CHAPTER I

INTRODUCTION

Hydrogen is considered as a promising alternative energy carrier due to its efficiency, cleanness. In addition, it can be derived from sustainable and renewable energy sources such as biomass, hydro, wind, solar, and geothermal. Hydrogen can be used as fuel in either internal combustion engines or fuel cell applications. Thus, it is aimed as fuel employed in vehicular applications, being used instead of fossil fuel. However, a major difficulty in such the hydrogen utilization is hydrogen storage due to its low molecular weight leading to low energy density in volumetric basis.

Hydrogen storage technology can be divided into three groups. Compressed hydrogen gas in high pressure cylinder and cryogenic hydrogen storage systems are the conventional technology. Although these two technologies have been employed with a prototype hydrogen power vehicle; volumetric constraint, safety concerns and economic point of view are still barriers to utilize them commercially. These reasons lead to further hydrogen storage technology development, which is solid state hydrogen storage. This method stores hydrogen by using solid media materials as a hydrogen carrier such as hydride materials and nanostructure materials (Satyapal *et al.*, 2007). Although solid state hydrogen storage seems to be promising to use with automotive applications, their disadvantages include low reversible hydrogen capacity, too high desorption temperature, and low hydrogen desorption rate. Thus, none of solid state materials has met the target for a successful transition to hydrogen-fueled transportation specified by the US Department of Energy (DOE), which requires the hydrogen storage capacity more than 6 wt% and energy density more than 5.4 MJ L^{-1} (http://www.sc.doe.gov/bes/hydrogen.pdf).

Previously, many attempts have been made to improve and identify materials that can be applied for on-board hydrogen storage for fuel cell applications. Metal hydrides are considered to be attractive hydrogen storage media because they can be modified and improved for their reversibility, hydrogen desorption rate and temperature of hydrogen desorption. Among many studied hydrides, sodium aluminum hydride or sodium alanate ($NaAlH_4$) seems to be a prominent racer. $NaAlH_4$ can reversibly desorb/absorb hydrogen under relatively mild conditions

when $NaAlH_4$ is doped with Ti-based catalyst (Bogdanovic and Schwickardi, 1997). However, its reversible hydrogen capacity is still low, not to the DOE target yet. In addition, more understanding on the hydrogen desorption/re-absorption mechanism of $NaAlH_4$ is needed for further development of hydrogen storage materials.

The main purpose of this thesis was to develop the reversible hydrogen capacity of $NaAlH_4$. Firstly, effects of transition metals ($TiCl_3$, $ZrCl_4$, $HfCl_4$, and VCl_3) on the hydrogen desorption/re-absorption of $NaAlH_4$ were studied. It was found that the formation of a by-product, $NaCl$, from metal chloride and the segregation of the desorbed hydride cause the lower reversible hydrogen capacity of $NaAlH_4$. Consequently, other forms of metal, Ti and TiO_2, were used as an additive in $NaAlH_4$ in stead of metal chloride. Carbon materials (graphite, activated carbon, and carbon nanotubes) were co-doped in $NaAlH_4$ to prevent the segregation and to increase the hydrogen diffusion in the desorbed hydride. In addition, possibility in using carbon nanotubes as hydrogen storage medium was also investigated.