
Progress in IFE Target Fabrication

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Presented by Dan Goodin

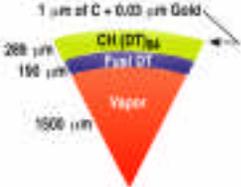
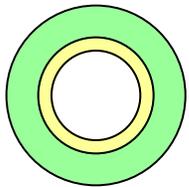
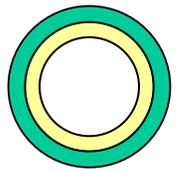
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University of California

San Diego



Overview of potential cradle-to-grave scenarios being investigated or considered

<u>Target Design</u>	<u>Target Fabrication</u>	<u>Filling</u>	<u>Layering</u>	<u>Injection</u>
 <p>Rad. Preheat (I)</p>	<p>Foam shell by microencapsulation Seal coat by interfacial polycondensation Gold coat by sputter-coating Characterization</p>	Permeation	<p>Cryogenic fluidized bed <i>Or</i> In-Sabot</p>	<p>Gas-gun <i>Or</i> Electromagnetic (Petzoldt)</p>
 <p>Empty Outer Foam (II)</p>	<p>Foam shell by microencapsulation Seal coat by interfacial polycondensation? <i>Or</i> Injection molding around GDP mandrel</p>	Permeation	<p>Cryogenic fluidized bed <i>Or</i> In-Sabot</p>	<p>Gas-gun <i>Or</i> Electromagnetic (Petzoldt)</p>
 <p>Thick Capsule (III)</p>	<p>Polymer shell by microencapsulation <i>Or</i> Coatings by GDP or spray-dry in a fluidized bed</p>	<p>Permeation <i>Or</i> Liquid Injection</p>	<p>Cryogenic fluidized bed <i>Or</i> In-Sabot</p>	<p>Gas-gun <i>Or</i> Electromagnetic (Petzoldt)</p>

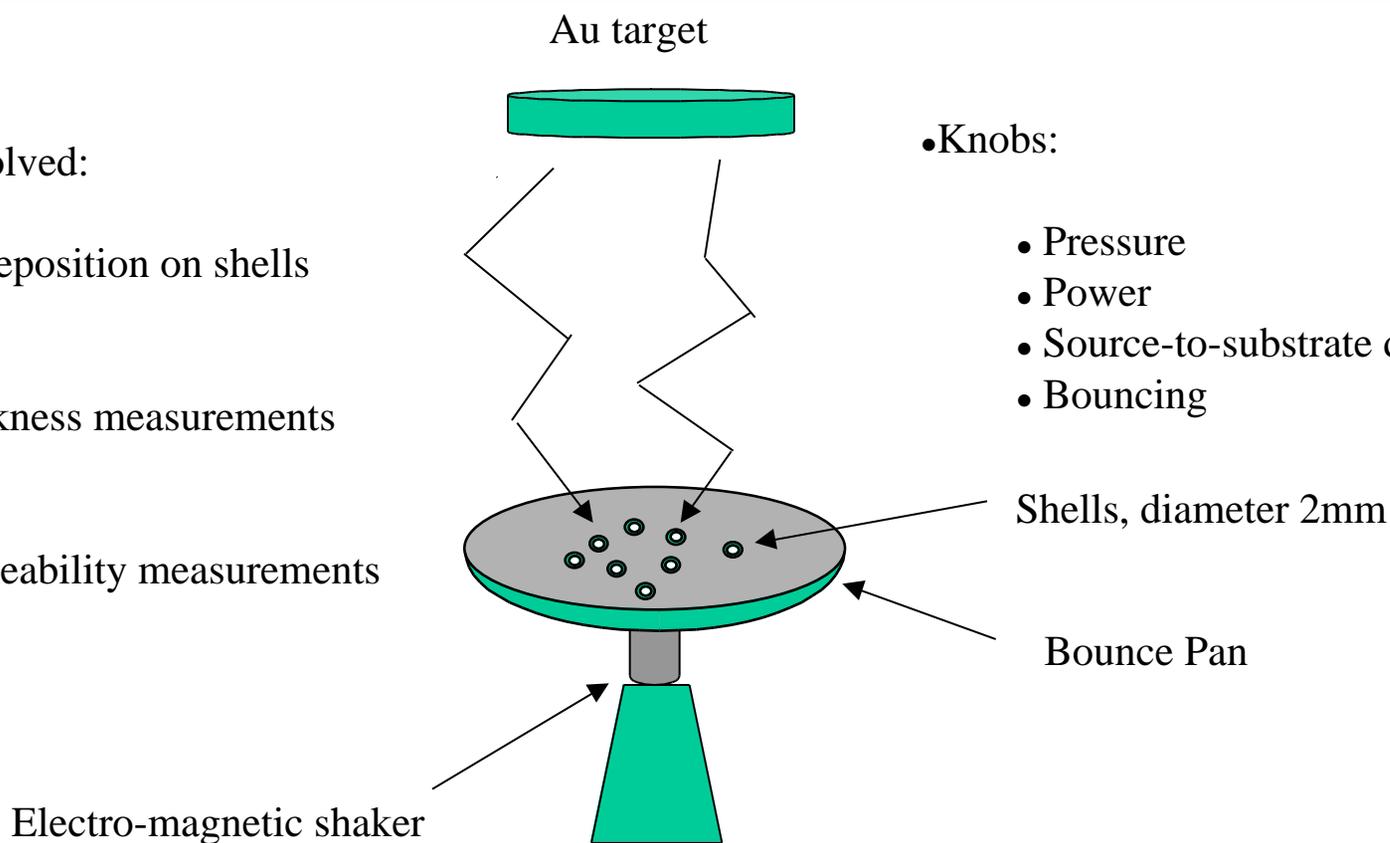
PAMS shells have been gold coated in a sputter-coater for permeation measurements

- Issues involved:

- Au deposition on shells
- Thickness measurements
- Permeability measurements

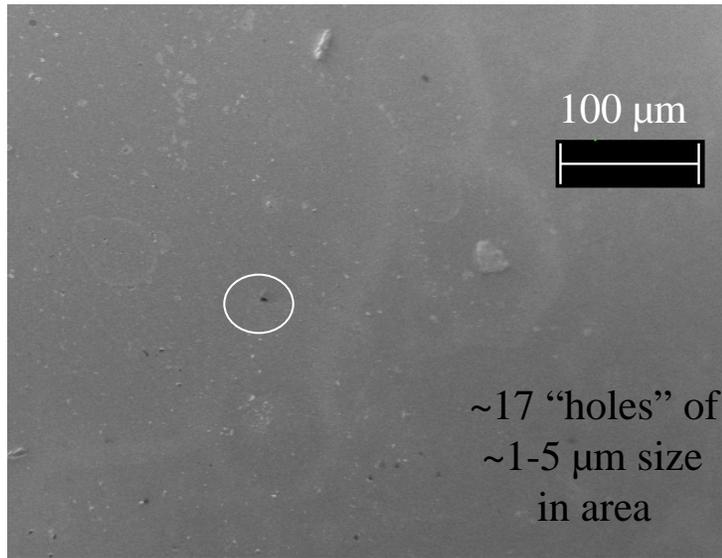
- Knobs:

- Pressure
- Power
- Source-to-substrate distance
- Bouncing

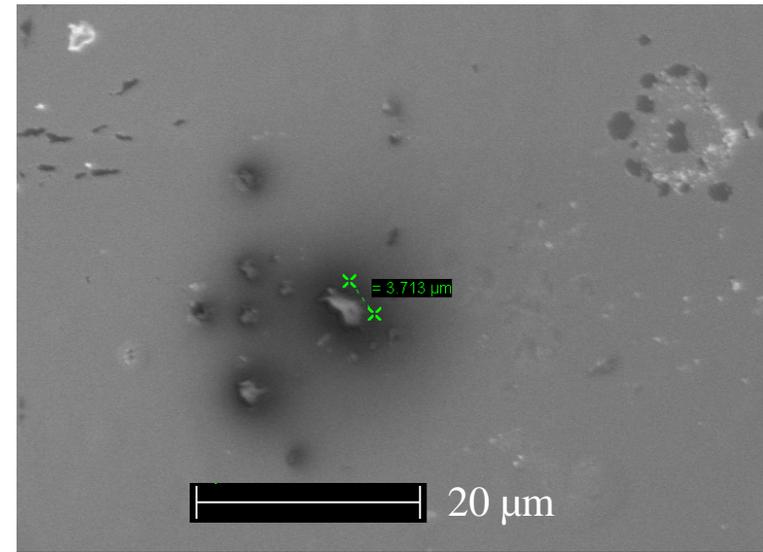


.... Success so far is being able to coat spherical shells and to permeate gasses through them

Varying degree of defects are observed in first coatings - probably from shell to shell collisions

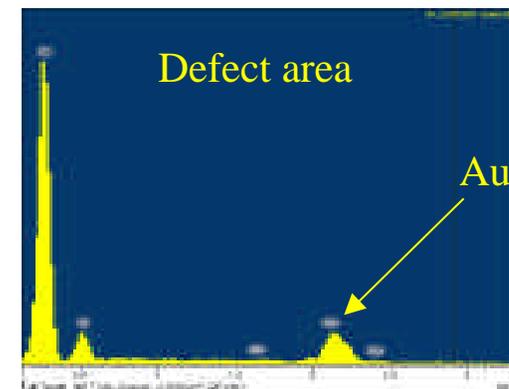
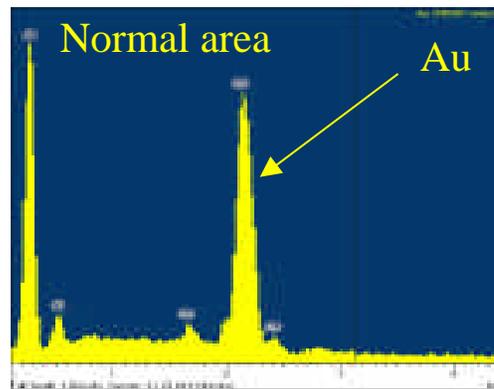
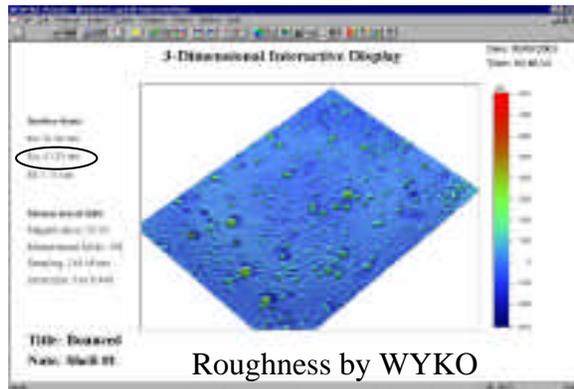


SEM image
of Au
coated
polymer
shell
Debris a
problem at
this point?



250 \AA , Permeability $\sim 0.1x$ that of mandrel

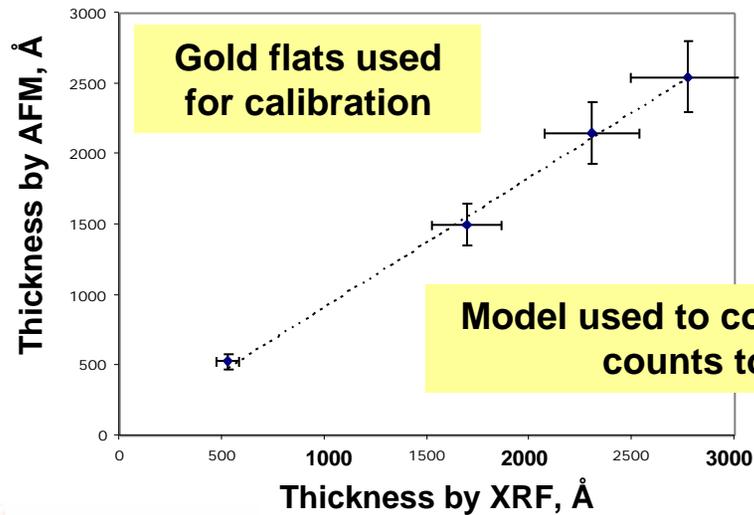
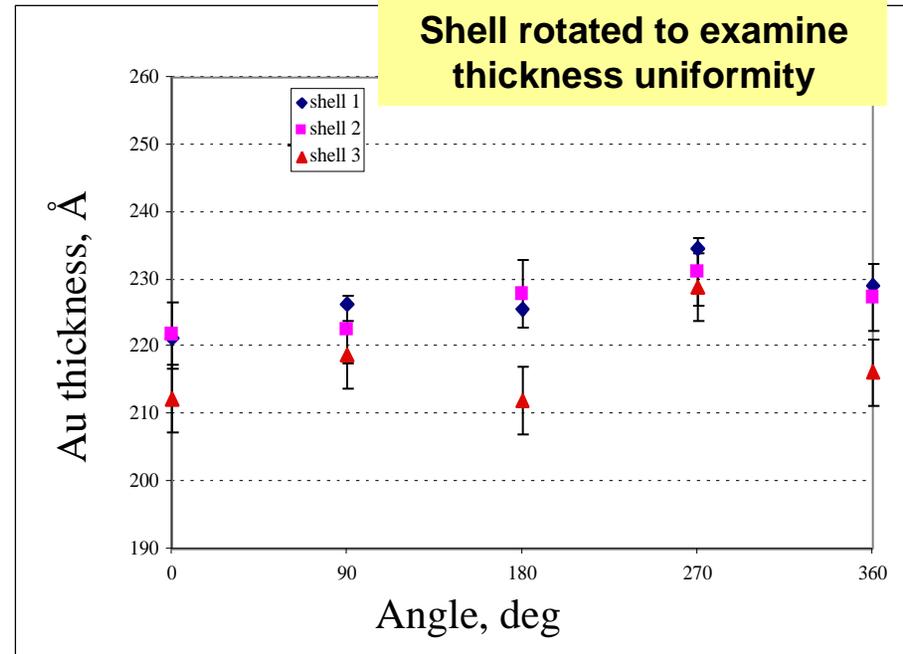
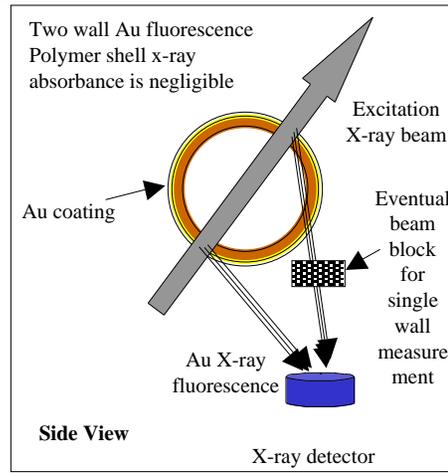
200 \AA , Permeability $\sim 0.2x$ that of mandrel



.... EDX shows reduced gold within the defects



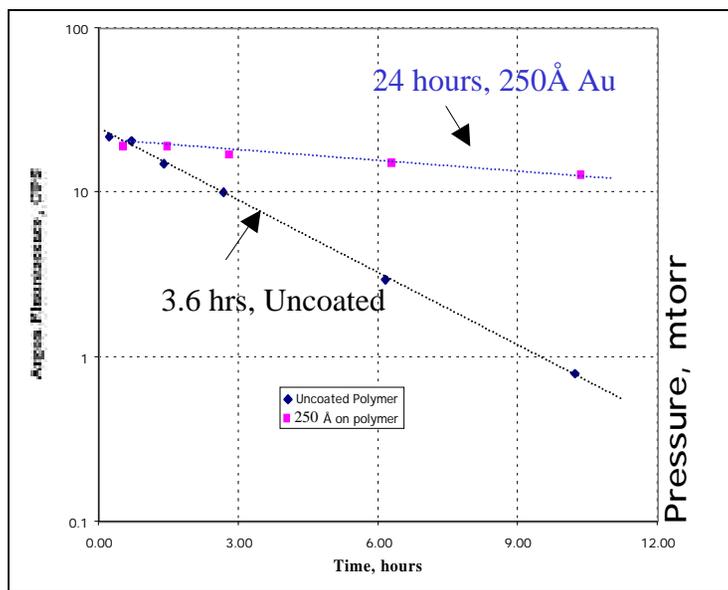
X-ray fluorescence was used to determine gold coating thickness



.... Initial thickness uniformity was 4-7%

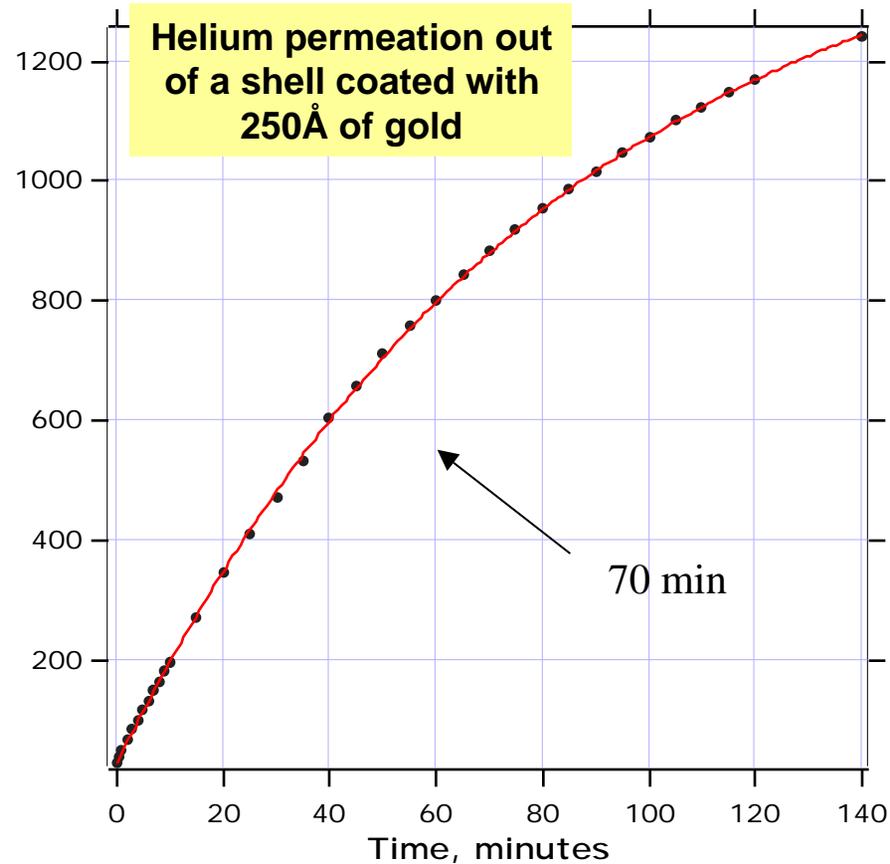
.... XRF gave accurate measure of thickness on flats

Initial samples show about 10x longer to fill with gold coating applied



Argon could be permeated through the gold-coated shell at room temperature

Large area defects are likely not responsible for all of permeation as their estimated area < 300th of shell area.



Helium permeation out of a shell coated with 250Å of gold

For the uncoated shell measured 8 min



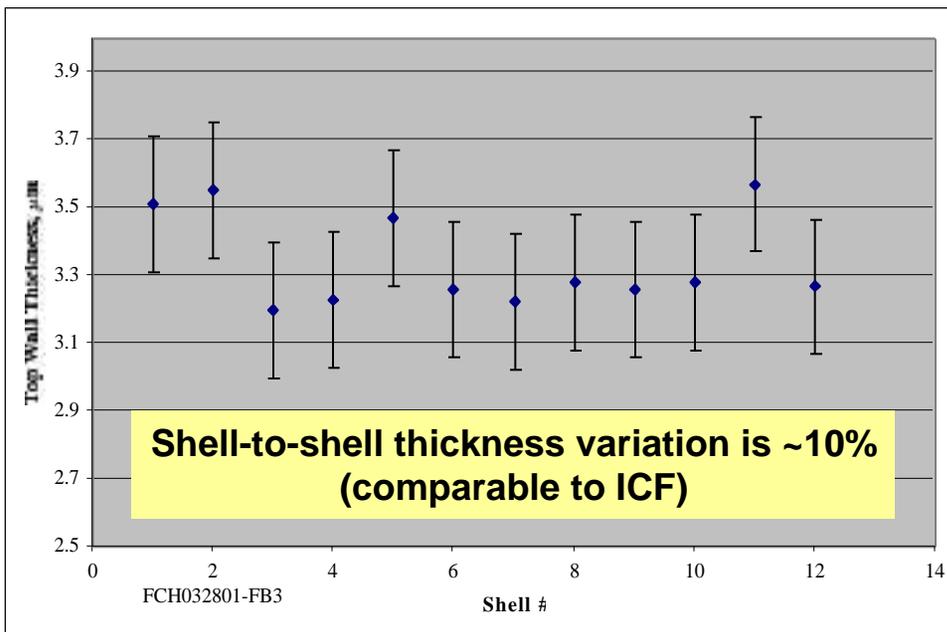
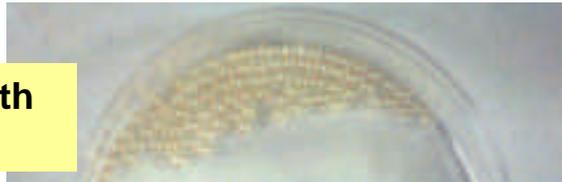
.... Next: measure HD, vary conditions



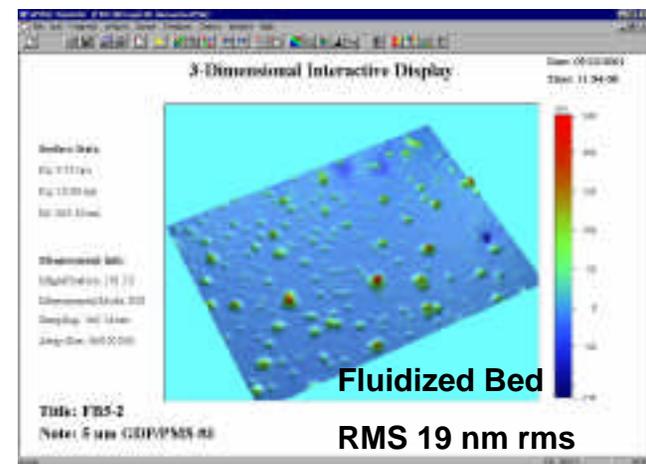
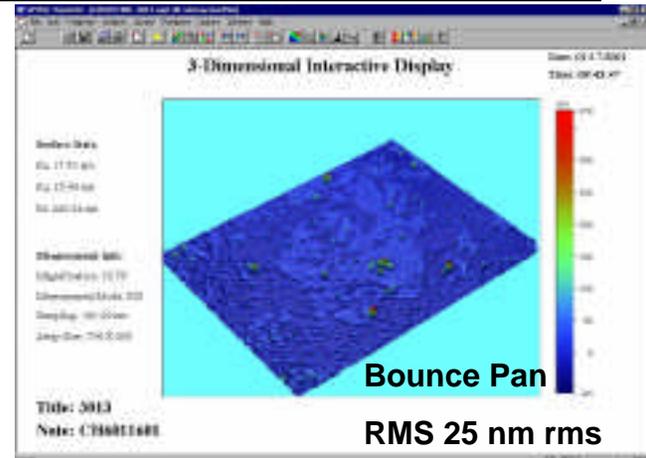
Fluidized bed GDP coating - multiple runs have shown reproducible thickness and coating rates

- 5 runs at nominal conditions gave consistent results
- Further runs will investigate effect of gas flow and RF power

Shells coated with
~3 μm of GDP



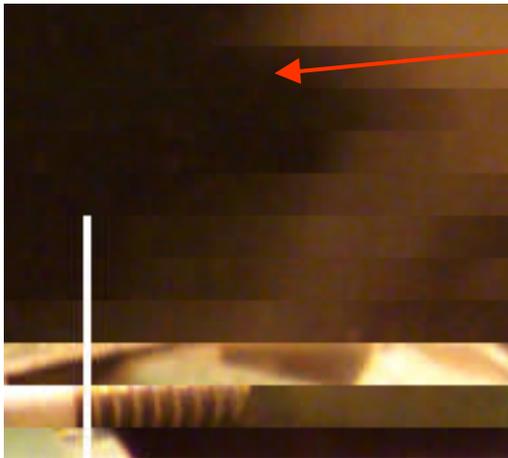
Shell-to-shell thickness variation is ~10%
(comparable to ICF)



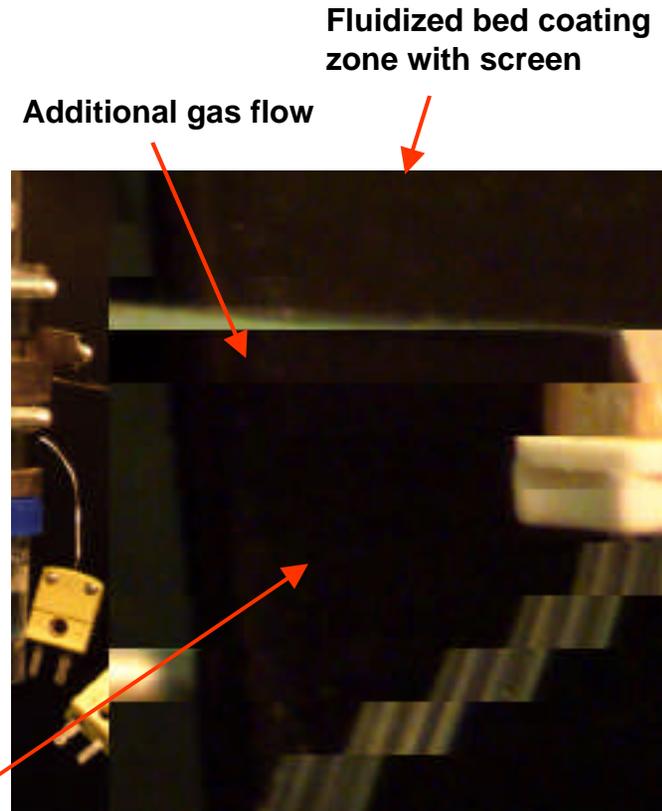
.... On comparable mandrels, the coating roughness is comparable

An alternative mass-production coating method is solution spray-drying in a fluidized bed

- Initial coatings with 7% polyamic acid (polyimide precursor) in DMSO
- Approx. 2 mm diameter PAMS mandrels; 100 capsules coated in 8 hour run
- Other solutions possible - PVA, other polyimide precursors, etc.
- Process uses inexpensive, commercially available components



Aerosol microspray
4-8 micron droplets



Additional gas flow

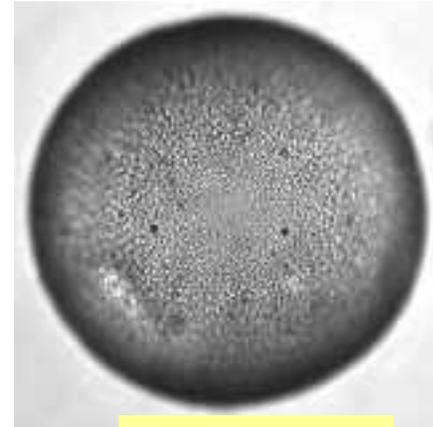
Fluidized bed coating zone with screen

Nebulizer creates microspray

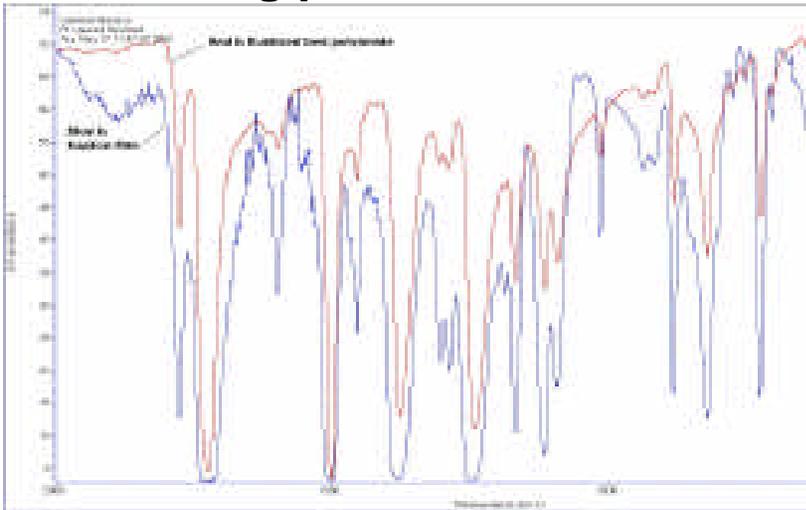
Nebulizer gas flow

Solution spray-drying results are encouraging

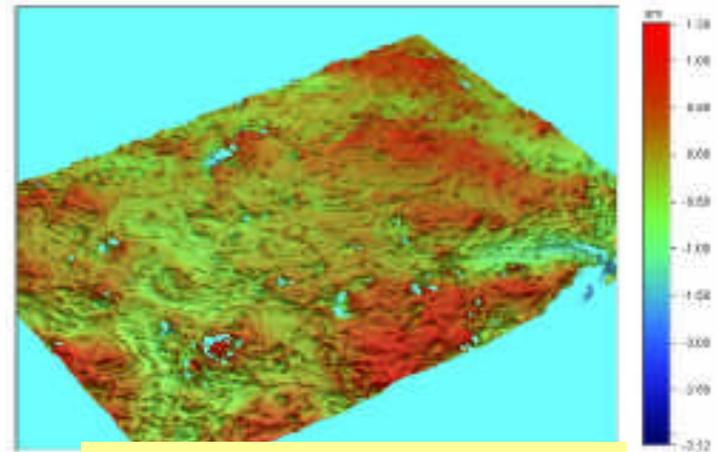
- Were able to demonstrate polyamic acid coatings in a fluidized bed in just a few weeks of effort
- Imidized at 300°C with std. process; removed PAMS
- Wall thickness ~1.5 microns; fully imidized by FTIR
- Surface finish is rough; working on vapor smoothing process in the bed



2 mm PI capsule



FTIR spectra of PI capsule (red) matches Kapton HN film spectra (blue)



WYCO image of PI capsule surface



.... If successful, other potential applications possible



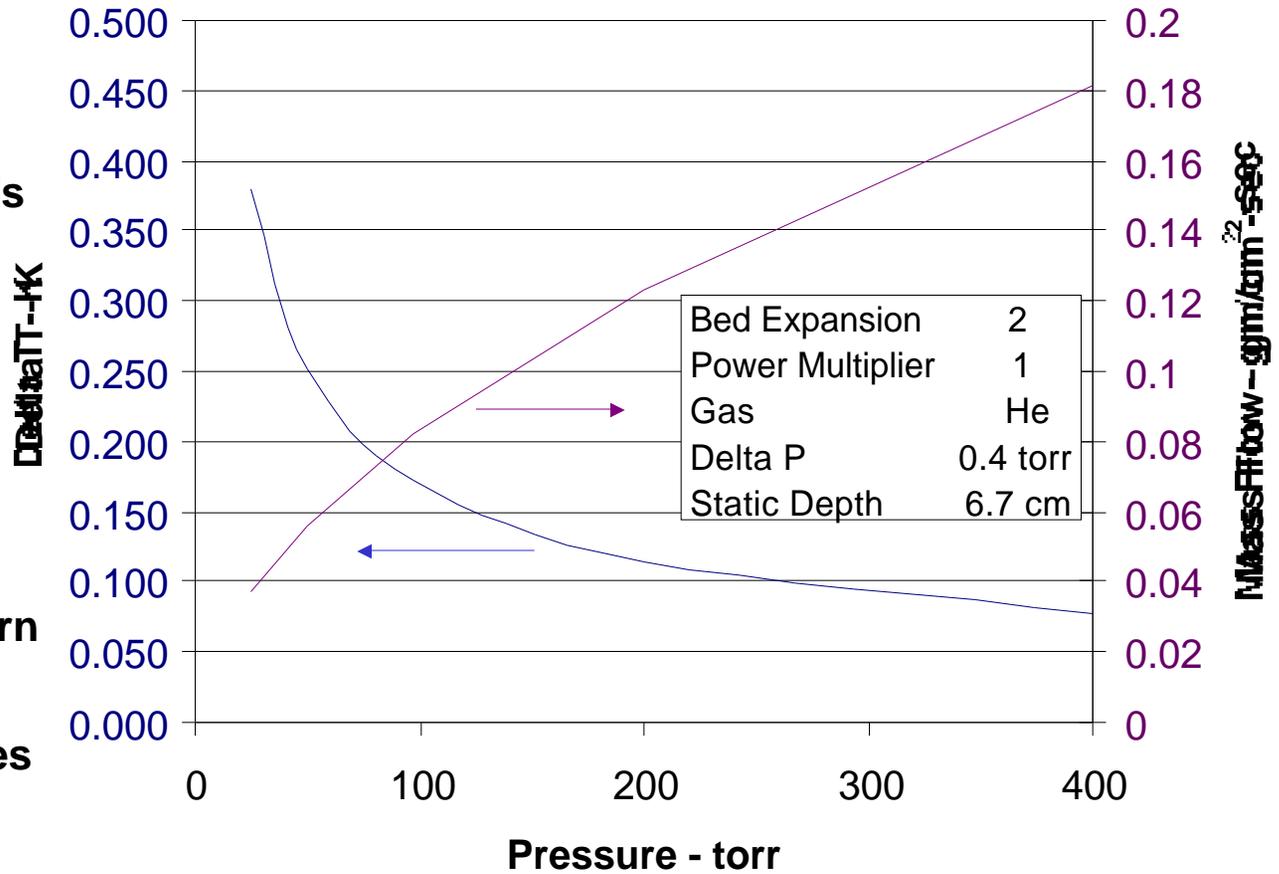
Evaluation of cryogenic fluidized bed layering is ongoing with Schafer/GA/LANL personnel

- **Coordination meeting at Schafer April 6, 2001**
 - GA, LANL, Schafer - preliminary process selections
 - Agreed to avoid precise temperature ramping (as for NIF) for batches
 - Goal for layering time of 15 minutes with 10-30X energy input
 - Basic fluidized bed requirements outlined, including:
 - Temperature uniformity around shell: $\pm 25\mu\text{K}$
 - Temperature control on incoming gas: $\pm 10\text{mK}$
 - Bed gradient control: To be evaluated
 - Maximum hold time after layering: 24 hours
 - Maximum time after filling before shot: 5 days
- Agreed to evaluate options such as HD or DD as fluidizing medium



It is extremely difficult to remove the heat from the targets in a “simple” fluidized bed concept

- Light targets require little fluidizing gas
- Pressure limited to avoid crushing thin-walled shells
- Much higher pressures possible for thick-walled shells
- Higher gas flows cool better but expand the bed and make it violent
- Cracking/erosion a concern at high expansion factors
- Augmented layering makes it much worse

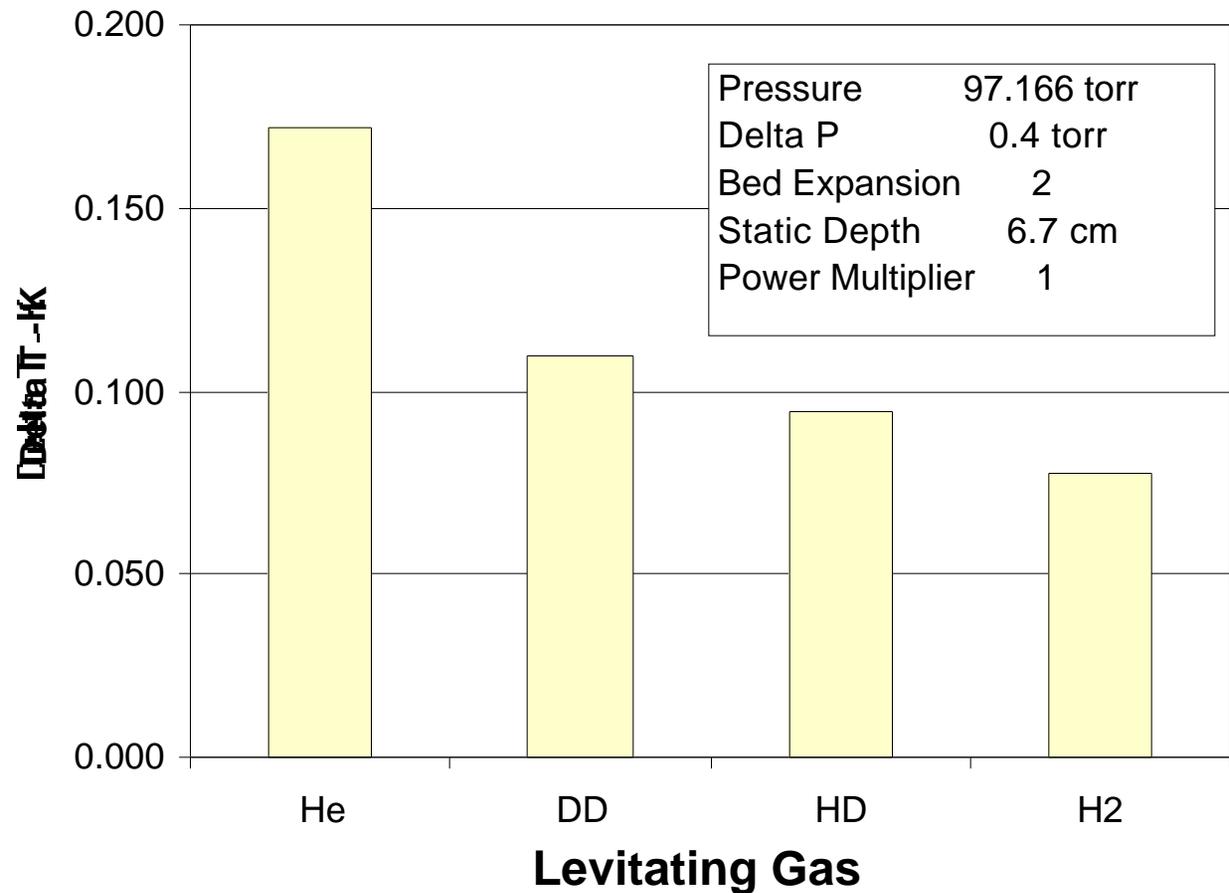


.... A number of options are being evaluated



Use of hydrogen isotopes reduces the bed ΔT somewhat - but doesn't solve the issue

Pressure for hydrogens are limited to their vapor pressure at the coldest point in the system



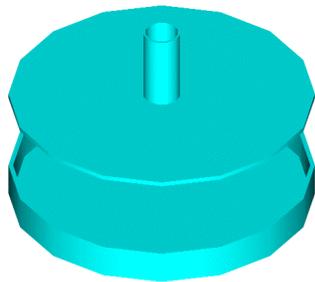
.... More creative options are needed!



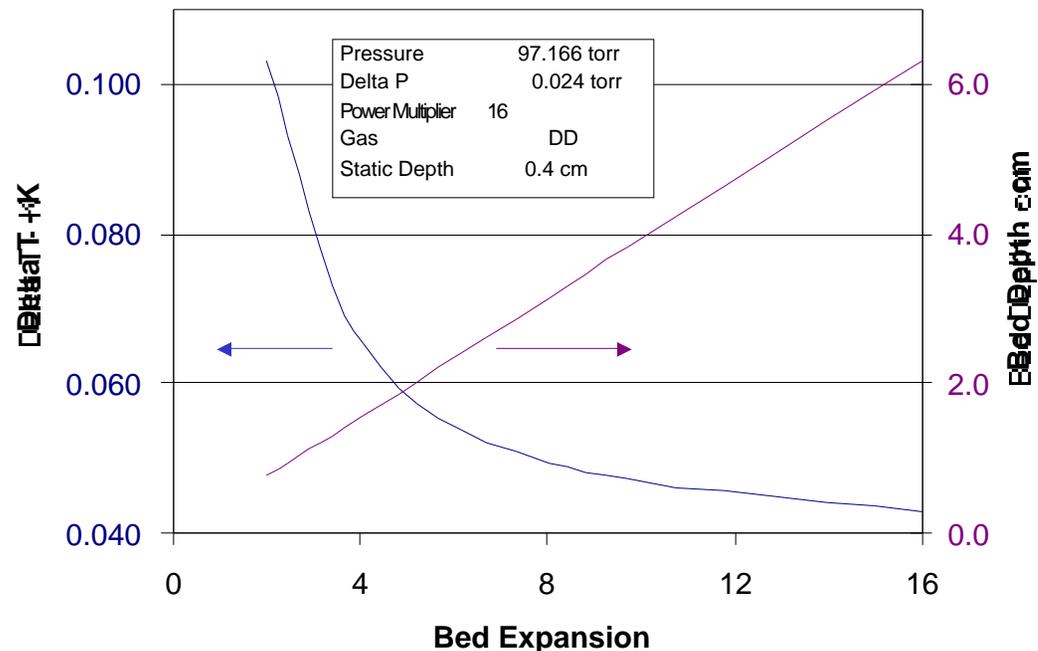
There are a number of potential solutions

- Live with “large” ΔT – it may even be good
 - Rapid temperature cycling produces a constant average wall temperature
 - Temperature cycling tends to dissolve smaller crystallites and may lead to single crystal growth
- Shallow beds aren’t really that large (~40 cm) if the layering time is short

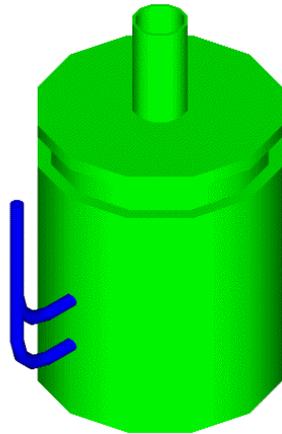
SHALLOW WIDE BED



15.75” I.D. for a 15 minute target supply

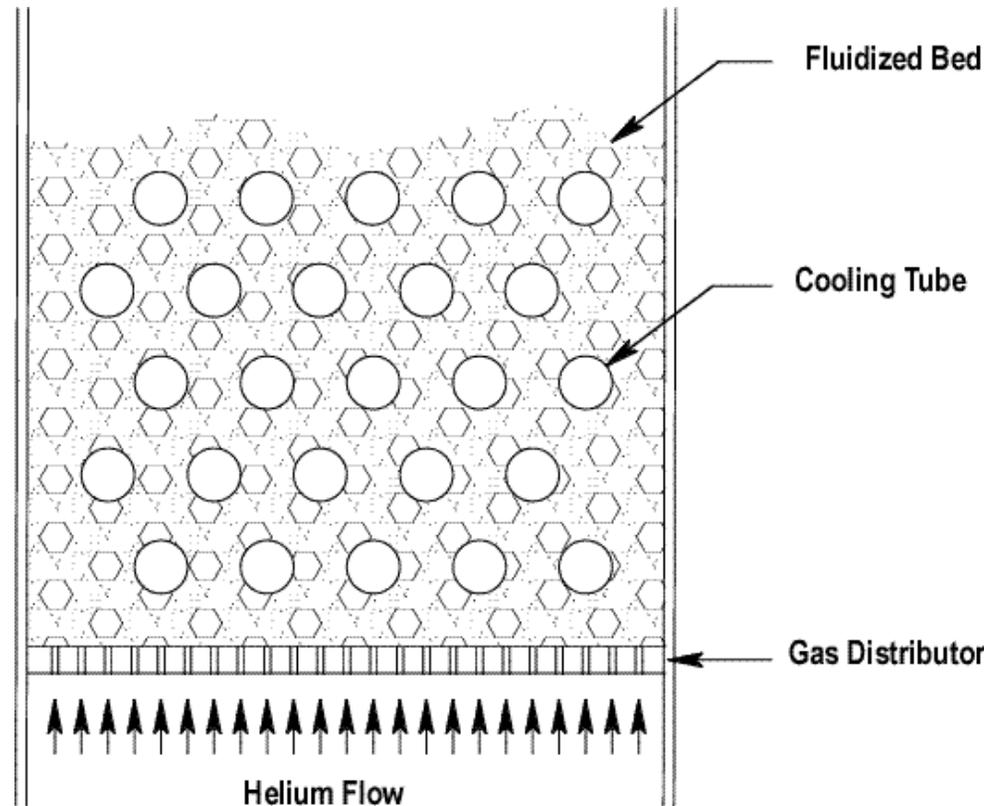


Introduce cooling tubes into a deep bed - effectively make a stack of monolayers



*7.87" I.D. x 8.66" tall
for a 15 minute target
supply*

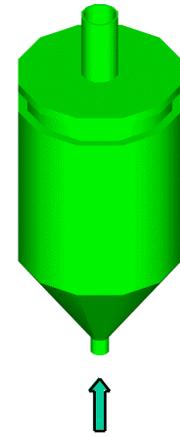
Concern over collisions with stationary tubes making cracking worse



.... Backup to monolayer

Other “advanced” solutions to be considered

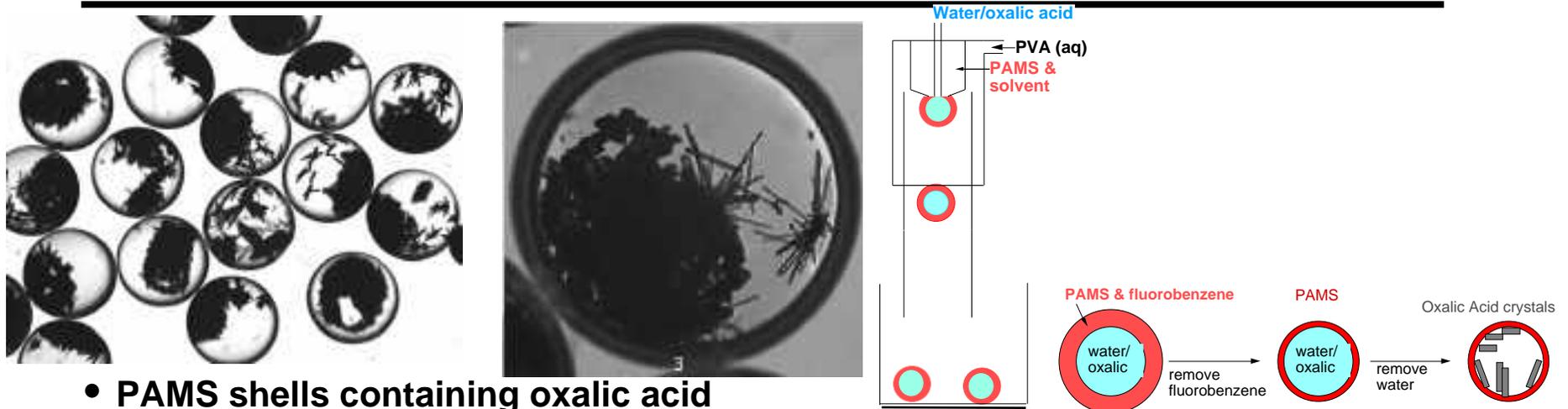
- Add HD or H₂ mist to the fluidizing gas
- Add D₂ snowballs to bed
 - Sublimating solid D₂ in bed will maintain constant, thermodynamically defined temperature (18.2K at 97.166 torr)
- Use “rotary kiln” geometry to give continuous delivery of layered targets
 - Add D₂ snow with targets at entrance to “kiln” such that it is all gone at the exit



INJECT HYDROGEN MIST
INTO FLUIDIZING GAS

.... Evaluations are continuing, meanwhile a demonstration of fluidized bed layering with room temperature surrogates is being pursued

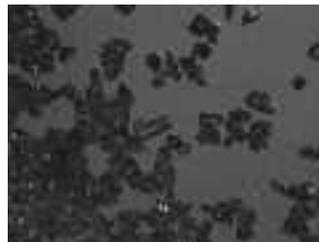
Demonstrate mass layering with a room temperature surrogate - instead of hydrogen



- PAMS shells containing oxalic acid
- Oxalic acid dissolved into inner water droplet stream for capsule production
- Capsules have OD of 1030 μ m and wall of 19 μ m, oxalic acid in shell equivalent of 13 μ m layer
- Diffusion of neopentyl alcohol into larger GDP shells next



Neopentyl Alcohol

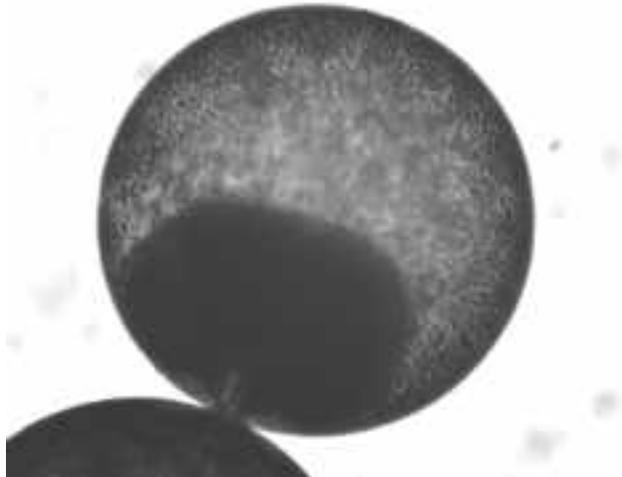


Oxalic Acid

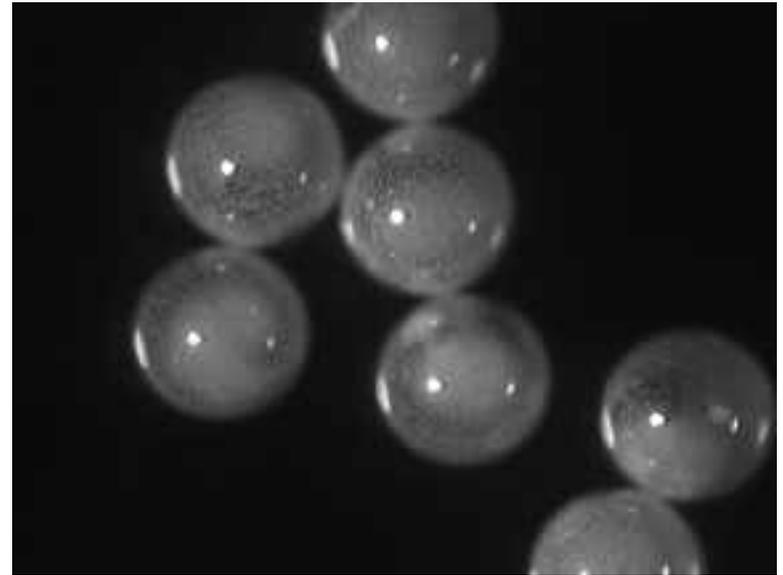


Fluidized bed mass layering is starting to show hints of success

- 2.5 hrs, 45°C, Low IR
- More than 50% had acid coverage over entire inner surface
- ~100% showed some acid movement
- Bed held ~2000 capsules, 3 broke in ~6 hrs in 3 retrievals from bed

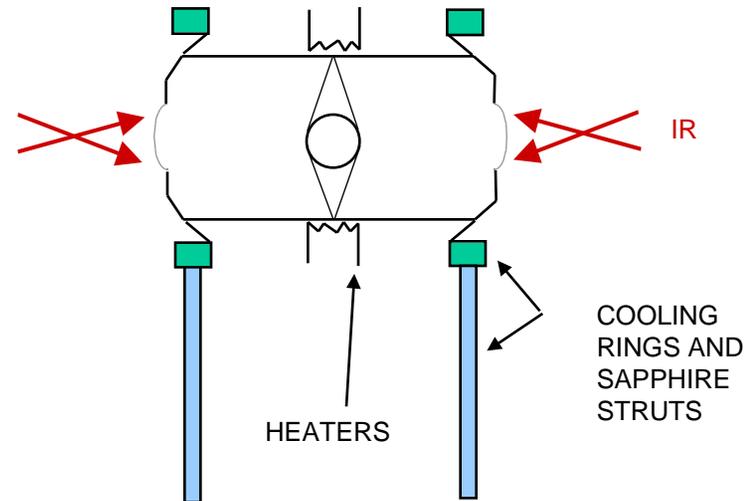
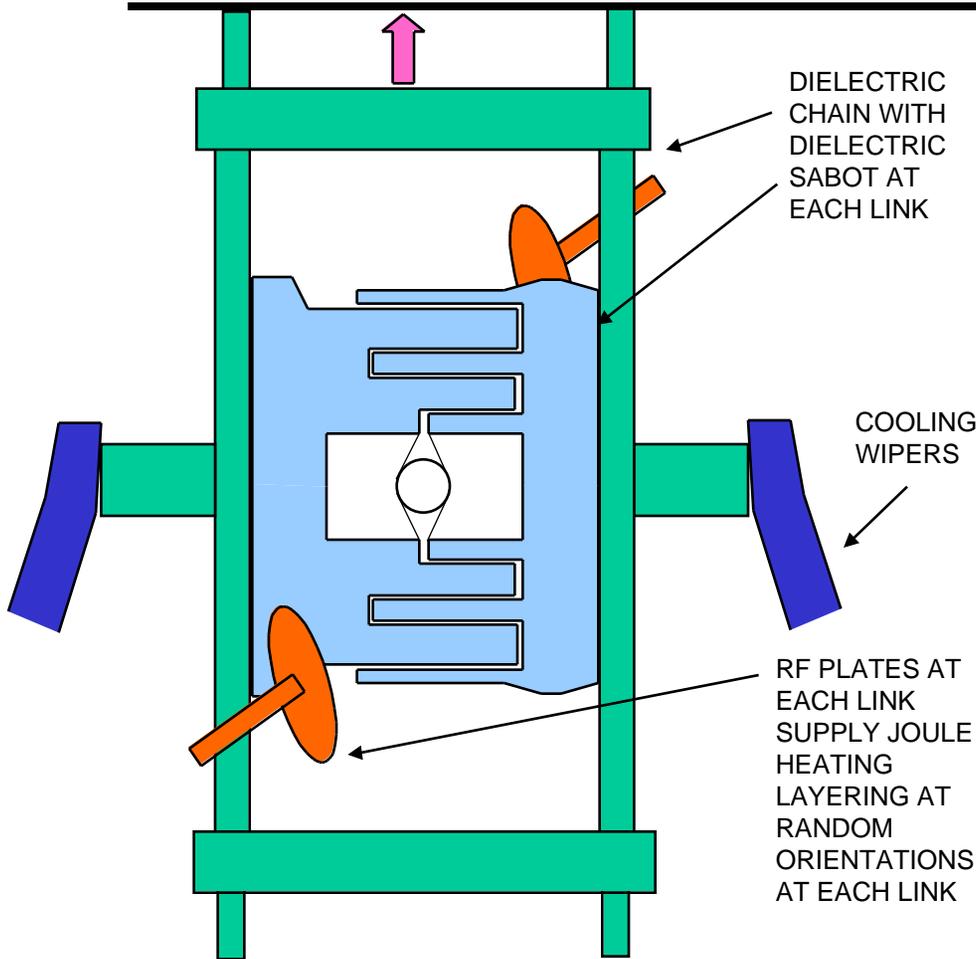


Back-lit view



Top-lit view

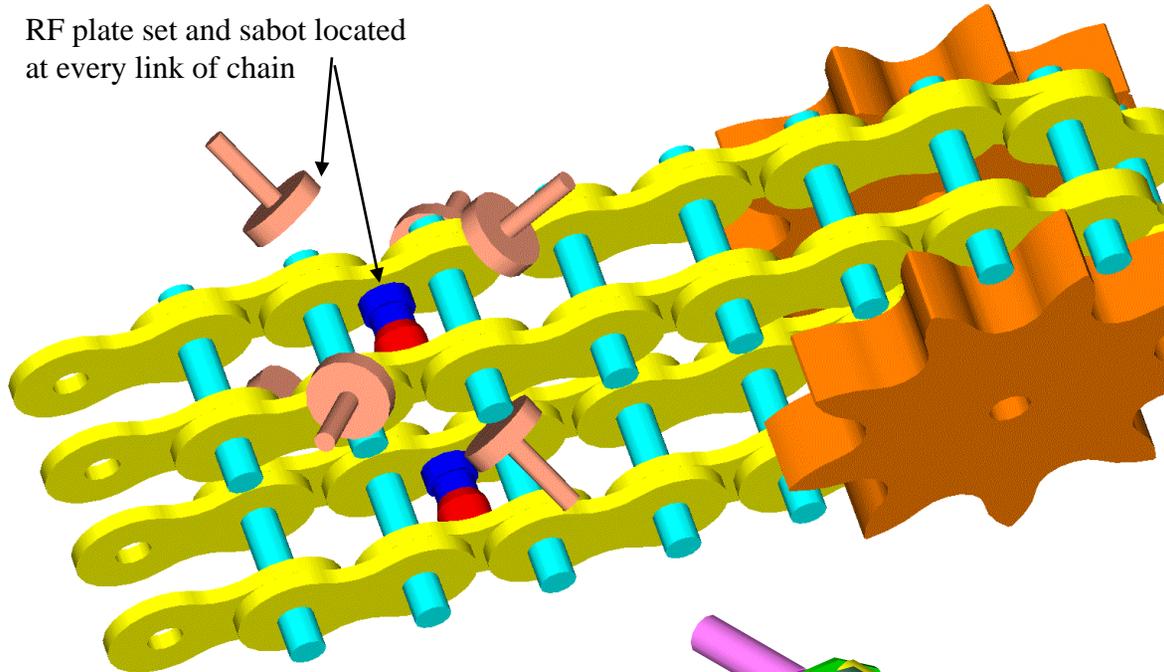
Layering a capsule in a sabot is akin to layering a capsule in a hohlraum



- For hohlraum, ends cooled and constant thickness walls heated at waist by IR or heaters
- For sabot, chain cools ends and waist made hotter by tailored thermal conductance (thinner at waist)
- For 5 cm links, 5 Hz shot rate and 15 min layering time need 225 m of chain
- Chain may be serpentine into smaller volume (10 m x 4.5m x 1m)

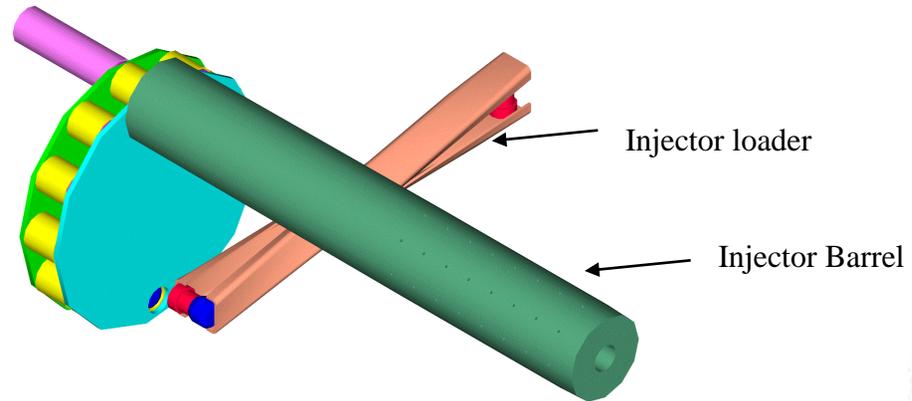
Layering “Ammo-Belt” makes layering a continuous, determined process, however has many parts

RF plate set and sabot located at every link of chain



1. Target filled and cooled in permeation cell
2. Targets loaded into sabots
3. Sabot slipped into links of chain
4. target layered in chain stations
5. sabot pushed out of chain into injector loader

- Dielectric chain and sabot used
- RF E-field direction cycled around at each station to maintain layer uniformity
- As links approach injector, RF power reduced and temperature adjusted to 18.2K



Summary and conclusions

High-Z Coatings

- Gold coatings placed onto shells
- Thickness and uniformity measured and in range of interest
- Permeation through coating is possible
- Optimization and parametric studies needed

Target Coatings

- GDP fluidized bed coater setup
- Showing reproducible results and good coatings
- Ready for parametric studies
- Solution spray-drying methods showing promise

Layering

- Fluidized beds being evaluated, not so simple but many options
- Layering of surrogate being used to demonstrate potential for methods
- In-sabot method being evaluated as alternate

.... Cradle-to-grave scenarios for target fabrication, filling, layering, and injection are well underway

