STUDY ON THE HYDROGEN STORAGE PROPERTIES OF $NaAlH_4$ COMPOSITES USING TAGUCHI METHOD.

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Abstract

Hydrogen is the perfect energy carrier for future transport, such as automotive applications. Hydrogen has attracted a great deal of interest among researchers as an ideal energy carrier used as a medium for transport and energy storage. In this study, the Taguchi Method is chosen as an effective statistical approach for analysing optimum factors and response in the selection of improved hydrogen storage properties of $NaAlH_4$. One of the most useful solid hydrogen storage materials is $NaAlH_4$. Researchers have widely studied complex metal hydride composites in the form of ABH_4, where A is an alkali metal and B is a group III element, previously in solution as proton acceptors to increase H_2 adsorption abilities. In this study, two factors, namely materials and catalysts, were considered for the optimum condition of onset decomposition temperature, activation energy, and hydrogen release, and whether the factors were important or negligible. Data were analysed using the ratio of signal to noise (S/N) and the variance of analysis (ANOVA). Secondary data from previous research were used to analyse using the Taguchi method. The ANOVA analysis results show that catalyst shows significant effect for the decomposition of temperature and activation energy. In the other hand, material show it is insignificant for all the parameters. Based on the "smaller the better" reaction of the decomposition temperature, the optimum amount and factors for the overall S/N ratio are $NaAlH_4$_$LiBH_4$ without catalyst at 125°C. In the case of hydrogen release, the "larger the better" the optimum conditions are the $NaAlH_4$_$LiBH_4$ material with NbF_5 catalyst at 8wt. %. In the meantime, the $NaAlH_2$_MgH_2 material is the best criterion for activation energy which, is "smaller, the better" for optimum conditions without a catalyst at 54.3kJ/mol. The signal-to-noise ratio study showed that the catalyst had the most important effect on the control parameters tested. Therefore, the Taguchi method can be an excellent technique for enhancing the potential preparation of selective materials and catalysts for hydrogen storage.

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1. Introduction

1.1 Background of Study

For potential transport systems, such as automobile applications, hydrogen is the ideal energy carrier. Hydrogen has drawn a lot of interest from scientists as an energy carrier used as a means to move and store energy. Hydrogen preservation in solid form is one of the alternate methods [1] owing to its high gravimetric potential and the desirable protection criteria relative to compressed gas and liquid hydrogen storage. In this way, one of the main obstacles in building the hydrogen economy is hydrogen storage. Future storage requirements may not be met by comparatively advanced storage facilities, such as high-pressure gas or liquids. Among other products, chemical or mechanically combined hydrogen retention has possible benefits over other types of storage. Intensive research on metal hydrides to reinforce hydrogenation properties has recently been conducted [2].

As a hydrogen storage medium, $NaAlH_4$ was particularly essential since it was noticed that $NaAlH_4$ could reversibly store and release hydrogen when doped with Ti in 1997. Later, doping of $NaAlH_4$ with metal catalysts was documented, and numerous doping techniques, including direct ball milling synthesis and wet chemical reaction, were developed. The inclusion of catalysts helps to adjust the hydrogen storage properties of $NaAlH_4$ efficiently, thus improving the dehydrogenation and reversibility kinetics. In the creation of active species in the catalyzed NaAlH4, catalysts play a crucial function, either during ball milling or during the desorption phase [3].

To improve the hydrogen storage potential of $NaAlH_4$, numerous experiments have been carried out, such as doping with different forms of catalysts and destabilization with other hydrides [1, 4-17]. It is important to implement the principle of destabilizing or reactive hydride composites. To build a new intermediate to permit hydrogen discharge properties and thermodynamics and kinetics, at least two hydrides are consolidated and exothermically reacted. Using this theory, researchers have proposed a number of studies on these materials [1].

1.2 Problem Statement

So far, detailed attempts have been reported on how to improve the storage properties of $NaAlH_4$ hydrogen by introducing a catalyst or nanoconfinement[18]. To increase the hydrogen storage ability of $NaAlH_4$, a range of studies have been performed, such as doping with various forms of catalysts and destabilization with other hydrides[1, 4-17]. To evaluate the optimum state of materials and catalysts, the Taguchi process is used to know the materials and catalysts are appropriate for obtaining the optimum condition of the temperature of initial decomposition, activation energy and amount releases of hydrogen and if they are significant or insignificant. Taguchi defines the 'log' function of the target output as the objective function for data processing and optimization as Signal-to-Noise Ratios (S/N). The optimal architecture is selected[19] because of the best control factor ranges with the maximum S/N ratios. Signal to noise (S/N) ratio data used to analyze a control factor optimum situation and ANOVA analysis data used to analyze a control factor important. In this study, the data from previous research were used to be analyzed using the Taguchi approach in this report.

1.3 Objective

To perform:

1. Analysis of variance (ANOVA) on decomposition temperature, hydrogen release, and activation energy. **(Maimunatun Nawar Mohd Yazan)**
2. Analysis of signal to noise (S/N ratio) on optimum decomposition temperature, hydrogen release and activation energy. **(Iffat Asymawie Mod Zahari)**, **(Nurul Izzah Ahmad Shakri)**,**(Nur Diana Abd Razak)**

2. Literature Review

2.1 Previous Research

Previous experiments have used many methods for researching the properties of hydrogen storage and the catalytic role of composites of hydrogen energy ($NaAlH_4$). The solid-state storage materials widely researched are metal hydrides and complex hydrides. Since it was noticed in 1997[20] that $NaAlH_4$ is capable of reversibly storing and releasing hydrogen when doped with Ti, $NaAlH_4$ has been of special interest as a hydrogen storage medium. $NaAlH_4$ doping with metal catalysts has subsequently been reported and numerous doping techniques, including direct ball milling synthesis [21] and wet chemical reaction[22] have been established. The inclusion of catalysts tends to effectively modify the hydrogen storage properties of $NaAlH_4$ and, as a result, increase the kinetics and reversibility of dehydrogenation[6]. Catalysts play a crucial function, either during ball milling or in the desorption process, in shaping active species in the catalyzed $NaAlH_4$. NbF_5-doped $NaAlH_4$, for example, increased the desorption temperature at 125 ° C, followed by hydrogen release of approximately 4.5 wt. H_2 percent[4]. It also registered a dehydrogenation rate that was approximately three to four times higher than its counterpart[3].

Ogdanovic and Schwickardi stated in 1997[4], that their groundbreaking work was that $NaAlH_4$ could reversibly absorb and absorb hydrogen after doping with a Ti-based catalyst under moderate conditions[20]. Because of its comparatively high hydrogen ability, the research of $NaAlH_4$ as a functional hydrogen storage medium has since aroused considerable interest. NbF_5 has recently been an effective catalyst for lowering the temperature of dehydrogenation and improving the sorption kinetics of magnesium hydride[23], and borohydride[24]. Intensive catalytic action against the activation of Mg-H and B-H bonds and the dissociative chemisorption of hydrogen molecules has been shown to have Nb-based catalysts. More recently, Ismail et al. have also shown that by incorporating NbF_5, the desorption properties of $LiAlH_4$ can be greatly improved, suggesting NbF_5's catalytic function against the weakening of the Al-H bond[25]. The low reversibility of $LiAlH_4$, however, renders NbF_5-doped $LiAlH_4$ unsuitable for functional usage as a hydrogen storage material[4].

Much of the study on the coordination of hydrogen hydride storage materials carried out over the last few decades has concentrated on improving low reversibility, reducing high reaction temperatures, and improving poor kinetic efficiency. $NaAlH_4$ is a successful hydrogen storage nominee, and Jepsen et al. [26] stated that $NaAlH_4$ mass production is entirely feasible. The potential storage ability of $NaAlH_4$ for hydrogen will exceed 7.3wt. Percentage (<500 °C) in three phases, 5.5wt.%. For realistic purposes, percent (<300 °C) is known to serve[27]. However, due to its sluggish desorption kinetics, the functional