Novel Applications of Hollow Glass Microspheres
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Traditional Applications for HGMS
   Low density fillers for composites with polymers and concrete
   Thermally insulating paint
   Thermally insulating tapes
   Syntactic foams for submersibles
   Targets for laser fusion systems (D/T filled)

Modern Applications for Hydrogen-Filled HGMS
   Hydrogen storage
   Hydrogen separation and purification
   Radiation shielding for manned space flight
HYDROGEN-FILLED HOLLOW GLASS MICROSPHERE

ADVANTAGES:
• Cheap, plentiful raw materials
• Established technology
• Readily recycled
• Light-weight
• High strength
• Safety
• Flow properties

DISADVANTAGE:
• Slow hydrogen release rate
HOLLOW GLASS MICROSPHERE PRODUCTION

Flame spraying method for producing microspheres
HOLLOW GLASS MICROSPHERES
Photo-Enhanced Outgassing

Data shown are for 0.5 wt% Fe$_3$O$_4$ doped CGW 7070 glass
Photo-Enhanced Outgassing

Data shown are for 2.0 wt% Fe$_3$O$_4$ doped CGW 7070 glass
IDENTIFYING THE CRITICAL PARAMETERS

- Glass membrane composition
- Glass dopant identity
- Glass dopant concentration
- Illumination intensity
- Illumination wavelength
Data shown are for glasses doped with 2.0 wt% Fe₃O₄
Dopant Identity

Data shown are for doped CGW 7070 glass
Comparison of Outgassing Rates from Glasses Doped with Nickel and Iron Oxides.

**Optically-Induced Outgassing**

![Graph showing outgassing rates]

- 2.0 wt% \( \text{Fe}_2 \text{O}_3 \)
- 0.5 wt% NiO
- Undoped CGW-7070 glass

Comparison of Outgassing Rates from Glasses Doped with Nickel and Iron Oxides.
Data shown are for doped CGW 7070 glass
Data shown are for 0.5 wt% Fe$_3$O$_4$ doped CGW 7070
Data shown are for 2.0 wt% Fe$_3$O$_4$ doped CGW 7070 glass
**ACTIVE WAVELENGTH RANGE**

- **EXTENDED HOT MIRROR**
- **COLD MIRROR**
- **HOT MIRROR**

Dark bands are regions with optical transmission <40%.
PVT Measurement System
Helium Outgassing Curves for Borosilicate HGMS
**ONGOING WORK**

- Produce hollow glass microspheres doped with transitional metal of choice
- Demonstrate optically-induced outgassing of hydrogen from hollow glass microspheres
- Evaluate designs for integrating hollow glass microspheres into a complete storage system
SUMMARY

• Hollow glass microspheres have many attractive features as a hydrogen storage medium

• Optically-induced outgassing of hydrogen from glass is significantly faster than conventional heating

• Current work seeks to demonstrate feasibility using hollow glass microspheres
HYDROGEN SEPARATION and PURIFICATION

Flow mixed gases through a bed of HGMS at elevated temperatures/pressures

Hydrogen will diffuse through glass, but CO, CO\textsubscript{2}, H\textsubscript{2}O, H\textsubscript{2}S, etc. will not

When H\textsubscript{2} appears in exit stream, stop flow

Evacuate bed, capture hydrogen released at temperature, or

Cool, “freeze in” hydrogen, remove HGMS
Hydrogen will be retained and then released when surrounding atmosphere has lower partial pressure of hydrogen than is present in HGMS.

Transport filled HGMS to use site.

Reheat to release hydrogen, or

If doped, use photo-enhanced diffusion to release hydrogen.

Return empty HGMS for reuse.
Status of Separation/Purification Studies

Conceptual at present, but all known behavior of gas permeation in glasses indicates that this will work with existing technology and commercially available HGMS.

Testing will use PVT system used for hydrogen storage studies, which is operational.

Studies will be carried out during next 12 months.

After that, just needs someone with money to commercialize!
RADIATION SHIELDING (NASA)

Outer space has “Galactic Radiation Spectrum”

High energy particles, neutrons, protons, alpha particles, gamma rays, x-rays, etc.

$^{56}\text{Fe}$ is most favored of high energy nuclei and is very damaging to humans and spacecraft

Other “high-energy, high-Z” radiation includes $^{16}\text{O}$, $^{28}\text{Si}$, and $^{12}\text{C}$
Radiation Spectrum

Iron nuclei

Distribution of HZE particles produced by the sun
Shielding Criteria

Hydrogen is most effective shield against Fe nuclei

Currently use high density polyethelene (≈2 gm/cm$^3$)

Composite of PE/HGMS would be much lower density
≈0.5 to 0.7 gm/cm$^3$

HGMS filled with high pressure hydrogen will yield comparable hydrogen density, with lower bulk density

Glass can contain B, Li, Cd, Sm, and/or Gd for neutron absorption as well, i.e. multipurpose shielding
Status of Shielding Studies

Composites are being made using commercial HGMS, yield of good material is improving

Need stronger HGMS or lower stress process

Developing lithium aluminoborate glasses for producing HGMS

Radiation testing will occur during FY06

Posters presented at this conference covering several aspects of this work
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