Aluminum-Rich Bulk Alloys: an Energy Storage Material for Splitting Water to Make Hydrogen Gas on Demand

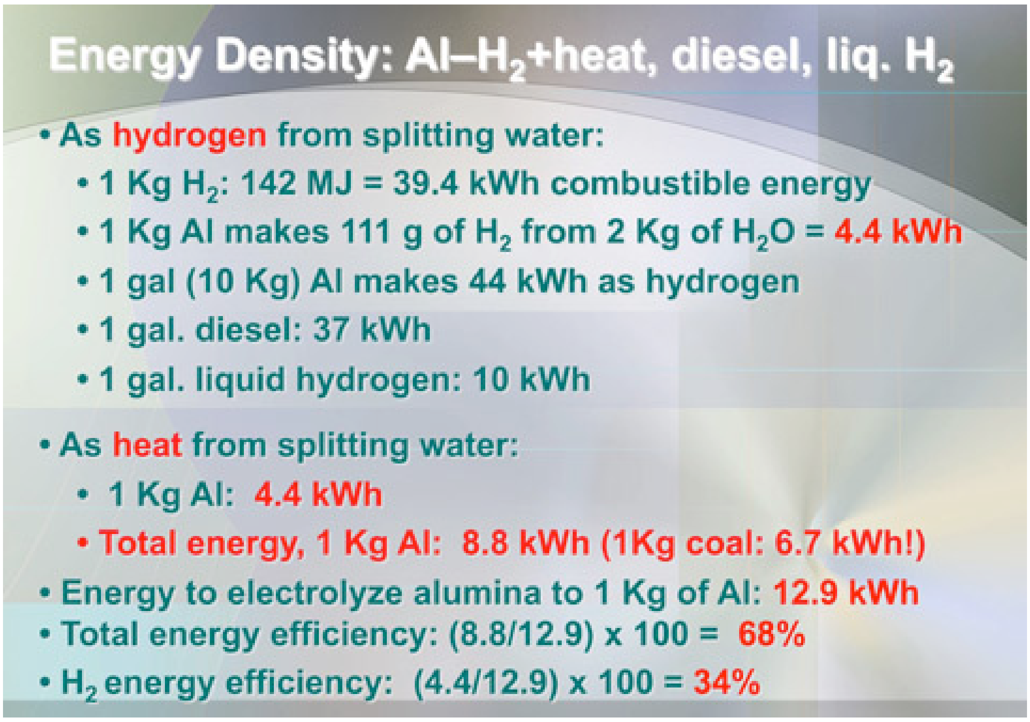
The two major barriers to realizing a viable large-scale hydrogen economy are hydrogen storage and economically viable “green” hydrogen production. The current two preferred methods of hydrogen generation are water electrolysis and the decomposition of natural gas (methane). Even though both methods are approaching economic viability neither of them are “green.” Electrolysis to make hydrogen, although green in itself, uses grid electricity which is produced by burning coal; hence, electrolytically produced hydrogen gas is not green. Methane, CH_4, when oxidized to produce hydrogen gas, also produces carbon dioxide, and water; hence, it is also not green.

Online Resources

nanoHUB	Online presentation [Aluminum: a safe, economical, high energy density material for energy storage, transport and splitting water to make hydrogen on demand]
YouTube	YouTube [http://www.youtube.com/watch?v=dhroR7oELwA]
YouTube	YouTube: Hydrogen powered engine demonstration
YouTube	YouTube: Aluminum-water reaction generating hydrogen demonstration
NPR	NPR: Talk of the Nation [Scientists Seek New Ways to Generate Hydrogen]

Energy Density

Hydrogen is stored mainly in very high-pressure tanks, liquid hydrogen, metal hydrides, etc. All, methods to date suffer from low energy density, either as low mass density or low volume density. And most methods suffer issues of reversible hydrogen liberation and regeneration.



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On the other hand Al metal is a safe, abundant, renewable, high energy density *(see above)* material that when formed into an Al-rich alloy with only a 5 wt% mixture of gallium (Ga), indium (In), and tin (Sn), will efficiently and rapidly split water the make hydrogen on demand, *(see images 1 and 2)*. Since the small Ga and In components are expensive but inert *(see image 3)*, they can economically be recovered by mechanical separation, e.g. using a centrifuge.


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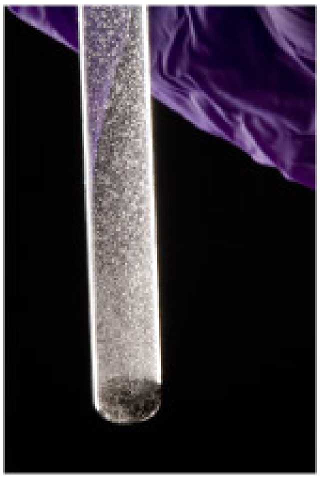
95 wt.% Al – 5 wt.% GaInSn (vendor alloy)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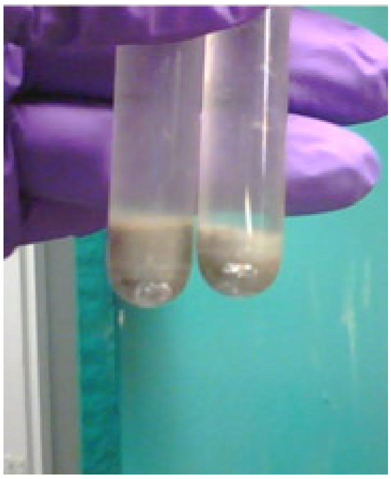
A sample of “50-50” Al-GaInSn splitting water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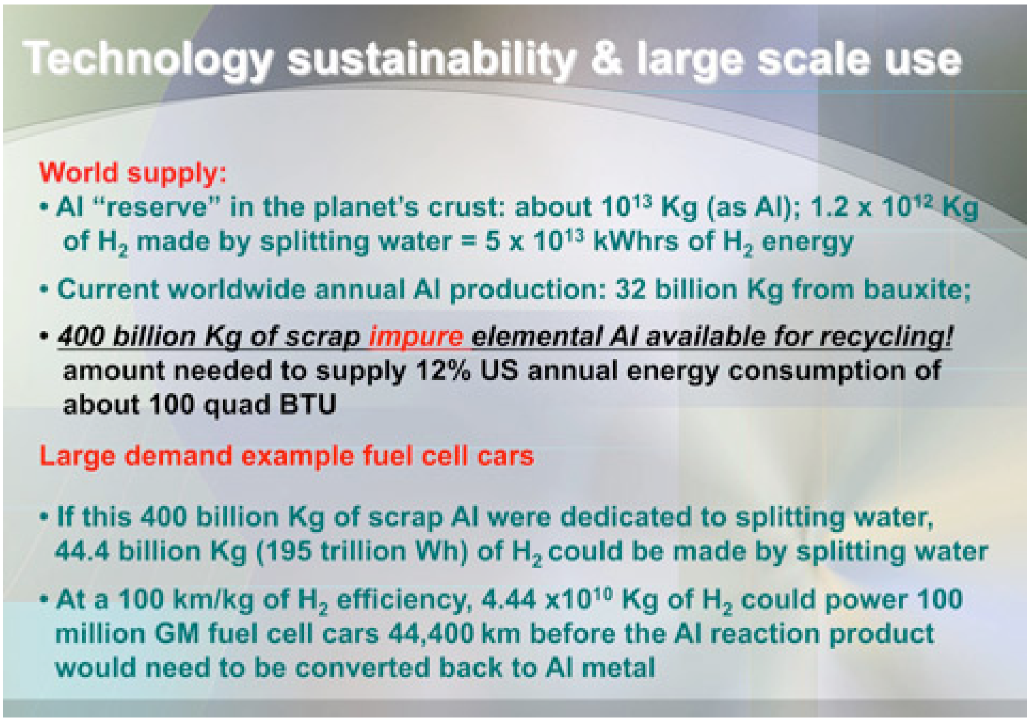
Complete centrifuge recovery of GaInSn alloy

The reaction that produces hydrogen by splitting water with the Al alloy is:
$2Al + 6\ H_2O$? $3H_2 + 2Al(OH)_3$

Technology sustainability and large scale use

The total energy produce per kg of Al is 8.8 kWh; half as heat and half as the energy of combustion of hydrogen. The spent Al(OH)3 is easily rejuvenated back to metallic Al using the well-established commercial Hall-Heroult electrolysis. Currently carbon electrodes are used, thus generating some carbon dioxide, but a commercial TiB_2 electrode technology for Al smelting has been developed by the De Nora Company to displace carbon electrodes. Since most smelting operations are done with hydroelectric power, i.e. not using fossil fuels, Al smelting could become totally green.

Before we need to worry about smelting aluminum hydroxide to recover Al, however, we can use the 400 billion kg of scrap metal on the planet that has already had its carbon footprint amortized. Therefore, this Al is green and can produce 44.4 billion kg of hydrogen or nearly 195 trillion Wh of hydrogen energy *(see below)*.



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Scale of possible applications/markets

Finally, there are many applications for which this technology could be used:

- **Small**: 1-100 mW and 10 W-hrs, e.g. PDAs, laptops, i-pods, etc.
- **Medium**: 1-200 kW and 10-10000 kW-hrs, e.g. auxiliary power, cars, boats, fuel enrichment, etc.
- **Large**: > 5000kW and > million kW-hrs, e.g. trains, ships, subs, off-grid community power, base load peak power demand, storage for wind and solar power.