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Jason Graetz, John J. Vajo

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Controlled Hydrogen Release from Metastable Hydrides

Jason Graetz and John J. Vajo
HRL Laboratories, LLC
3011 Malibu Canyon Road, Malibu, CA 90265 USA

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Abstract

Metastable hydrides are an interesting class of hydrogen carrier since many offer high volumetric and gravimetric hydrogen densities and rapid hydrogen release rates at low temperatures. Unlike reversible metal hydrides, which operate near equilibrium, metastable hydrogen carriers rely on kinetic barriers to limit or prevent the release of hydrogen and can be prepared in a stabilized state far from equilibrium. Despite the advantage of low temperature hydrogen release, this type of one-way thermolysis reaction can be difficult to control since the hydrogen release rate varies with temperature and composition. Here we developed a kinetic rate equation from a series of isothermal measurements, which describes the relationship between temperature, hydrogen release rate and composition for aluminum hydride. This equation is necessary to thermally control the rate of hydrogen release throughout decomposition. This equation was used to run a fuel cell at a controlled rate of ~1 wt%/hr. Although the equation established in this paper relates specifically to aluminum hydride, the method used is applicable to other metastable hydrides.

1. Introduction

Hydrogen is a versatile fuel that can easily be converted into useful energy, either through combustion (e.g., internal combustion engine) or through a fuel cell where it can be used to generate electricity for portable electronics, vehicles or stationary applications. However, the challenge of hydrogen storage continues to limit the widespread use of hydrogen, especially at the small and medium scales (e.g., << 1 kg H_2) where high pressure or cryogenic systems become less practical. Metal hydrides may provide a solution to hydrogen storage since they exhibit high volumetric hydrogen densities (2x the density of liquid hydrogen) and are reasonably scalable since they often uptake and release hydrogen under moderate temperatures and pressures.

The release of hydrogen from a metal hydride can be initiated through a variety of methods, the most common of which is a thermolysis reaction (temperature stimulated hydrogen release), where the temperature of the hydride is raised above the equilibrium temperature for a given hydrogen partial pressure. Conversely, hydrogen uptake occurs when the temperature is lowered below the equilibrium temperature for a given partial pressure. In this scenario, the rate of