschmidt AG), with intermetallic alloys powders acting as catalysts. The fraction of catalyst added to MgH_2 represents approximately 10 wt.% in each

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Fig. 1. Pressure–composition isotherms of various types of metal hydrides [1].

case. The mixtures were sealed in a 30 mL hardened stainless steel vial set. The vial was vigorously agitated for 20 h under argon atmosphere. A Spex CertiPrep 8000M mixer (Metuchen, NJ) was used for synthesis of sorption nanocomposites. Details on this nanoscale grinding method were previously described elsewhere [1]. Oxidation and/or hydroxide formation were avoided by storing and handling the samples and starting powders in a glove box filled with pure argon. The alloys were prepared by arc-melting the metallic mixtures in argon atmosphere on a water cooled copper heart. The intermetallic alloys were activated (hydrided) prior to milling by direct reaction with high-pressure hydrogen of 25 atm at 300 °C in the case of Mg_2Ni and at ambient temperature for the other ones.

The other composites were prepared using a similar approach, except for $\text{MgH}_2\text{-(Zr}_7\text{Ni}_{10}\text{-AX21)}$, $\text{MgH}_2\text{-CMgNi}_3$ and $\text{MgH}_2\text{-Zr}_{47}\text{Ni}_{53}$. In the case of $\text{MgH}_2\text{-(Zr}_7\text{Ni}_{10}\text{-AX21)}$ 0.2 mol%, AX21 activated carbon was milled with $\text{Zr}_7\text{Ni}_{10}$ catalyst, and then the resulting catalyst particles were milled with pure MgH_2 for 20 h. The super activated carbon used in the experiment is the well-known AX-21 (Anderson Development Co.) exhibiting a BET surface area of *circa* 2800 m²/g and a total pore volume of 1.1 cm³/g. To prepare $\text{MgH}_2\text{-CMgNi}_3$ 2 mol% nanocomposite, the ternary compound containing Mg–C–Ni (MgCNi_3 , non-oxide perovskite) was first synthesised by synergic combination of mechanical alloying and isothermal heating, according to the procedure reported by Ferretti et al. [8].

The chosen composition of the $\text{Zr}_{47}\text{Ni}_{53}$ alloy (47 wt.% Zr, 53 wt.% Ni) corresponds to an eutectoid composition solidifying at 1070 °C. The alloy was obtained by arc-melting a pellet containing appropriate amounts of ZrH_2 (–325 mesh, 99% pure) and Ni powder (3 μm , 99.7% pure), previously mixed and compressed at a pressure of 15 tonnes/cm², under vacuum. The resulting alloy button was crushed into pieces before being utilized to prepare the composite. One part of these pieces was used in the as-melted condition, while others were annealed 24 h at 1000 °C inside an evacuated-quartz capsule. Two samples of composite were obtained: either with as-cast or with annealed $\text{Zr}_{47}\text{Ni}_{53}$ alloy.

2.2. Characterization and cycling

Changes in thermodynamic and kinetic properties of Mg-hydride nanocomposites were determined by carrying out advanced volumetric hydrogen titration and cycling experiments [1]. The microstructure was determined by scanning electron microscopy (SEM) using a field emission scanning electron microscope Hitachi model S4700. The X-ray diffraction analysis was performed on a Rigaku diffractometer with monochromated $\text{Co K}\alpha$ radiation. Specific surface areas of the sample before and after cycling were determined by the Brunauer, Emmett and Teller (BET) technique using nitrogen in a Quantachrome micro-metric adsorption analyzer at 77 K. Before analyses, heat treatment in a vacuum (10^{-6} atm) at 300 °C was applied for several hours.

The samples were characterized and cycled at 250 and 300 °C under ultra high purity hydrogen absorption pressure of 10 atm and a desorption pressure of 0.25 atm. Instantaneous absorption and desorption hydrogen flow rates were

measured under the same conditions. The hydrogen sorption rates were determined by measuring directly the rates at which hydrogen is added or extracted to or from the sorption nanocomposites to maintain a constant pressure. The hydrogen sorption rates were monitored by a Brooks's mass flow rate controller. Before starting every absorption/desorption experiment, 200 mg-samples were outgassed for at least 30 min at a vacuum pressure of 10^{-6} atm.

3. Results and discussion

Results of the activation of various Zr_xNi_y alloys are presented in Fig. 2. Generally, the alloys formed stable hydrides at ambient temperature. After activation, ZrNi absorbed nearly 2.50 H-wt.%, while $\text{Zr}_7\text{Ni}_{10}$ and $\text{Zr}_9\text{Ni}_{11}$ absorbed about 1.40 H-wt.%. The activation process metamorphosed alloys into fine powders. This transformation was beneficial since it generated a more homogeneous catalyst particle distribution after milling. Indeed, it was observed that the catalytic enhancements were more important when the hydrogenated catalysts were milled with MgH_2 [1].

Before starting the desorption and PCT experiments, the Mg-based nanocomposite samples were cycled until the desorption rates were stabilized. Dynamic desorption experiments at 250 °C were undertaken on MgH_2 -catalyst sorption materials (Fig. 3a and b), and the corresponding desorption flow rates were obtained at 250 and 300 °C (Fig. 4a and b).

Desorption kinetic properties calculated from measured curves are listed at Table 1. The oscillations observed on the kinetic curves of Fig. 4a were ascribed to the relatively small difference between desorption plateau pressures and hydrogen pressure in the reactor. Such oscillations were not displayed on the desorption flow rate curves obtained at 300 °C, since the pressure variations in the reactor were negligible in comparison to the driving pressure at the same temperature. It should also be noted that the kinetic measurements at 250 °C showed a better representation of the influence of the various catalysts, since hydrogen diffusivity in the sorption material, which increases with temperature, is by far less important at 250 °C than 300 °C. At high temperatures, high hydrogen diffusivity effectively hides the catalytic effect of the alloys. Considering the time at which the hydrogen desorption flow rates became approximately nil

Fig. 2. Activation of Zr_xNi_y catalysts at 23 °C and 25 atm.

Fig. 3. (a) Desorption kinetics of different Mg-nanocomposites at 250 °C. (b) Desorption kinetics of selected Mg-nanocomposites at 250 °C.

on the 250 °C curves, important variations of this time occurred with different catalysts. However, at 300 °C, this time is approximately equal for all catalysts, indicating that dehydrogenation at this temperature does not significantly depend on the inter-metallic alloys catalytic properties.

Catalytic addition of Zr₄₇Ni₅₃ to MgH₂ resulted in the fastest desorption time and highest initial desorption rate, which are 11 min and 0.71 H-wt.%/min, respectively (Fig. 3a). The maximum flow rate of 20.4 cm³/(min g) measured at 250 °C on MgH₂-Zr₄₇Ni₅₃ 10 wt.% was also the highest among all the samples (Fig. 4a). This result constitutes a significant improvement in comparison to that obtained with nanocrystalline MgH₂, which desorbed the hydrogen in about 90 min at 300 °C [1]. Annealing the sample increased the desorption time by a small factor, reaching 13 min, while desorption rate decreased slightly to 0.66 H-wt.%/min. The maximum flow rate at 250 °C diminished somewhat to 17.8 cm³/(min g) when MgH₂-Zr₄₇Ni₅₃ 10 wt.% was annealed. The second most efficient catalyst of the set studied in this work was Zr₉Ni₁₁.

MgH₂-Zr₉Ni₁₁ 0.2 mol% nanocomposite desorbed hydrogen in approximately 16 min at 250 °C, its initial desorption rate was 0.52 H-wt.%/min and its maximum flow rate was approximately 19.0 cm³/(min/g) at 250 °C. The nanocomposite MgH₂-Zr₉Ni₁₁ 0.2 mol% takes 5 min more than MgH₂-Zr₄₇Ni₅₃ 10 wt.% to desorb hydrogen, but the former can absorb 0.5 H-wt.% more than the latter. The worst discharge time, around 77 min, was obtained with MgH₂-Mg₂Ni 2 mol% nanocomposite. Furthermore, the results show (Fig. 3b) that Zr₇Ni₁₀ alloy concentration had a strong effect on the desorption characteristics of the composite. Among all the samples, the highest and lowest desorbed hydrogen amount measured were respectively 6.01 H-wt.% and 4.50 H-wt.%.

Pressure-composition isotherms were also obtained at 250 and 300 °C for each of MgH₂ samples added with various catalysts (Fig. 5a and b). Table 2 depicts the isothermal sorption properties extracted from the PCT curves as displayed in Fig. 5a and b. The intermetallics significantly increased desorption plateau pressure of MgH₂. Since the plateau pressures decreased exponentially with diminishing temperature,

Fig. 4. (a) Dehydrodrating rates of different Mg-nanocomposites at 250 °C. (b) Dehydrodrating rates of different Mg-nanocomposites at 300 °C.

lifting desorption plateau pressures are necessary to obtain a material that desorbs hydrogen at lower temperatures. The relatively high plateau pressures at 250 and 300 °C generated sufficient driving force to allow hydrogen desorption,

which represents a major improvement with respect to pure MgH₂.

While higher desorption plateau pressures are linked to faster hydrogen discharge, other factors such as hydrogen diffusivity in

Table 1

Desorption kinetic properties of different ball-milled Mg-nanocomposites (initial pressure of 1 psia and initial discharge rates calculated between 0 and 5 min)

Sample	Initial discharge rate at 250 °C (H-wt.%/min)	Discharge capacity at 250 °C (H-wt.%)	Discharge time at 250 °C (min)	Peak flow rate at 250 °C (cm ³ /(min g))	Peak flow rate at 300 °C (cm ³ /(min g))
MgH ₂ -Mg ₂ Ni 2 mol%	0.05	6.01	77	8.5	101.5
MgH ₂ -TiAl _{0.1} V _{0.04} 5 mol%	0.13	5.77	54	11.1	115.9
MgH ₂ -ZrNi 1 mol%	0.12	5.90	56	14.2	130.9
MgH ₂ -CMgNi ₃ 2 mol%	0.12	5.68	55	9.3	107.0
MgH ₂ -Zr ₇ Ni ₁₀ 0.2 mol%	0.20	5.91	34	15.7	133.4
MgH ₂ -V 3 at.%-Ti 2 at.%	0.31	5.59	32	11.7	153.9
MgH ₂ -Zr ₉ Ni ₁₁ 0.2 mol%	0.52	5.88	16	19.0	141.2
MgH ₂ -Zr ₄₇ Ni ₅₃ 10 wt.% (annealed)	0.66	5.37	13	17.8	140.9
MgH ₂ -Zr ₄₇ Ni ₅₃ 10 wt.%	0.71	5.42	11	20.4	165.6
MgH ₂ -(Zr ₇ Ni ₁₀ -AX21) 0.2 mol%	0.13	5.64	45	N/A	N/A
MgH ₂ -Zr _{0.33} Cr _{0.33} Ni _{0.33} 4 mol%	0.22	4.96	32	N/A	N/A
MgH ₂ -Ti _{0.2} Zr _{0.8} Ni 2 mol%	0.35	4.50	20	N/A	N/A
MgH ₂ -Ti _{0.39} Ni _{0.61} 5 mol%	0.19	4.86	35	N/A	N/A

Fig. 5. (a) Pressure–composition isotherms of different Mg-nanocomposites at 250 °C. (b) Pressure–composition isotherms of different Mg-nanocomposites at 300 °C.

the absorbing nanomaterial influence desorption times. Indeed, the MgH₂-Zr₇Ni₁₀ 0.2 mol% and MgH₂-(Zr₉Ni₁₁) 0.2 mol% nanocomposites have nearly equal desorption plateau pressures at 250 °C, but the former takes two times more to desorb hydrogen than the latter. Moreover, the desorption plateau pressure of MgH₂-Mg₂Ni 2 mol% is among the highest measured for all the samples, while it desorbs hydrogen completely within the longest period of time. This indicates that the catalysts do not only lift desorption plateau pressures, but also have a strong effect on the overall hydrogen desorption kinetics of MgH₂ nanocomposites.

Mg crystallite sizes were estimated by X-ray diffraction experiments (Table 3). It is clear that the nature of the catalyst milled with MgH₂ had an important influence on Mg grain size. However, it is clearly shown that the kinetic enhancements were not solely due to Mg crystal reduction. Indeed, the smallest estimated nanocrystallite was obtained for MgH₂-ZrNi 1 mol% nanocomposite, but ZrNi ranks among the alloys providing the least kinetic improvements, proving that the intermetallic compounds themselves have played a truly intrinsic catalytic role in hydrogen desorption. BET specific surface area analyses were undertaken on some of catalyzed MgH₂ samples. MgH₂-Zr₉Ni₁₁ 0.2 mol%, which desorbs hydrogen completely

approximately twice as fast as MgH₂-V 3 at.-%-Ti 2 at.%, has a specific surface area of 20.3 m²/g, while the measured value for MgH₂-V 3 at.-%-Ti 2 at.-% was 12.3 m²/g after cycling [9]. Figs. 6 and 7 show the X-ray crystal structure and SEM micrographs analysis carried out on MgH₂-Zr₄₇Ni₅₃ nanoma-

Fig. 6. X-ray diffraction patterns performed on MgH₂-Zr₄₇Ni₅₃ nanocomposite before and after cycling.

Table 2
Isothermal sorption properties of various ball-milled Mg-nanocomposites

Temperature (°C)	Absorption plateau pressure (atm)	Desorption plateau pressure (atm)	Maximum H (wt.%)	Absorption plateau slope (d ln(P)/d H/M)	Desorption plateau slope (d ln(P)/d H/M)	Hysteresis (ln(P _{abs} /P _{des}))
MgH₂–Mg₂Ni 2 mol%						
250	0.65	0.19	6.21	0.97	0.67	1.22
300	2.53	1.39	6.08	0.67	0.12	0.60
MgH₂–TiAl_{0.1}V_{0.04} 5 mol%						
250	0.88	0.10	6.09	2.50	0.29	2.15
300	2.54	1.00	6.00	1.03	1.61	0.93
MgH₂–ZrNi 1 mol%						
250	0.70	0.16	6.34	1.56	1.92	1.50
300	2.25	1.16	6.14	0.73	0.67	0.66
MgH₂–CMgNi₃ 2 mol%						
250	0.87	0.10	5.69	1.93	1.85	2.18
300	3.36	1.14	5.64	1.47	0.88	1.08
MgH₂–CMgNi₃ 2 mol%						
250	0.64	0.20	5.59	1.2	0.85	1.17
300	2.31	1.28	5.81	0.63	0.33	0.59
MgH₂–V 3 at.%–Ti 2 at.%						
250	0.67	0.17	5.60	2.48	1.17	1.38
300	1.74	1.04	5.88	0.91	1.00	0.52
MgH₂–Zr₉Ni₁₁ 0.2 mol%						
250	0.67	0.21	5.95	1.88	1.86	1.16
300	2.10	1.30	6.03	0.63	0.27	0.48
MgH₂–Zr₄₇Ni₅₃ 10 wt.% (annealed)						
250	0.66	0.23	5.75	1.03	0.14	1.05
300	2.21	1.34	5.65	0.62	0.04	0.50
MgH₂–Zr₄₇Ni₅₃ 10 wt.%						
250	0.60	0.25	5.80	2.20	1.64	0.87
300	2.06	1.28	5.74	0.68	0.05	0.48
MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol%						
250	0.54	0.17	5.64	1.65	0.76	1.16
300	2.01	1.29	5.72	0.91	0.26	0.44
MgH₂–Zr_{0.33}Cr_{0.33}Ni_{0.33} 4 mol%						
250	0.65	0.19	5.31	1.65	0.97	1.24
300	2.09	1.29	5.36	0.89	0.38	0.49
MgH₂–Ti_{0.2}Zr_{0.8}Ni 2 mol%						
250	0.48	0.25	4.96	0.31	1.95	0.64
300	2.26	1.46	5.34	1.44	0.19	0.44
MgH₂–Ti_{0.39}Ni_{0.61} 5 mol%						
250	0.71	0.17	5.08	2.42	1.95	1.42
300	2.41	1.32	5.00	1.23	0.30	0.60

terial before and after cycling. The pattern after 1000 cycles reveals zirconium peak disappearance; this can be ascribed to Zr nanocrystals amorphization. The micrographs reveal that in the ball-milled state the nanocomposite particles have a dense structure whereas during the hydrogen absorption and desorption cycling the particles became porous with nanopores randomly distributed in the particles (Fig. 7).

Activated carbon was milled with Zr₇Ni₁₀ in order to verify if such addition would result in kinetic enhancements. It was believed that carbon would favour a more efficient catalyst particle distribution. Moreover, recent studies have demonstrated that co-milling metal hydrides with carbon improves hydrogen sorption kinetics [10–16], suggesting that carbon plays a cat-

alytic role. Zr₇Ni₁₀ was chosen for the experiment, among the Zr_xNi_y catalysts investigated in this work, because this particular composition is easier to activate, thus easier to turn into a fine powdery form. Unfortunately, AX21 addition had a detrimental effect on the desorption kinetics by raising the discharge time from 34 to 45 min and decreasing the discharge rate from 0.20 to 0.13 H-wt.%/min. Fig. 8 shows the X-ray diffraction patterns taken on MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol% and MgH₂–Zr₇Ni₁₀ 0.2 mol% after cycling. Mg₂Ni peaks are present in both curves, but the peak intensity at $2\theta = 52.4^\circ$ is much higher in the pattern of MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol%. Mg₂Ni peaks are also found in the diffraction patterns of every other MgH₂–Zr_xNi_y catalyst. The other difference between both curves shown in

Table 3

Mg crystallite size of the different ball-milled nanomaterials

Nanocomposite	Mg crystallite size (nm)
MgH ₂ –Mg ₂ Ni 2 mol%	52
MgH ₂ –TiAl _{0.1} V _{0.04} 5 mol%	52
MgH ₂ –ZrNi 1 mol%	37
MgH ₂ –CMgNi ₃ 2 mol%	49
MgH ₂ –Zr ₇ Ni ₁₀ 0.2 mol%	38
MgH ₂ –V 3 at.%–Ti 2 at.%	54 ^a
MgH ₂ –Zr ₉ Ni ₁₁ 0.2 mol%	43
MgH ₂ –Zr ₄₇ Ni ₅₃ 10 wt.% (annealed)	40
MgH ₂ –Zr ₄₇ Ni ₅₃ 10 wt.% (uncycled)	45
MgH ₂ –Zr ₄₇ Ni ₅₃ 10 wt.%	44
MgH ₂ –(Zr ₇ Ni ₁₀ –AX21) 0.2 mol%	46
MgH ₂ –Zr _{0.33} Cr _{0.33} Ni _{0.33} 4 mol%	42

^a See [9] for details.

Fig. 8, is related to the presence of ZrC peaks in the pattern of MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol% suggesting that milling carbon structures with Zr_xNi_y alloys increases the concentration of Mg₂Ni in the sample. It is believed that the observed kinetic slowdown of MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol% can be attributed to such a reduction phenomenon. Following milling and cycling, less catalyst particles in Zr_xNi_y form are present in the sample due to the high reactivity of zirconium with carbon, diminishing thus, the catalytic enhancements.

In order to find alternative intermetallic catalyst systems for improving desorption kinetic of nanocrystalline MgH₂, preliminary investigations on the catalysis potential featured by ternary compounds were carried out. With regard to MgH₂–MgCNi₃

Fig. 7. SEM micrographs taken on MgH₂–Zr₄₇Ni₅₃ 10 wt.% nanocomposite: (a) before and (b) after cycling.

Fig. 8. X-ray patterns taken on MgH₂–(Zr₇Ni₁₀–AX21) 0.2 mol% and MgH₂–Zr₇Ni₁₀ 0.2 mol% after cycling.

nanocomposites, the trend of the structural and superconductive parameters of the ternary catalyst compounds versus the rate and amount of the accumulated hydrogen was never investigated. The X-ray diffraction pattern of the milled and heated Mg₂NiH₄ and AX21 mixture is displayed at Fig. 9. This pattern confirms the formation of CMgNi₃ as well as the presence of traces of Mg₂Ni and graphite. The sorption results show that the catalytic ad-mixing of CMgNi₃ enhanced the discharge performance of MgH₂ by a factor of two, in comparison to the results obtained with the Mg₂Ni-doped MgH₂ hydride. Indeed, MgH₂–CMgNi₃ nanocomposite desorbed hydrogen with initial flow rate of 0.12 H-wt.%/min at 250 °C while MgH₂–Mg₂Ni desorbed hydrogen at lower initial flow rate of 0.05 H-wt.%/min.

More experimental analysis using various ternary alloy catalysts were also investigated and presented in Figs. 3a, 5a and 5b. The sorption experiments showed that the catalytic behaviours of these alloys and their influence on the dehydrogenation properties of MgH₂ nanocrystals were very different. The Ti_{0.2}Zr_{0.8}Ni alloy revealed to be the most active and induced the lowest discharge capacity.

Fig. 9. X-ray patterns taken after milling AX21 and Mg₂NiH₄ and heating the mixture.

4. Concluding remarks

- Hydrogen unloading results demonstrate that doping nanostructured Mg-hydride with activated alloys yields increased desorption kinetics and substantial reduction of discharge temperature of MgH_2 nanocrystals.
- $\text{Zr}_9\text{Ni}_{11}$ and $\text{Zr}_7\text{Ni}_{10}$ enhance kinetics, but not as much as eutectoid $\text{Zr}_{47}\text{Ni}_{53}$.
- The results also establish that, the stoichiometry of Zr_xNi_y catalysts has a strong influence on desorption kinetic properties. Indeed, $\text{MgH}_2\text{--Zr}_7\text{Ni}_{10}$ 0.2 mol% desorbs hydrogen in about twice the time taken in the case of $\text{MgH}_2\text{--Zr}_9\text{Ni}_{11}$ 0.2 mol%.
- $\text{MgH}_2\text{--Zr}_{47}\text{Ni}_{53}$ nanocomposite exhibits improved sorption and microstructure stability during cycling.
- The $\text{Zr}_7\text{Ni}_{10}$ catalyzed Mg-hydride ground with activated carbon show a reduction in the dehydriding rate, while the CMgNi_3 catalyst exhibits increased desorption flow.

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