An IMI Video Reproduction of Invited Lectures
from the 17th University Glass Conference

# Novel Applications of Hollow Glass Microspheres


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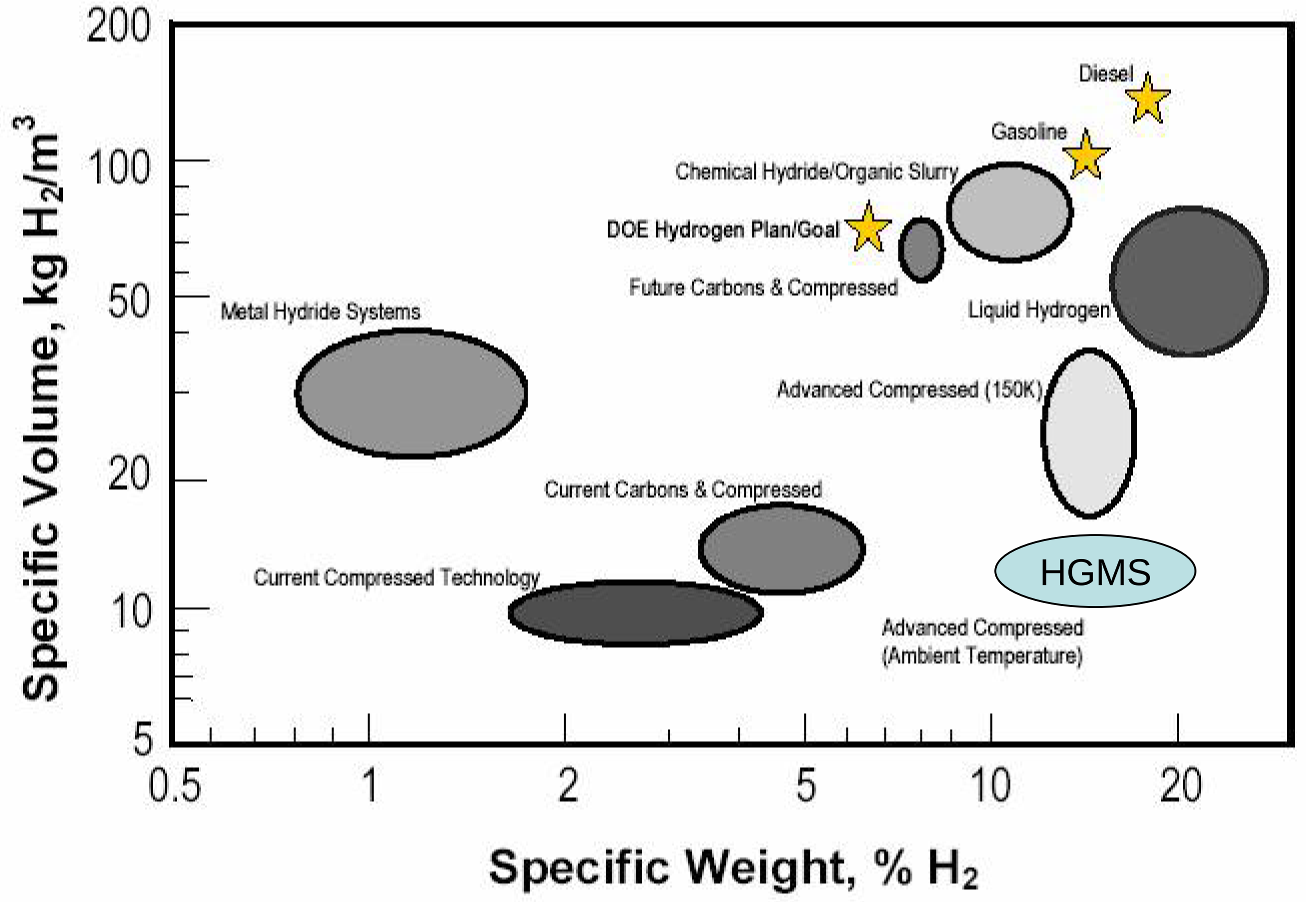
## Traditional Applications for HGMS

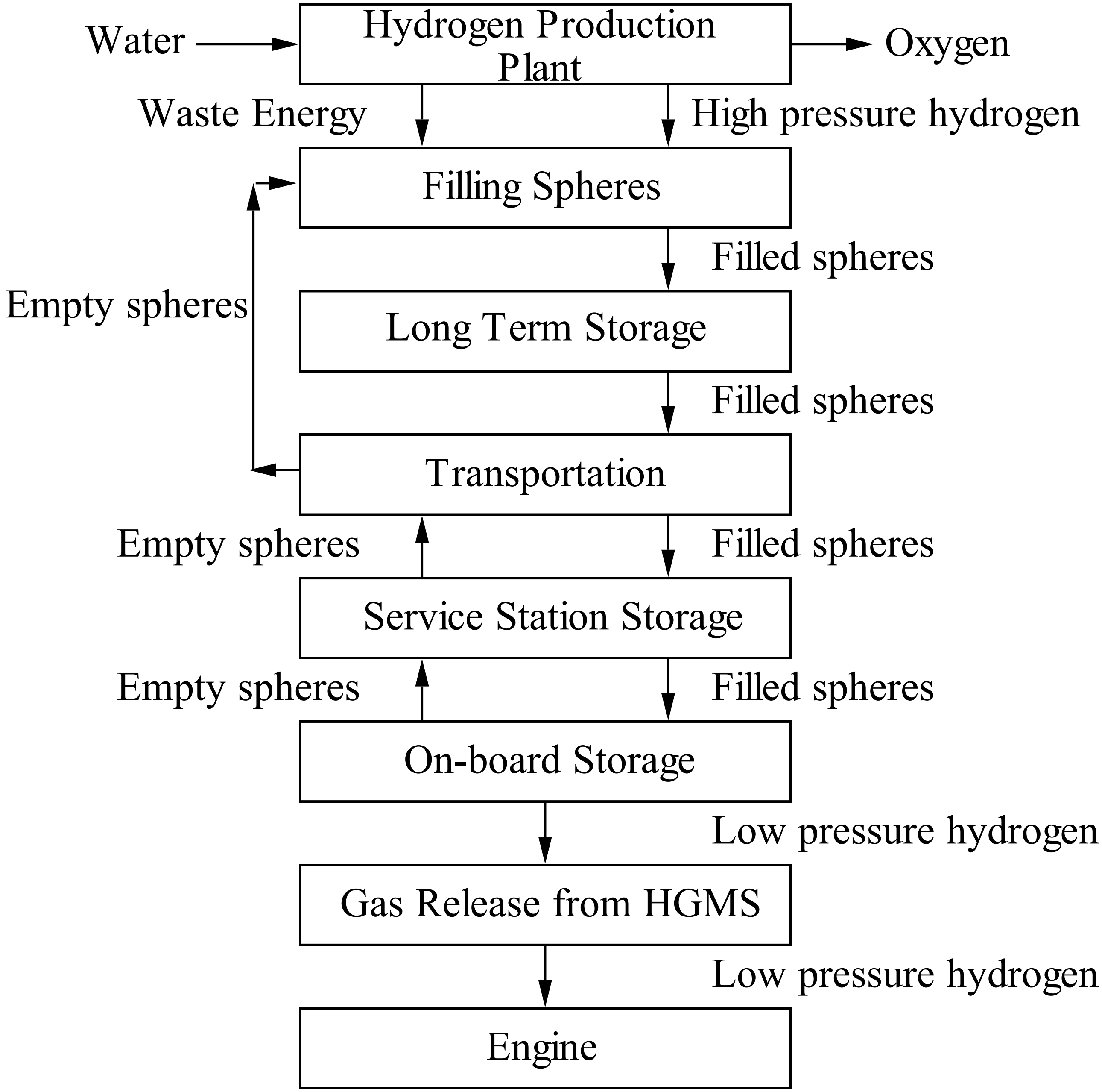
- Low density fillers for composites with polymers and concrete
- Thermally insulating paint
- Thermally insulating tapes
- Syntactic foams for submersibles
- Targets for laser fusion systems (D/T filled)

## Modern Applications for Hydrogen-Filled HGMS

- Hydrogen storage
- Hydrogen separation and purification
- Radiation shielding for manned space flight

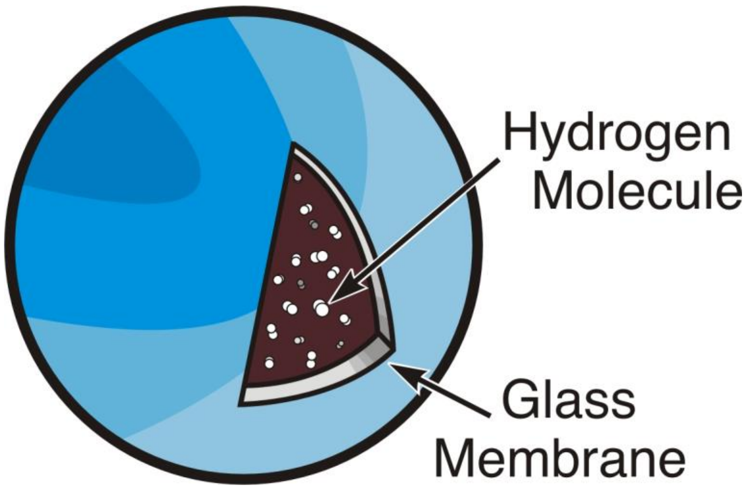


Specific Volume, kg $H_2/m^3$
200
100
50
20
10
5
0.5
1
2
5
10
20
Specific Weight, % $H_2$
Diesel
Gasoline
Chemical Hydride/Organic Slurry
DOE Hydrogen Plan/Goal
Future Carbons & Compressed
Liquid Hydrogen
Metal Hydride Systems
Advanced Compressed (150K)
Current Carbons & Compressed
Current Compressed Technology
HGMS
Advanced Compressed
(Ambient Temperature)



Water
Hydrogen Production Plant
Oxygen
Waste Energy
High pressure hydrogen
Filling Spheres
Filled spheres
Empty spheres
Long Term Storage
Filled spheres
Transportation
Empty spheres
Filled spheres
Service Station Storage
Empty spheres
Filled spheres
On-board Storage
Low pressure hydrogen
Gas Release from HGMS
Low pressure hydrogen
Engine

# HOLLOW GLASS MICROSPHERES (DOE)

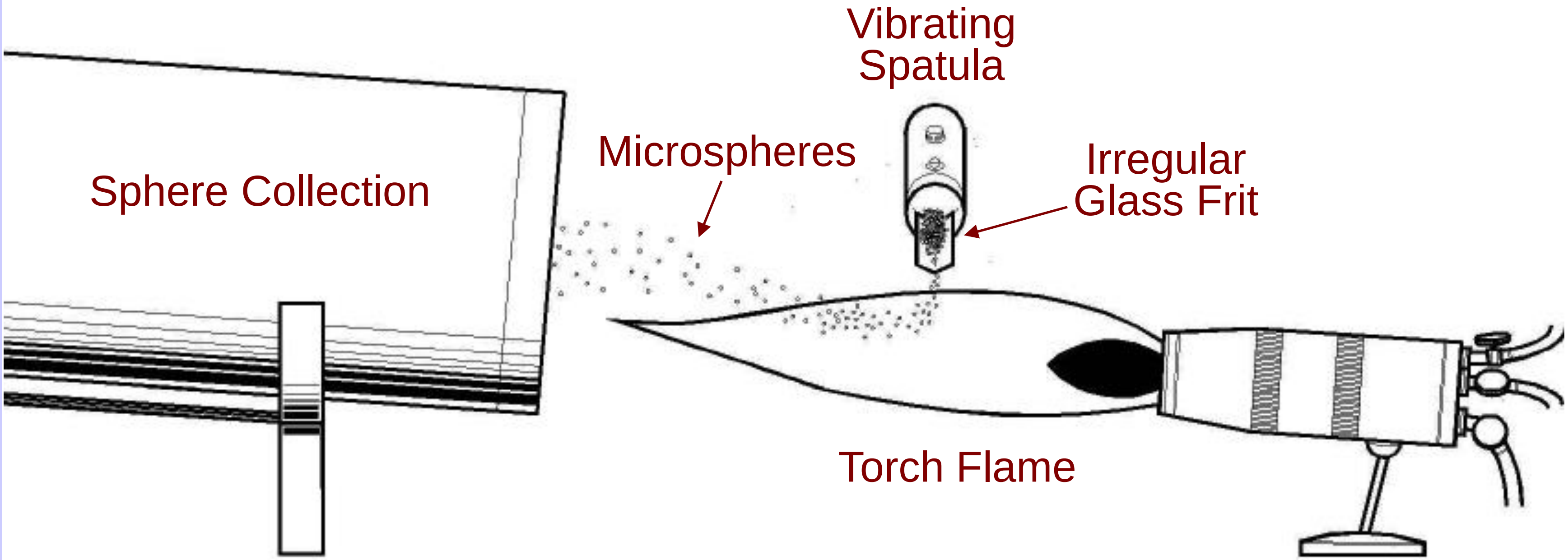



HYDROGEN-FILLED HOLLOW GLASS MICROSPHERE

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

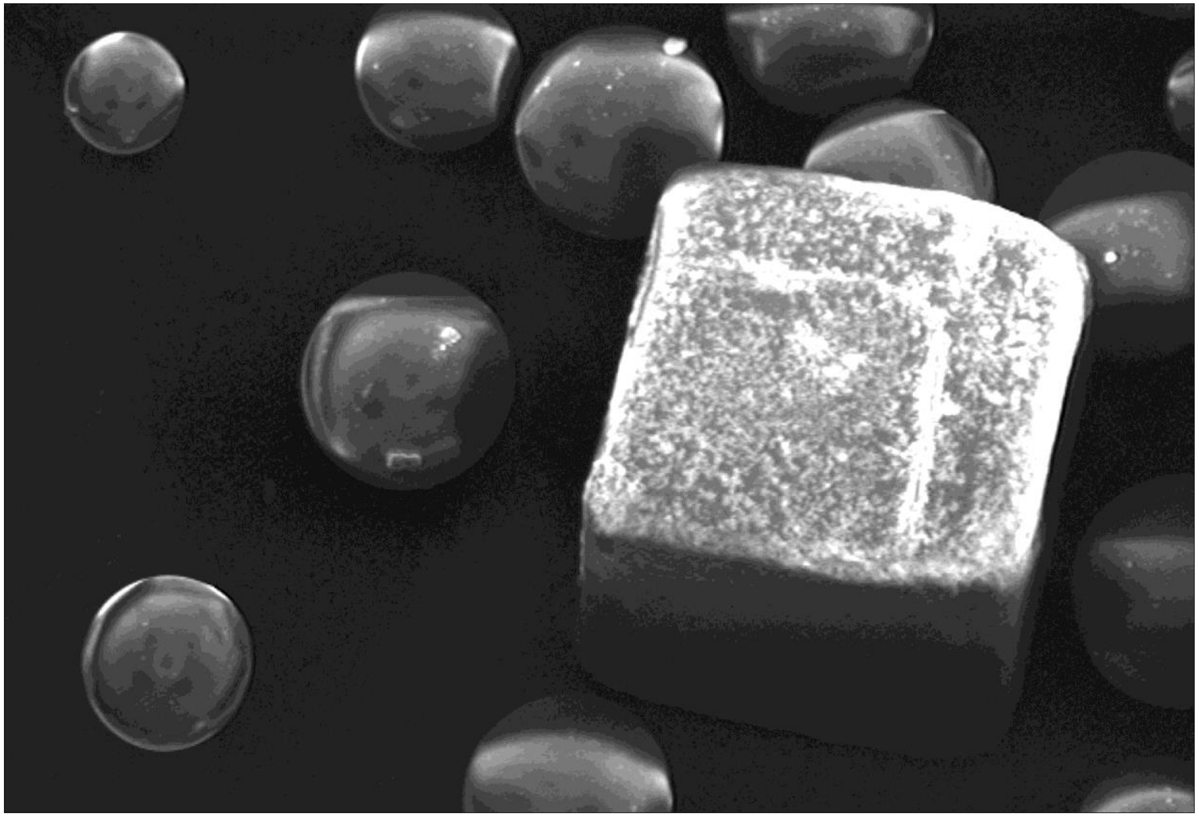
**DISADVANTAGE:**
- Slow hydrogen release rate

# HOLLOW GLASS MICROSPHERE PRODUCTION

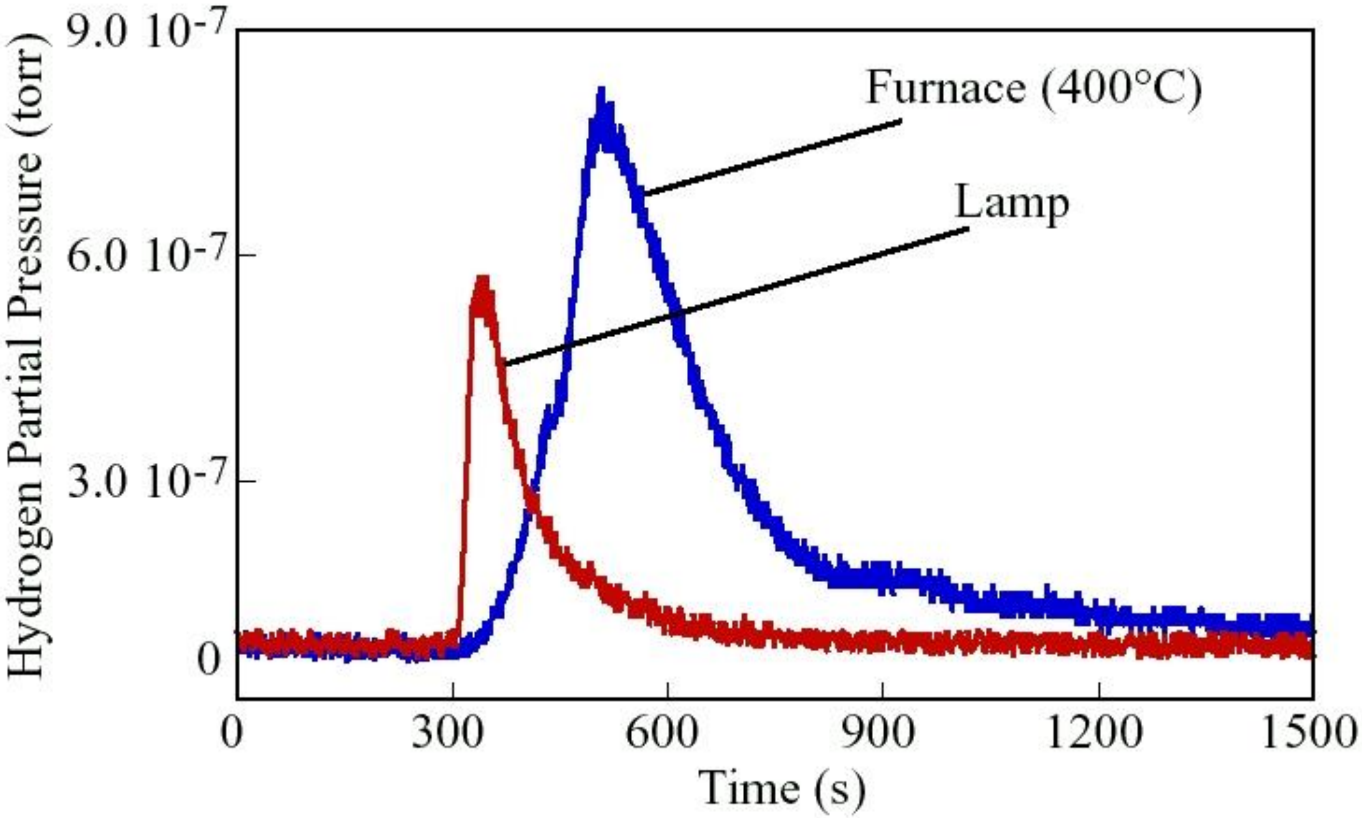



Flame spraying method for producing microspheres

# HOLLOW GLASS MICROSPHERES

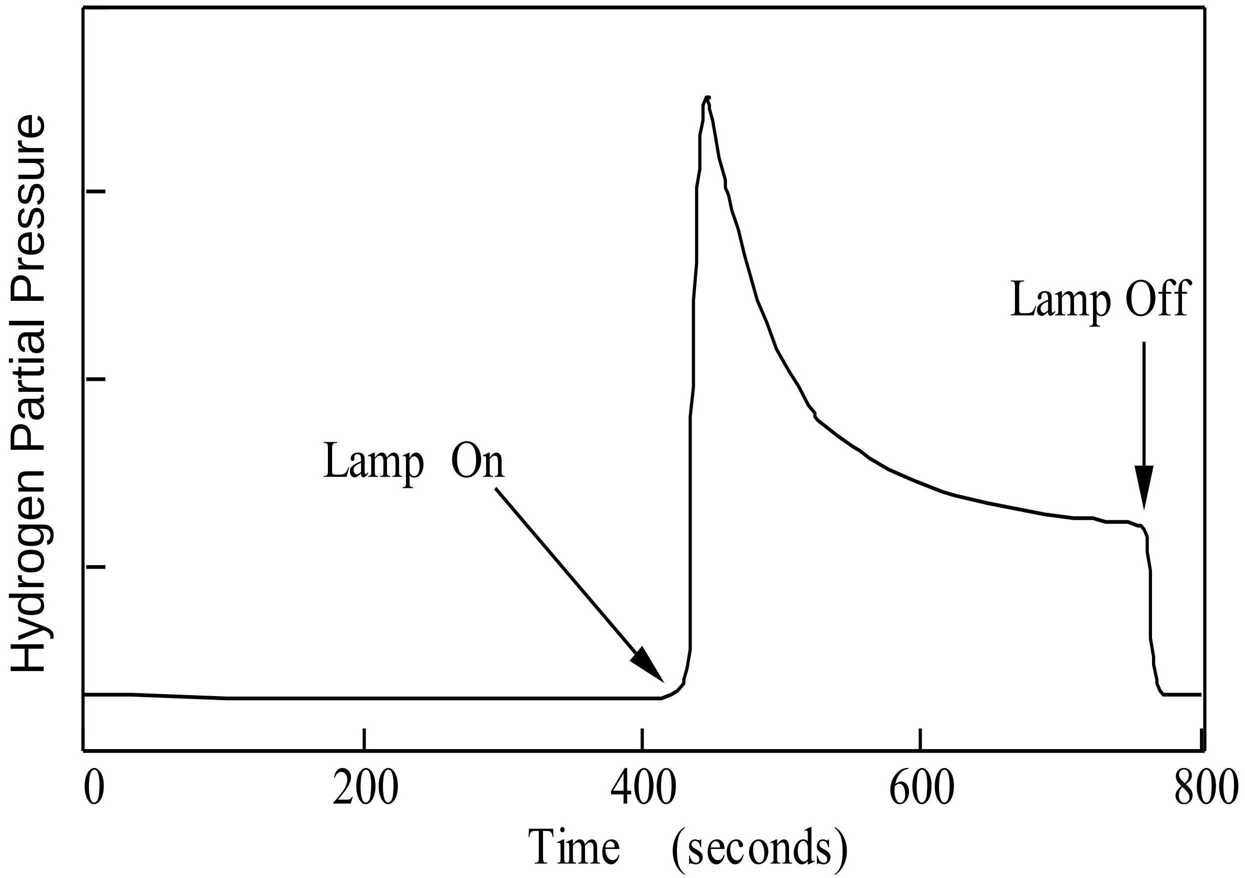


# Photo-Enhanced Outgassing




Data shown are for 0.5 wt% $Fe_3O_4$ doped CGW 7070 glass

# Photo-Enhanced Outgassing

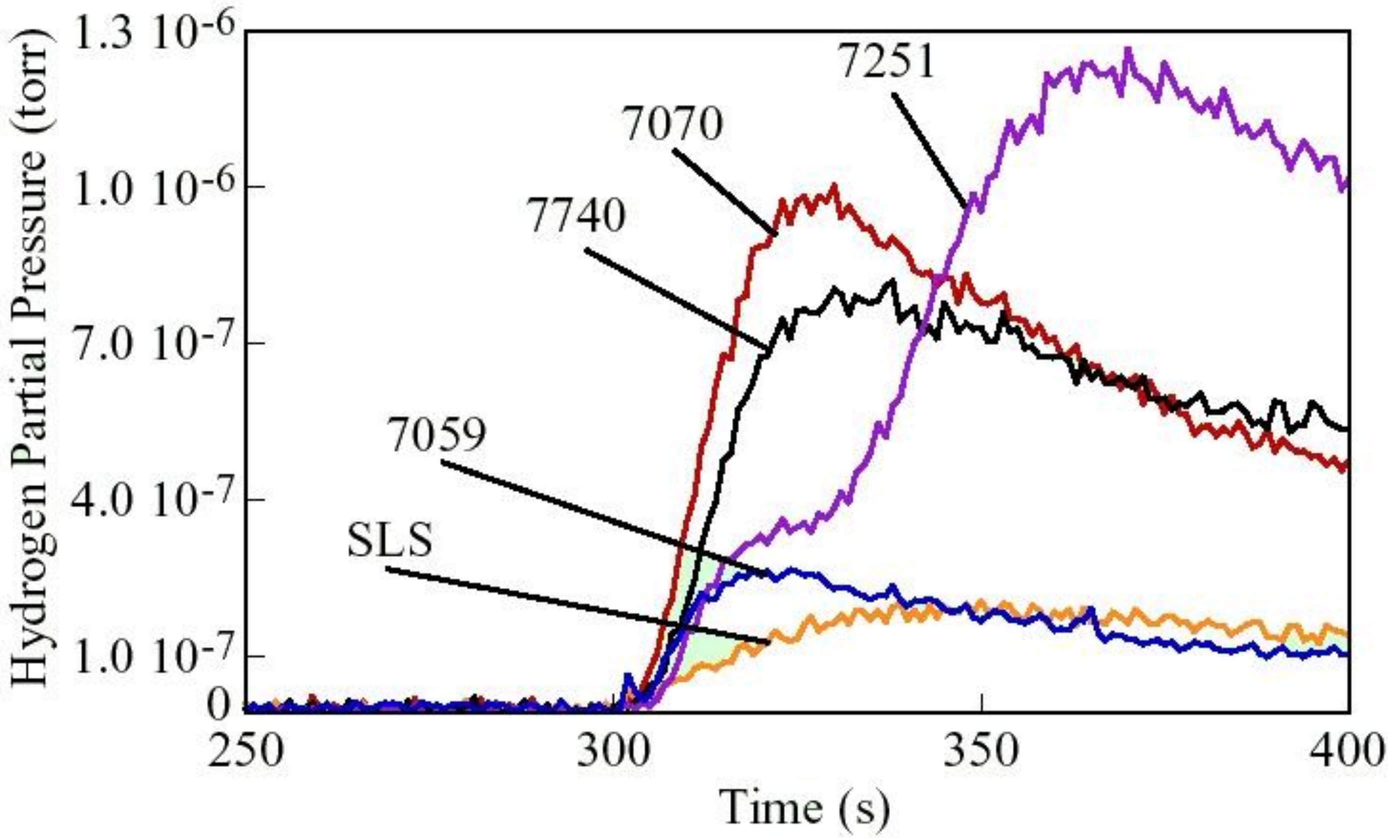



Data shown are for 2.0 wt% $Fe_3O_4$ doped CGW 7070 glass

# IDENTIFYING THE CRITICAL PARAMETERS

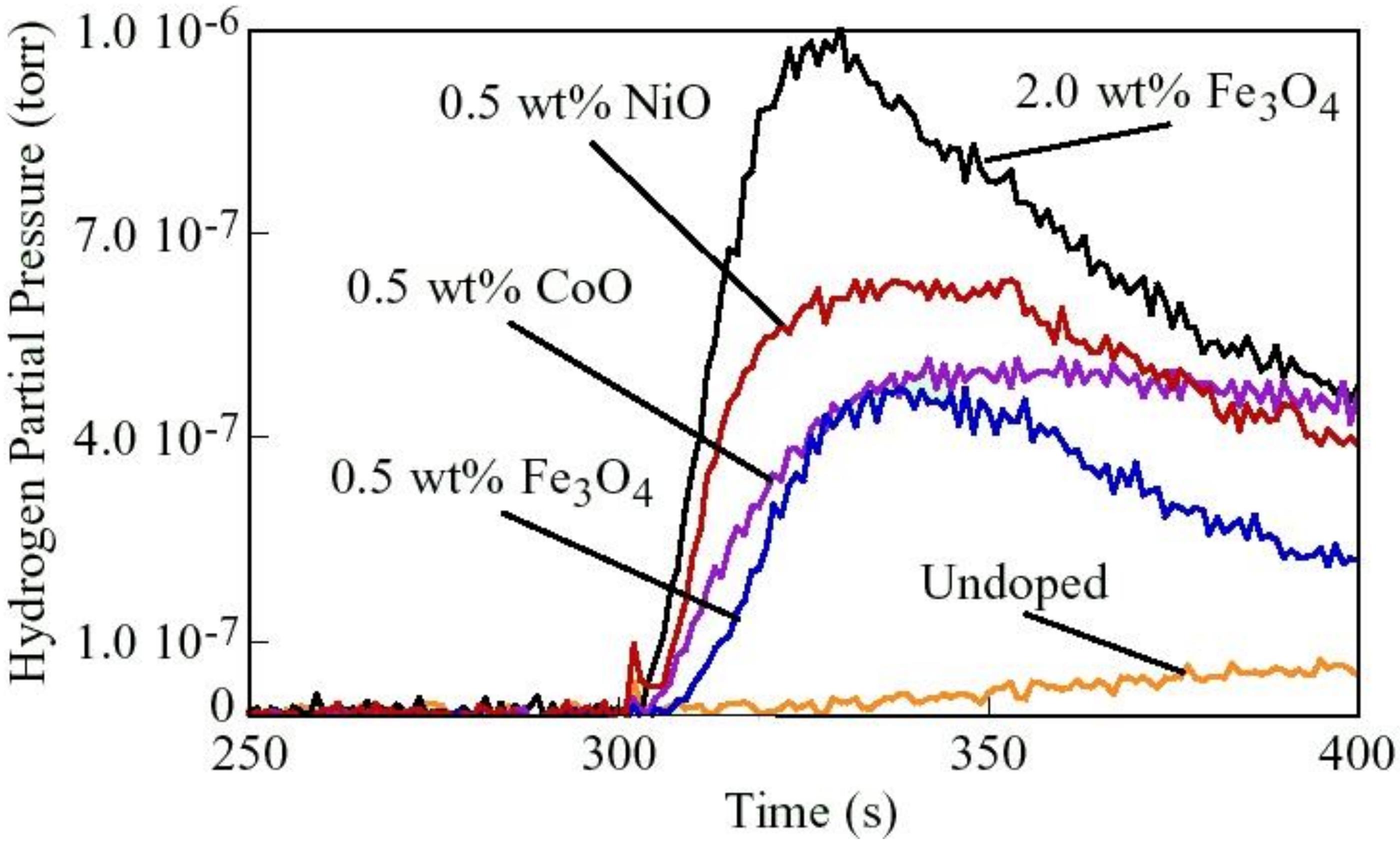
- Glass membrane composition
- Glass dopant identity
- Glass dopant concentration
- Illumination intensity
- Illumination wavelength

# GLASS COMPOSITION



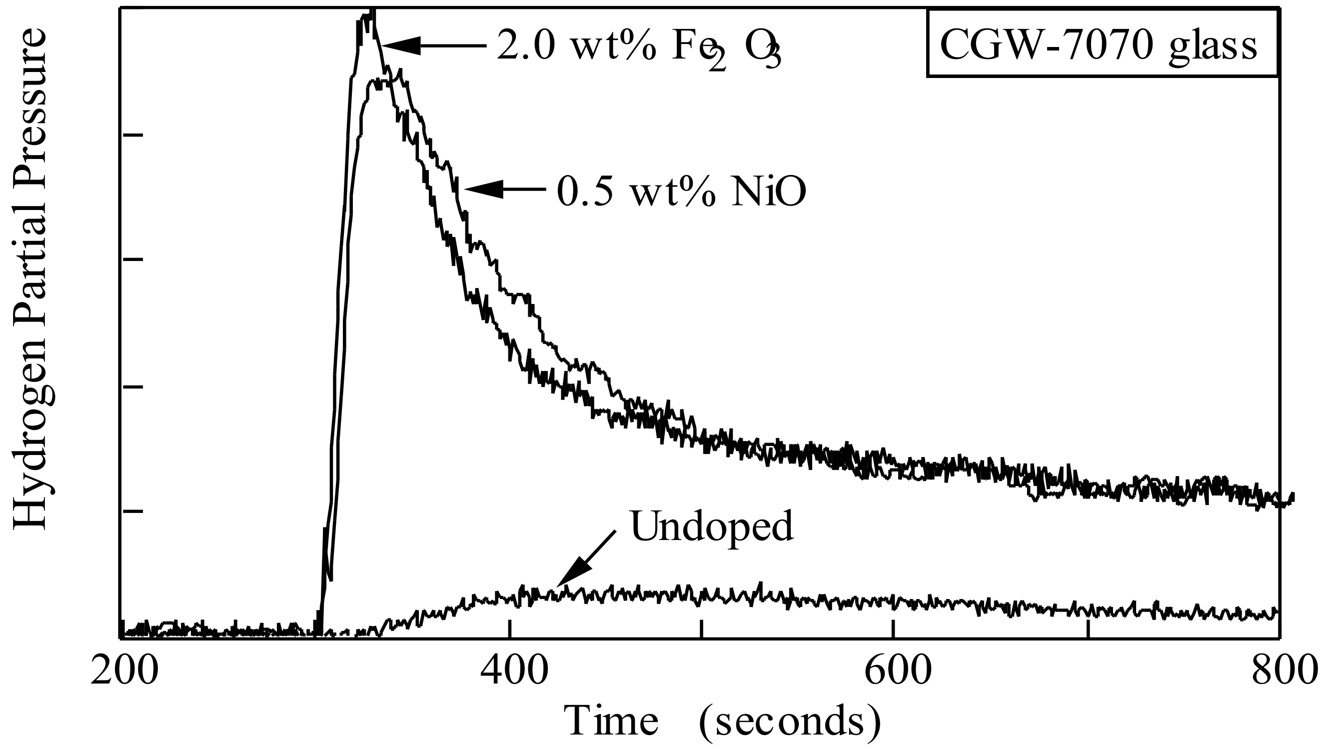

Data shown are for glasses doped with 2.0 wt% $Fe_3O_4$

# Dopant Identity



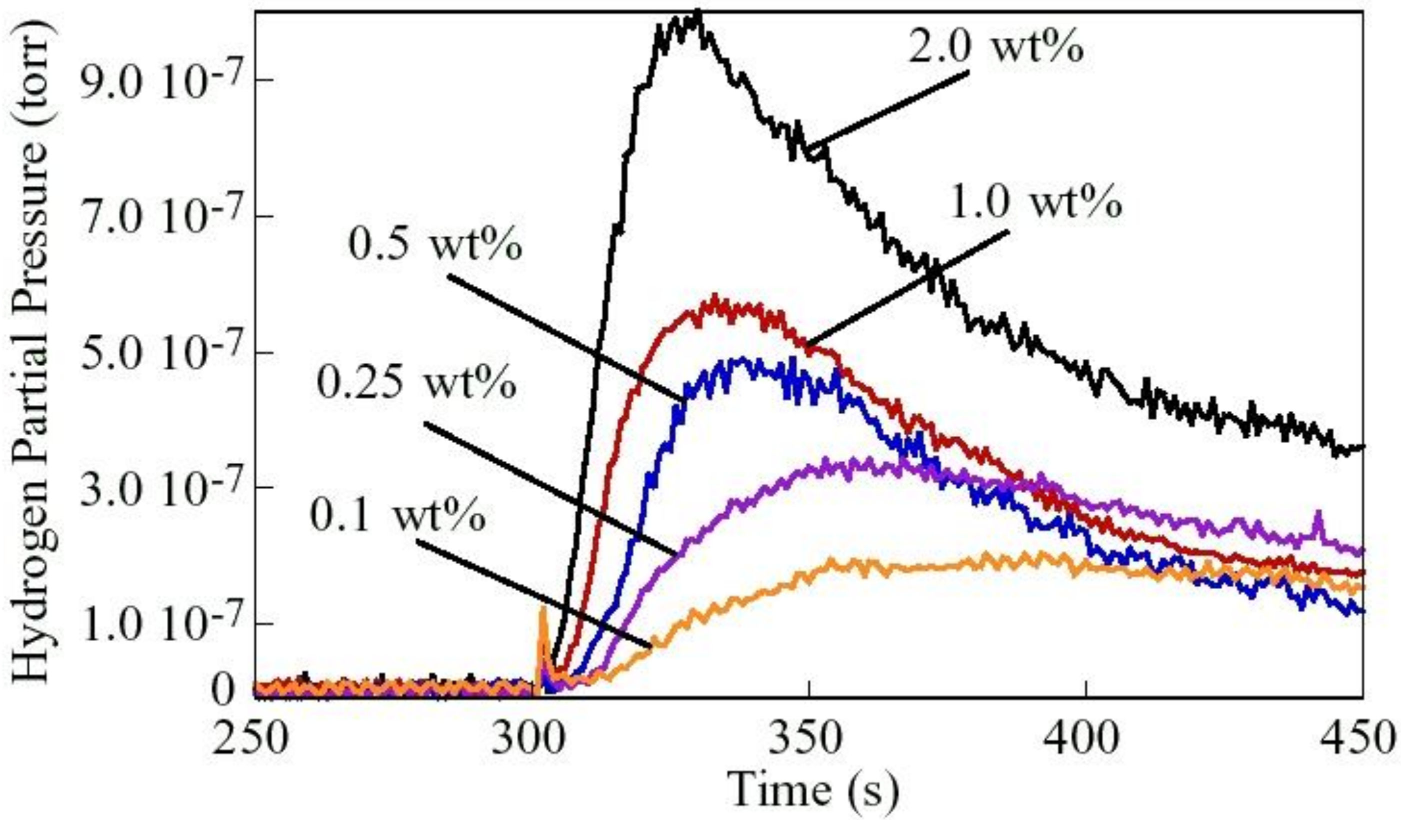

Data shown are for doped CGW 7070 glass

# OPTICALLY-INDUCED OUTGASSING



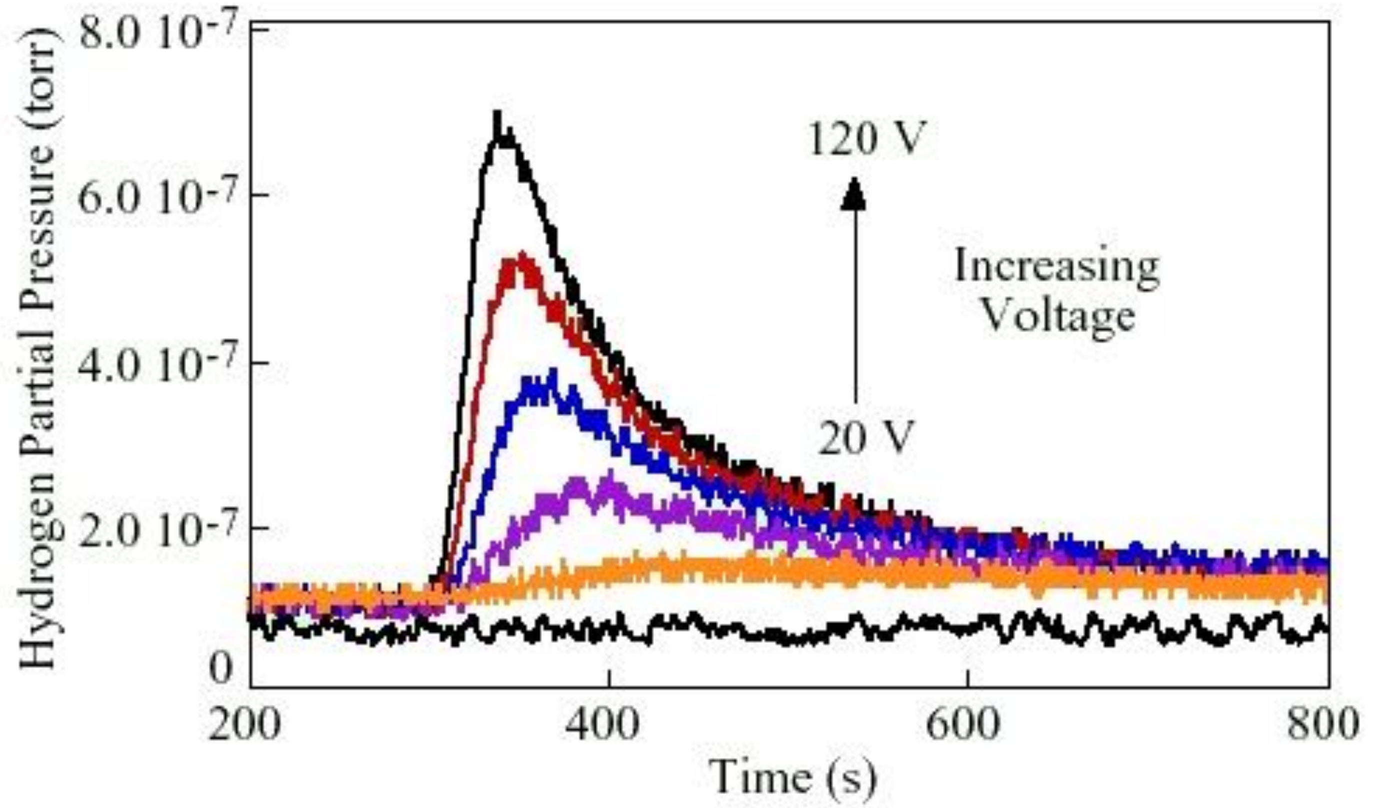

Comparison of Outgassing Rates from Glasses Doped with Nickel and Iron Oxides.

# DOPANT CONCENTRATION



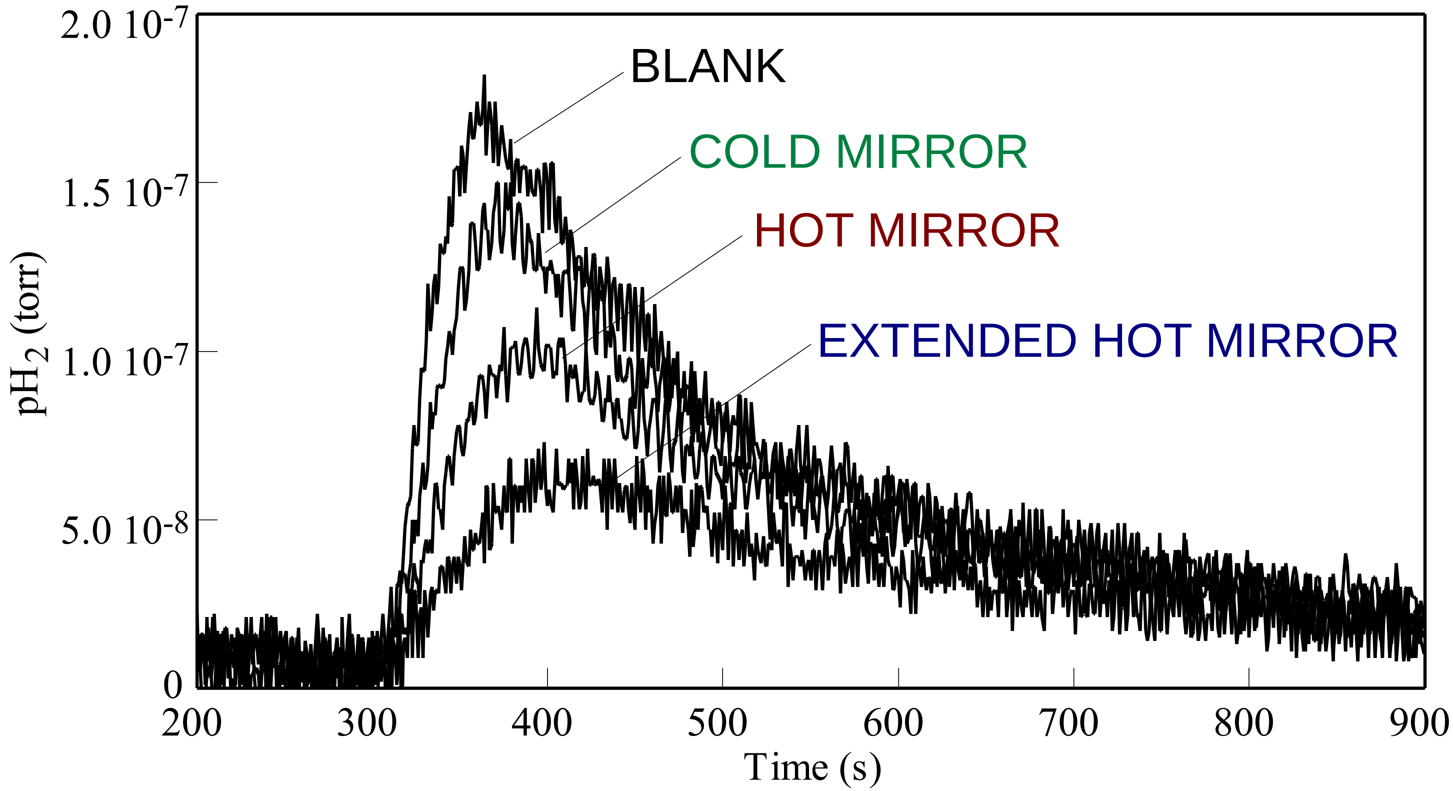

Data shown are for doped CGW 7070 glass

# ILLUMINATION INTENSITY



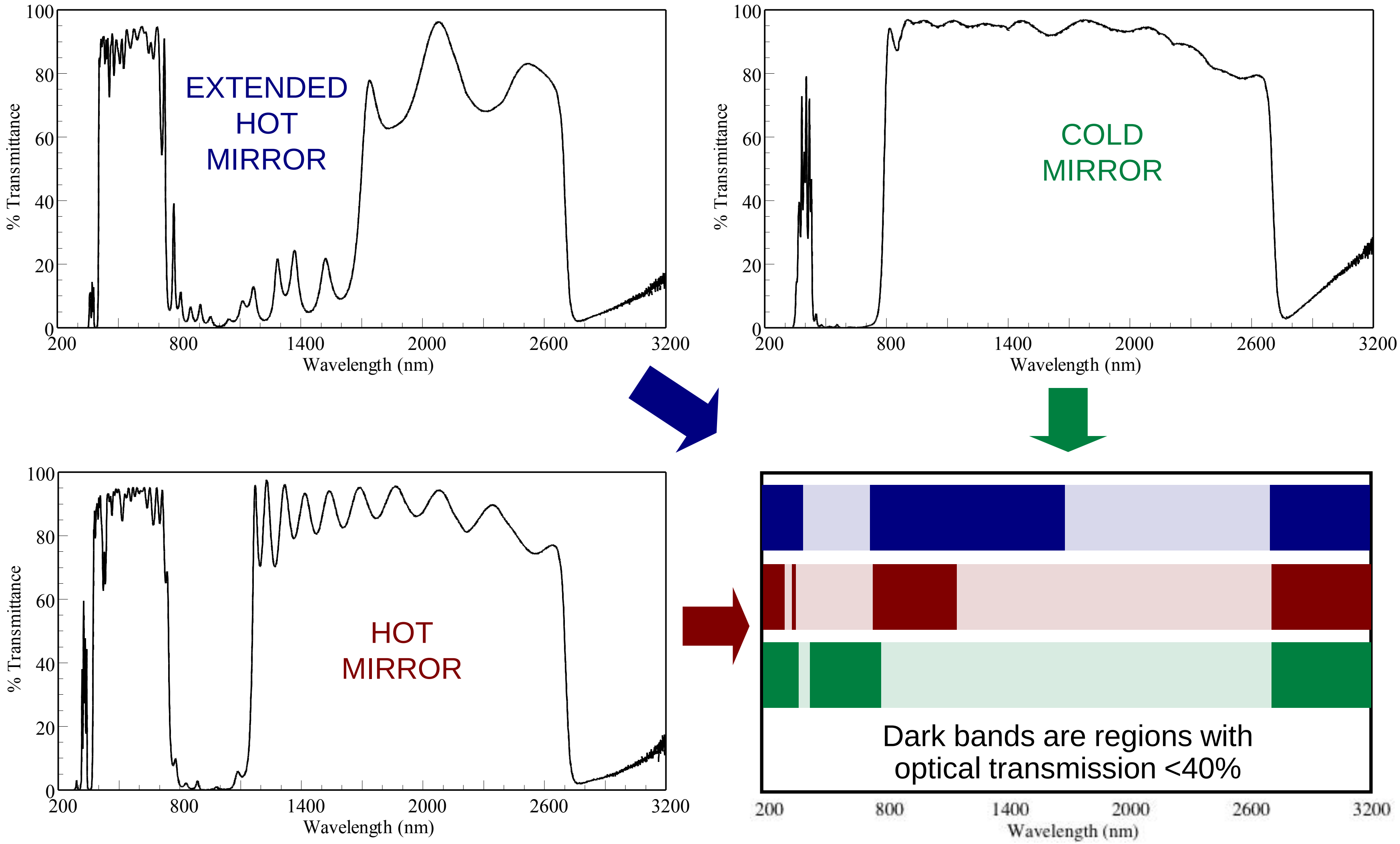

Data shown are for 0.5 wt% $Fe_3O_4$ doped CGW 7070

# ACTIVE WAVELENGTH RANGE

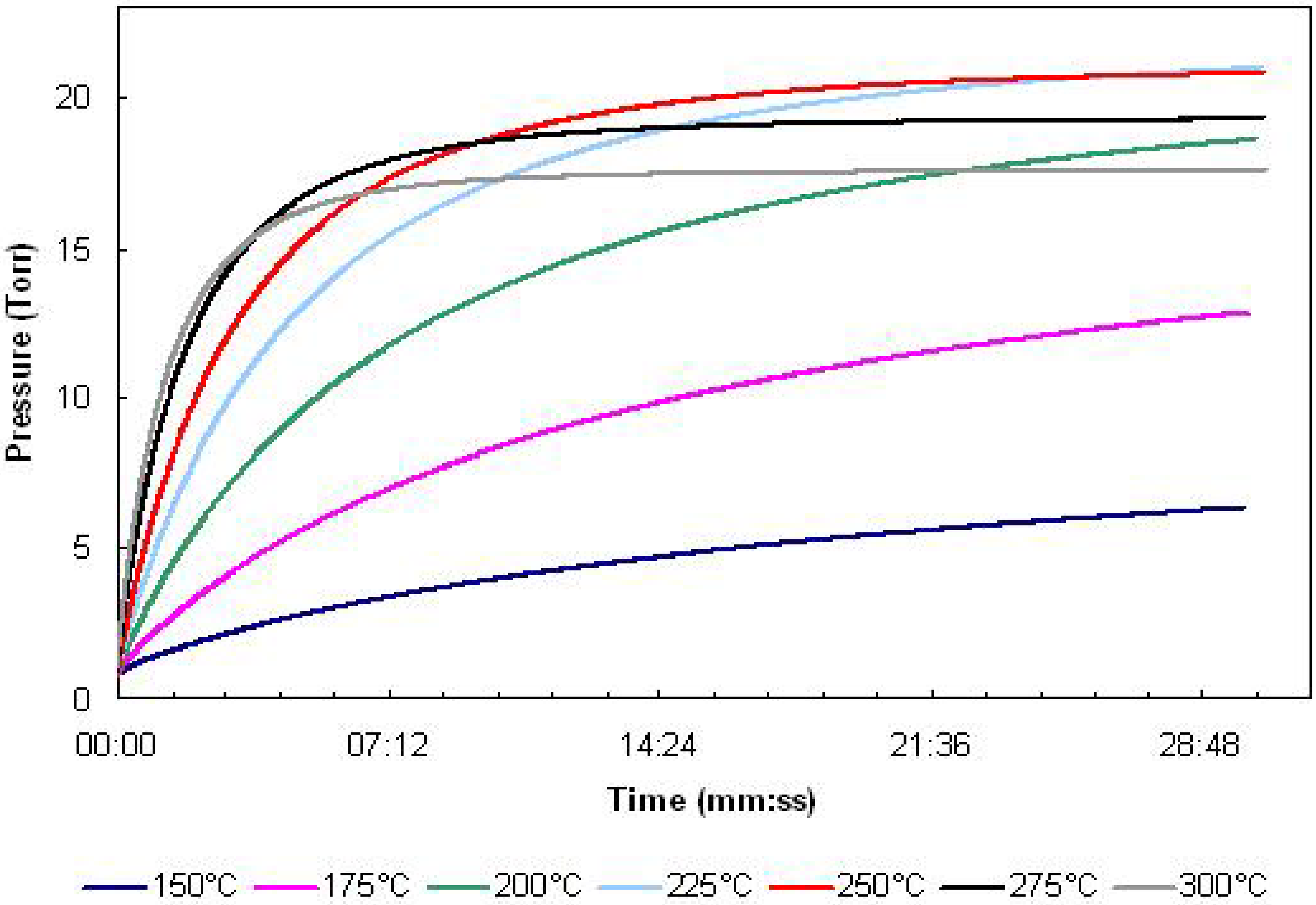



Data shown are for 2.0 wt% $Fe_3O_4$ doped CGW 7070 glass

# ACTIVE WAVELENGTH RANGE



# 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, $CO_2$, $H_2O$, $H_2S$, etc. will not

When $H_2$ 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

Conceptural 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)

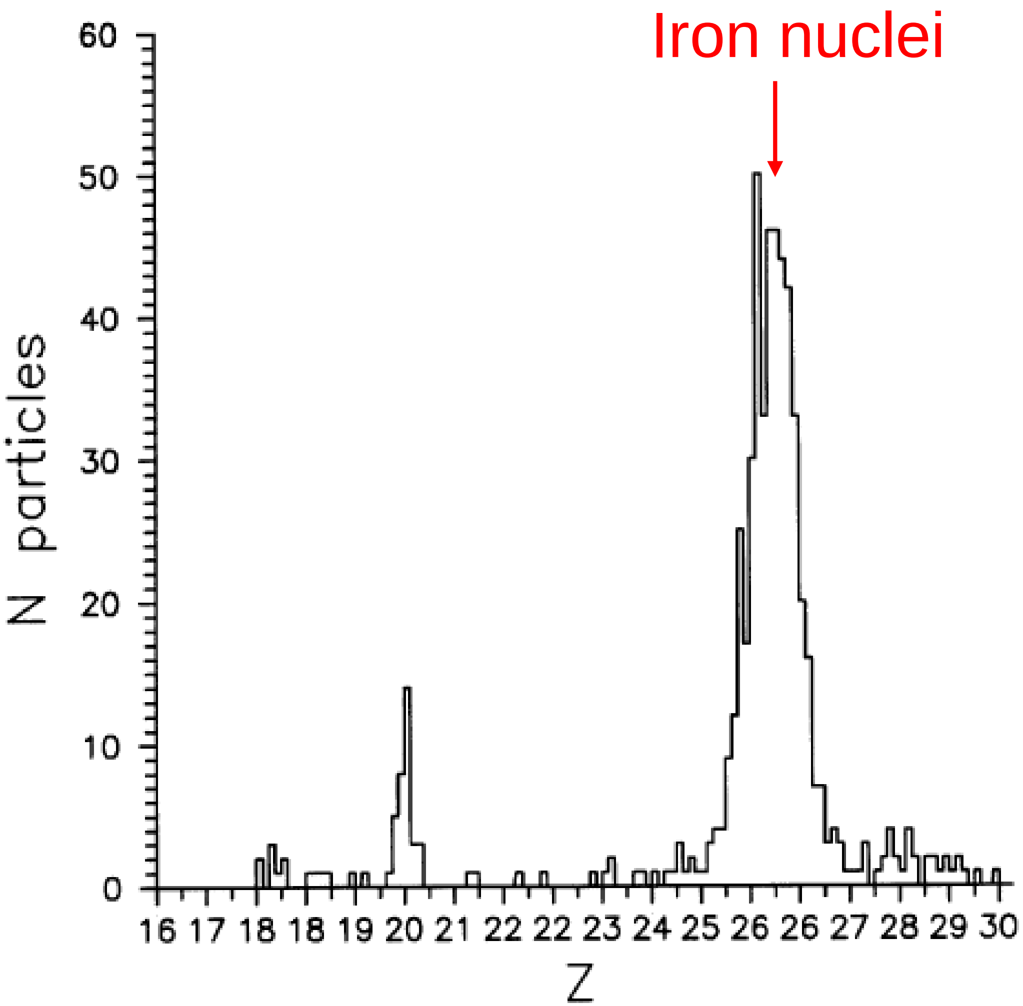
Outer space has “Galactic Radiation Spectrum”

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

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

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

# Radiation Spectrum




Distribution of HZE particles produced by the sun

# Shielding Criteria

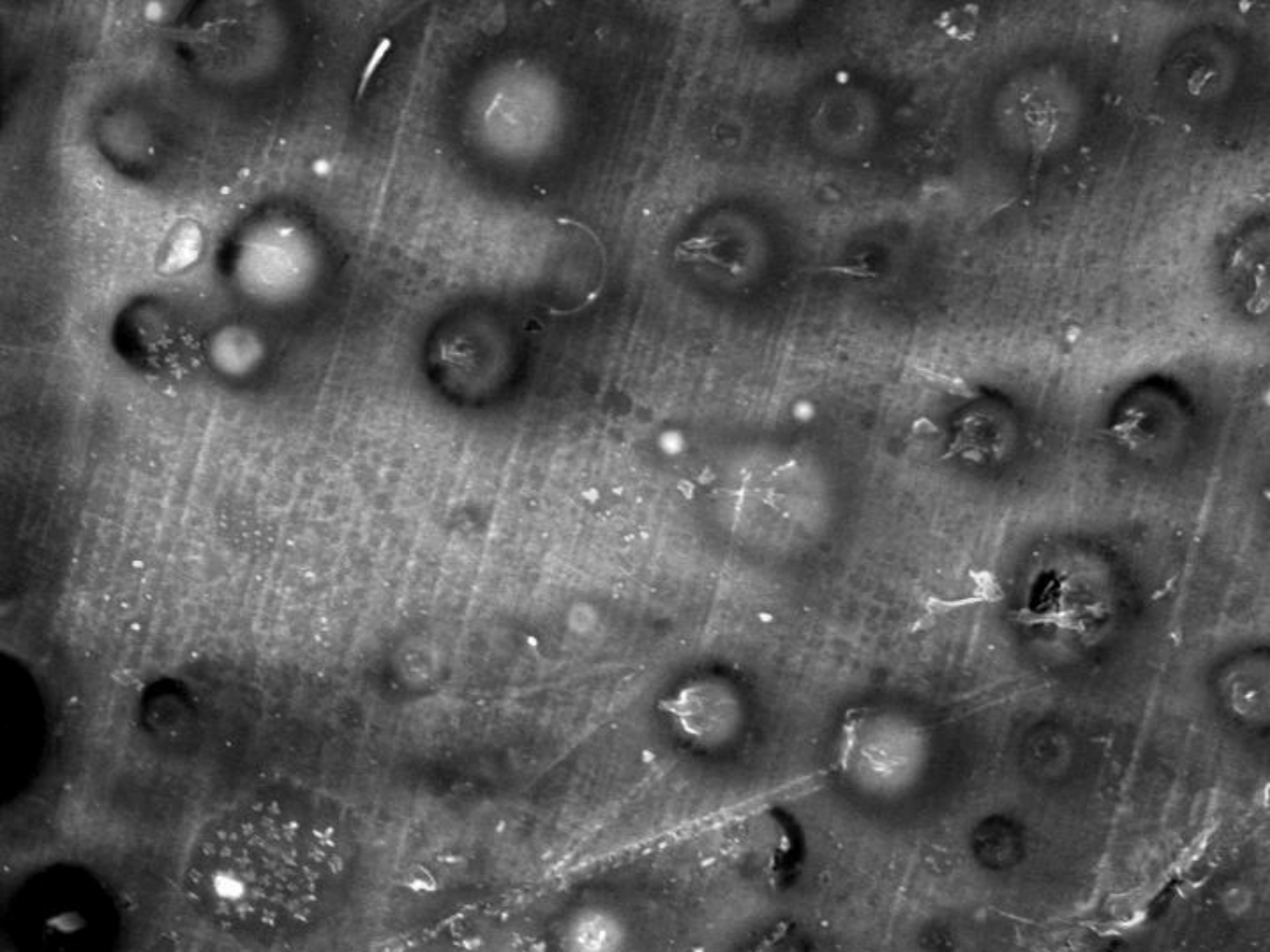
Hydrogen is most effective shield against Fe nuclei

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

Acknowledgments

Current Students

Melissann Ashton-Patton (NASA)
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Fabienne Raszewski (DOE)
Melodie Schmitt (CEER/EPA)
Josh Snyder (DOE)

Prior Students

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Doug Rapp (CEER/EPA)