Tumble Finishing of CH Capsules

20th Target Fabrication Meeting

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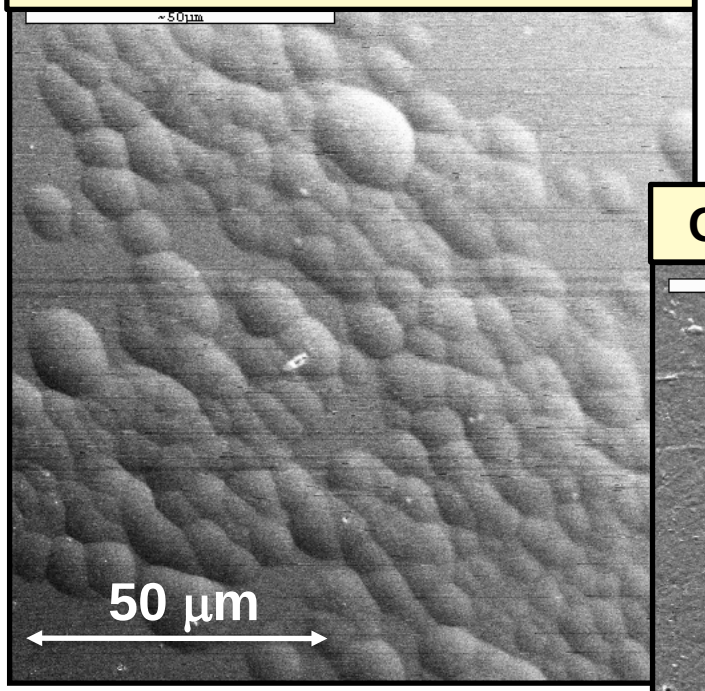
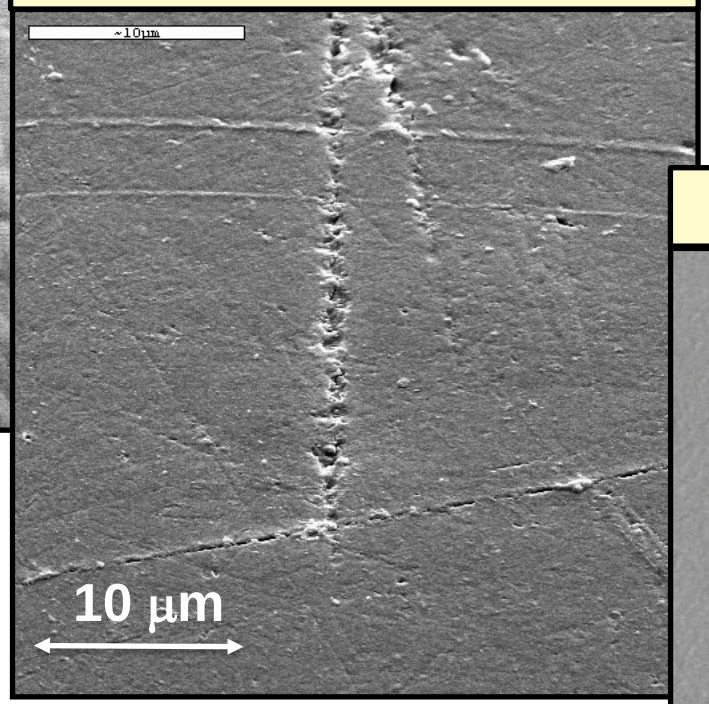
Surface quality of CH capsule has greatly improved with new finishing techniques

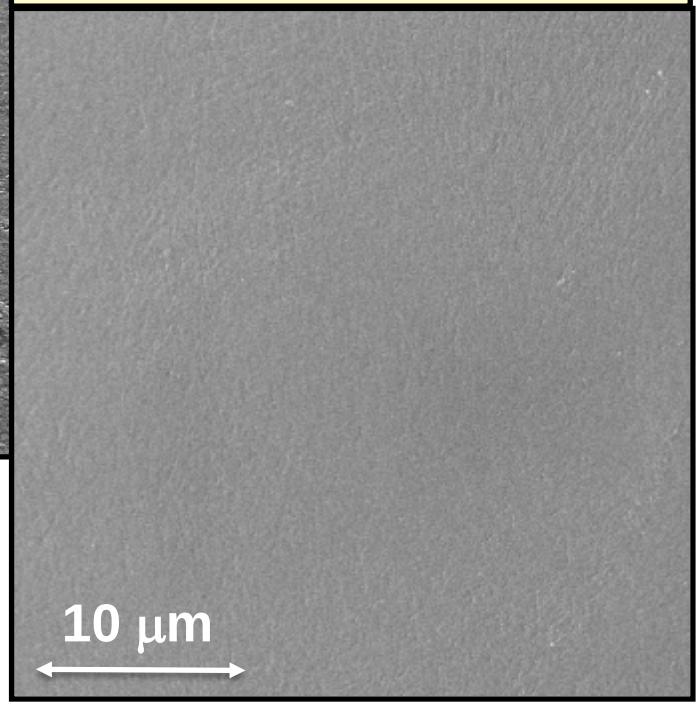
As-deposited CH Capsule



Conventional Polish (2009)



Tumble Finishing (2010)*



* Suratwala et. al. "Method and System for Polishing Solid Hollow Spheres" US Provisional Patent Application 61514430 Aug 2011

Three target parameters are experimentally tuned but many affect margin and uncertainty

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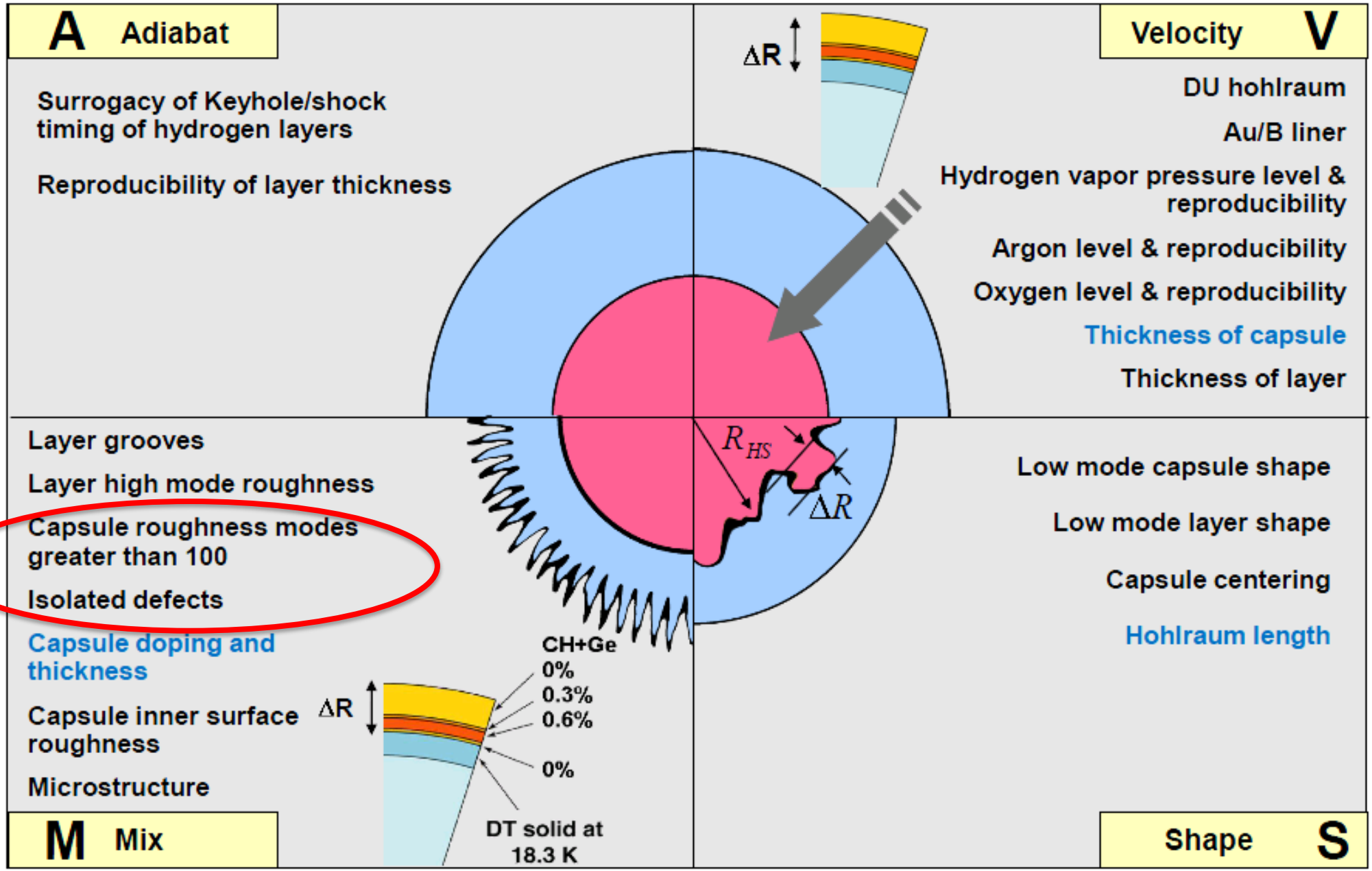
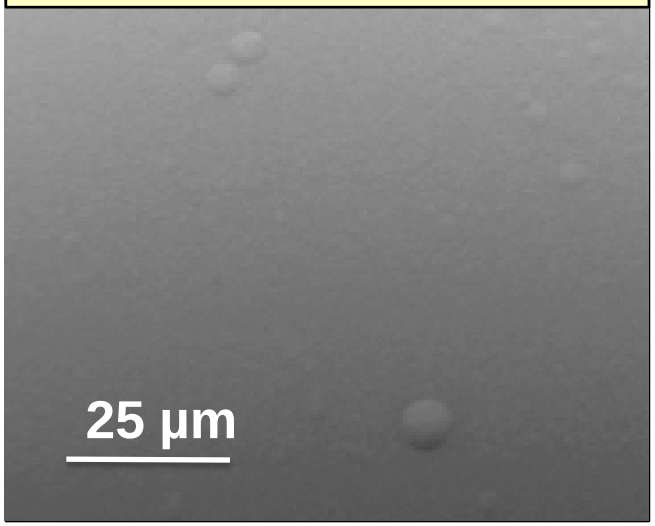
The National Ignition Campaign

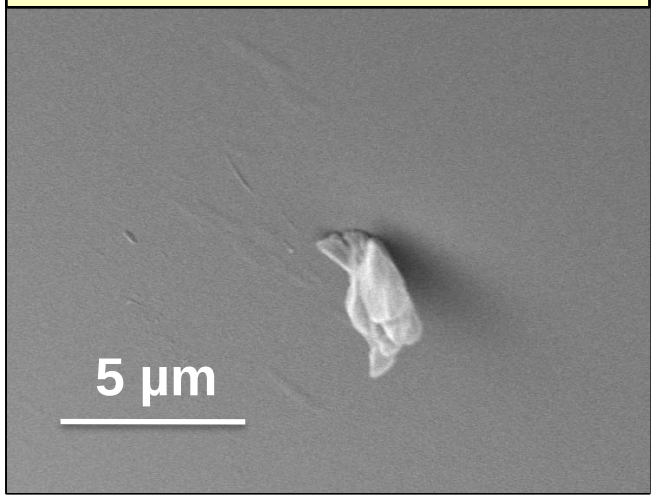


Capsule isolated defects that can increase mix fall into two categories

“Domes” from coating



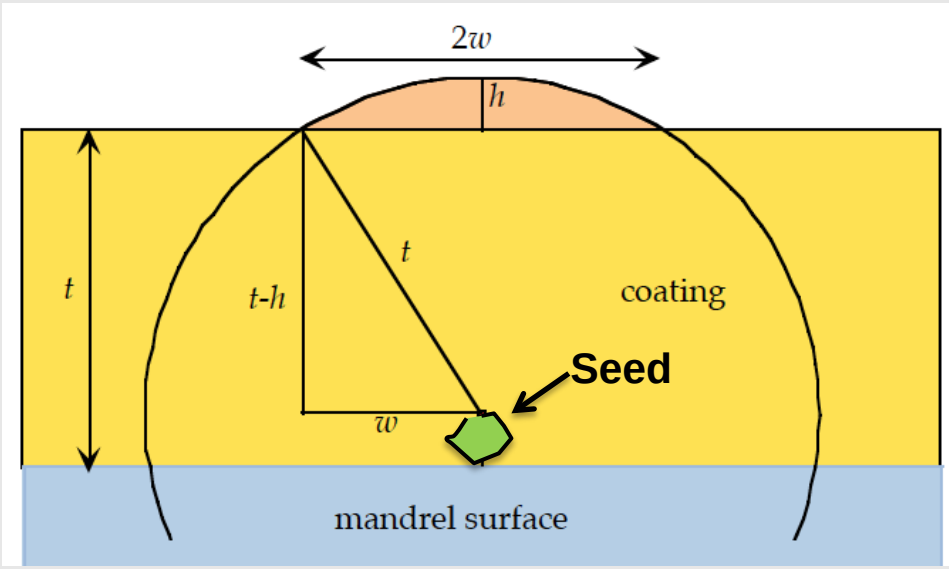
“Dust” from handling



- **Bumps formed during deposition of ablator (“domes”)**
  - **Typically < 80 µm in diameter, ~ < 2 µm tall**
  - **Specification: height ~ < 200 nm**
  - **Detection and quantification by interferometric mapping**
- **Debris accumulated during handling (“dust”)**
  - **Specification is < 30 μm^3**
  - **Cleanroom handling can reduce debris**
  - **Detection and Quantification is current focus**

Small defects on mandrels will grow into large "domes" on CH shells which affect mix mass

Omni-directional coating model of dome growth



1 µm spherical seed after 200 um coating: ~ 40 µm wide, 1 µm tall dome , 150 ng of mix mass

- **GDP coating is omni-directional**
- **Can predict dome size from seed size for coating thickness *t* and spherical seed of diameter *h***

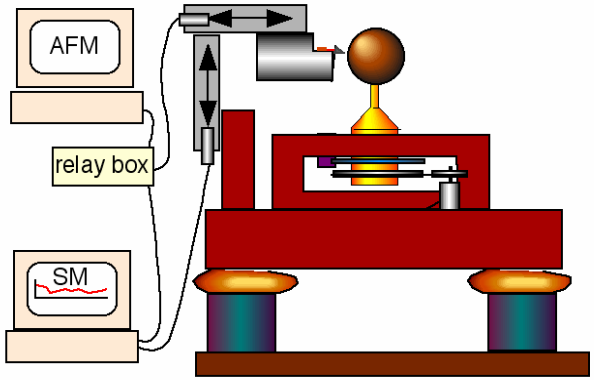
$$w = \sqrt{2ht - h^2} \approx \sqrt{2ht}$$

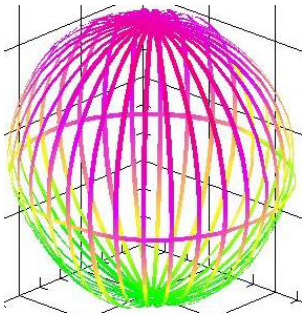
$$for\ h << t$$

- **Similar results for other seed shapes**
- **Height is unchanged**
- **Tested by various groups using seeds of known size (e.g. S. Letts, LLNL, various at GA)**

Various metrology tools are used to determine capsule shape, isolated defects and homogeneity

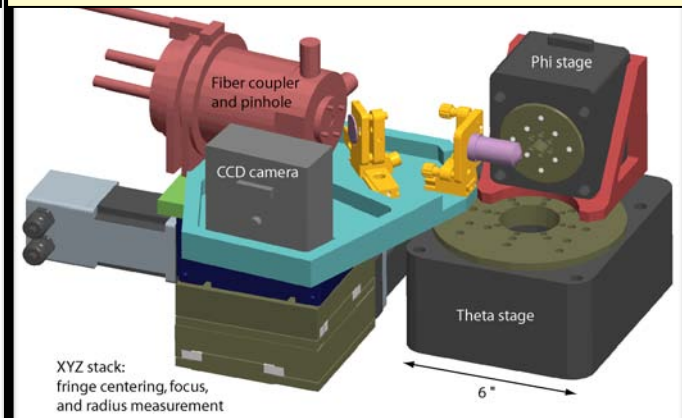
Atomic Force Spheremapper

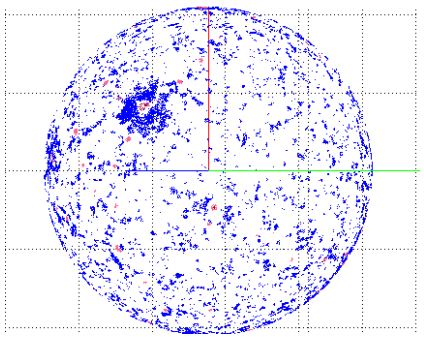




Shape and roughness

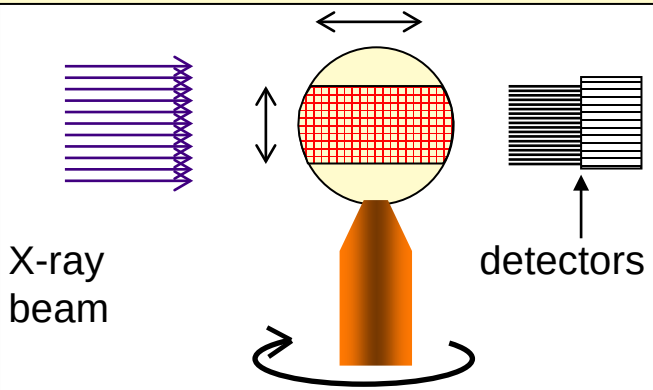
Phase Shifting Diffractive Interferometry (PSDI)

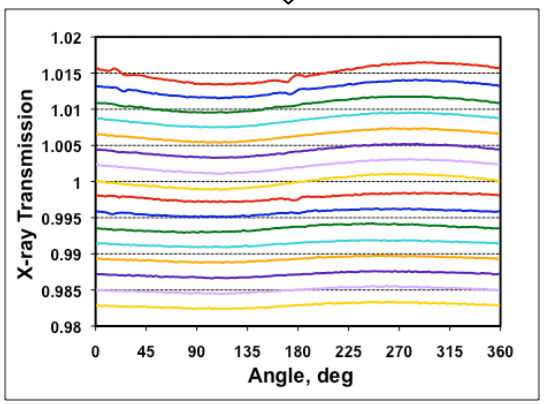




Isolated defects & uniformity

Precision Radiograph

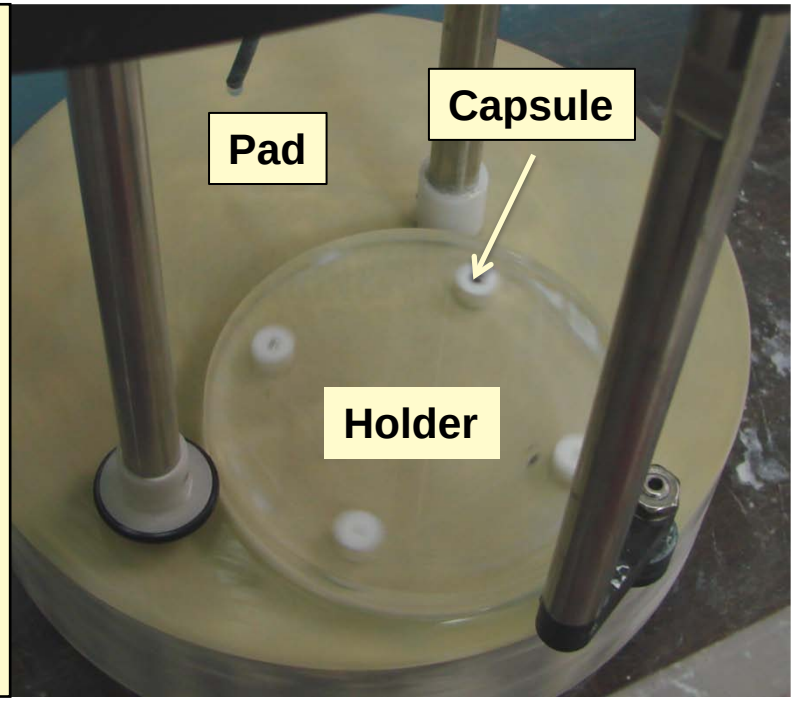




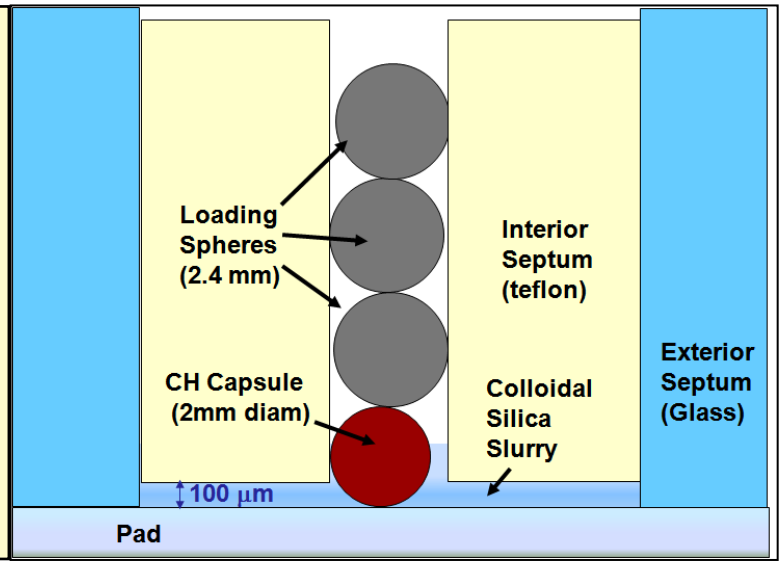
Uniformity

Conventional polishing methods are prone to scratching due to multiple interface contacts & exposure to rogue particles

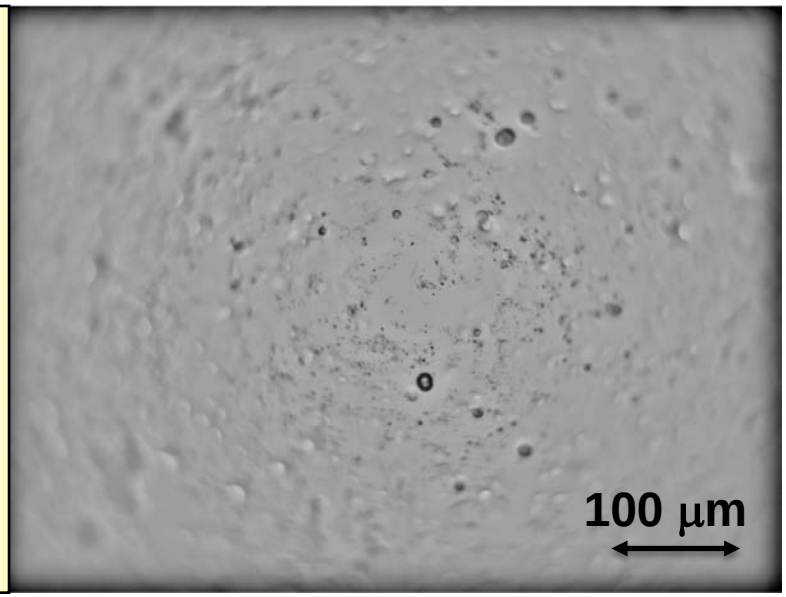
Polishing setup



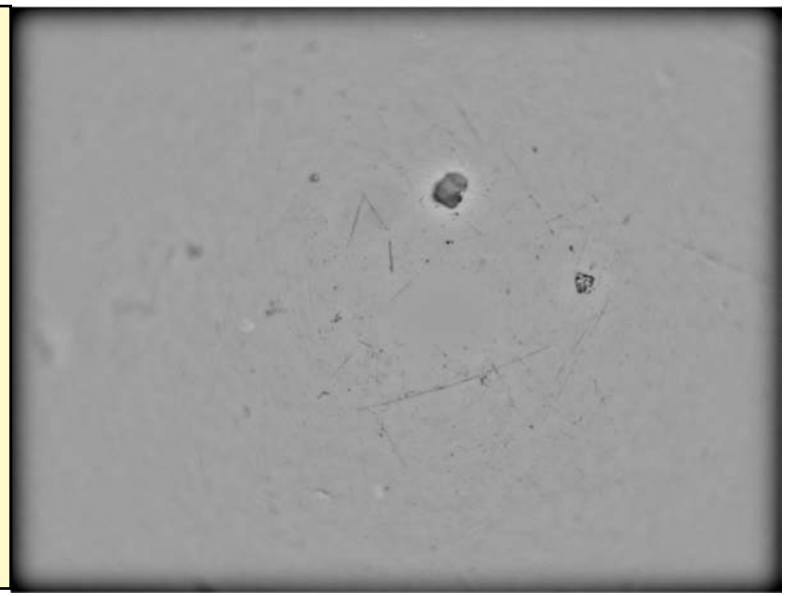
Cross Section



Before Polish

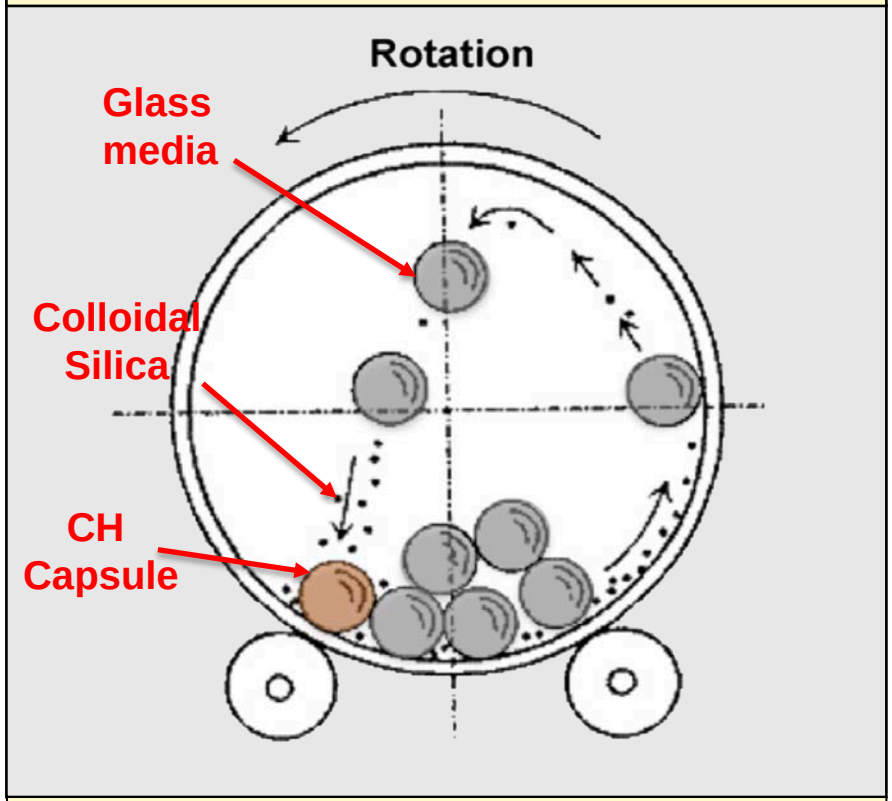


After Polish



A new method of polishing capsules called "Tumble Finishing" was developed in 2010

Cross Section View of Tumble Finishing



Rotation of holder moves media and capsule causing colloidal silica to randomly polish capsule surface

Compoents

1. Media – glass or metal spheres (load bearing)
2. CH capsule – material to polished
3. Polishing compound – colloidal silica
4. Lubricant – water & soap

Advantages

- Hermetically sealed
- No Septum interface
- Simple
- Slurry agglomerates are self-breaking

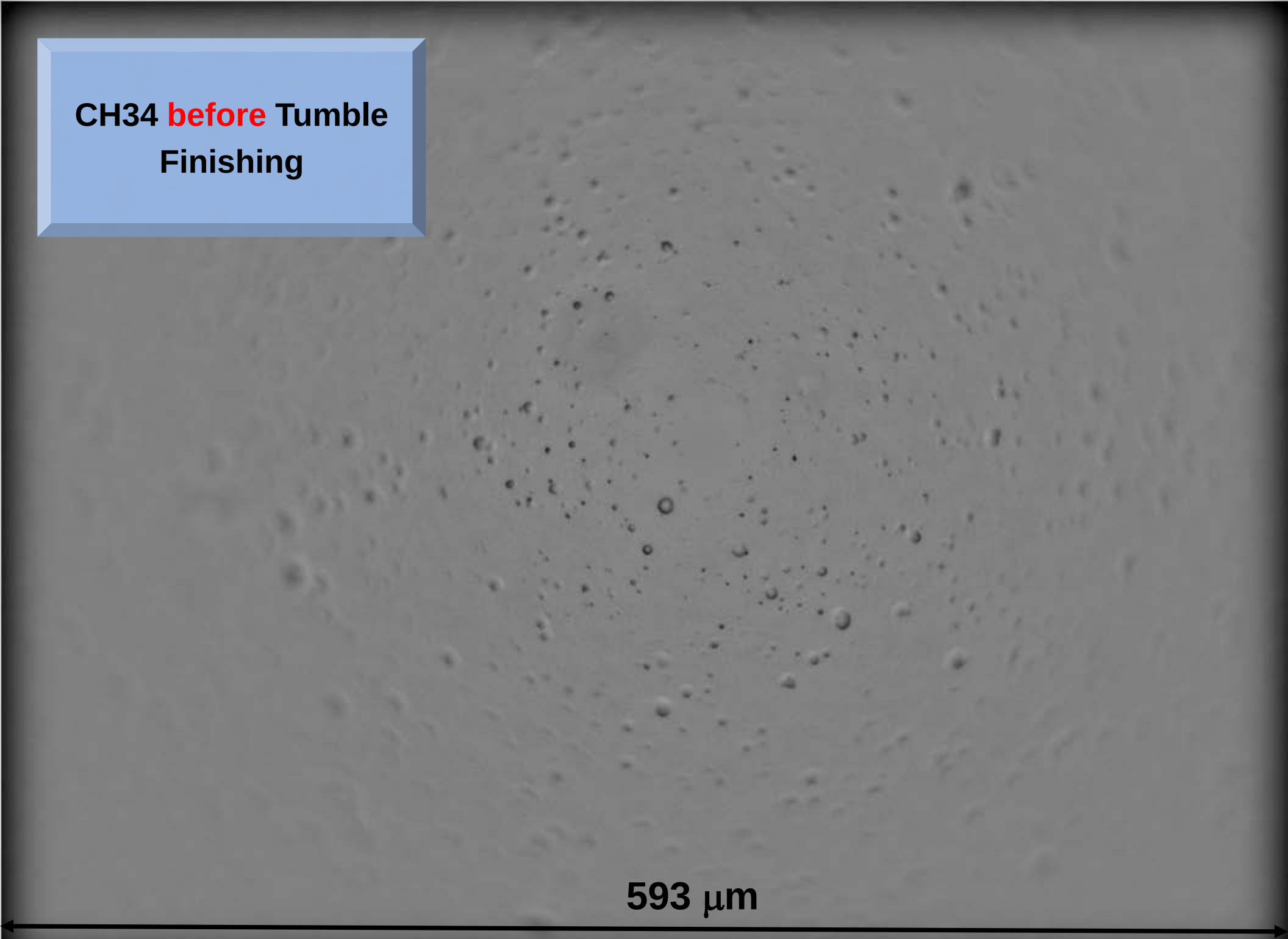
Disadvantages

- Possible embedding of colloidal silica and media
- Possible degradation of low/mid modes

Summary of Process development of Tumble Finishing

Issue	Mitigation
1. Drying Spots	Improved ultrasonic and high volume solvent rinsing process
2. Capsule Fracture	Operate in kinematics parameter space minimizing load at contact
3. Media Corrosion	Use borosilicate or zirconia media
4. Pits and scratches	Reduce asperities on media/vial; Perform operations in cleanroom
5. Convergence to planar surface	Select capsule for TF within process space; Increase removal rate or convergence rate; Use Lasik to pre-treat large defects
6. Mid mode degradation	Select capsule having low mid mode roughness for TF; Increase contact spot

CH34 before Tumble Finishing



CH34 after Tumble Polishing 24 hrs using SS spheres

593 μm

The dynamics of the tumbling media can be described using several characteristic terms

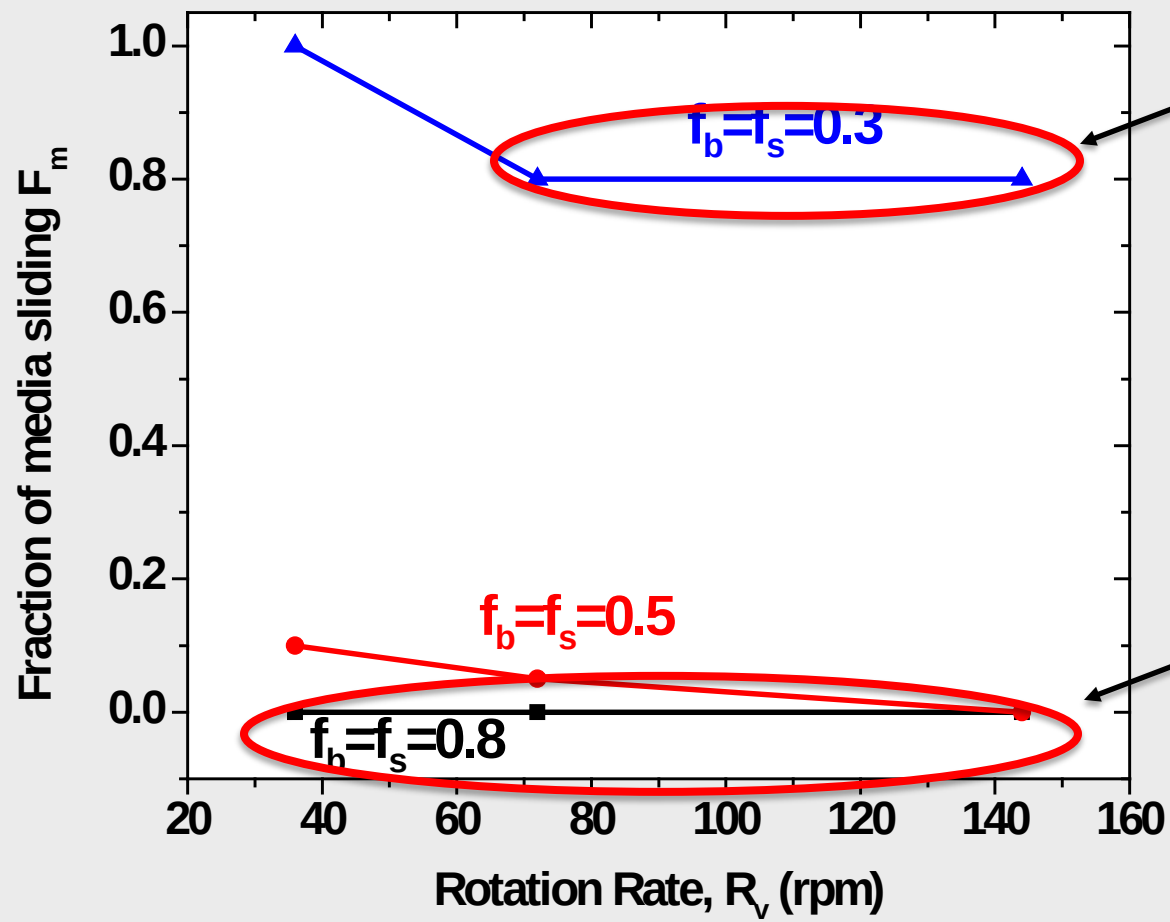
1)	V_{rot}	–	Rotation velocity of cylinder (controlled variable)
2)	V_{up}	–	Velocity of media on interior cylinder wall toward top of cylinder
3)	V_{down}	–	Velocity of media on interior cylinder wall toward bottom of cylinder
4)	V_{slide}	–	Velocity of media not touching cylinder wall
5)	F_m		Fraction of media traveling only on interior cylinder walls

Hypothesis

- High loads are realized with CH capsule due to media experiencing v_{down}
- Hence need to work in parameter space that drives toward $f_m \rightarrow 0$

Increasing the fill fraction (f_b; f_s) to 0.8 reduces F_m, which should reduces high velocities expected to cause fracture problem

Fraction of media sliding as a function of rotation rate and media/slurry fill fraction



Capsules fractured in <6 hrs

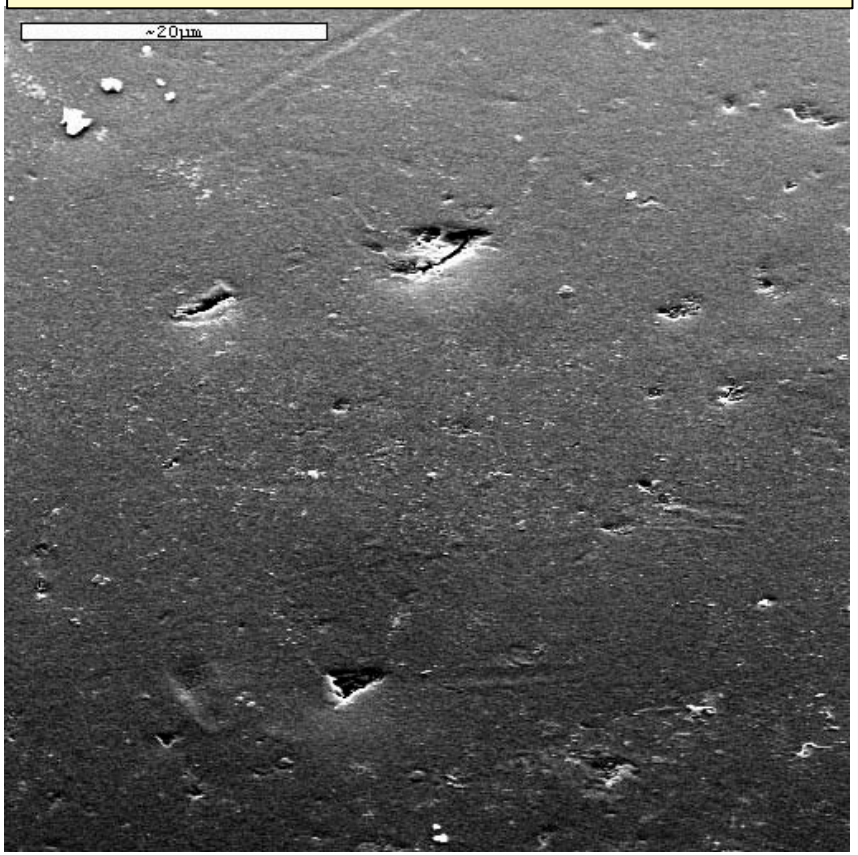
Capsules never fracture (>40 hrs)

CH74 BS glass

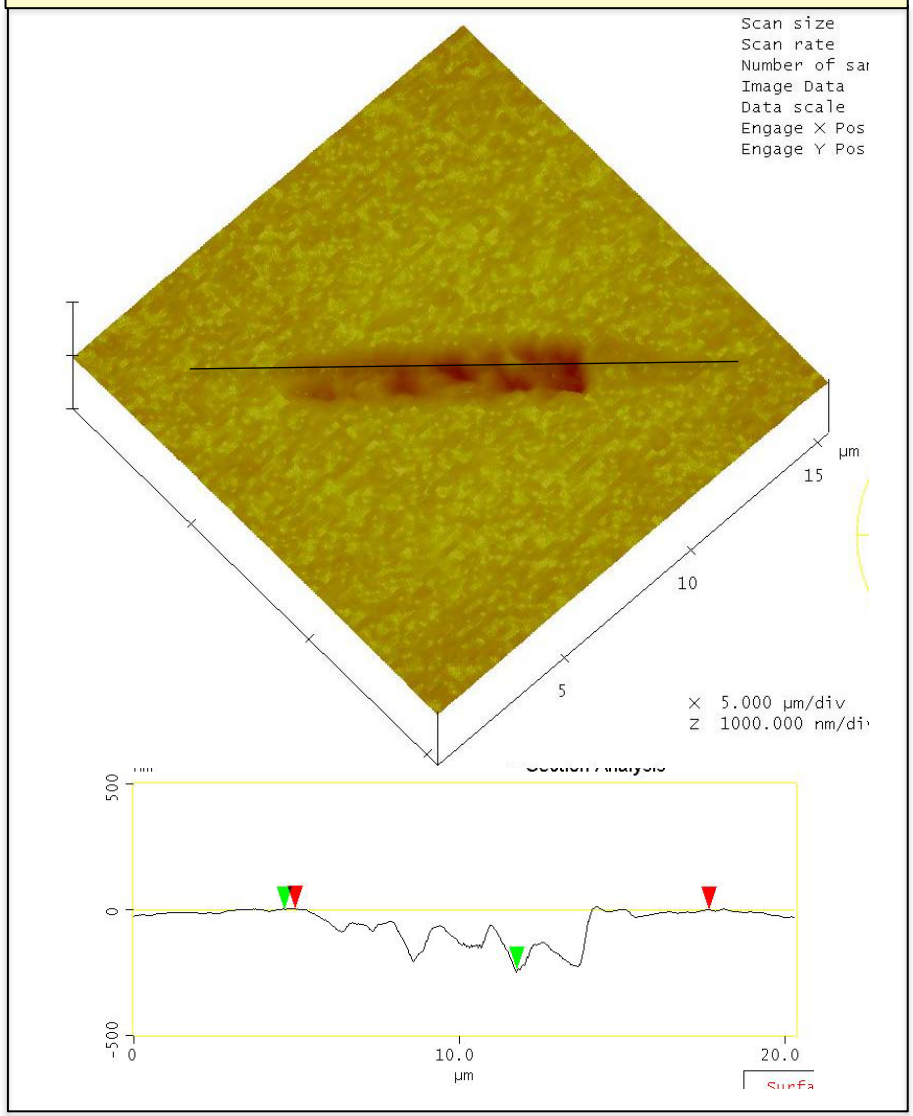
After Finish

Pits appear as static indentations with both plastic deformation and fractures

SEM Image of observed pits and scratches



AFM Image and lineout of observed pit



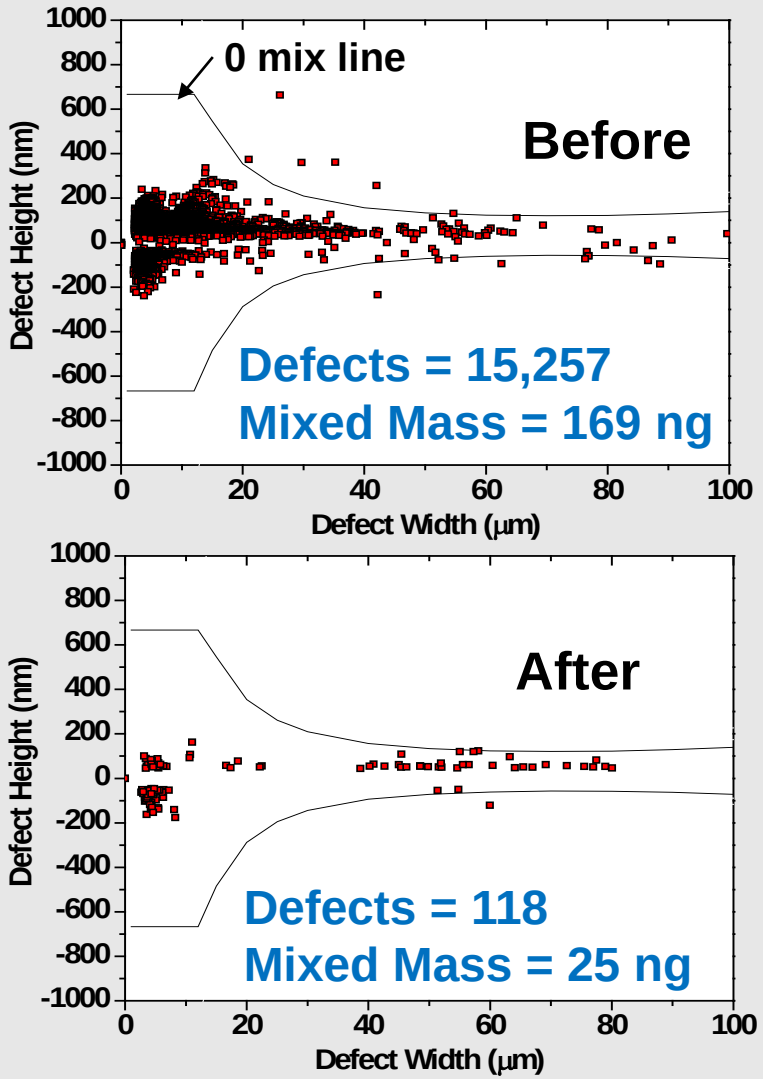
CH90 BS Glass

Polished media/vial

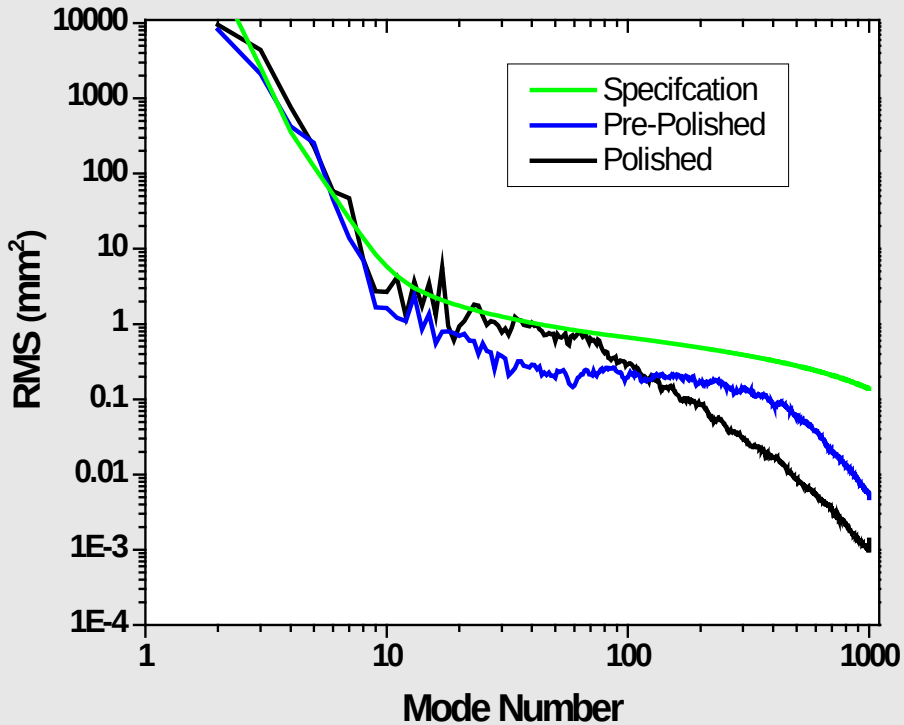
After finishing

Polishing reduces defect dome height and mix mass…

Typical capsule bump distribution before and after polishing*



Power Spectral Density vs mode number



…without degrading shape and mid-mode roughness beyond specification

*10CH70-07 GA Pre-Pilot

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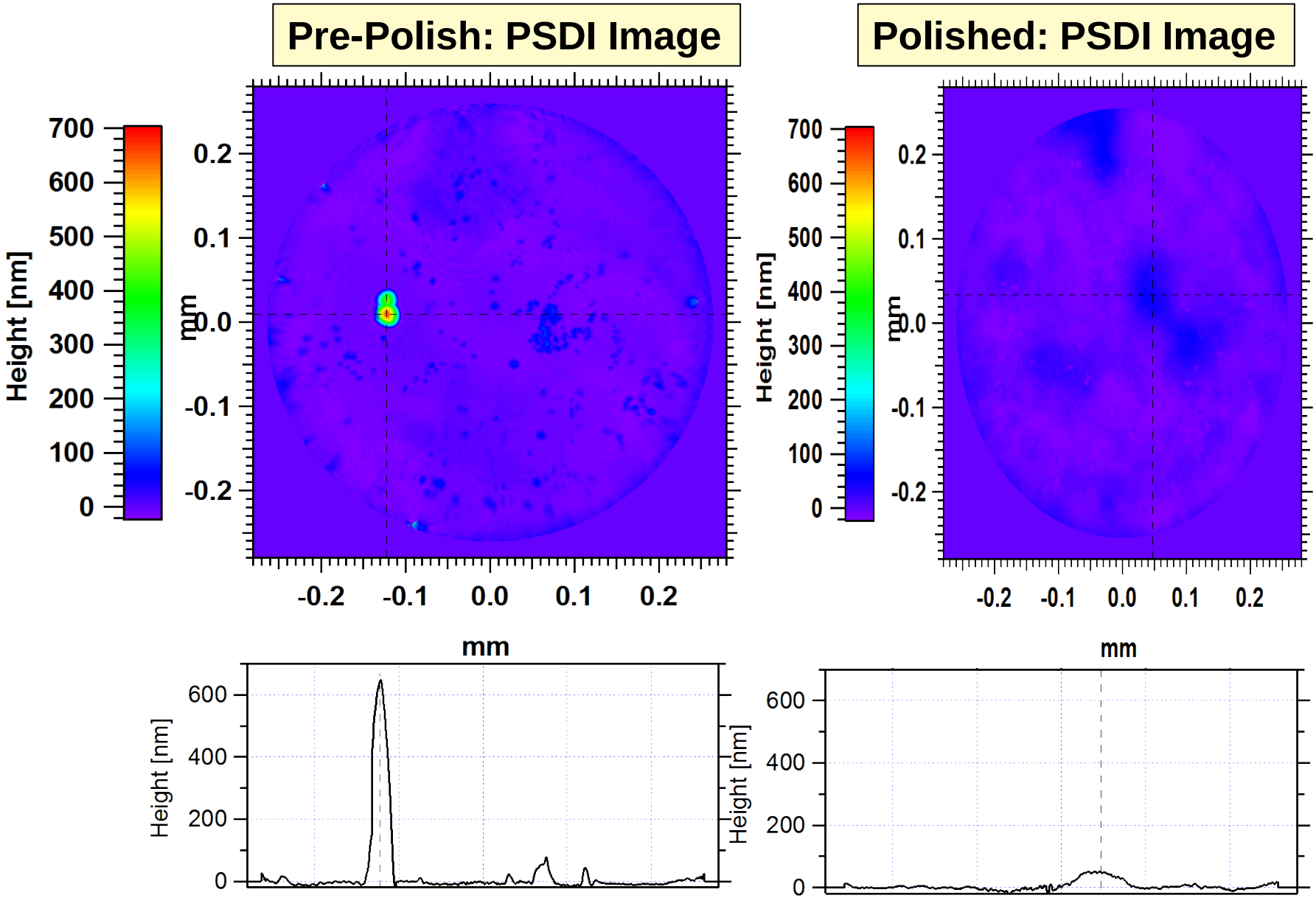
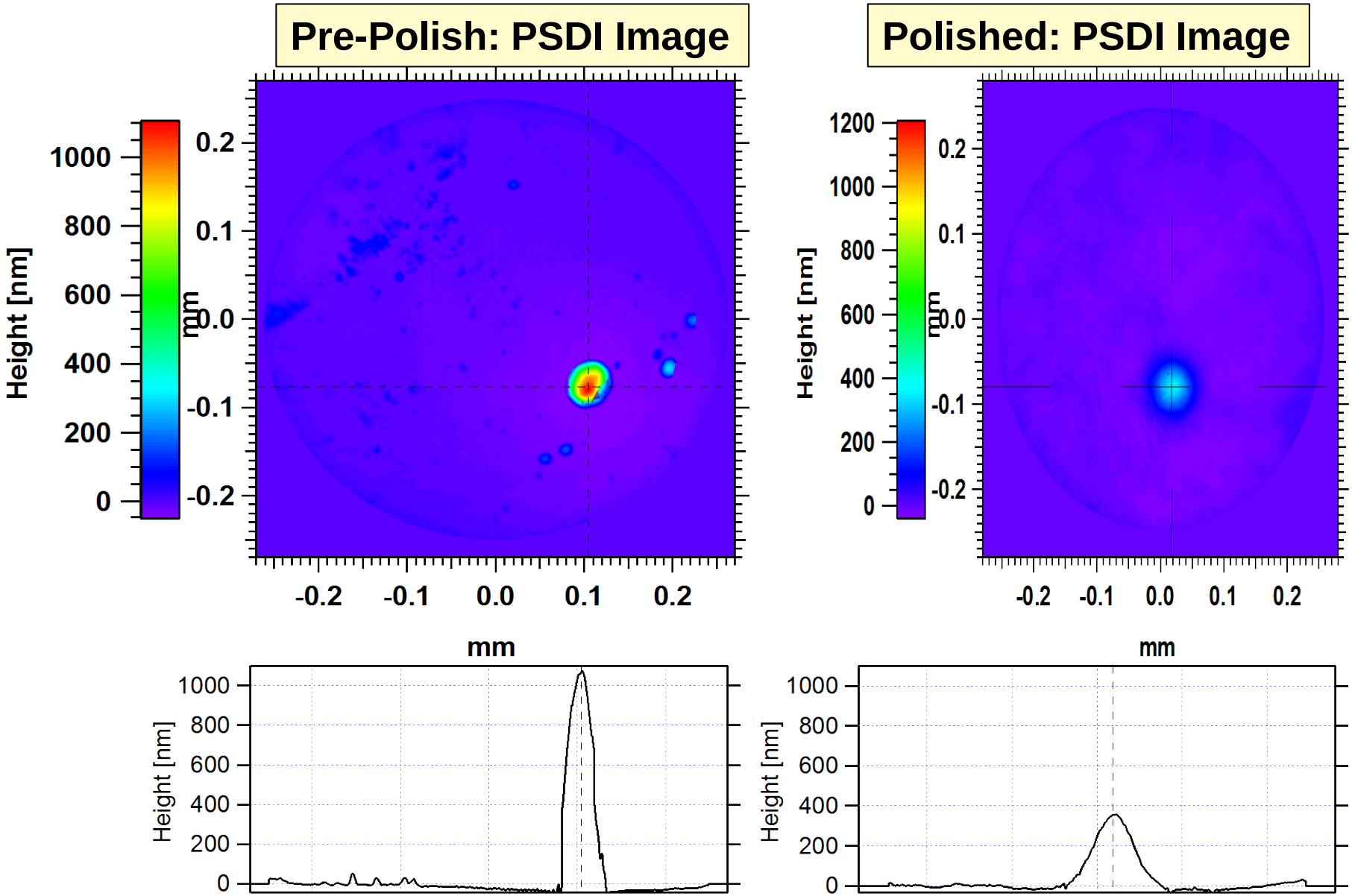
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Bumps with narrow widths are removed efficiently



CH101 8CH41-10 ID3443/339

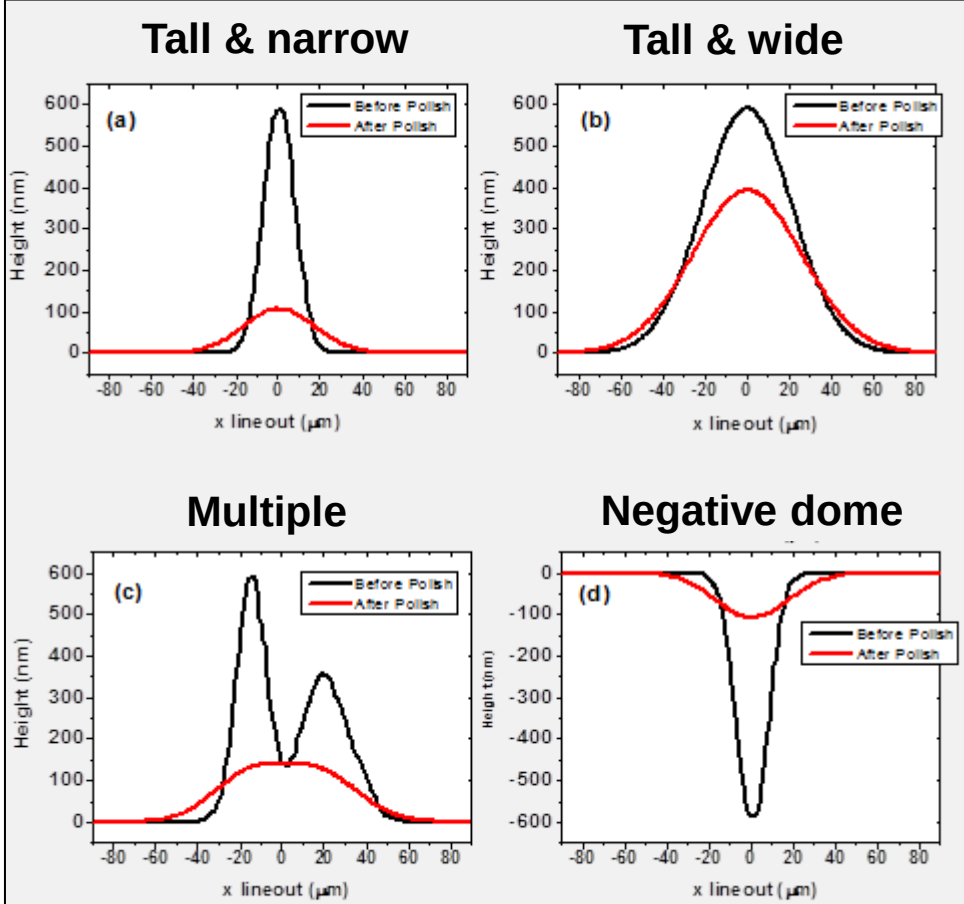
Wider bumps planarize much more slowly



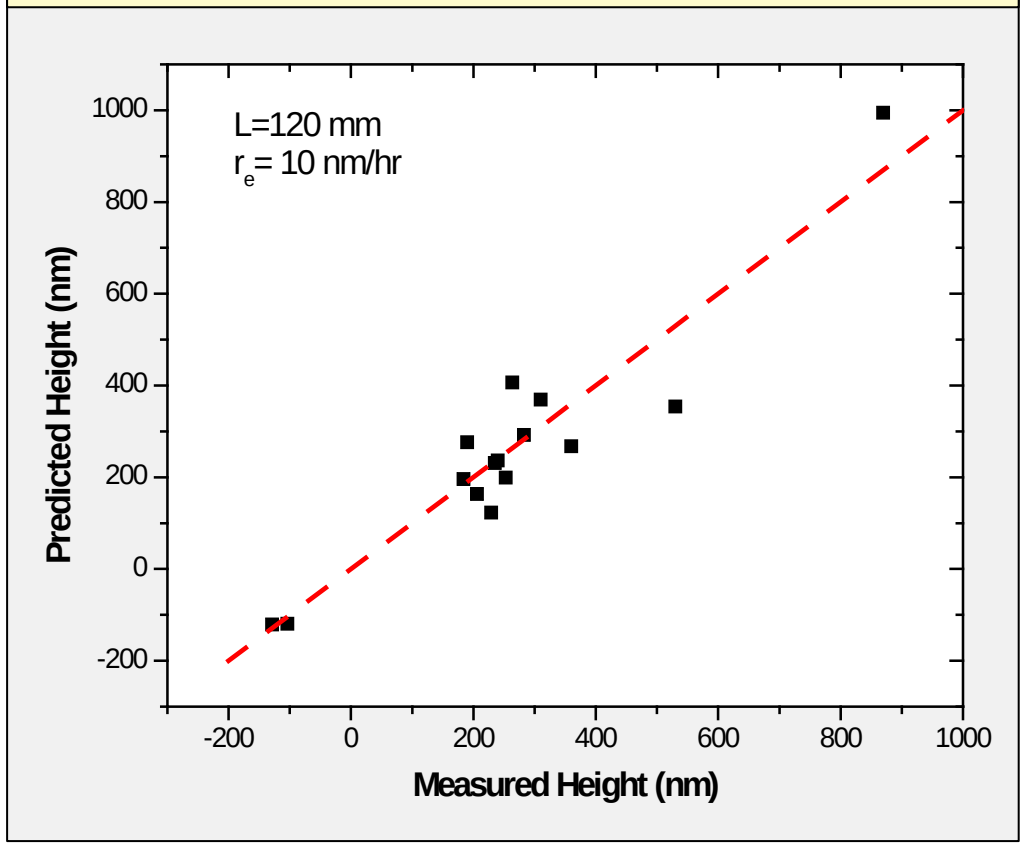
(CH101 8CH41-10 ID1696/480)

Convergence model for isolated Gaussian Bumps compares reasonably well to experimental data

Simulation of various dome shapes

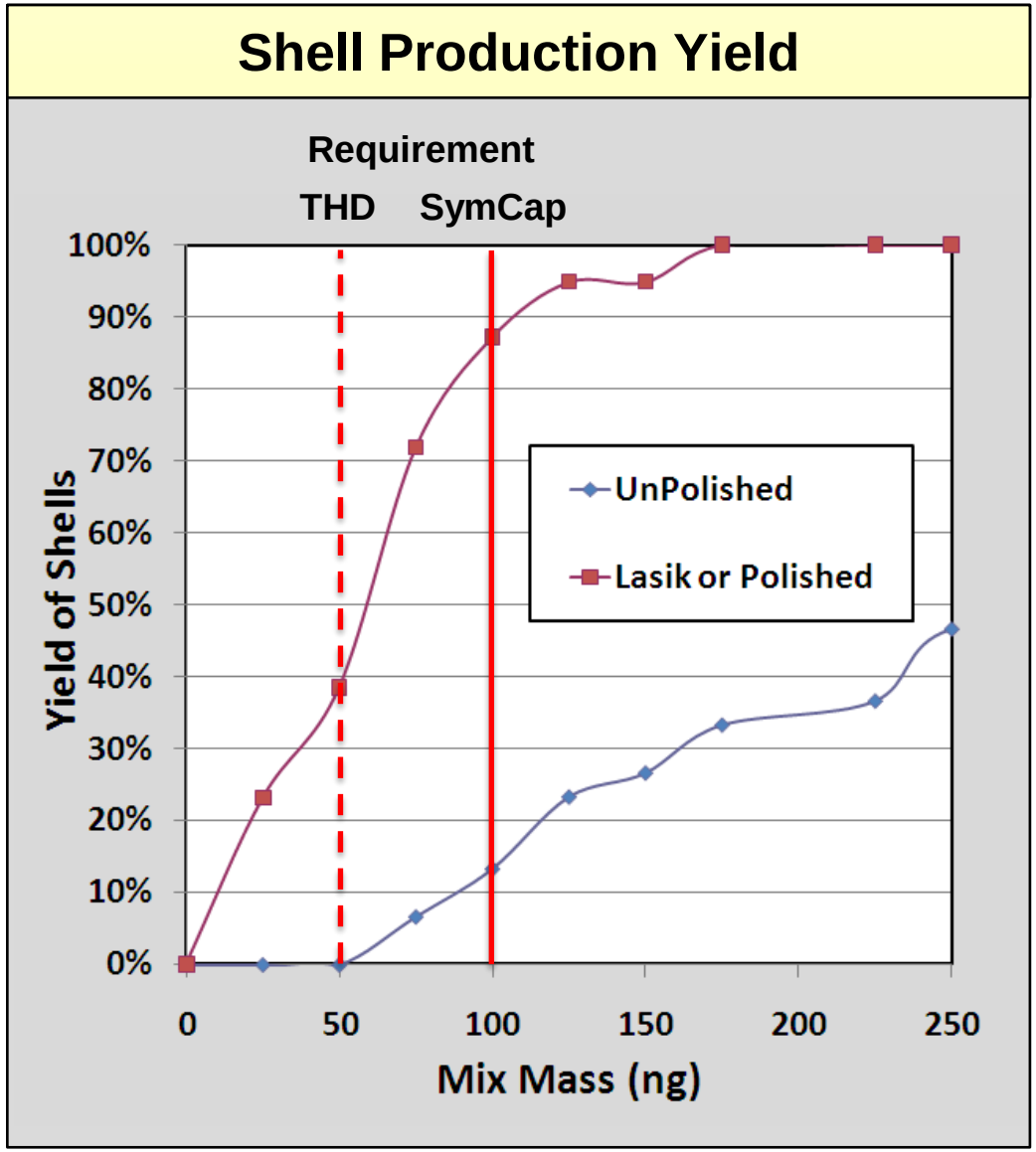


Predicted height using convergence model vs measured height



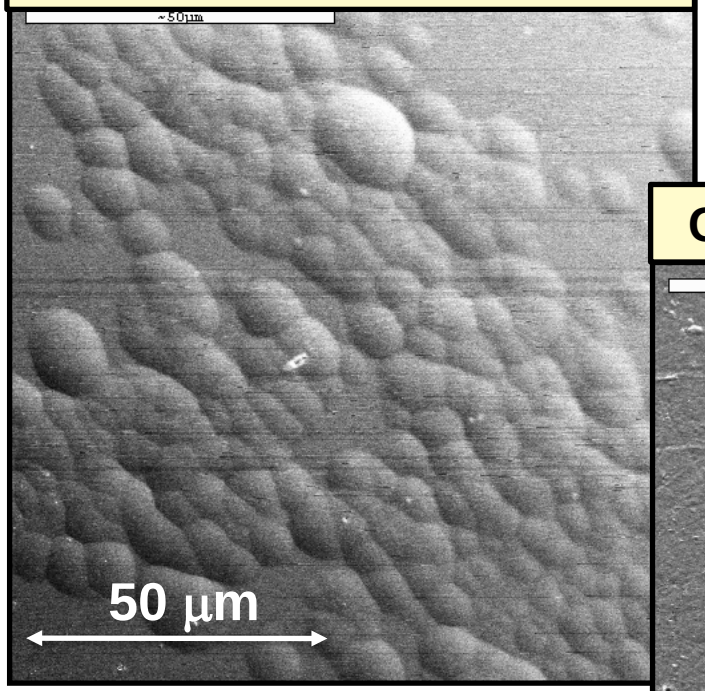
Lasik & Polishing increases the yield of target quality shells to levels suitable for production

- SymCap spec < 100 ng
  - Yield increase from 15% to 80%
  - Throughput of ~ 5 shells/wk
- THD spec < 50 ng
  - Yield increase from 0% to 35%
  - Throughput of ~ 2.5 shells/wk



Surface quality of CH capsule has greatly improved with new finishing techniques

As-deposited CH Capsule



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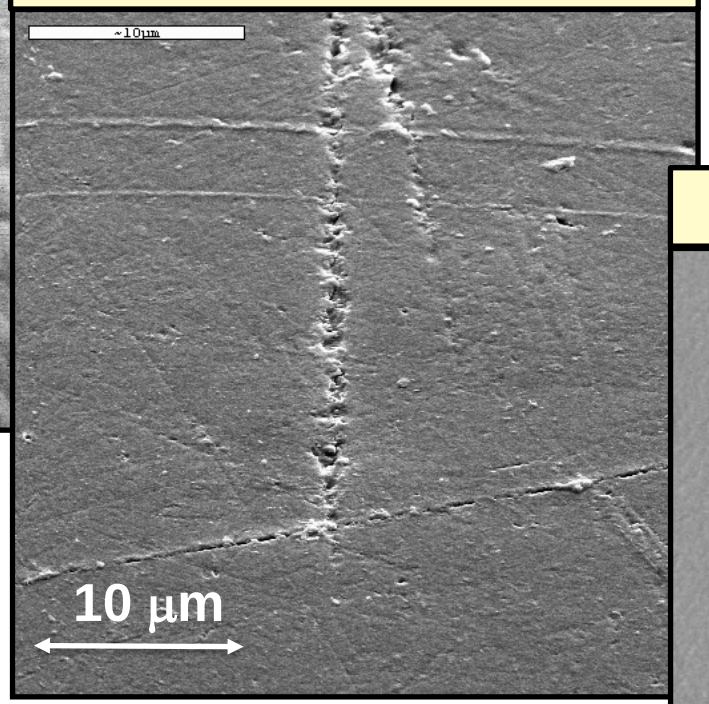

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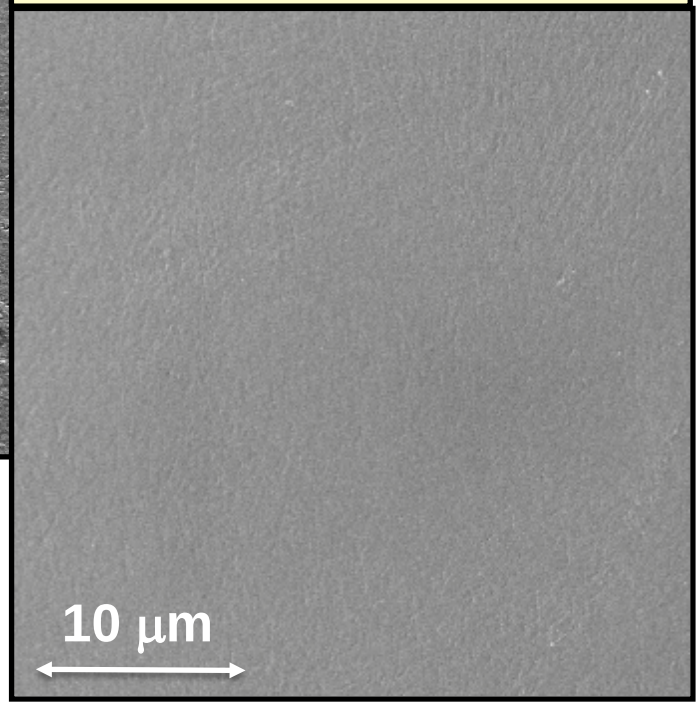

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