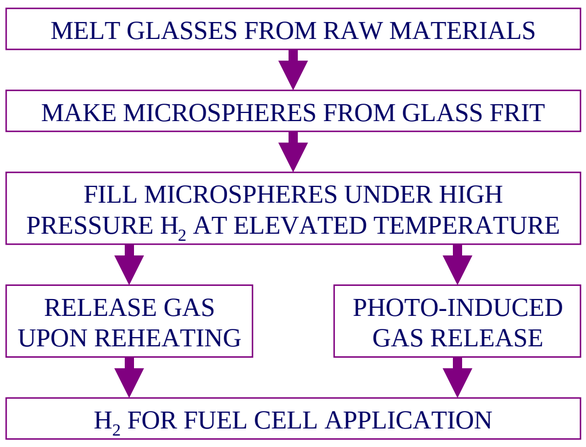
Accelerated Hydrogen Diffusion Through Glass Microspheres:

An Enabling Technology For A Hydrogen Economy

Concept

The recent discovery of photo-enhanced hydrogen diffusion in glass has allowed pressurized hollow glass microspheres to become a viable hydrogen storage technology.

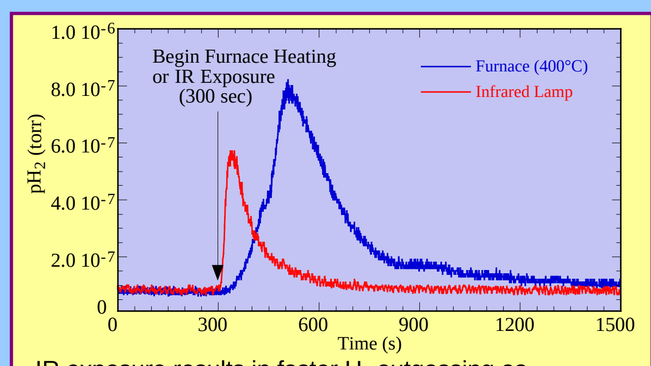


A saturation/outgassing technique has been used to monitor the hydrogen release rates from glasses of varied composition, thereby providing data necessary for developing a glass optimized for the microsphere hydrogen storage application.

Experimental Procedure

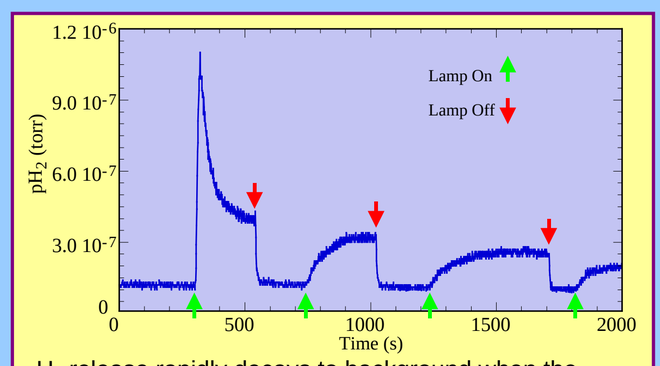
Glasses are prepared from reagent grade raw materials or by doping commercial glass frit. Samples are cut to ≈ 1 mm thick, ≈ 1.5 g of which are saturated at 500°C under ≈ 710 torr of H_2. Saturated glasses are outgassed under high vacuum while H_2 release is detected using a mass spectrometer. H_2 is removed by furnace heating or by exposing the sample to a 250W infrared lamp. The area under the full outgassing curve corresponds to the quantity of H_2 released and for a given set of saturation conditions represents the H_2 solubility.

Experimental Results



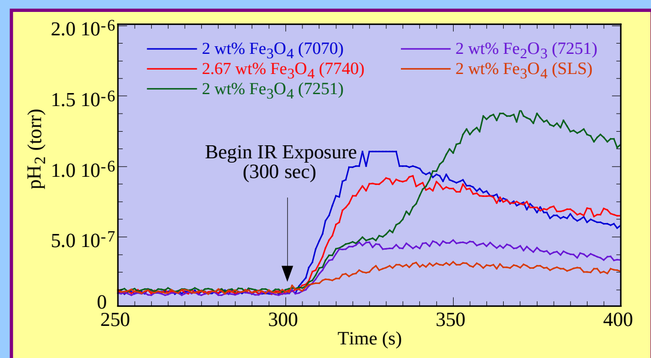
IR exposure results in faster H_2 outgassing as compared to furnace heating. Note the immediate onset of H_2 release upon IR exposure. Data shown for 0.5 wt% Fe_3O_4 doped CGW 7070.

Photo-Enhanced Outgassing



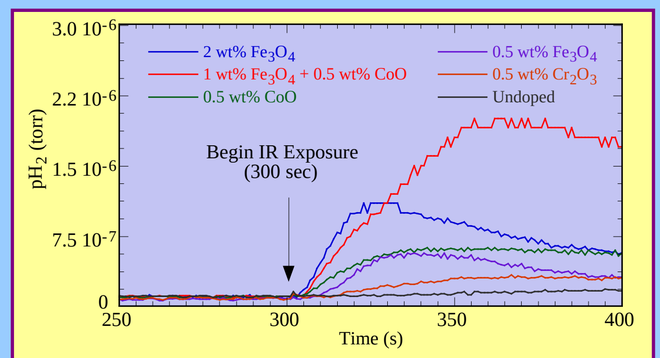
H_2 release rapidly decays to background when the lamp is turned off. Subsequent IR exposure quickly reestablishes the H_2 release. Data shown for 2 wt% Fe_3O_4 doped CGW 7070.

Infrared Response



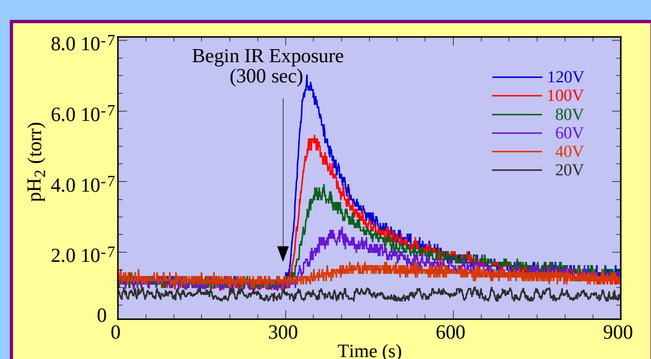
The effect base glass on the onset of H_2 release upon exposure to IR is shown. All glasses contain iron oxide. CGW 7070, a commercial borosilicate glass, outperforms the other base glasses.

Base Glass Study



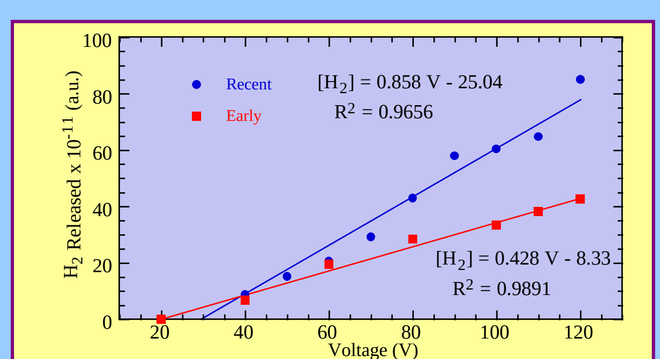
The effect of dopant on the onset of H_2 release upon exposure to IR is shown for CGW 7070. The undoped glass exhibits the poorest response while doping with 2 wt% Fe_3O_4 doped glass provides the best response.

Dopant Study



The effect of IR intensity on the H_2 outgassing response was investigated using a variac to control the IR lamp voltage. The response is proportional to voltage above 20V. Below 20V, no H_2 release occurs.

Infrared Intensity Study



The quantity of IR-induced H_2 release exhibits a linear dependence with voltage. The "recent" data are samples reacted with H_2 to produce a higher Fe^{2+}/Fe^{3+} ratio. Note the factor of 2 increase in slope of H_2 released.

Quantitative Voltage Response

General Observations

- IR provides faster outgassing response relative to furnace heating, a critical result for the H_2 storage and release application.
- The onset of H_2 outgassing is immediate upon IR exposure for doped samples as compared to undoped glasses, regardless of the base glass.
- Doped commercial borosilicate glasses such as CGW 7070 and CGW 7740 have higher H_2 permeability and are more suitable for study using this technique.

Specific Observations

- The amount of H_2 released upon exposure to IR is less than that from furnace heating, indicating a surface effect possibly limited by IR penetration depth. This effect is unlikely to be detrimental to the microsphere storage and release application.
- More H_2 is released with increased Fe_3O_4 concentration in CGW 7070 upon IR exposure.
- Optical spectroscopy indicates that repeated hydrogen loading and unloading reduces the oxidation states of the transition metal dopants, accompanied by hydroxyl formation.
- Current outgassing results indicate improved H_2 release from 0.5 wt% Fe_3O_4 doped CGW 7070 with higher Fe^{2+}/Fe^{3+} and increased hydroxyl content, both of which favor IR absorption.
- This results suggests improved performance with repeated use and offers a distinct advantage over metal hydride or carbon nanotube adsorption technologies that are susceptible to contamination.

Global Importance

- H_2 is a renewable fossil fuel replacement
- Elimination of greenhouse pollutants since H_2O is the only by-product
- Glass microsphere storage is a viable, environmentally friendly storage technology for the H_2 economy

Future Work

- Further investigation of dopant effects and H_2 reaction kinetics
- Use filters with current IR lamp
- Investigate alternate radiation sources
- Enhanced ingassing studies
- Glass optimization
- Demonstrate microsphere fabrication

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