Smooth High at% Silicon SiCH and Ultra-thin SiCH Capsules

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Experimental Objective

SiCH Capsule Goal: Smooth, cryo-quality, multilayered capsule with at least 9at% Si outer layer and SCD (strong CD) inner layer.

Reason: Enable mapping of high silicon content CH layers (>7at% Si) to determine optimum Si content for maximum yield at shot time.

Side Goal: Determined thinnest free-standing capsule that can be produced.

Four Routes for High Si Content SiCH/SCD Capsule Explored

1) SCD/PAMS → 7% SiCH → 7% SiCH/SCD/PAMS → 500C → 10% SiCH/SCD

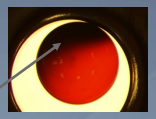
2) SCD/PAMS → 9% SiCH → 9% SiCH/SCD/PAMS → 300C → 9% SiCH/SCD

3) SCD/PAMS → 7% SiCH → SiCH/SCD/PAMS → 300C → 7% SiCH/SCD → 9% SiCH → 9% SiCH/ 7% SiCH/SCD

4) SCD → 9% SiCH → 9% SiCH/SCD

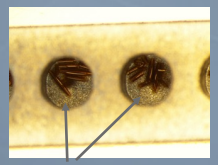
Method 1 - Pyro of 7% SiCH/SCD at 500C under N2

SiCH layer (10+ at% Si after pyrolysis SCD almost disappears.



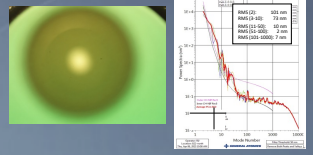
Dark area is SCD residue

Method 2 – 9+% Si on thin SCD pre-PAMS removal not viable

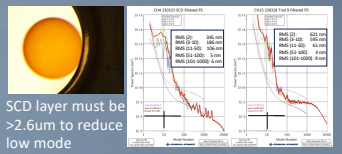


Stress during PAMS pyro rips shell apart

Method 3 – 1.3µm 7% Si on 2.3µm SCD pre-PAMS; 1.6µm 9% Si deposited on SiCH/SCD post-PAMS



Method 4 – Deposit 9% SiCH onto 2.6µm SCD capsule after PAMS pyro somewhat successful



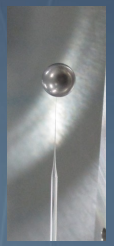
SCD layer must be >2.6um to reduce low mode roughness

High aspect ratio silicon doped GDP (6at% Si)have higher buckle pressure than un-doped GDP or SCD

Batch	OD (um)	Wall (um)	Survive 15 psia buckle	Survive 30 psia buckle	Youngs Modulus E (Gpa)
CH15-340526	~3100	6.5	No		<4.9
CH2-110815	~3150	8.8	Yes	No	>2.7 <5.4
CH2-100215	~3200	10.1	Yes	Yes	>4.0

Normal GDP expected buckle pressure (max) for 3150x8.8 µm 10.5 PSI
SCD expected buckle pressure (max) for 3150x8.8 µm 15.5PSI
E (normal GDP) = 1.9 Gpa
E (SCD) = 2.4 Gpa

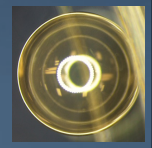
Superior buckle pressure allows for 3mm CFTA builds with capsules having <10um wall thickness



3.1mmx6.5µm SiCH (5at% Si) pre 1 atm buckle test

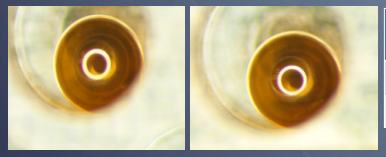
3.15mmx8.8µm SiCH (6at% Si) capsule after 1 atm buckle test

3.2mmx10.1µm SiCH (6at% Si) capsule after 2 atm buckle test



Capsules survived 20C → LN_2 → 20C temperature cycle test

Type 3



Batch 1 SiCH/SiCH/SCD 9%; 6-7%

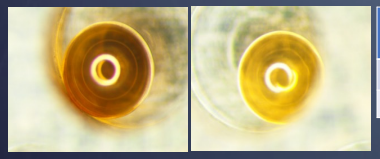
Batch 2 SiCH/SiCH/SCD 9%; 6-7%

Type 3 Buckle Strength

OD (µm)	Outer SiCH 9at% Si (µm)	Inner SiCH 6at% Si (µm)	Inner SCD (µm)	Total Wall (µm)	B. Pres. PSI	Youngs Modulus E (Gpa)
935	3.7	1.0	1.9	6.6	117	3.49
936	3.7	1.0	1.9	6.6	104	3.06

Note: For reference: E (SCD) = 2.4 GPa

Type 4



Batch 1 9% SiCH/SCD

Batch 2 9% SiCH/SCD

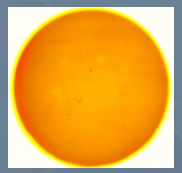
Type 4 Buckle Strength

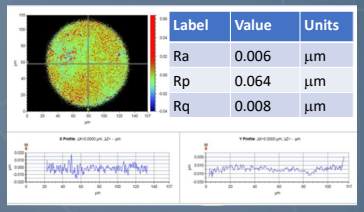
OD (µm)	Outer SiCH 9at% Si (µm)	Inner SCD (µm)	Total Wall (mm)	Buckle Pres. PSI	Youngs Modulus E (Gpa)
819	4.2	2.6	6.8	121	2.44
869	5.6	2.1	7.7	123	2.33

Note: All type 3 and Type 4 capsules tested survived 150 PSI fill pressure

Interesting future possibilities

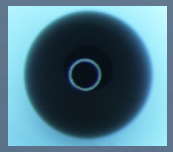
Free-standing SiCH capsule at 11at% Si is achievable by Pyro of 7% SiCH to 550C





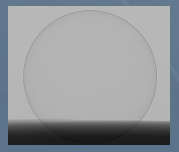
Label	Value	Units
Ra	0.006	µm
Rp	0.064	µm
Rq	0.008	µm

Possible replacement for glass



8at% SiGeCH pryo'd to 1100C In He

875x3.2 Noir Glass



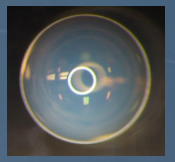
SigRay x-ray image demonstrating wall uniformity and very high aspect ratio

- 875x3.2 µm; d = 1.95g/cc
- 0.63g/cc Si after pyrolysis
- 0.05g/cc Ge after pyrolysis
- Buckle Pressure ~450PSI
- 10/10 capsules survived 20 atm DD fill
- He HL 2-4hrs
- No residual gas
- Youngs Modulus 50Gpa
- Stronger than conversion glass

Record? Thinnest, highest aspect ratio SiCH capsule to date

1750x1.1µm post PAMS

SnO_2 capsule



1280x4µm

Conclusions

1) Methods 3 and 4 (but not 1 or 2) were potentially viable routes for making multi-layered 9at% Si CH capsules.
2) Si doped capsules have higher Youngs Modulus than normal CH or SCD capsules.
3) 9at% Si SiCH can be deposited with sufficiently smooth surface finish but must be deposited after PAMS pyrolysis step.
4) Very thin high aspect ratio SiCH capsules can be made, but can they be handled?
5) "Black glass" as possible future replacement for SiO_2 glass? Not transparent but stronger than glass and fillable using standard glass capsule filling process.
6) Black glass, high carbon content with much lower silicon and oxygen content than glass.

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