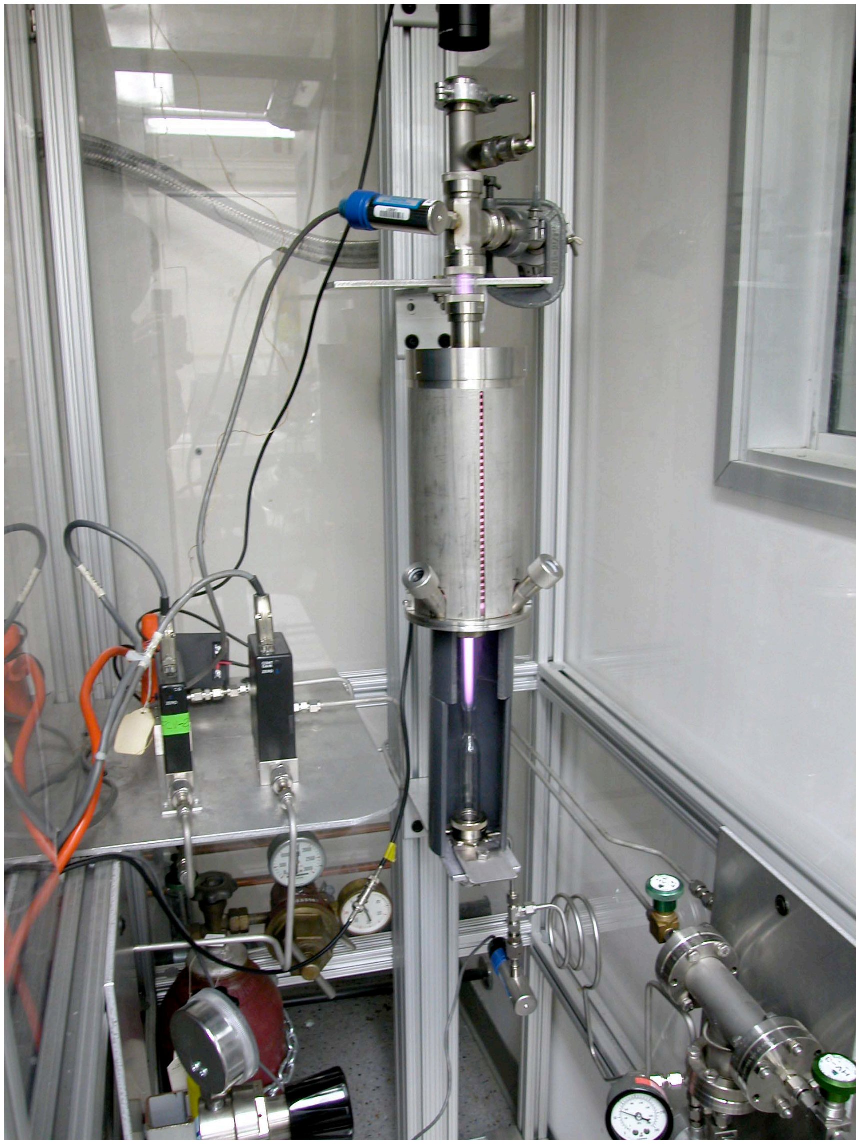
Research on Fluidized Bed for IFE Shell Fabrication

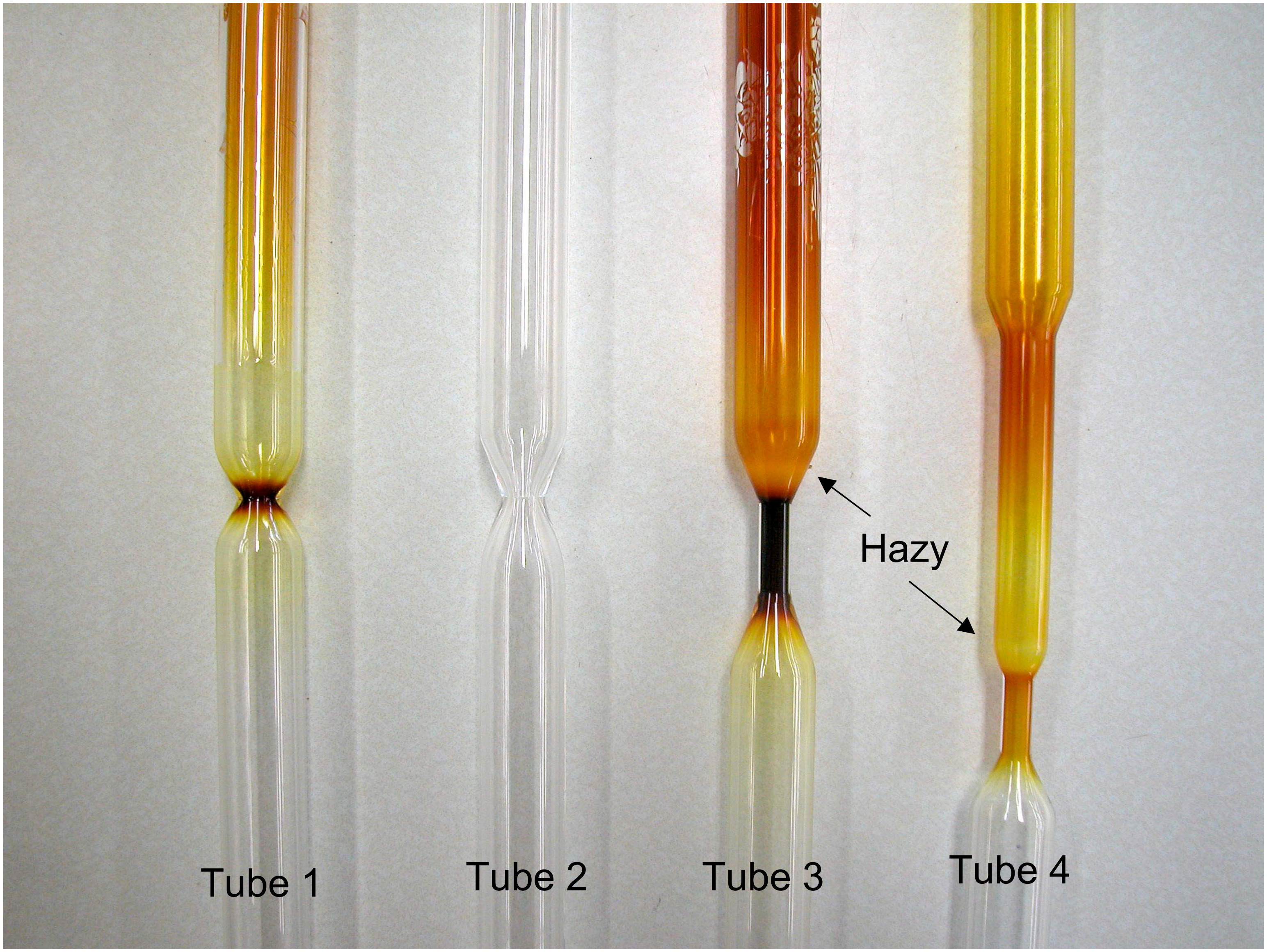
Feb. 2003

GDP Fluidized Bed



- Mission
  - Scale-up bounce pan
- Hardware
  - Brian Vermillion
  - Bob Stemke
- Optimize Process
  - Rate
  - Surface
  - Stress
  - Arcing
- Understand Mechanism
- Investigate Scalability

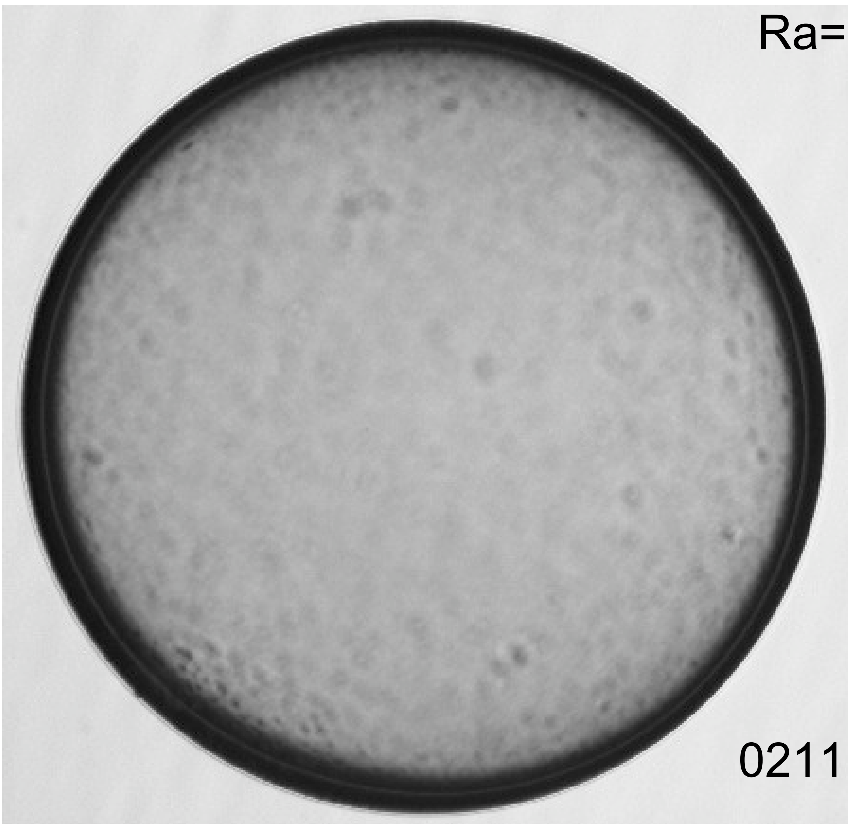
Four Tube Designs

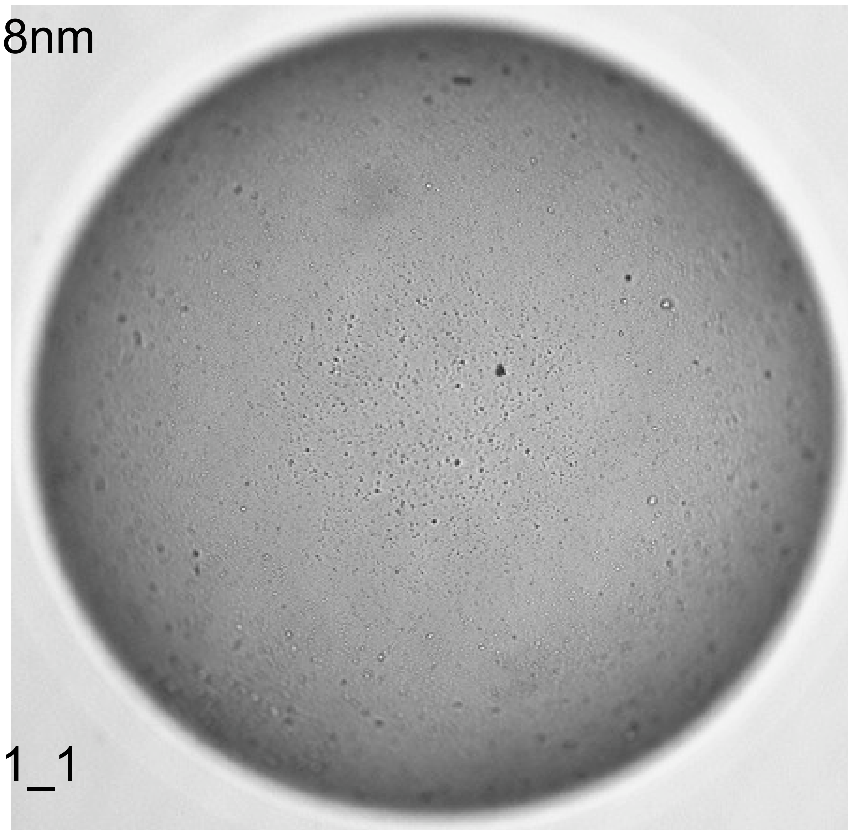


Benchmark: 1.2um/hour on 30 shells

Transparent & brownish colored

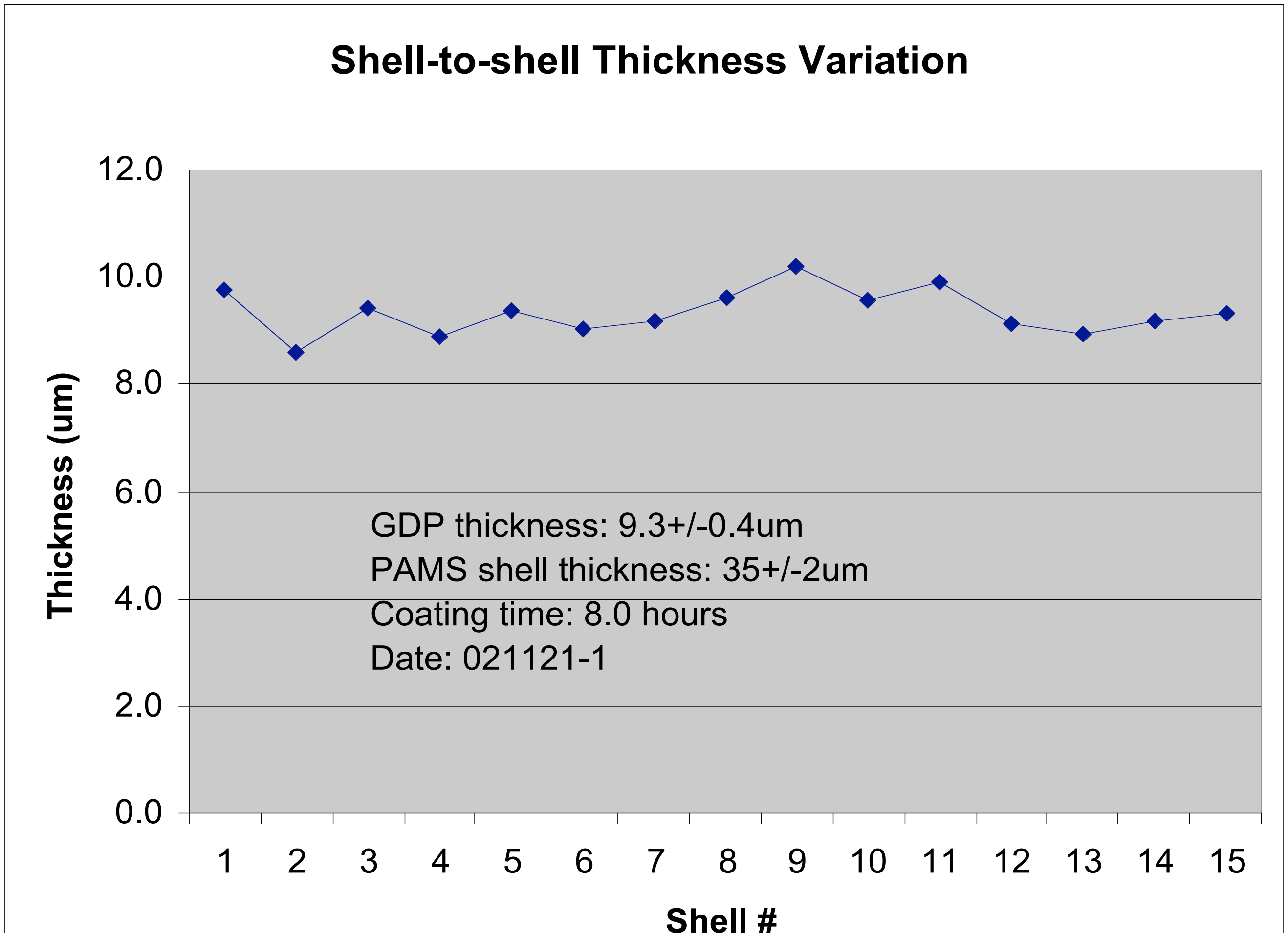
Moderate surface roughness



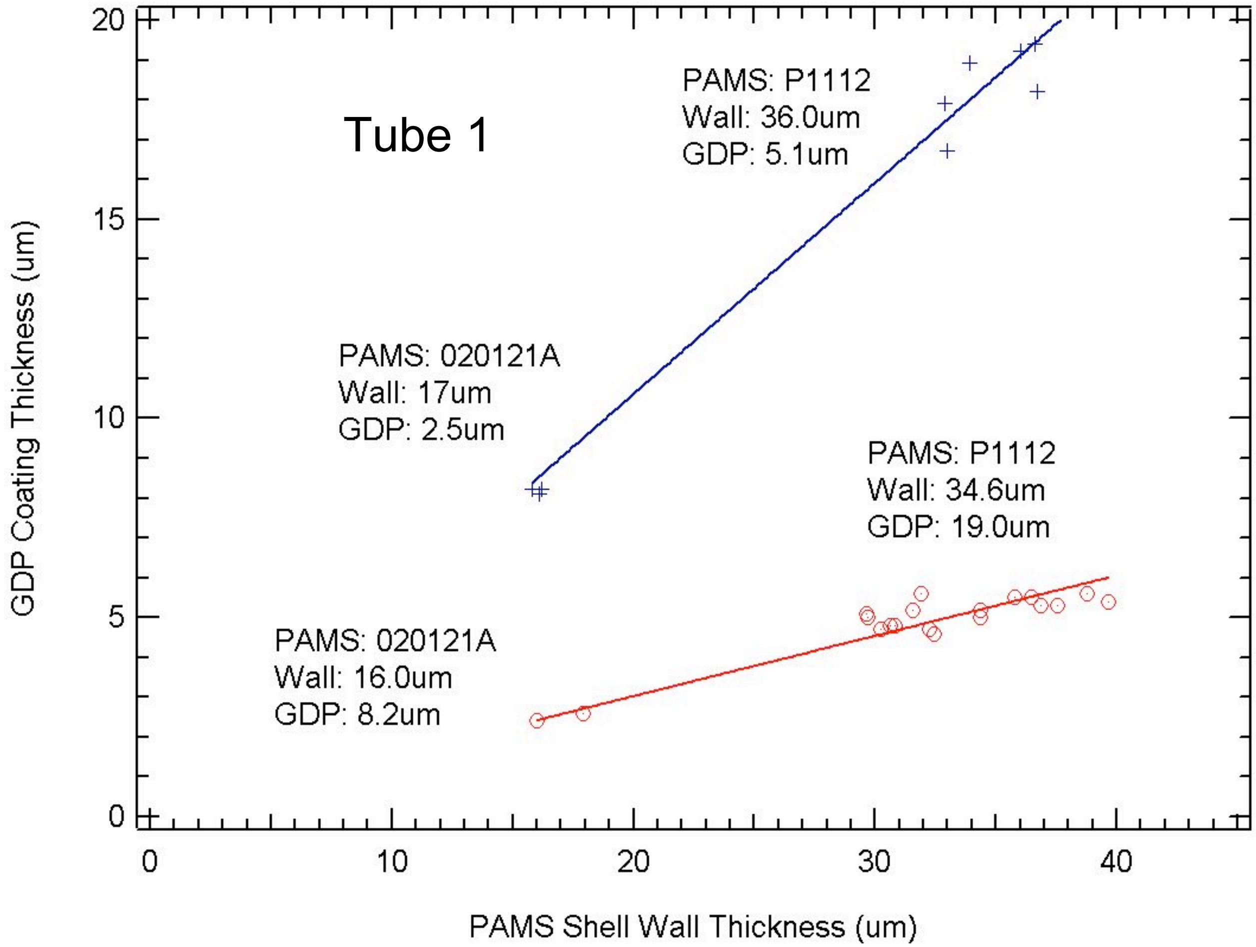


16.8um GDP on 2000um diameter PAMS shell with 35um wall

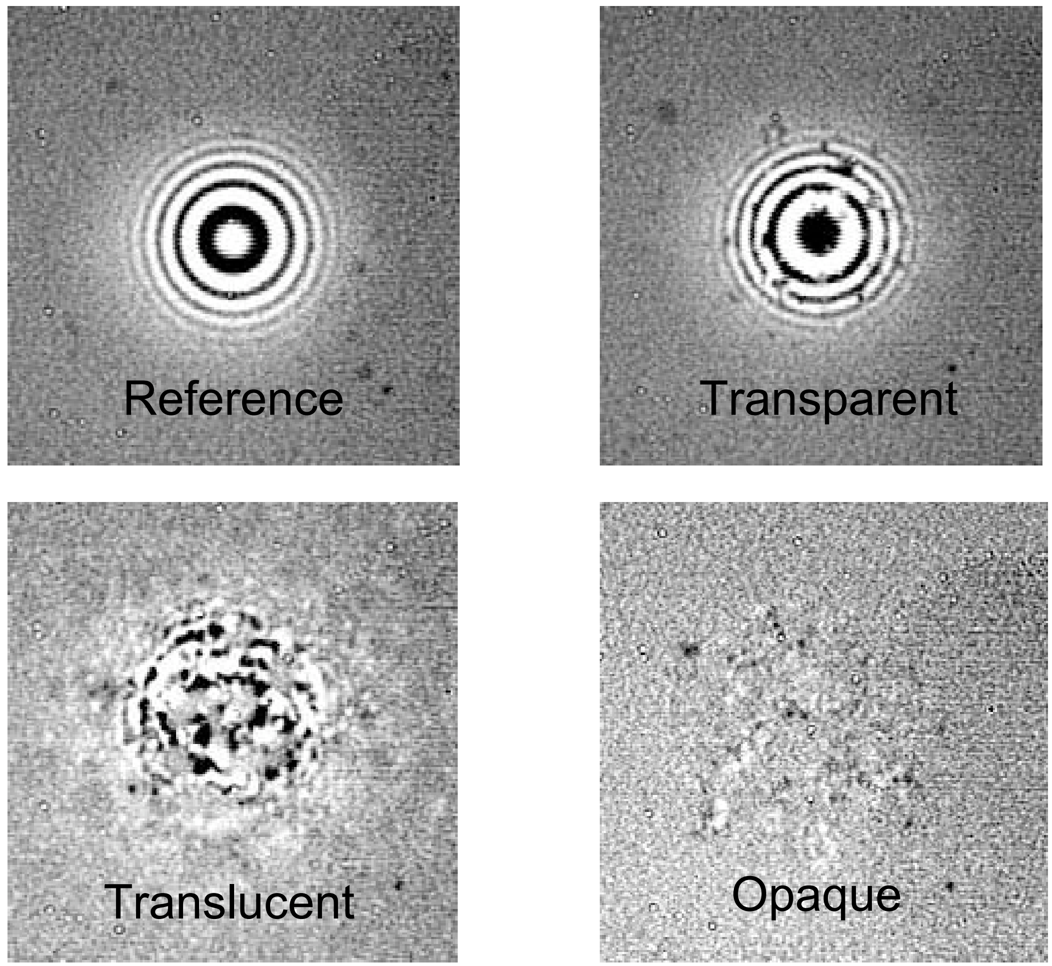
Within-Batch Thickness: 5%



Rate Depends on Wall Thickness

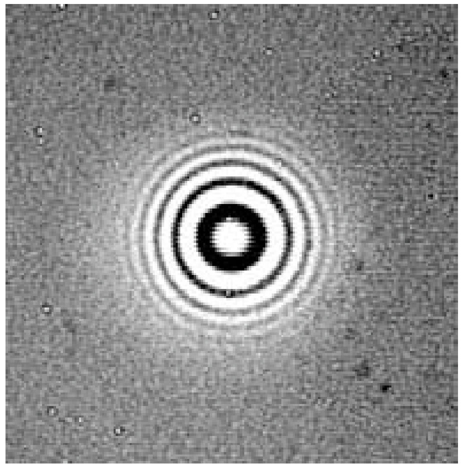


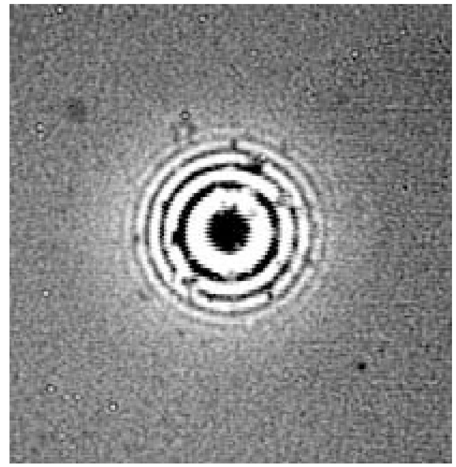
Terminology: Transparency



Visual Transparency Achieved on All Four Tube Designs

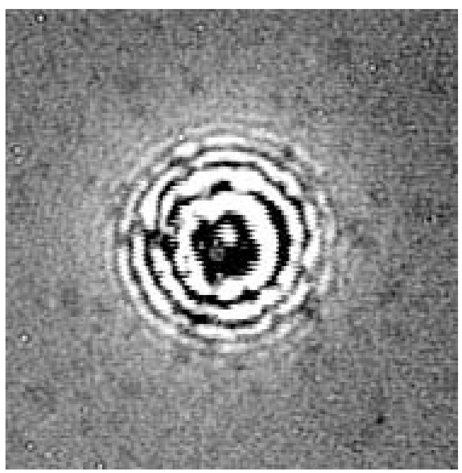
Reference
PAM1113
Uncoated

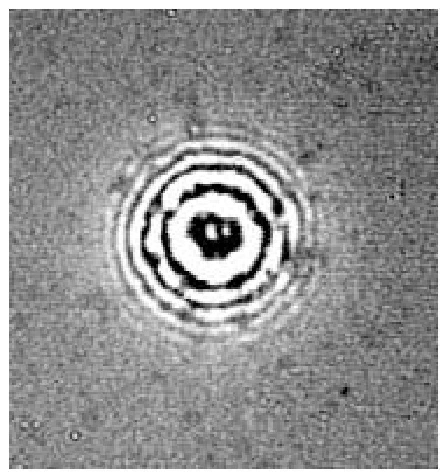




021111_1
Tube 1
16.8um
30 Shells

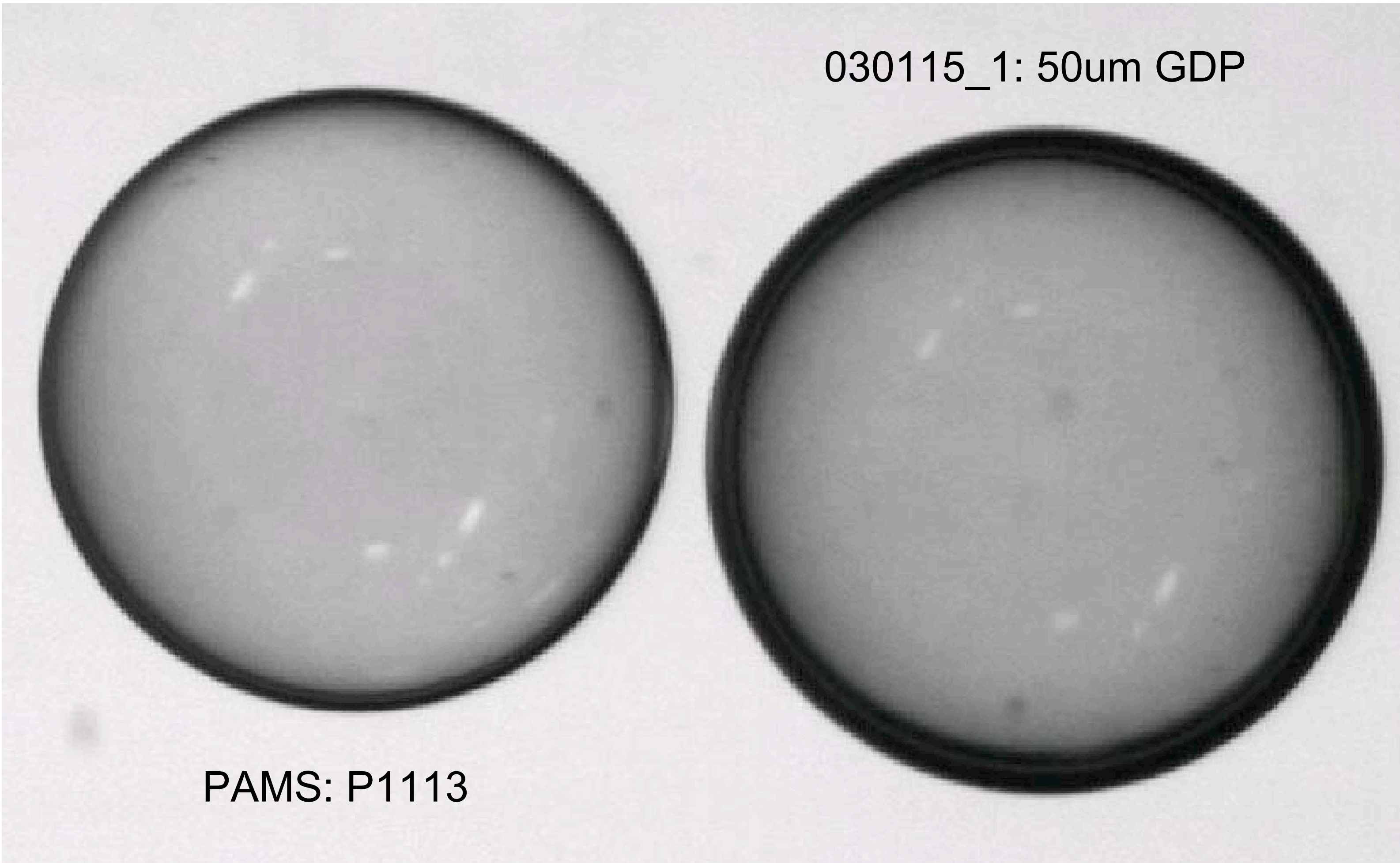
021218_2
Tube 3
14.3um
28 Shells





030108_1
Tube 4
11.1um
33 Shells

Surface: State-of-Art



Surface: 50um GDP

Mag: 101.1 X

Mode: PSI

Dat

Tin

Best Surface Area: Ra=2.5nm

Typical Area: Ra=5-10nm

Surface Statistics:

Ra: 2.47 nm

Rq: 3.90 nm

Rz: 33.54 nm

Rt: 41.73 nm

Set-up Parameters:

Size: 736 X 480

Sampling: 83.07 nm

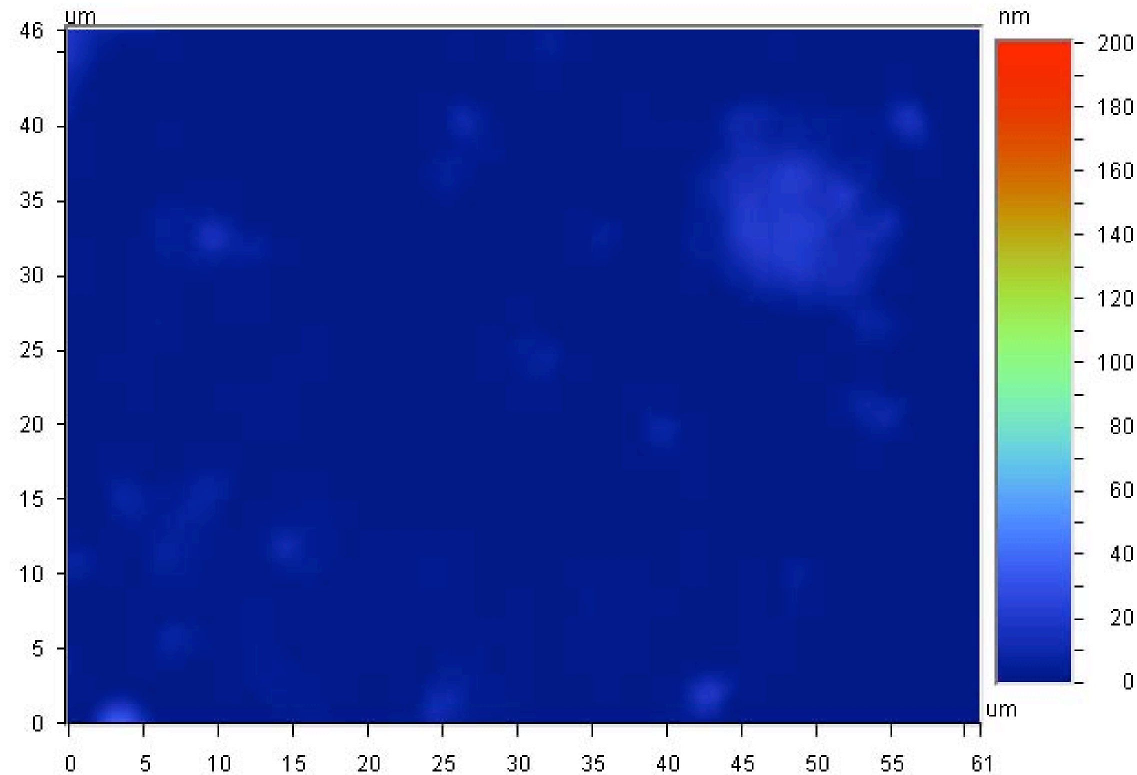
Processed Options:

Terms Removed:

Curvature & Tilt

Filtering:

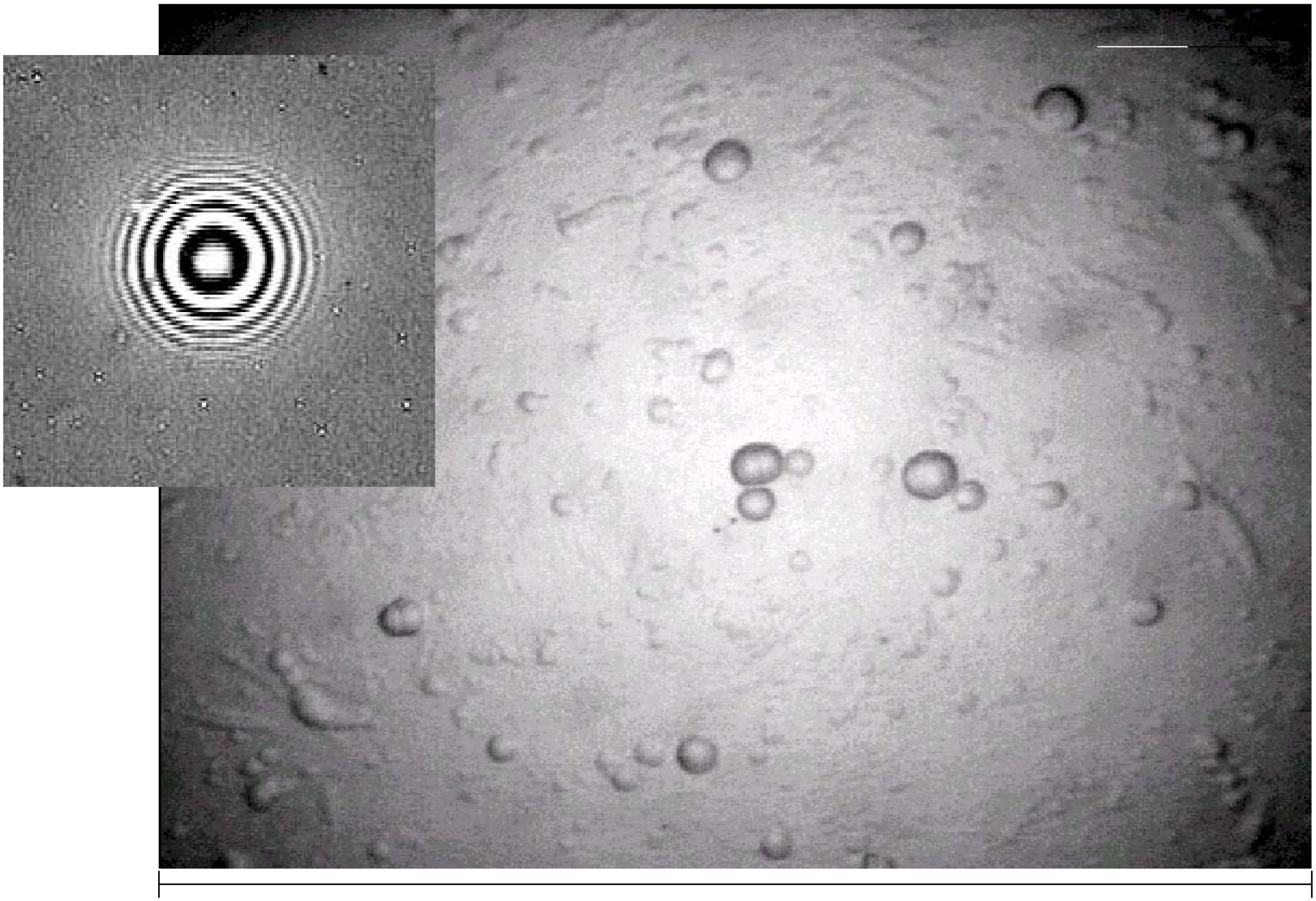
None



Title: 030115_1

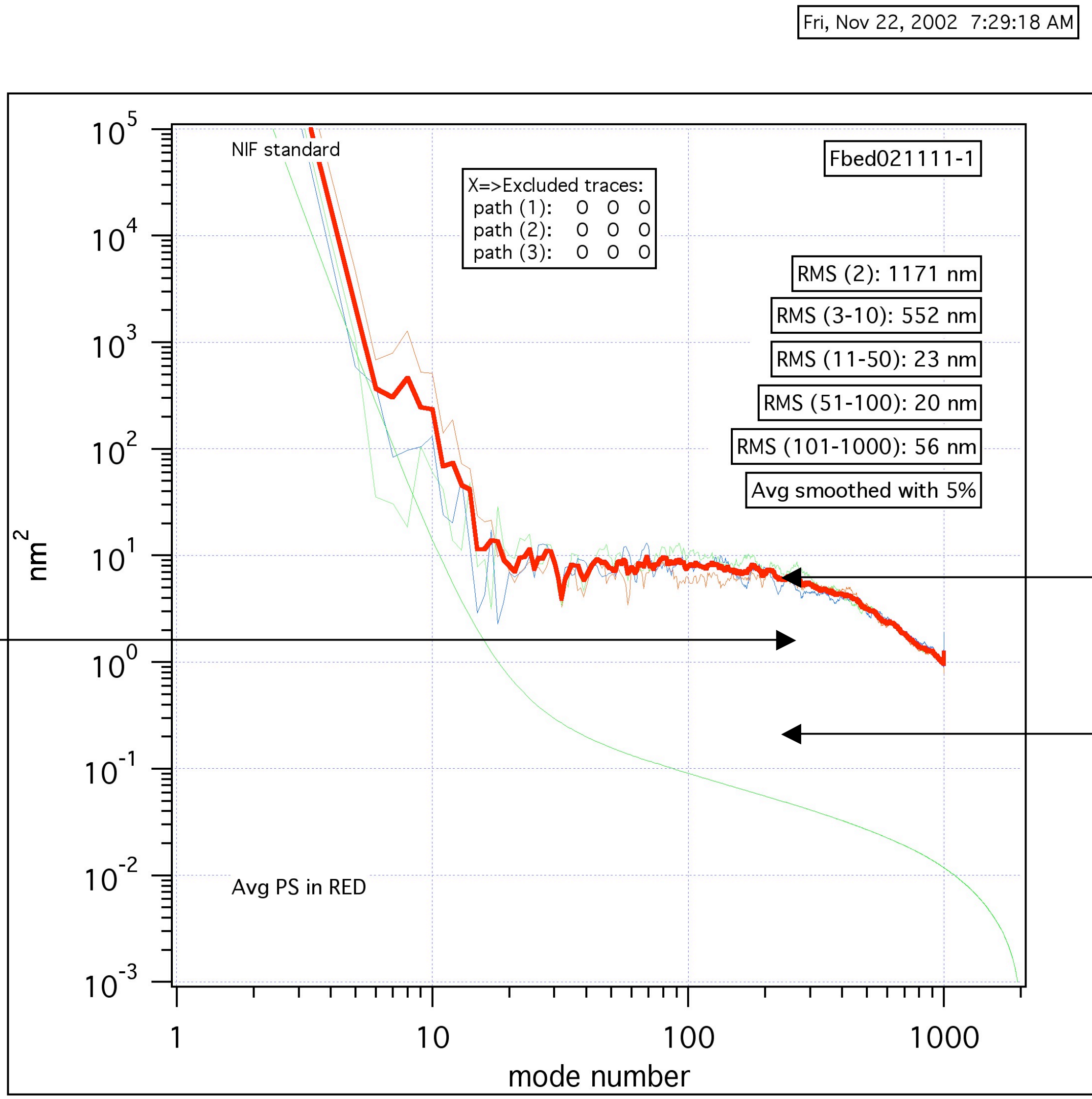
Note: 50um GDP on P1113 PAMS Shell

Surface: 50um GDP



300um

AFM Spectrum of 16.8um GDP



New:
Ra=5-10nm
for 50um GDP

Old:
Ra=18nm
for 17um GDP

for 5um GDP?

Surface: 275um GDP

Mag: 101.1 X

Mode: PSI

Da

Tir

Best Surface Area: Ra=58nm

Typical Area: Ra=80-140nm

Surface Statistics:

Ra: 58.84 nm

Rq: 77.25 nm

Rz: 446.43 nm

Rt: 459.08 nm

Set-up Parameters:

Size: 368 X 240

Sampling: 166.14 nm

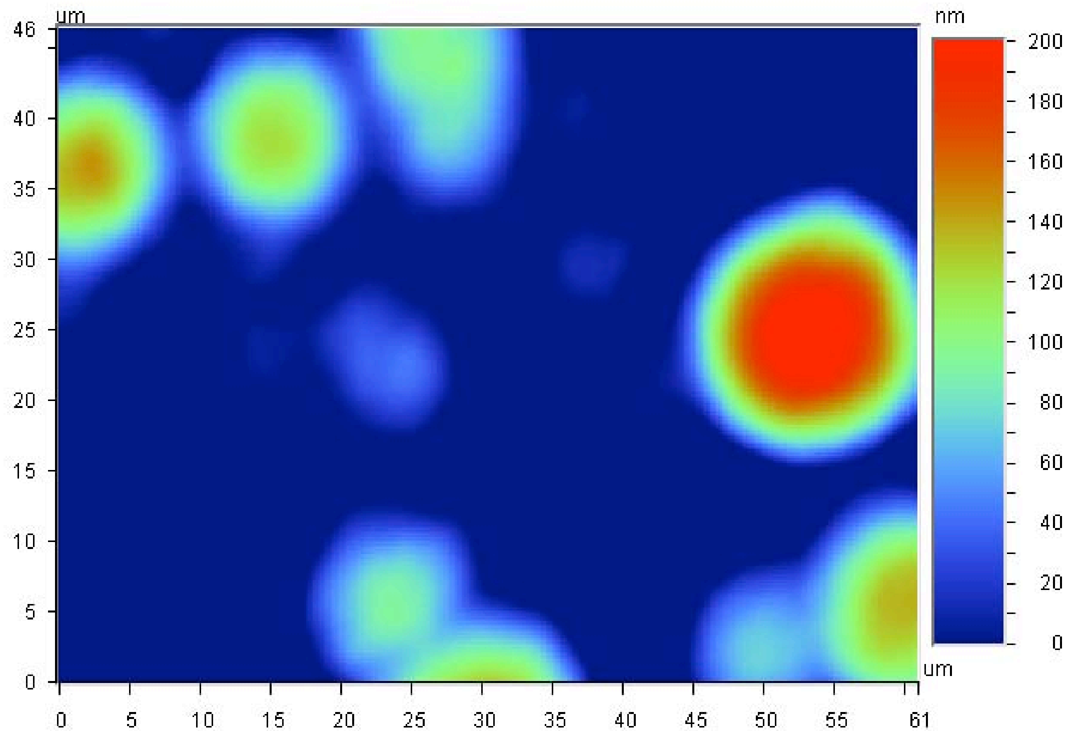
Processed Options:

Terms Removed:

Curvature & Tilt

Filtering:

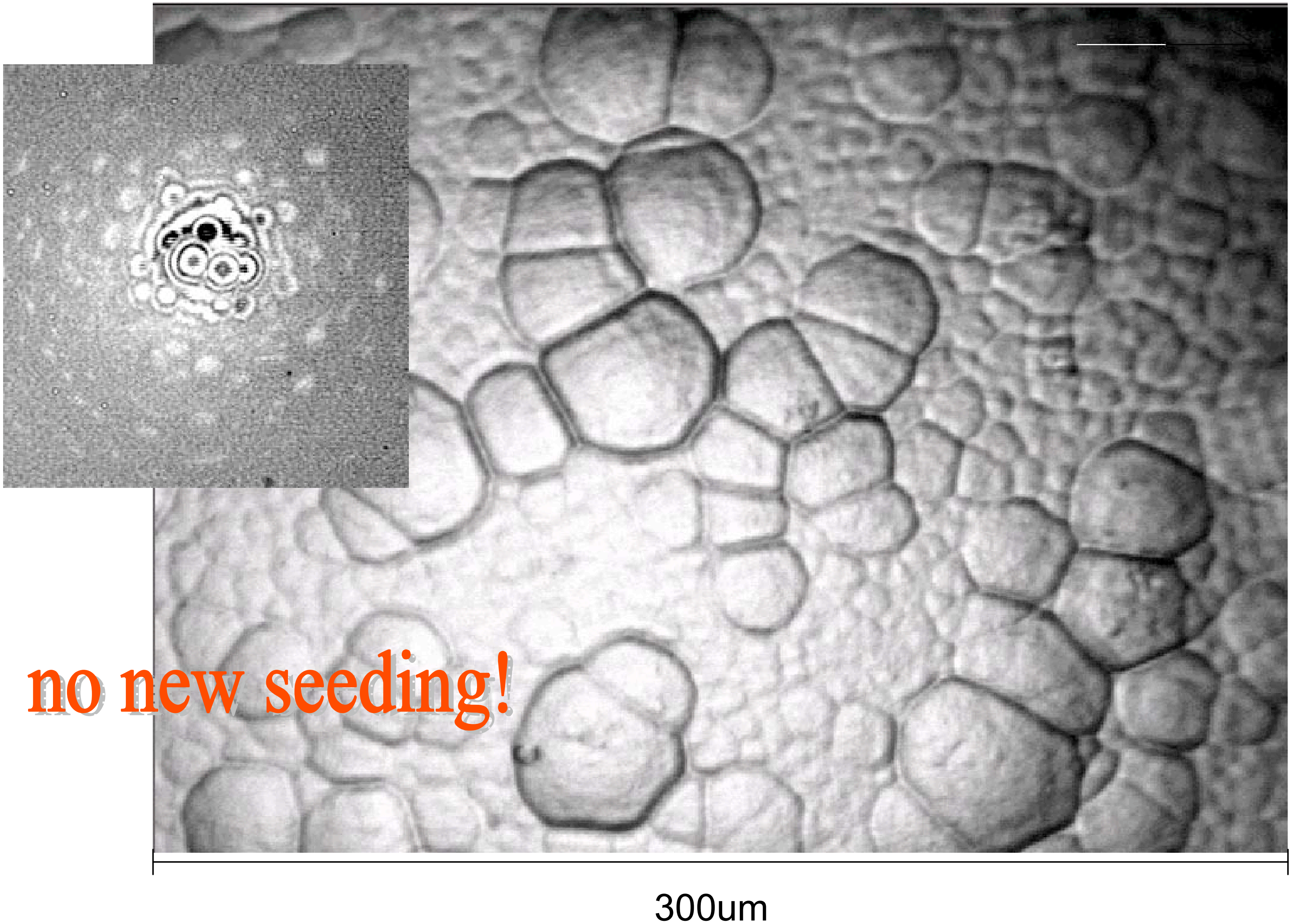
None



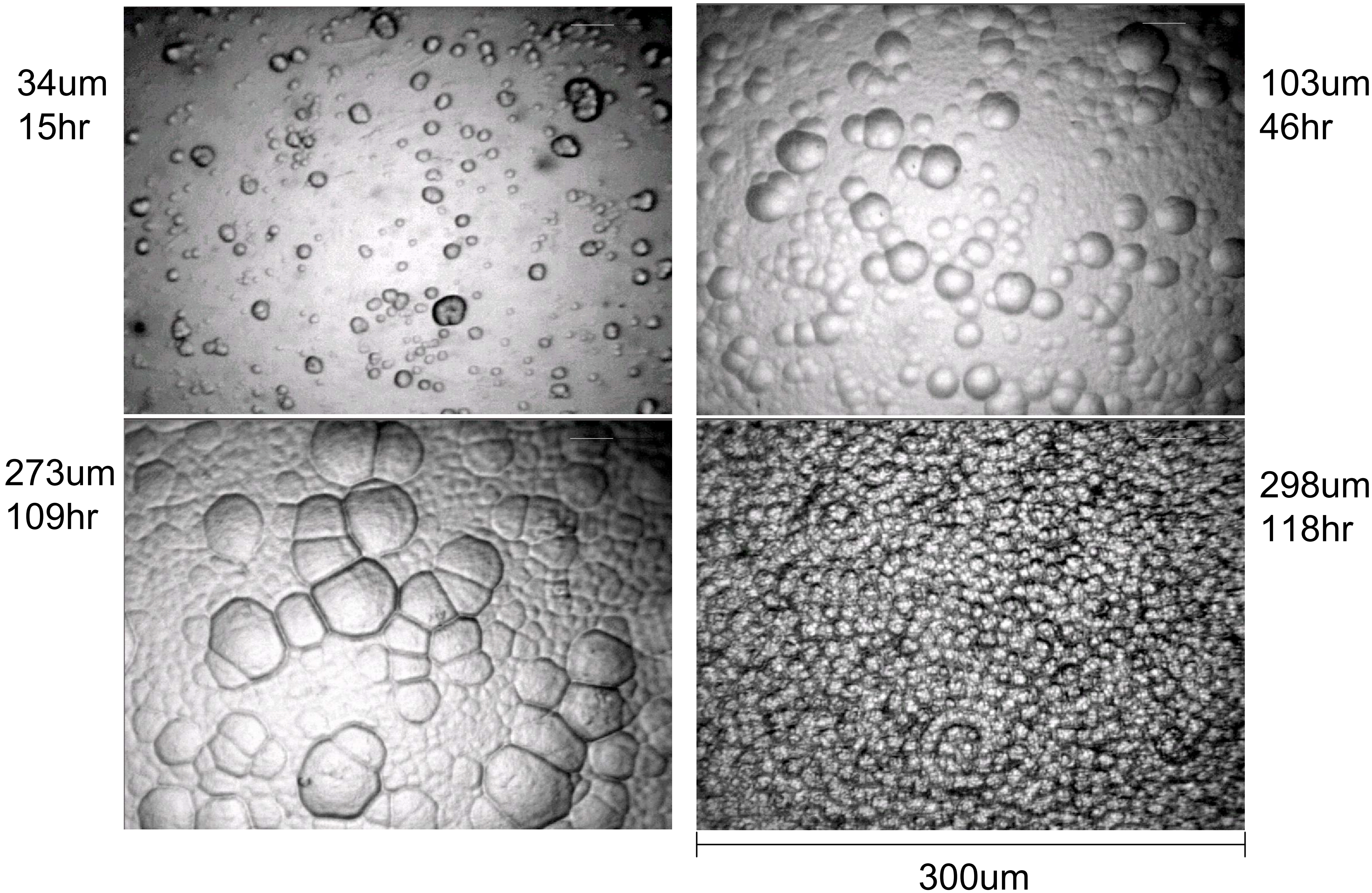
Title: 030125_1

Note: 275um GDP on P1113 PAMS shell

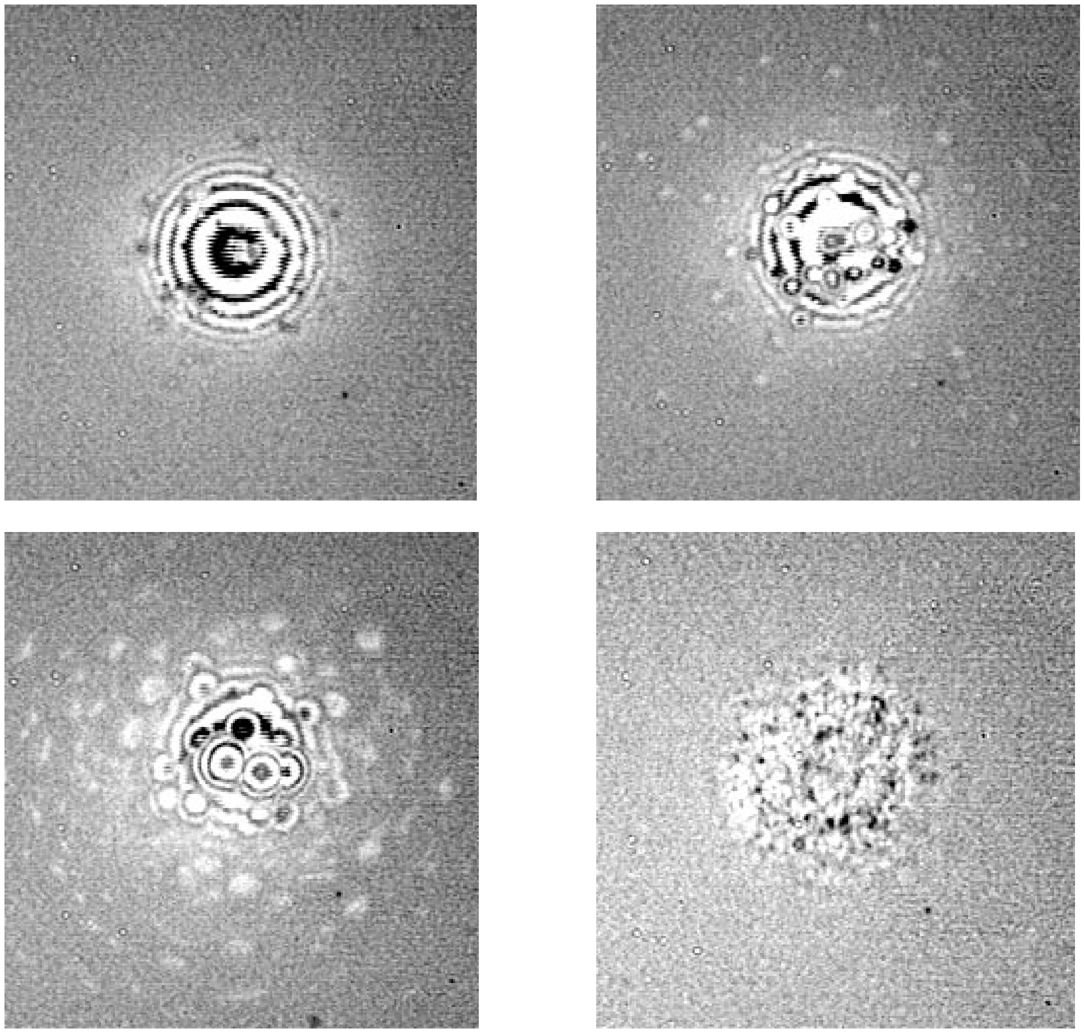
Surface: 275um GDP



Morphology Evolution



Morphology Evolution



34um
15hr

103um
46hr

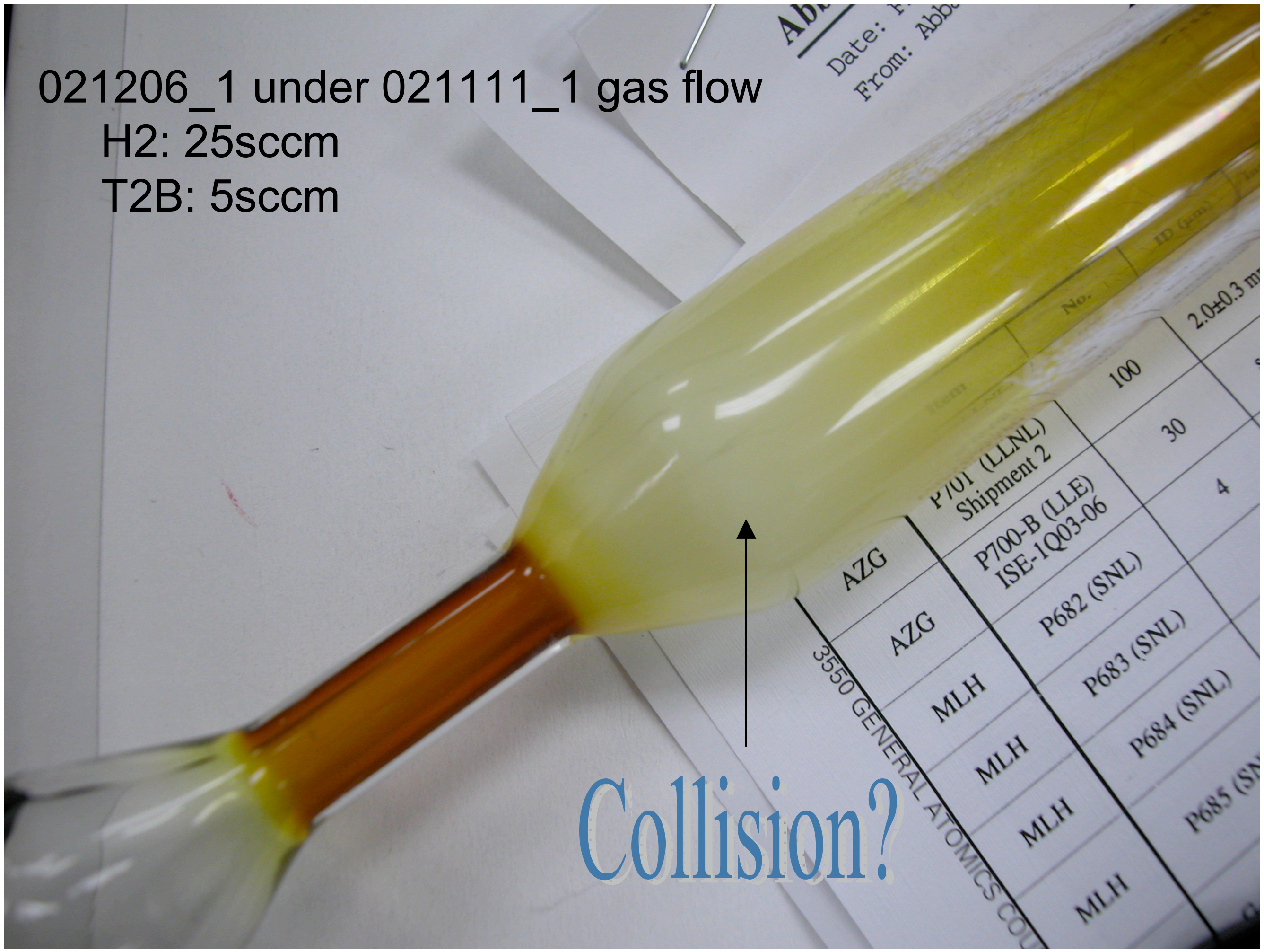
273um
109hr

298um
118hr

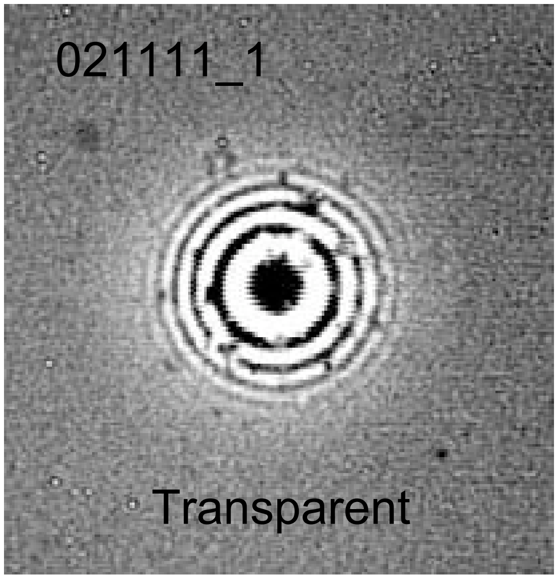
Roughening Mechanism

- High-Impact Collisions induce damage
  - Roughness on shell and bed is linked
    - – Bed is the only hazy region
    - – Without shell, bed is clear
  - Roughness improves with reduced flow
    - – Best results with ~2x minimum flow
  - Roughness improves with reduced # of shells
- Gas phase precipitation uncertain

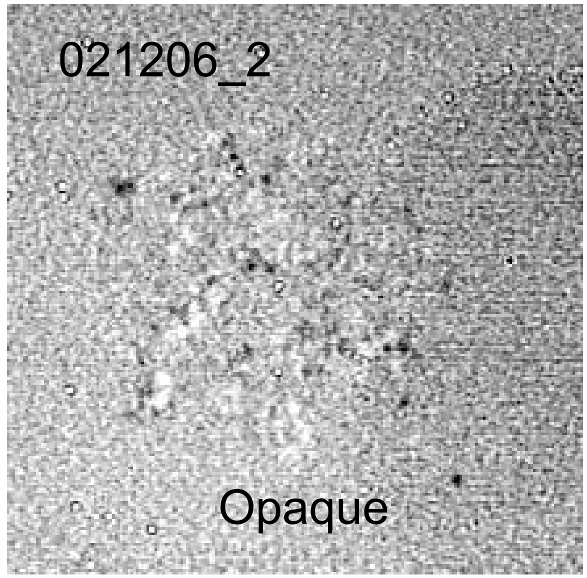
Tube: Hazy where shells bounce



Low flow produces better result

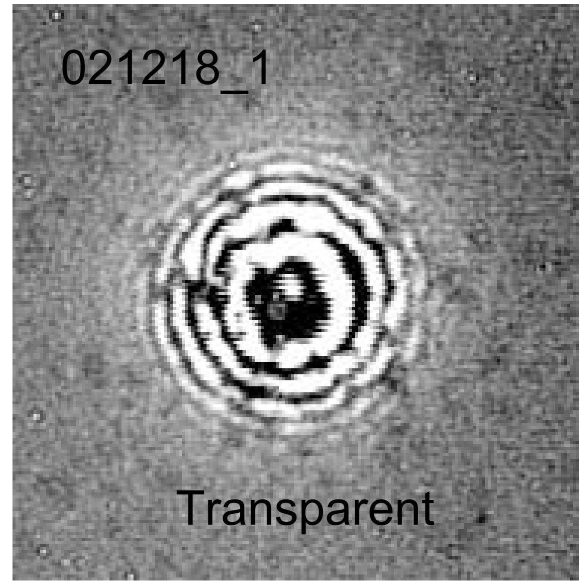


Tube 1
H2: 25sccm
T2B: 5sccm



Tube 3
H2: 25sccm
T2B: 5sccm

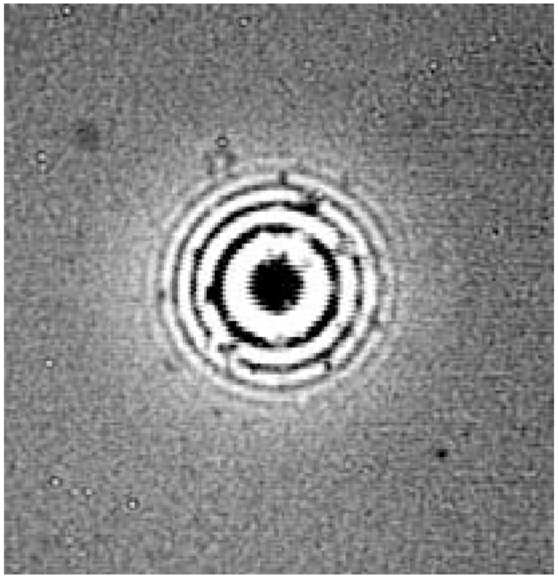
Collision?



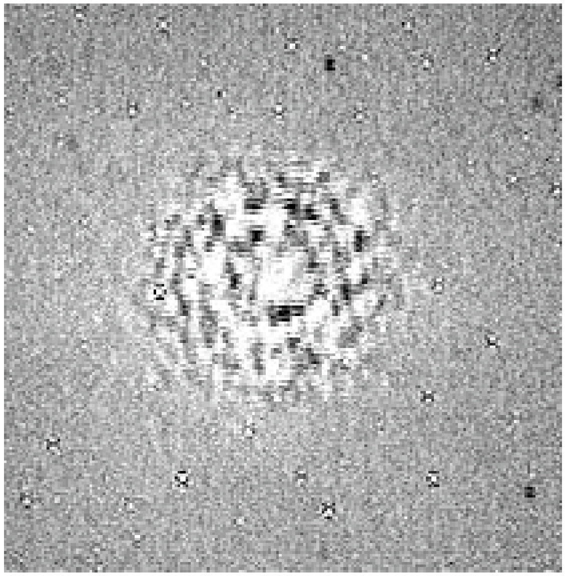
Tube 3
H2: 12sccm
T2B: 0.25sccm

↑
dep. rate comparable

Shell # Matters



021111_1
30 Shells

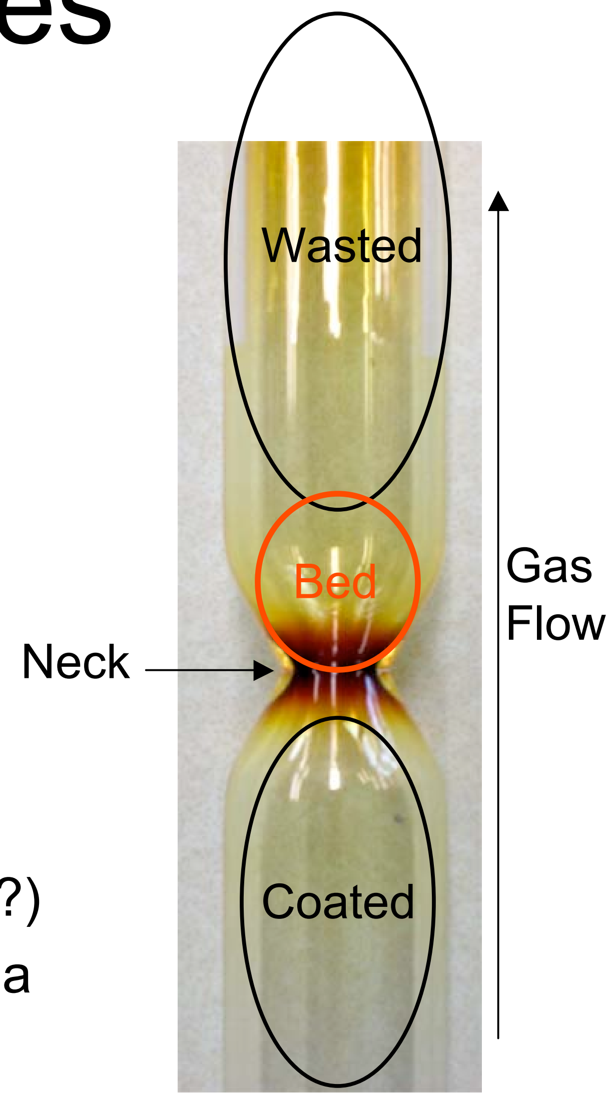


021113_1
200 Shells

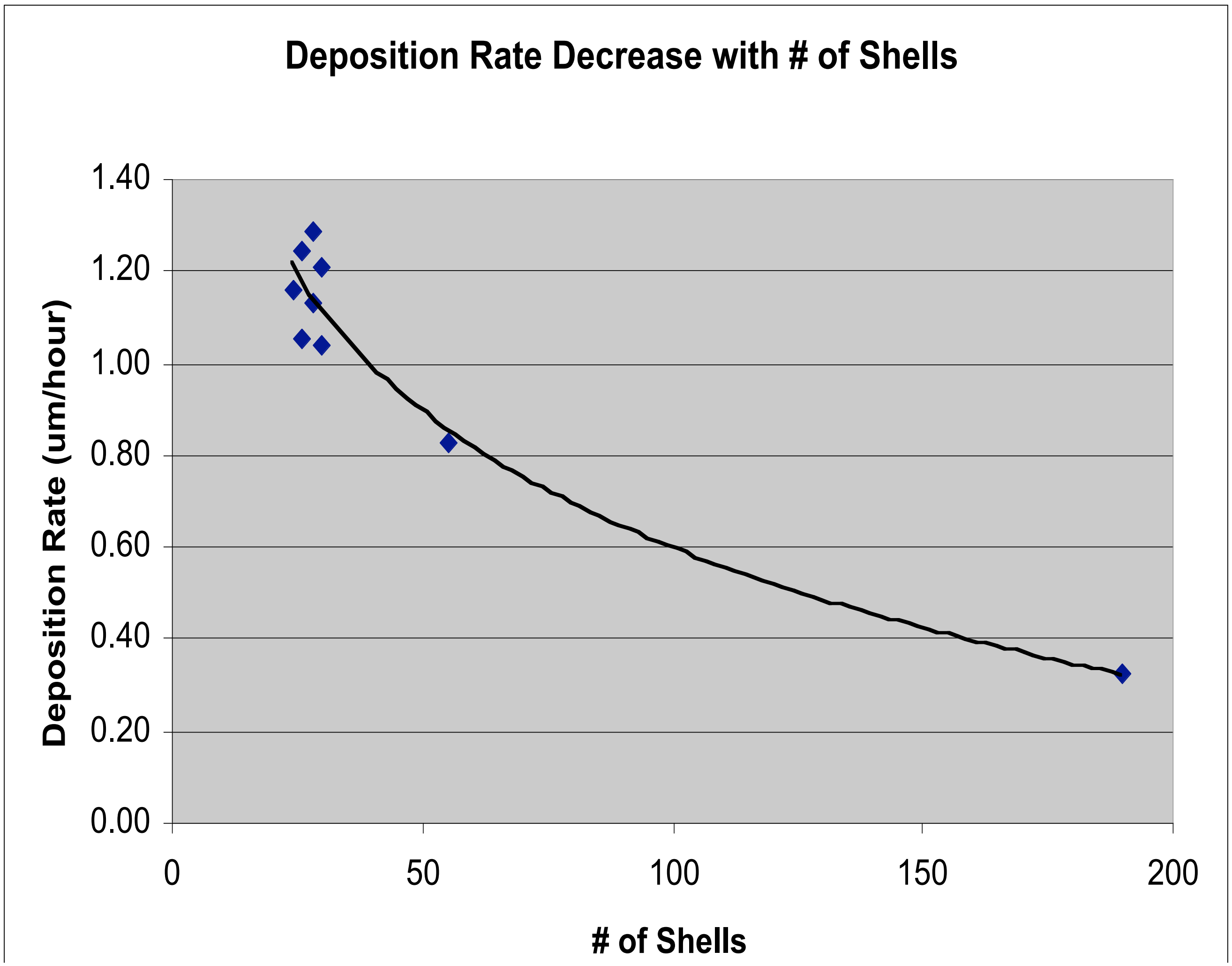
Collision?

Scalability Issues

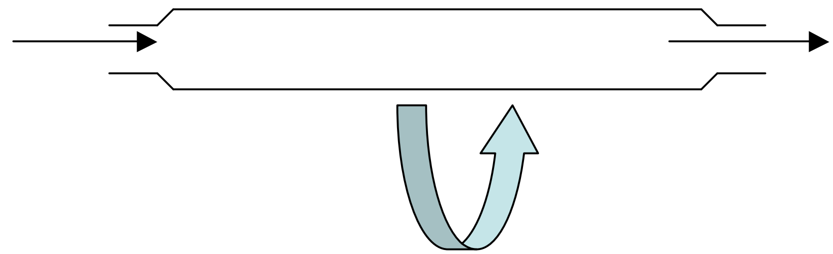
- Reduce high-impact collisions
  - delink plasma & bouncing
- Free radicals formed upstream are responsible for shell coating
  - downstream plasma wasted
    - Brownian motion against jet stream
  - coating occurs from the shell bottom
    - neck or frit deplete supply
    - preferential growth under gravity
  - large traveling length may induce seeding (?)
  - 0.5mm sheath around shell excludes plasma



Depleted Free Radical Supply



Ideas

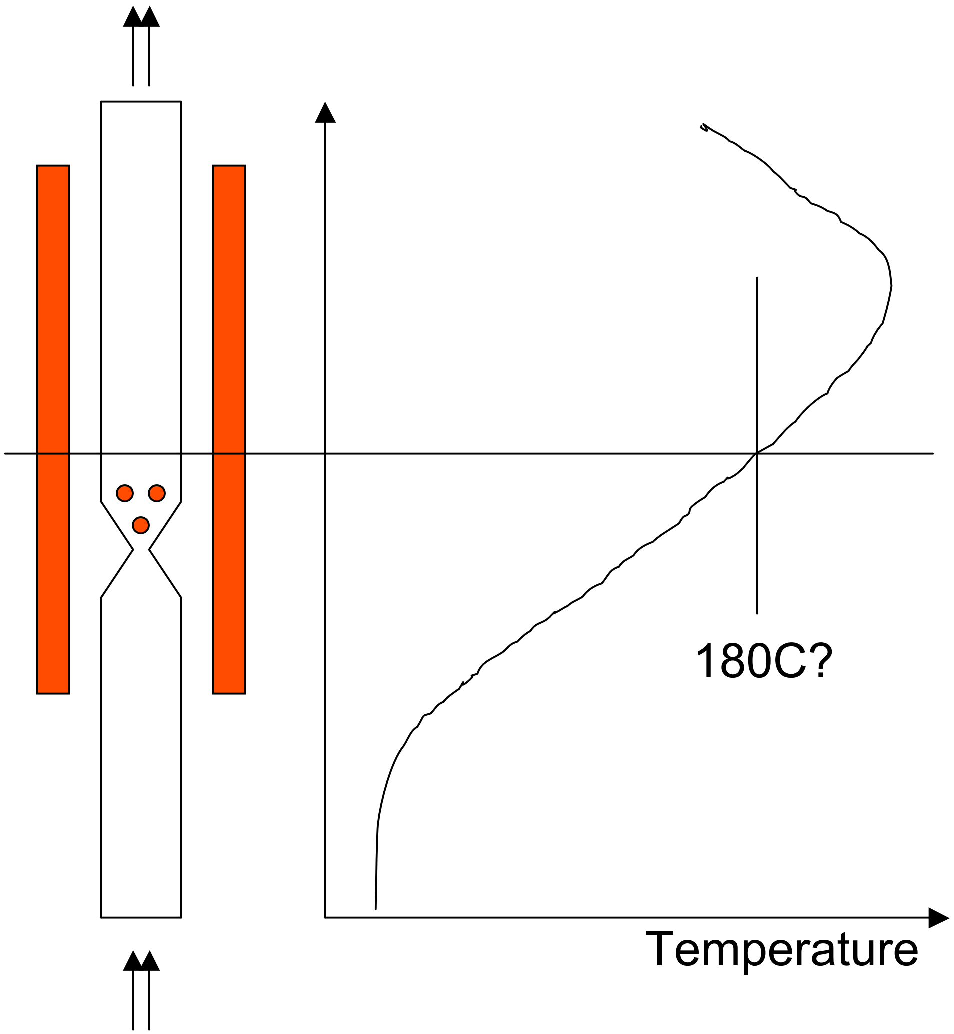


- Microgravity?
  - Rotating drum
  - Tilted tube
- Magnetic Confinement?
  - axial field reduces tube coating
    - Rich Stephens
- Capacitive plasma?
  - more scalable than inductive plasma
    - Lloyd Brown

Conclusions

- Demonstrated high deposition rate.
  - 1-2um/hr
- Demonstrated good surface morphology.
  - 50um GDP with Ra<10nm
  - NIF curve reachable for thin layer
- Good results on small batches only.
  - 30 shells
- Identified high impact collision as main surface roughening mechanism.

Temperature is an issue

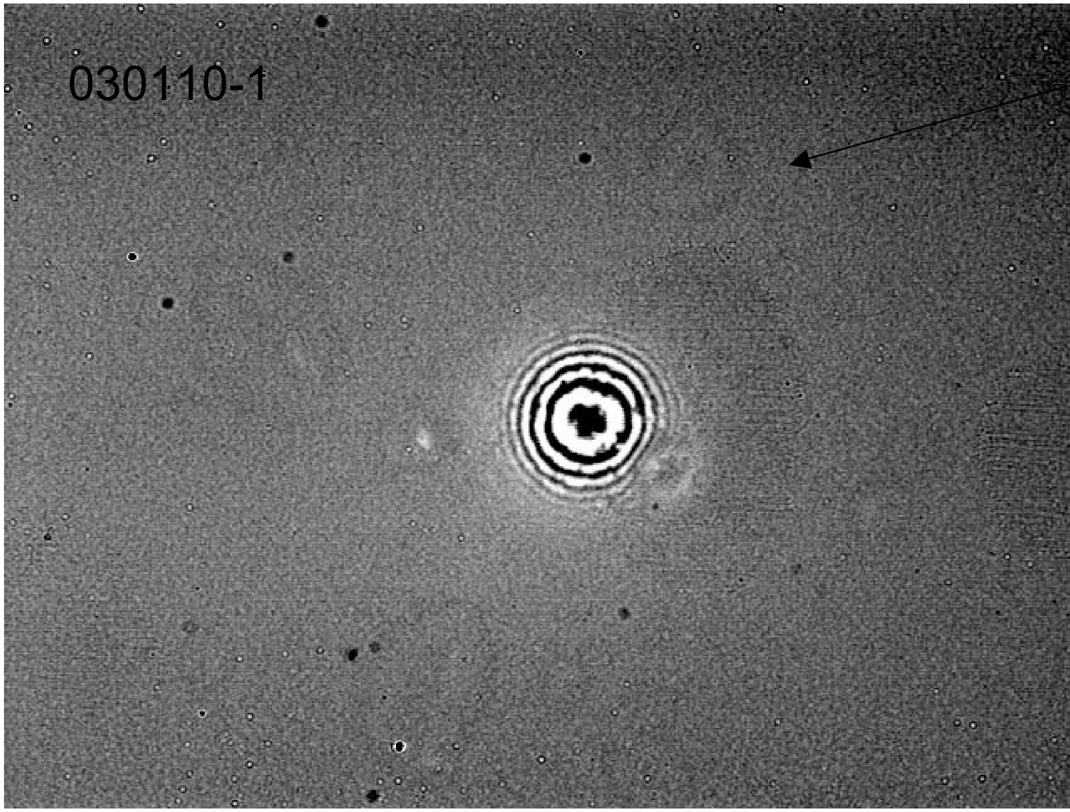


At 20W, only bottom 1/3 of the coil is usable.

PAMS melts in minutes in upper section.

Borderline conditions exist where evaporation affects visual.

Borderline Temperature



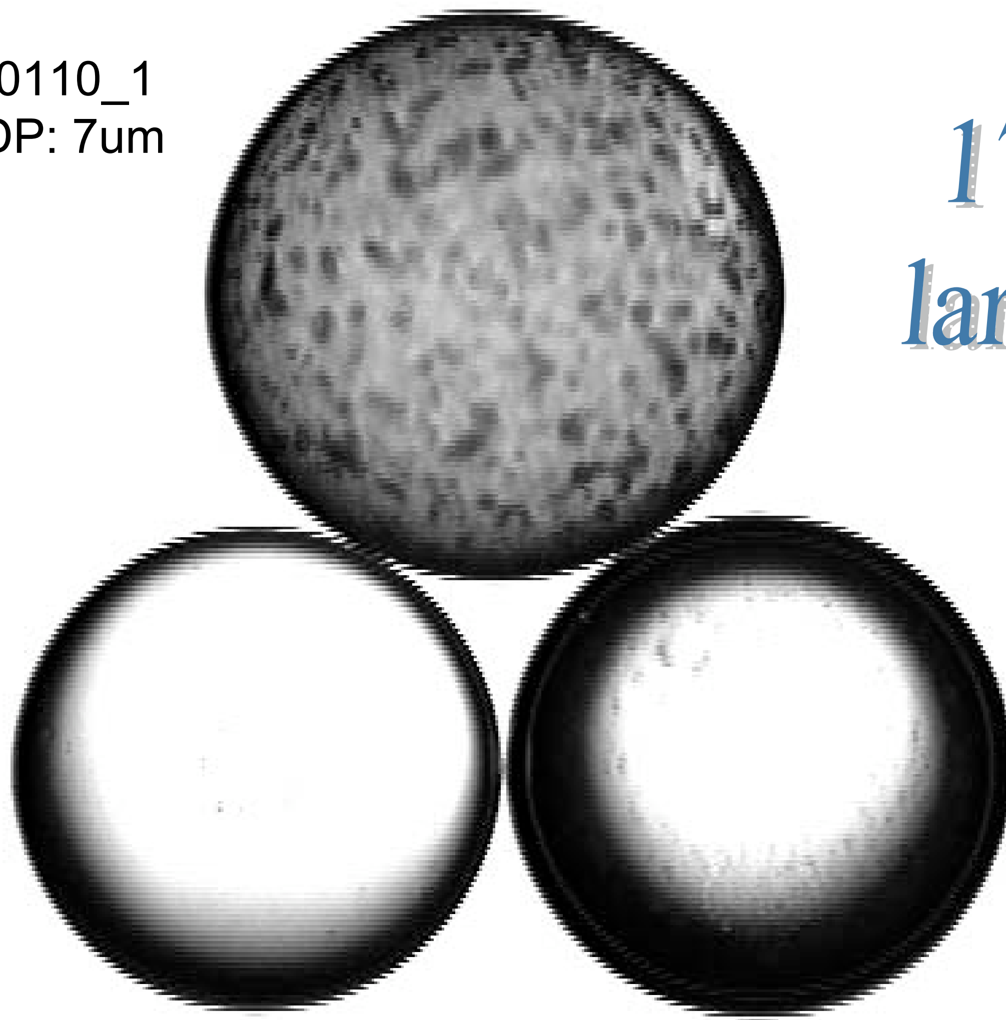
Melting?

Before:
D=2047um
W=34um
C=3um
P1113

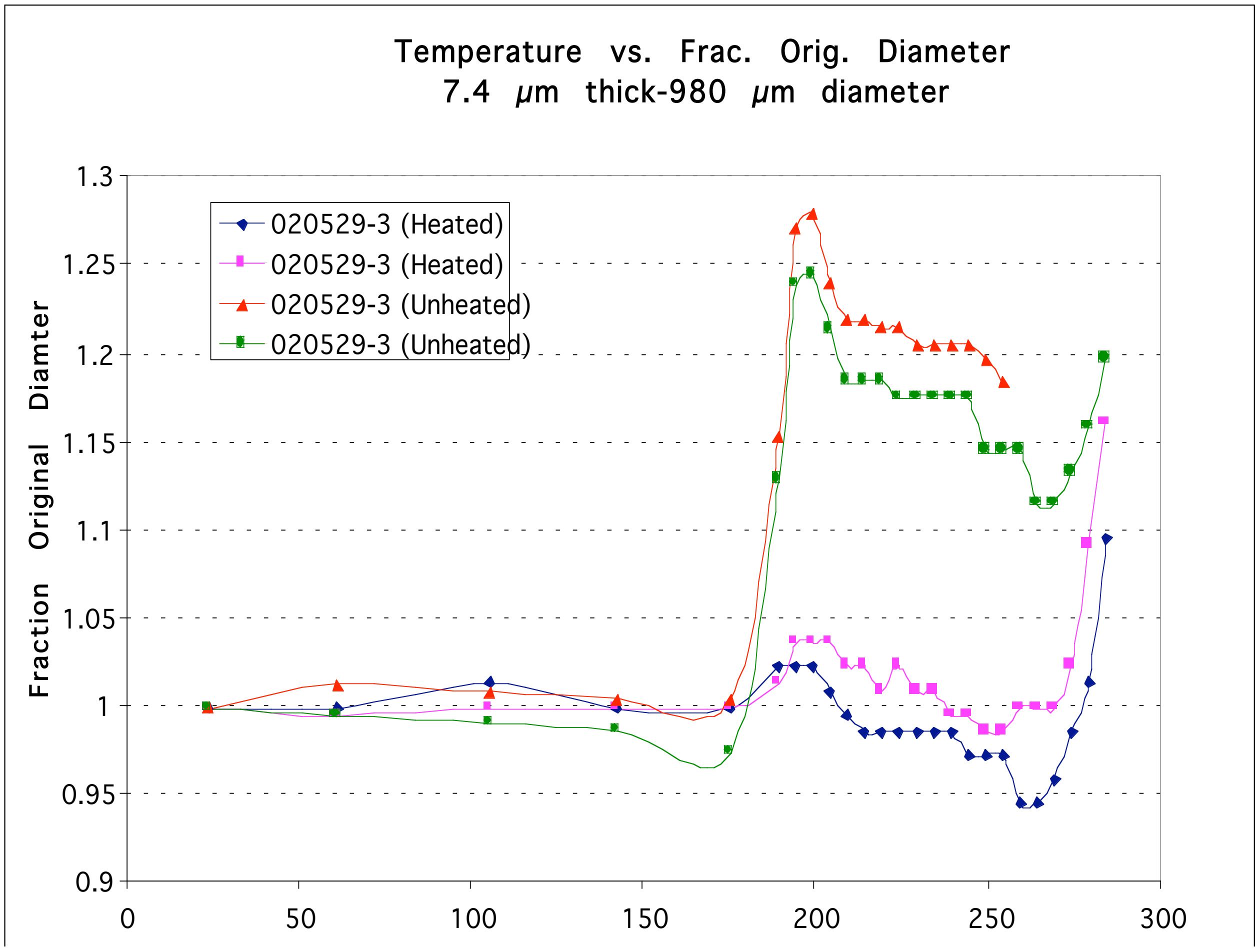
After:
D=2390um
W=14um
C=15um
GDP=7um

sublimation+permeation=> loss of mass

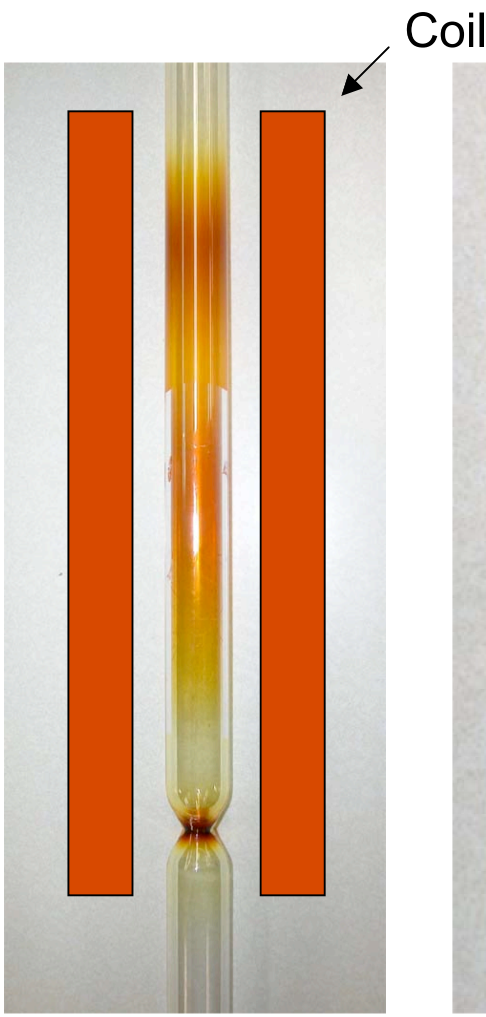
Shell Swells



From Abbas Presentation



Motivation for Tube 3



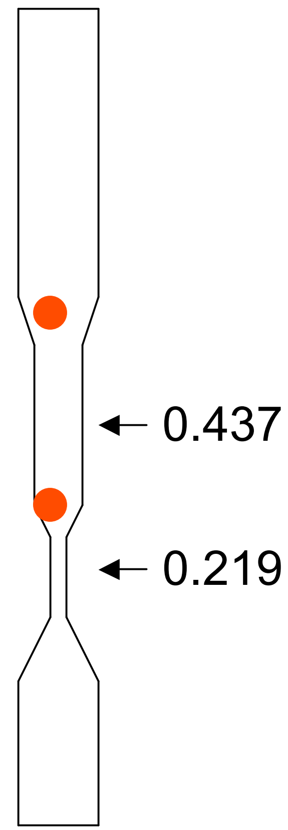
Tube 1

Tube 1

- Plasma confined
  - Pressure too high
    - Narrower tube
  - Localized deposition
    - Wall thkn sensitive
- Tunnel effect
  - Shells with kinetic E
    - Need longer neck
- Tube-to-tube variation
  - Manufacturing: ID
  - Modeling: $V_{terminal}$

Motivation for Tube 4

- Open the Z dimension
  - for mass production
  - limited testing
    - hazy, slow dep. rate
      - strong collisions
        - » due to non-laminar flow
      - temperature non-uniformity
        - » process window less than 4”
- Two bed locations
  - lower bed
    - similar to tube 3
  - top bed
    - wait for new MFC



Tube 4