IAF SPACE POWER SYMPOSIUM (C3)
Space Power System for Ambitious Missions (4)

Author: Prof. Peter Schubert
Indiana University - Purdue University Indianapolis, United States

LONG DURATION SOLID-STATE HYDROGEN STORAGE FROM ISRU MATERIALS

Abstract

Hydrogen storage is vital for use in fuel cells and nuclear thermal rockets (NTR), both of which benefit from low-energy reservoirs available for long durations. A novel method of solid-state storage using catalytically-modified porous silicon can be fabricated entirely from materials found on the moon and in asteroids, requiring only a fixed quantity of re-usable reagents to be brought from earth. Consumables include silicon, aluminum, iron, and water, all of which can be extracted from suitable regolith ore bodies. An aluminum pressure vessel containing granular porous silicon particles is recharged by hydrogen pressures of 0.8 MPa. Once charged the hydrogen storage subsystem can be maintained at any temperature from 0 to 373 K for an indefinite period, suitable for lunar nights or months-long trips to main belt asteroids. Discharge is facilitated by heating above 393 K, provided by IR, resistive, or metal foam heat conductors embedded in the particulate bed. Systems-level volumetric and gravimetric storage metrics are 39 g/l and 5.8 percent w/w, respectively, comparable to cryogenic hydrogen storage in size and mass. The embodied energy in storing the hydrogen is very small, less than 2 percent of the embodied chemical energy, which makes it more efficient than cryogenic at 40 percent. Silicon and aluminum can be extracted from regolith using isotopic separation by charge/mass ratio. Iron and nickel are harvested from lunar regolith by electromagnets, and used as the catalyst to mediate between gaseous hydrogen and monatomic surface adsorbed hydrogen. Deposition is accomplished via carbonyl gases, which require a quantity of CO, which is recovered after each use. Making the silicon porous requires hydrofluoric acid (HF), which will need to be supplied from earth. The hydrofluorosilicic acid byproduct can be heated to decompose into HF vapor and silicon dioxide. The HF is condensed and re-used, and the silicon dioxide is a waste byproduct which can be formed into quartz objects such as portals and glassware. A lunar factory with a mass of 30 MT can produce complete hydrogen storage vessels, assuming that electronic control can be provided by the remainder of the power system. Being granular the size and shape of such vessels are essentially unlimited. One example is two-meter thick shell sections for a deep space crew cabin for radiation protection. The hydrogen therein could be withdrawn as a back-up supply of fuel, or for a final Hohman transfer burn just before refueling.