Germanium Doped Glass Capsules via Glow Discharge Plasma

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23nd Target Fabrication Meeting
Annapolis, Maryland
Apr 23-26, 2019

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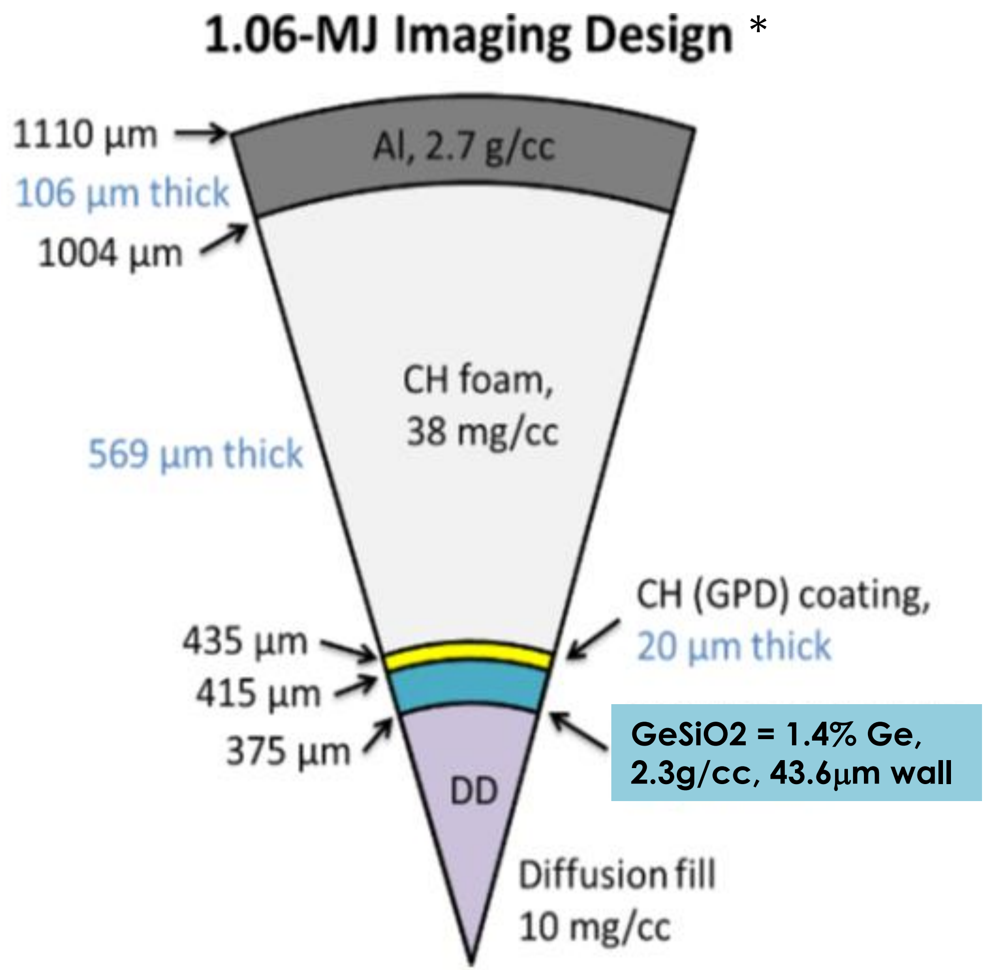
Work supported by U.S. Department of Energy under Contracts DE-NA0001808 and Under Contract 89233118CNA000010.

GENERAL ATOMICS

Ge-doped glass capsules were important for NIF Double Shell Energy Transfer Experiments

- **Ge doping for shell contrast during implosion**
- **D2 diffusion fillable**
- **Thick wall to meet mass requirements (m_r/m_{is+t} ~ 1)**



* Elizabeth Merrit et al, "Experimental study of energy transfer in double shell implosions" (accepted for publication in Physics of Plasmas 2019).

GENERAL ATOMICS

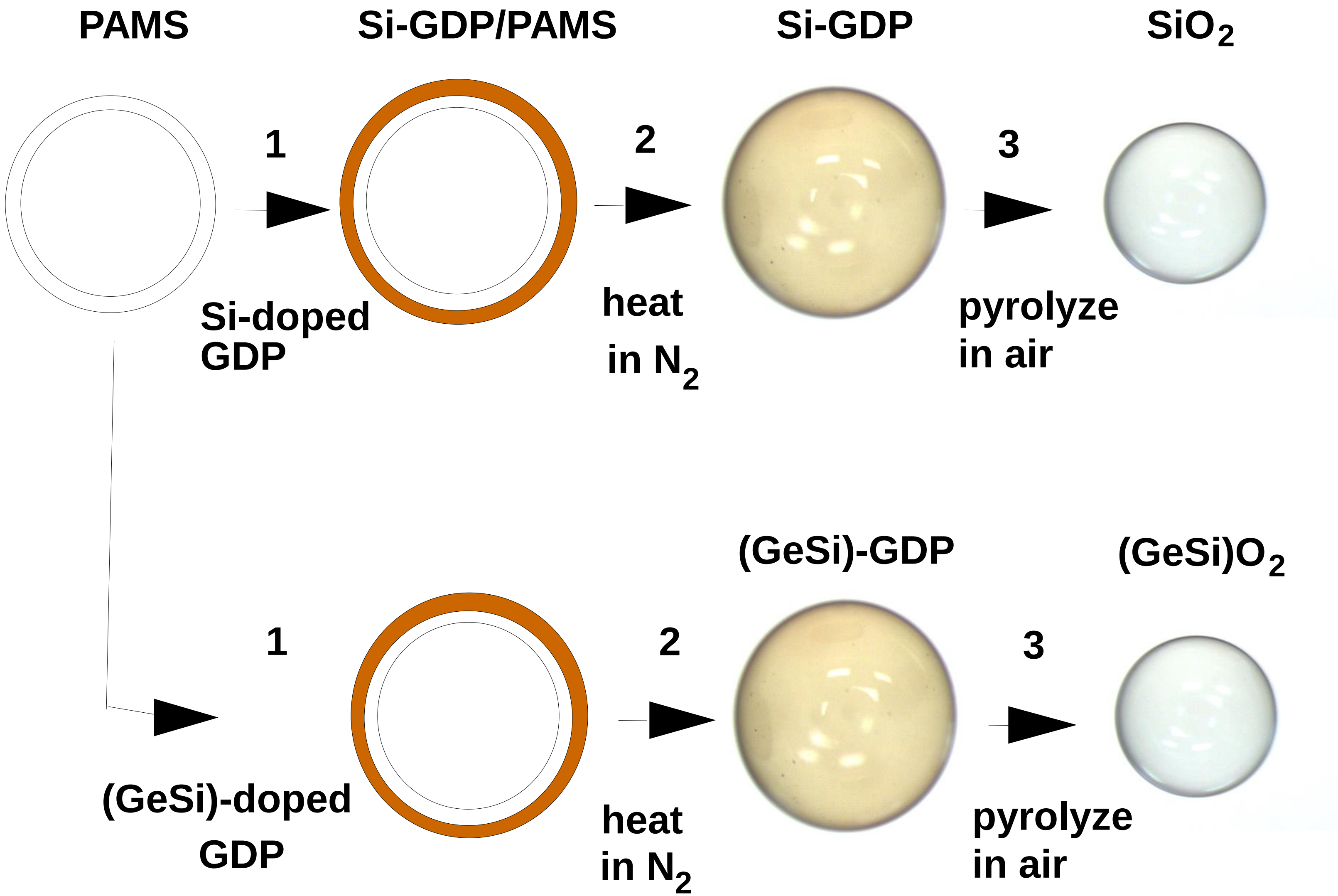
Ge doped glass capsules for Energy Transfer Experiments needed additional development

Partially densified, thick-walled, undoped glass capsules were made for the initial double-shell experiment in 2017. This next phase required:

- **fully densified Ge doped glass capsules**
- **wall thickness to a >35μm in thickness**
- **very high burst/buckle strength (>50atm)**
- **very long DD HL at room temperature**
- **method to DD fill GDP coated, Ge doped glass**

Bottom line…. We succeeded! Both the ablator and the inner shell trajectories observed for the first time.

Ge doped glass is made using the SiGDP to glass process



Early Ge doped glass proof-of-principle experiment looked promising

GeSi GDP

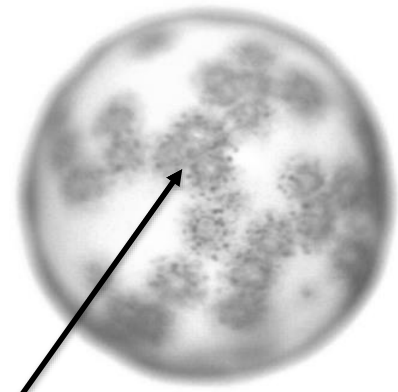
5% Si
1% Ge
Remainder CHO

Partial conversion

$GeSiO_2$ (530C)

28% Si
6% Ge
66% O

Full densification



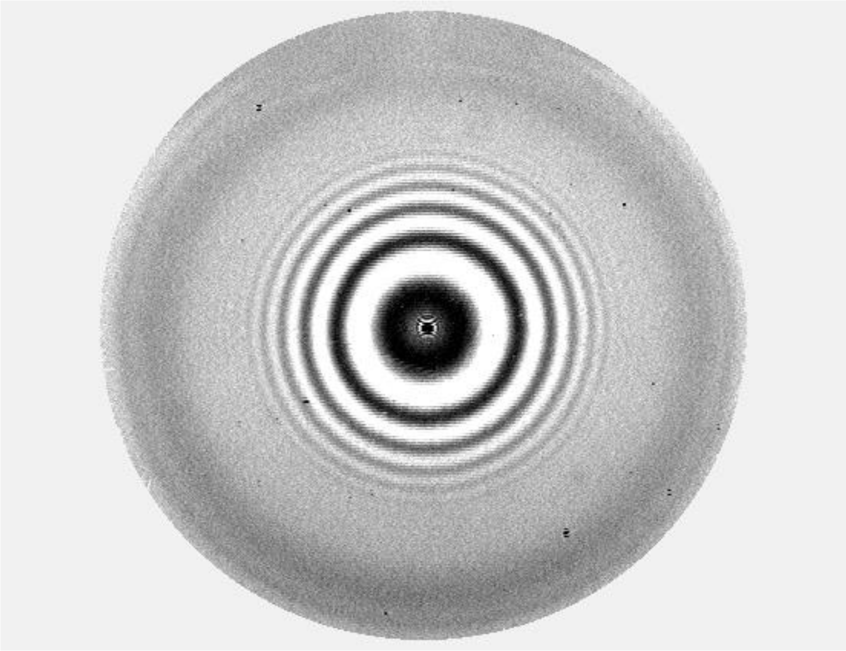
$GeSiO_2$ (960C)

28% Si
6% Ge
66% O

Patch areas higher in Ge content by EDXS

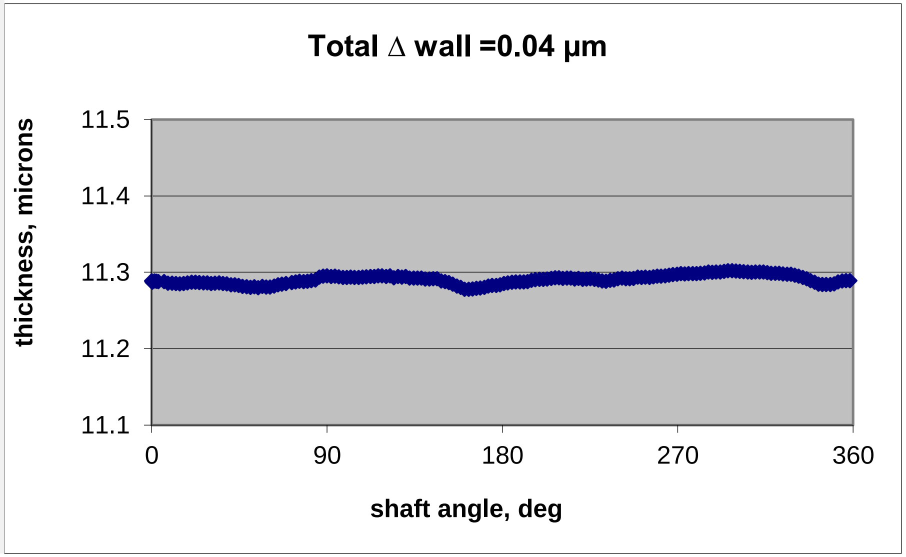
Decreasing Ge content to 1.4 at% produced high quality capsules at full densification

$GeSiO_2$ shell



1 mm

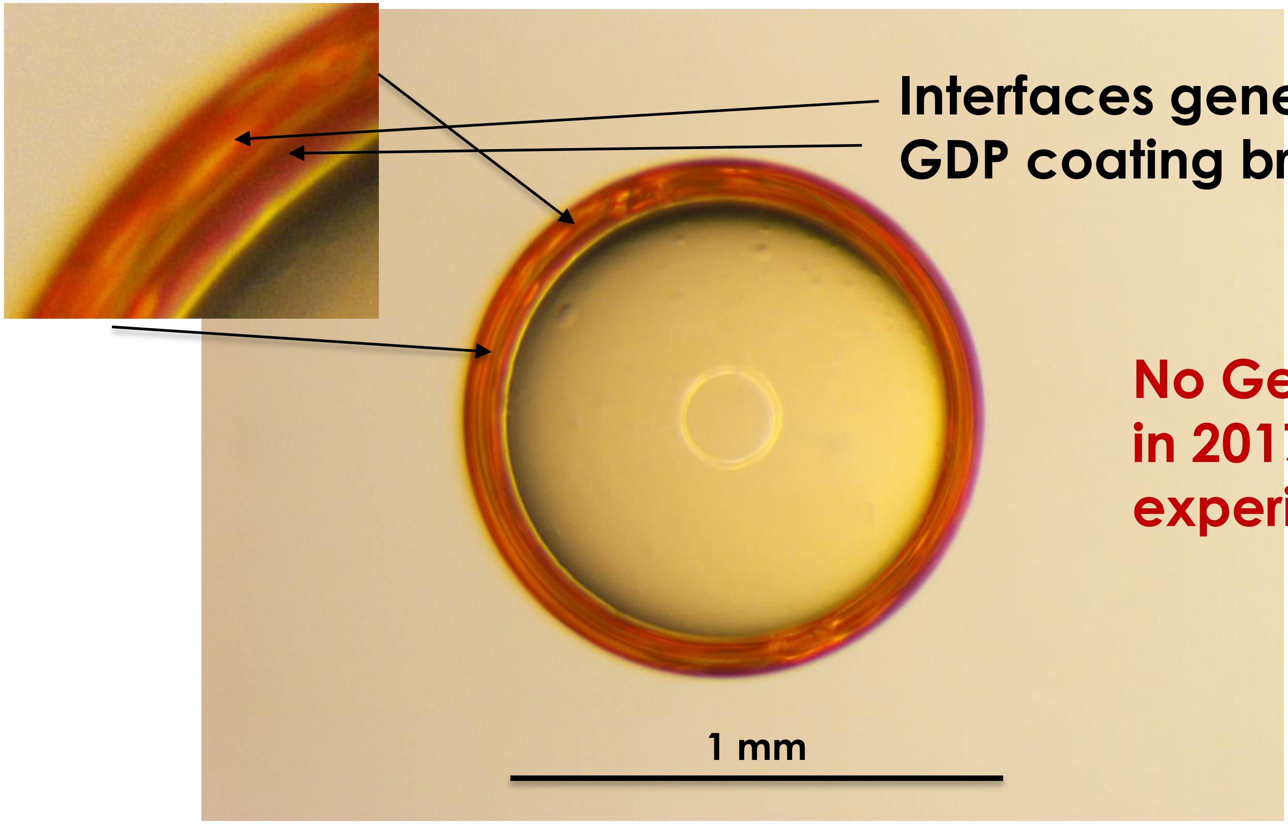
Wall-mapper wall uniformity



GENERAL ATOMICS

Next up – increase $GeSiO_2$ wall thickness to >35μm using information from LANL Double-Shell experiments* in 2017…

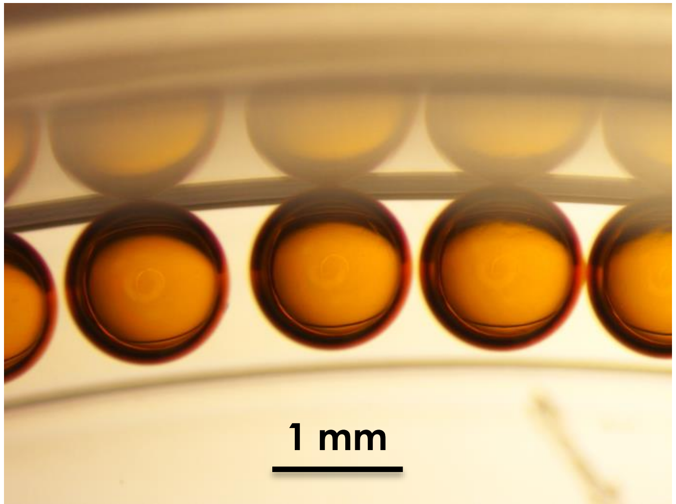
Hemi shell post PAMS pyro



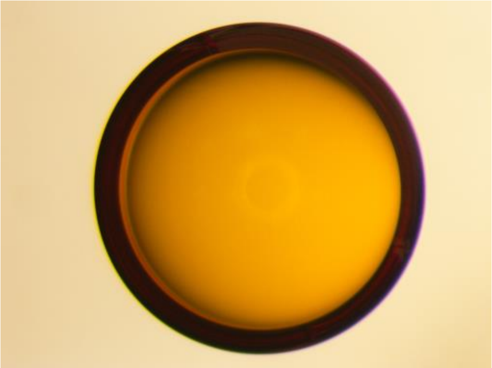
Interfaces in SiGDP wall cross-section suggest breakpoints during coating increase likelihood for failure during pyrolysis

* Progress Toward Fabrication of Machined Metal Shells for the First Double-Shell Implosions at NIF- Tana Cardenas et al., FST (2018)

No "breakpoint" SiGDP run had the desired result

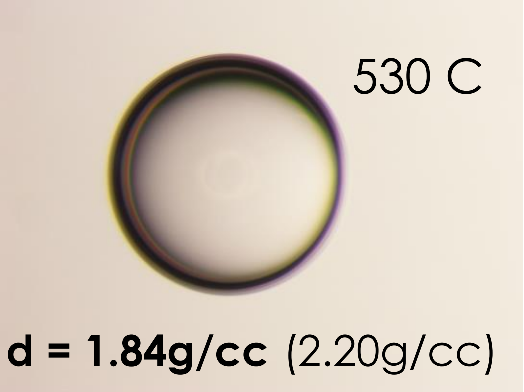


Majority (>50%) survived PAMS pyro intact



Conversion in air

(not fully densified)

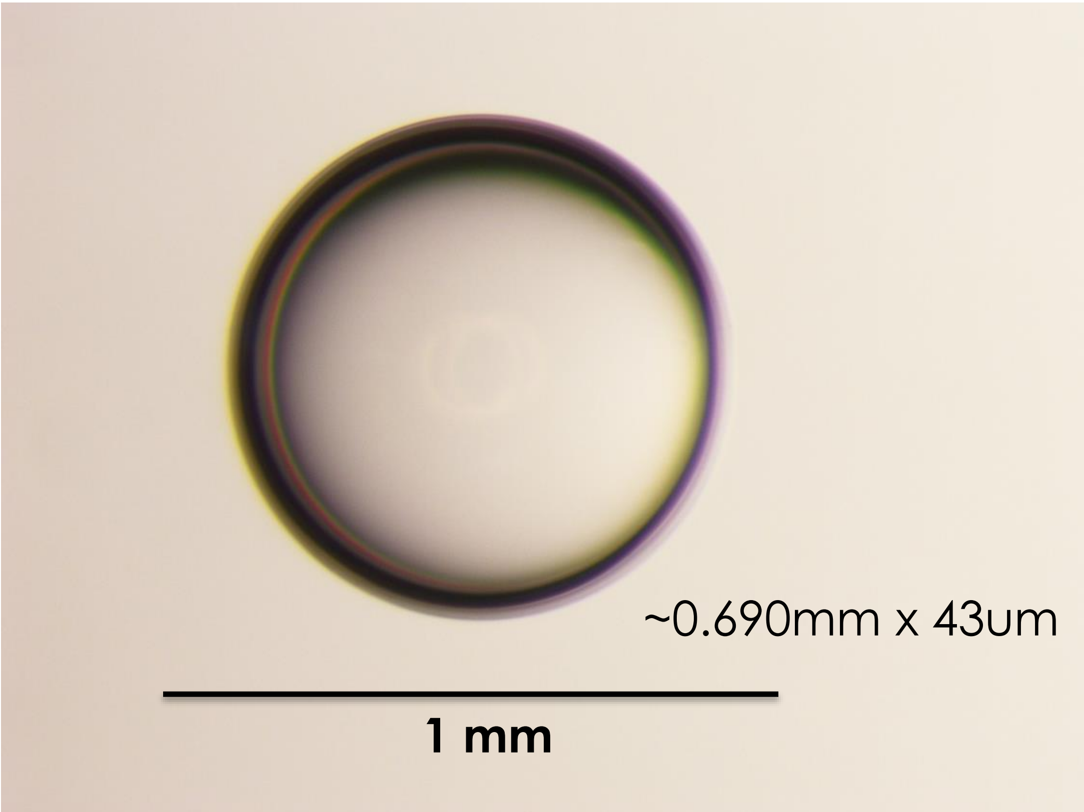


~1mm x 70μm SiGDP capsule

~700μm x 36μm glass capsule

Full densification not attempted in time for 2017 experiment

No-breakpoint run for GeSiGDP went very well also >50% yield after conversion to glass



Capsule after conversion to full density $GeSiO_2$ glass

d = 2.26 g/cc; at% Ge = 1.4

Ge-Glass capsules properties were tested and found to be suitable for the Energy Transfer experiments

Very Strong → (He tested) Buckle Strength >100atm
Burst Strength > 60atm

Appropriate size
~700μm OD
>35 μm wall
→ Glass OD (μm) ~ 690μm
Wall thickness (μm) = 43μm

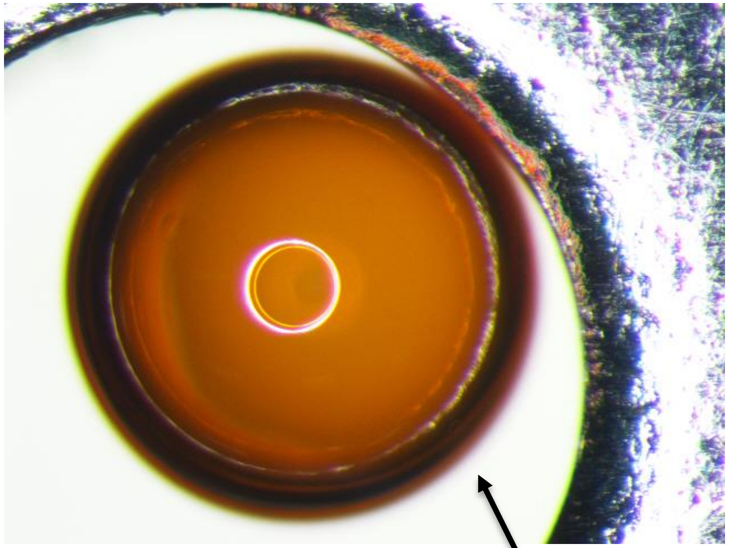
Very long DD HL but still fillable by permeation → He HL = 19.6 hrs at 20C
DD HL ~ 12,700 hrs (530 days)
~ 20 hrs at 260C

Sufficient [Ge]
>1%
→ [Ge] = 1.4at% (0.11g/cc Ge)
Density = 2.26 g/cc

Based on DD HL results capsules were filled with DD at high temperature prior to CH overcoat

DD HL much to long at low temperature to fill after CH overcoat (~12,700 hrs)

~72 hrs of coating time needed for CH overcoat; calculated loss of DD is minor for 72 hrs at 80C (<5%)



By Interferometry:

Pre CH DD fill pressure = 62+/- 5atm

Post CH DD fill pressure = 61+/- 5atm

Final Ge-glass capsule after DD fill and CH overcoat

Glass shell research for future experiments continues - a trial to make a pure GeO_2 capsule shows promise

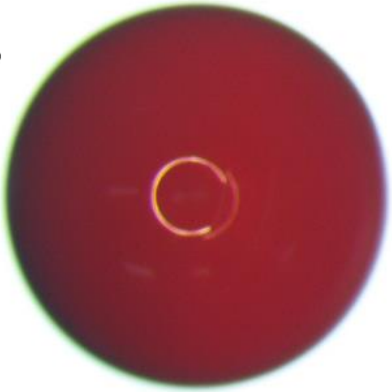
Ge-GDP

1 mm

1.6mm x 13μm

~6.3at% Ge-GDP by XRF
Post-PAMS removal

530C in air
GeO_2?



1 mm

~1.05mm x 8μm
(~35% shrinkage)
d = 3.2 g/cc
He HL <1min

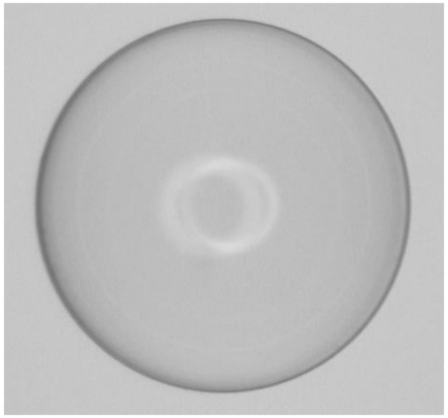
GENERAL ATOMICS

High Z (Pb) doped glass has been of interest in the past -Tin (Sn) doped glass capsules look very promising

1 mm

~1.6mm x 10.5μm

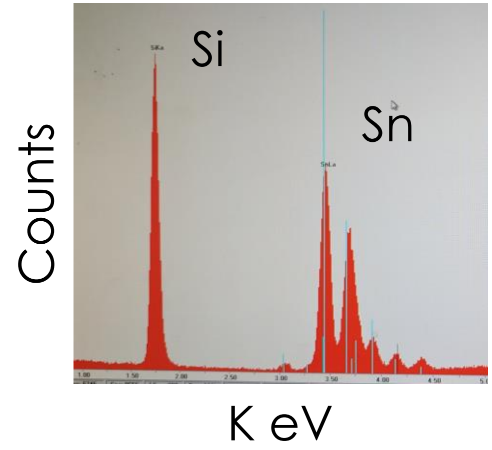
SnSi doped GDP
Post PAMS removal



1 mm

~1.05mm x 7μm

Sn doped glass
capsule

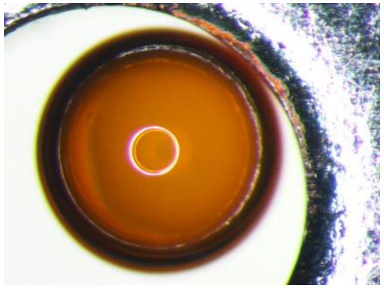


XRF of glass capsule

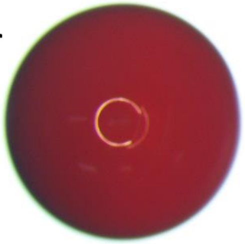
Note: Pb doping was considered but the precursor is not readily available

Summary – Ge doped capsules for ET expts achieved; Tin doping and pure GeO_2 possible new additions

First observation of the inner shell trajectory in Double-shell Energy Transfer experiments
Elizabeth Merrit et al, "Experimental study of energy transfer in double shell implosions“ (accepted for publication in Physics of Plasmas 2019).



Nearly pure(?) GeO_2 capsules show promise



Tin (Sn) doped GDP capsules made for first time

Tin doped glass capsules made for first time