Hoppe Glass Capsules Properties Synopsis

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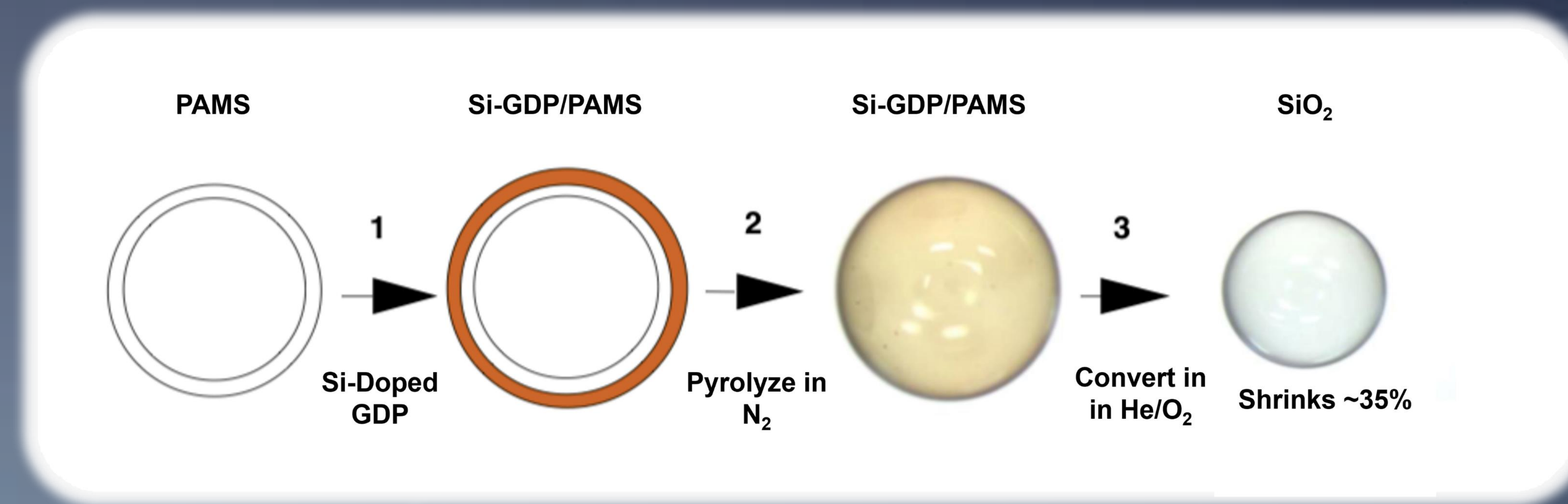
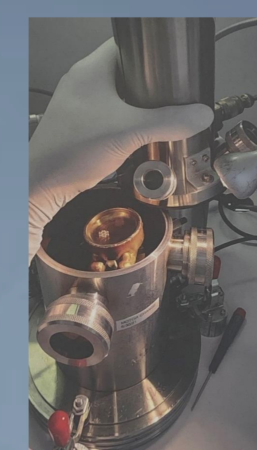
1. ABSTRACT

Drop Tower (DT) glass and Hoppe Glass (HG) shells are frequently used in Inertial Confinement Fusion (ICF) experiments as primary and auxiliary targets. Glass capsules are desirable due to their high strength and low permeability to deuterium/tritium gas mixtures at room temperature. DT glass capsules have been produced and experimentally used for over 40 years. However, they suffer from certain limitations. Larger DT glass shells must travel further down the drop tower tube to reach their full size, and GA's drop tower dimensions restrict the maximum size to 1500 µm. Additionally, DT shells suffer from high elemental composition variation capsule to capsule. Discovered in the 1990s by Dr. Martin Hoppe, Hoppe Glass shells introduced new capabilities that made it possible to fabricate capsules with diameters greater than 1 mm and more tightly controlled dimensions and chemical properties. After careful consideration, GA has started moving away from DT shells to HG shells to supply targets to ICF experiments. The fabrication, metrology, and advantages and limitations of HG shells will be discussed in the poster.

3. FABRICATION

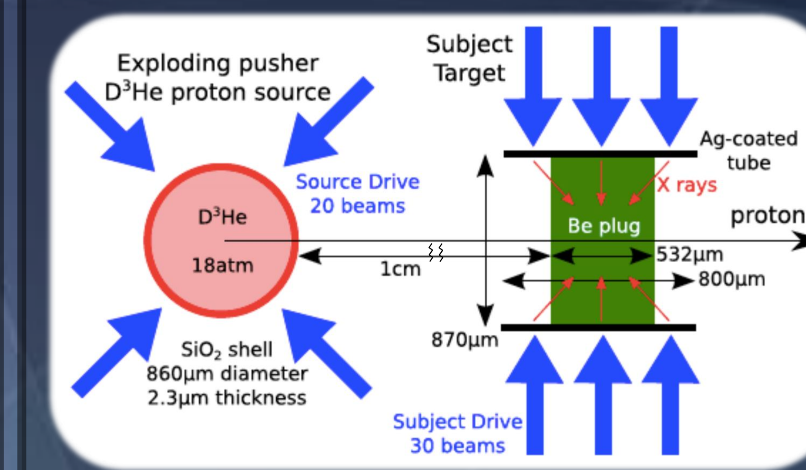


Hoppe glass fabrication process



1. The production of the Hoppe glass capsules starts with depositing Si or Ti-doped GDP onto PAMS. Capsules are coated using plasma-enhanced chemical vapor deposition with tetramethyl-silane, trans-2-butene and hydrogen as stock gas.
2. The mandrels are then removed by heating the capsules to 300°C in the presence of inert N_2 gas. This causes the PAMS to depolymerize and diffuse out of the permeable GDP layer, leaving only the doped GDP.
3. During the final stage, the Si/Ti-GDP capsules are converted into SiO_2. This process removes the carbon and hydrogen in the capsules, converting it to CO_2 and trace amounts of CO and water, some of which remains trapped inside.

5. GLASS CAPSULES AS PRIMARY TARGETS



D^3He capsules used as exploding pusher

Primary Target:

- Diagnostic development
- Neutron detector calibration implosion

6. PROPERTIES AT A GLANCE

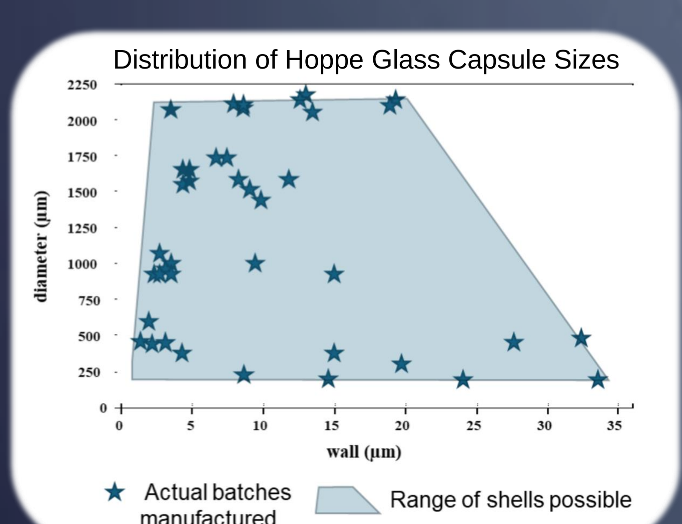
Property	Hoppe Glass	Drop Tower Glass	Glow-Discharge Polymer	Polystyrene
Tensile Strength (Gpa)	0.29	0.54	0.081	0.045
Young's Modulus (Gpa)	40.8	40.8	1.9	3.4
Molecular Composition	SiO_2	SiO_2 + Misc. Contaminants[1]	Amorphous Hydrogenated Carbon	$(C_8H_8)_n$
Density (g/cc)	2.20	2.20	1.03	1.07
Index of Refraction @ ~535nm	1.470	1.470	1.585	1.634
Deuterium Gas Half-Life (hrs)	~4	~7200	~0.5	~0.1
OD Variance[2] (%)	1.2	8.2	1.1	1.5
Wall Thickness Variance[2] (%)	13.4	58.4	5.5	11.4

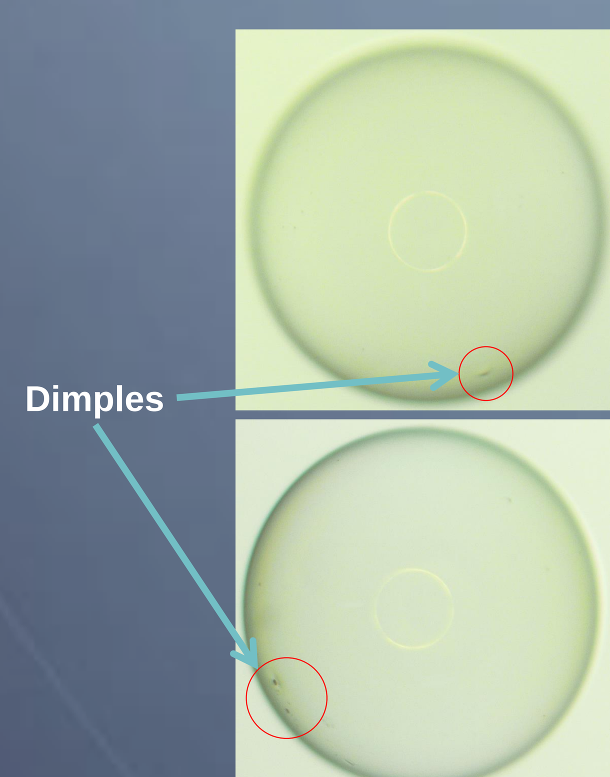
1. Contaminants include Na, K or Rb and occasionally Ca. These Impurities increase the strength of DT shells but greatly decrease their permeability to He/H gas.
2. Variance calculated from batches of 40 shells for each material, $Variance = \frac{Batch\ Range}{Batch\ Average}$

2. ADVANTAGES AND DISADVANTAGES

Hoppe Glass Capsule Common Order Sizes

Diameter (µm)	Wall Thickness (µm)
420	3
860	3
1100	4
1600	5





Defects in Hoppe glass capsules

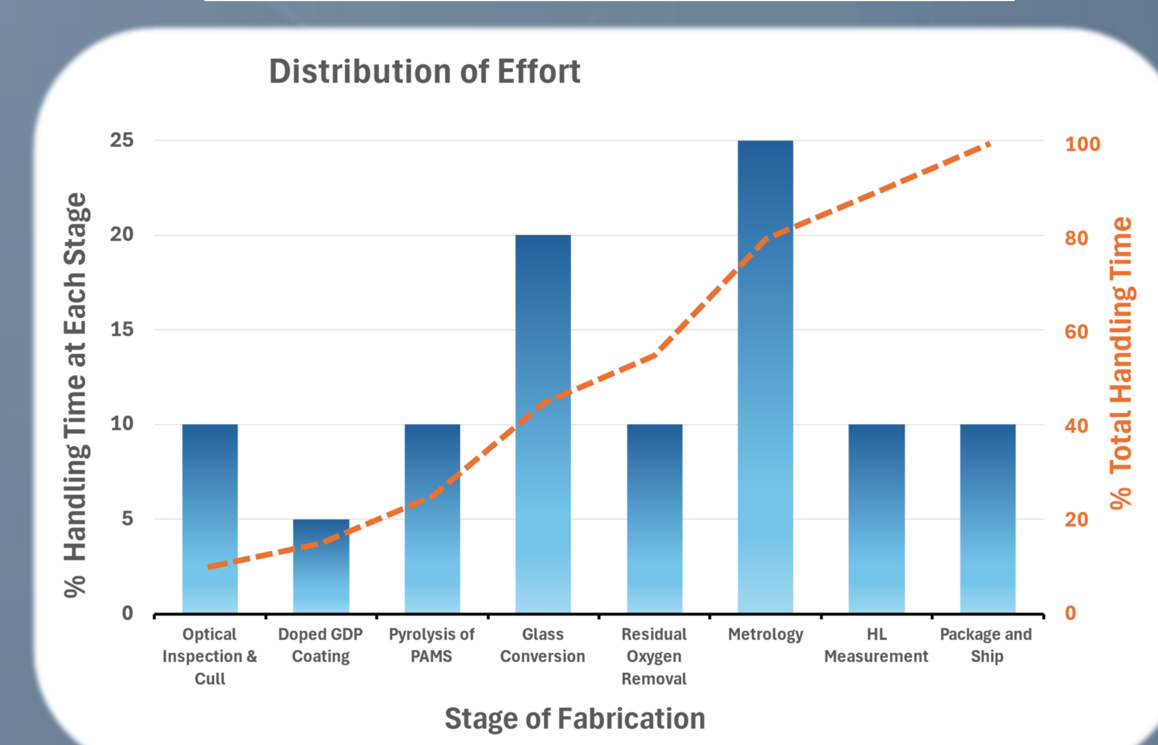
ADVANTAGES OF HOPPE GLASS CAPSULES

- More control over the dimension of the glass capsules.
- OD and wall thickness is similar within a singular batch
- ODs>1300 µm is achievable
- Hi-Z diagnostic gases can be introduced during the conversion step
- Diagnostic gases pass through the permeable GDP and are trapped when it converts into glass
- The capsule walls can be doped with Ge or Sn

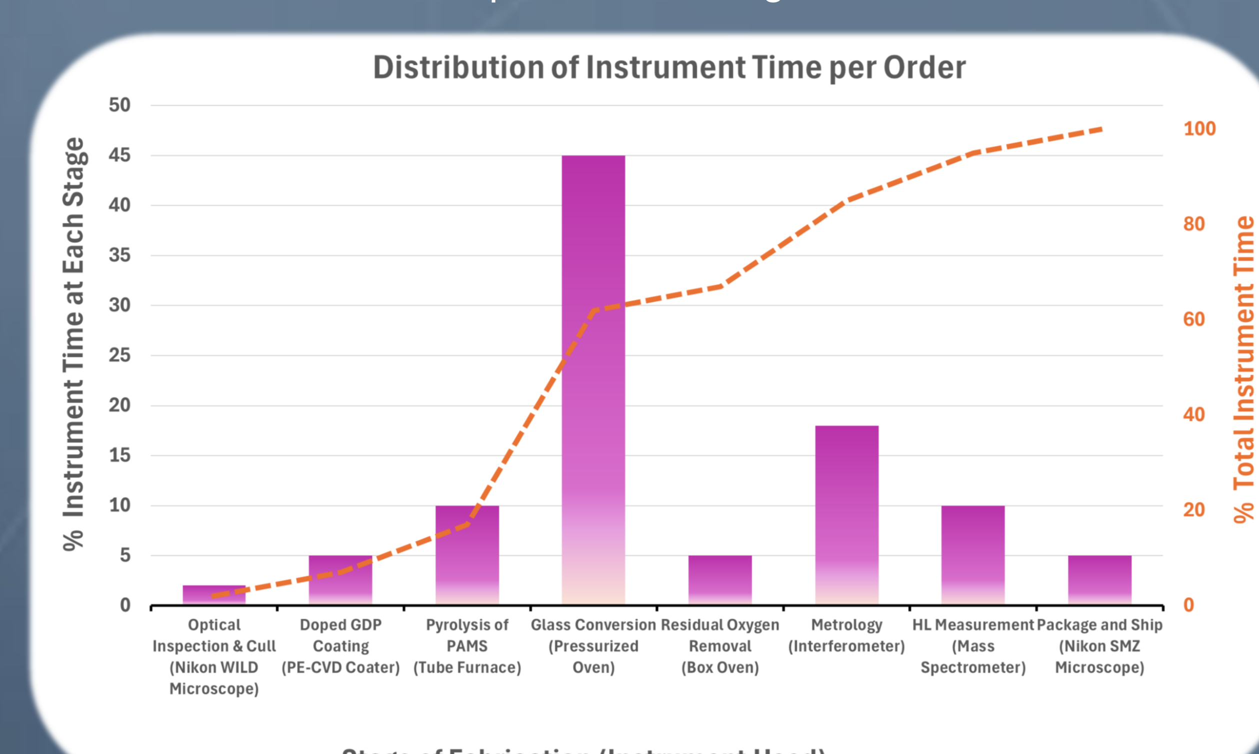
DISADVANTAGES & LIMITATIONS OF HOPPE GLASS CAPSULES

- Fabrication, from selection of mandrels to delivery, takes about 6 months
- Rough surface finish at high order mode (>100)
- Aspect ratio (OD/wall) kept at 250 or lower for best results on surface finish, as surface defects (such as small dents, wrinkles or dimples) increase in frequency on
- HG shells must be heated before being filled with gas
- Gas fills of HG shells take days (2-6) due to their low buckle pressure

4. FABRICATION EFFORT & TIME

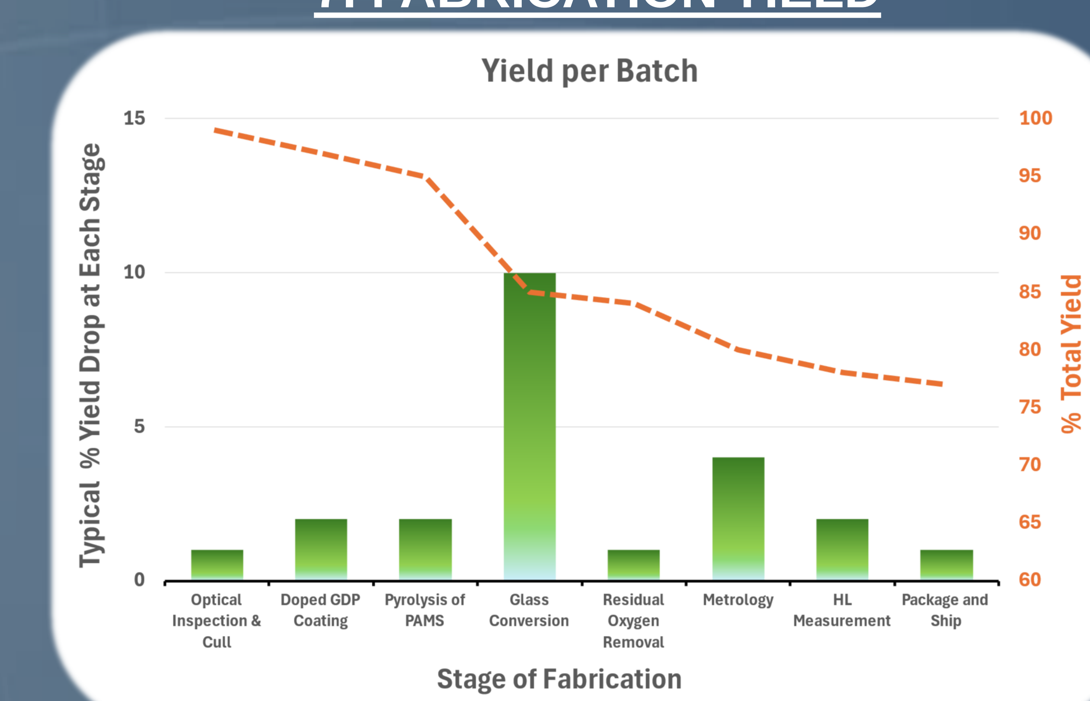


- Glass Conversion and Metrology constitute the bulk of the operator handling time



- Glass Conversion and Metrology take up the majority of the instrument time as well

7. FABRICATION YIELD



- Glass Conversion and Metrology impact the yield the most dramatically
- Shells break during conversion
- Shells are rejected for being outside of specification during Metrology

8. CONCLUSIONS

- Hoppe glass capsules are made from Si-doped GDP that is converted into SiO_2
- HG capsules require a processing time of about 6 months from mandrel selection to delivery
- Dimensions within a batch are very tight but vary between batches
- HG capsules can support a wide range of diameters and wall thicknesses, and are mainly limited by their aspect ratio
- The dimensional control and permeability of HG shells is driving the decision to transition away from DT shells