Storage and usage of hydrogen

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1. Introduction [1]

Hydrogen is considered to be the most promising new energy carrier to replace fossil fuels. The use of hydrogen in practical applications such as fuel cell driven vehicles and portable-devices, however, requires the development of safe and efficient hydrogen storage technologies/materials. High-pressure (>35 MPa) and cryogenic (< 20 K) hydrogen storage technologies may not be so practical for the applications due to safety concerns and weight/volumetric constraints. This has prompted challenging efforts to develop solid–state hydrogen storage materials; exhibiting, for example, hydrogen densities greater than 5–6 mass% (hydrogen per total weights), reaction temperatures/pressures lower than 423 K/15 MPa.

“Metal borohydrides”, with the composition of $M(BH_4)_n$ containing wide variation of metals (M), boron (B), and hydrogen (H), have attracted growing interest due to their high hydrogen density (7–18 mass%). Theoretical and experimental studies to optimize the thermal stability (or “lower the reaction temperature”, because of ones mostly higher than 423 K) of $M(BH_4)_n$ as advanced hydrogen storage materials are to be explained in the following section 2.

Also, the recent researches have successfully revealed multi–functional aspects of $M(BH_4)_n$, viewpoint from energy–saving microwave processing, advanced neutron shielding for fusion reactor, and some other topics; all relating to future energy needs. Parts of them will be briefly described the section 3.

2. Metal Borohydrides for Hydrogen Storage Needs [2-5]

Hydrogen storage properties of the series of metal borohydrides $M(BH_4)_n$ (M = Li, Na, K, Mg, Ca, Cr, Cu, Zn, Al, Sc, V, Y, Ti, Zr, Hf, and their combinations; n = 1–4) have been investigated theoretically and experimentally.

The theoretical study on bonding nature of $M(BH_4)_n$ indicated that the charge transfer from M to BH_4 complex is a key feature for the stability of $M(BH_4)_n$. Moreover a good correlation between the stability of $M(BH_4)_n$ and electronegativity of M can be found, which is represented by a simple linear relation. $M(BH_4)_n$ were actually synthesized via metathesis reaction; $MCl_n + nLiBH_4 \rightarrow M(BH_4)_n + nLiCl$. Then the reaction properties of $M(BH_4)_n$ were investigated experimentally. The results indicate that the hydrogen desorption temperatures of $M(BH_4)_n$ lower efficiently with increasing the value of electronegativity of M.

Therefore, M (or their combinations) with appropriate values of electro- negativity can be selected to optimize the stability (and "lower the reaction temperature) of $M(BH_4)_n$, depending on the application fields of hydrogen storage.

3. Metal Borohydrides for Future Energy Needs

3.1 Energy–Saving Microwave Processing [6,7]

The effects of microwave irradiation on metal borohydrides, such as $LiBH_4$, $NaBH_4$, and KBH_4, were investigated experimentally. $LiBH_4$ was self-heated by microwave absorption at a temperature above 380 K, at which more than 13 mass% of hydrogen is rapidly desorbed. This is due to a change in the conductivity accompanied by a structural transition of $LiBH_4$. The energy-saving microwave processing will be suitable integrated with the hydrogen storage technology.

3.2 Advanced Neutron Shielding [8]

Neutron transport calculations were performed, by Drs. T. Hayashi and K. Tobita, Japan Atomic Energy Agency (JAEA), to evaluate the capability of metal borohydrides as advanced shielding materials of fusion reactor. $Mg(BH_4)_2$ can reduce the thickness of the outboard shield by 23 %, compared to the combination of steel and water. A mixing $Mg(BH_4)_2$ with steel produces large effects also in the gamma-ray shielding. Experimental studies are now being carried out.

4. Conclusion

"Metal borohydrides" provide rather rich chemistry, physics, and materials science; all relating to hydrogen and the other future energy needs. Further fundamental and applicational studies on them are highly expected.

5. References

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