Process Control for 2G HTS Conductors

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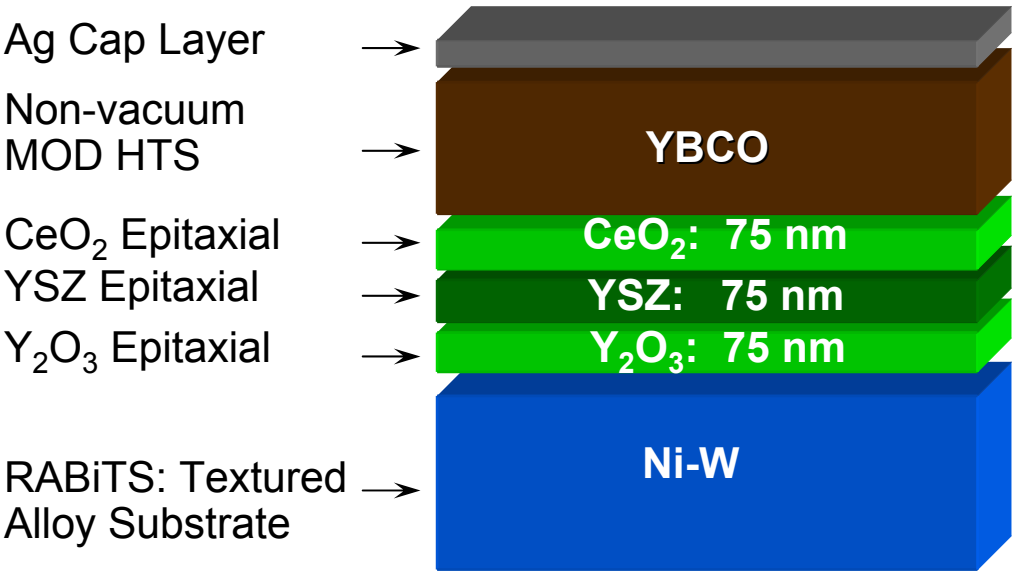
Outline:

Process Control

Process Understanding

- Study Parameter Space
- Scaling of Deposition zone

RABiTS™ / MOD 2G Architecture



- Fully continuous process (Reel-to-Reel)
- Low cost wide web processing

Transition to Production

- Meet product specifications
- Repeatable process

} **Capable Process**

- Key Input Variables (KIV) determine Key Output Variables (KOV)

  "Control the product by controlling the process within spec limits"

- Requirement: Thorough process understanding (KIV ↔ KOV)

Process control of KIV's within parameter windows provides process stability

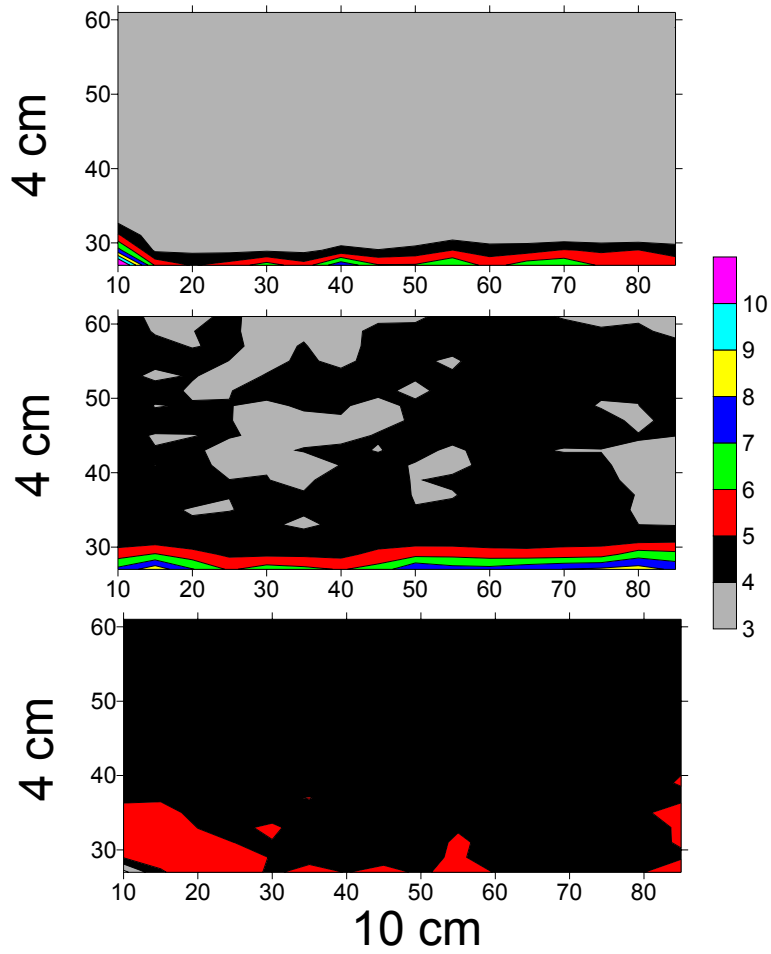
Example: 4 cm Y_2O_3 seed deposition by reactive sputtering

[Specht – ORNL]

Y_2O_3(004)
rocking curve
FWHM
phi=0

Y_2O_3(004)
rocking curve
FWHM
phi=90

Y_2O_3(222)
true in-plane
FWHM



Typical texture
NiW Substrate:
True $\Delta\Phi$ = 4.4 – 5.5˚

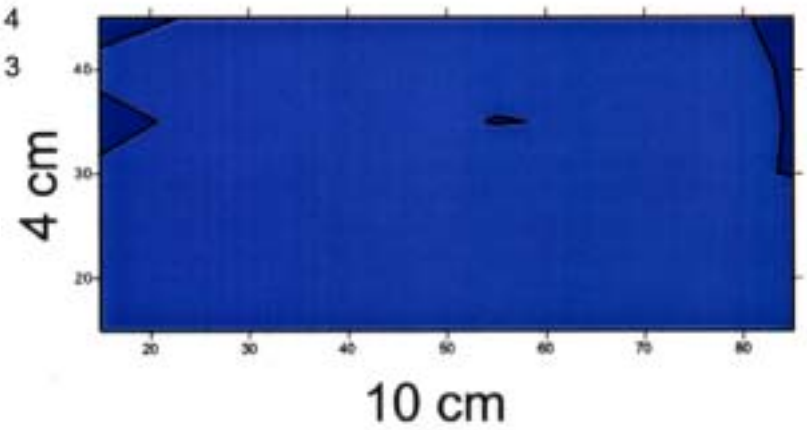
Width is major cost divider – requires homogeneity

Initial YSZ deposition conditions

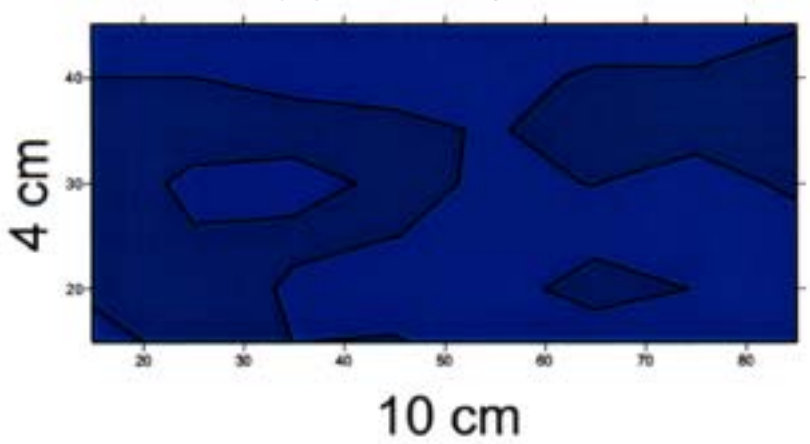
In-plane texture
True Φ (˚)

[Goyal – ORNL]

Y_2O_3 (222)
True ΔΦ = 5.2-6.2˚



YSZ (111)
True ΔΦ = 6.4-7.4˚



Homogenous result after R2R deposition

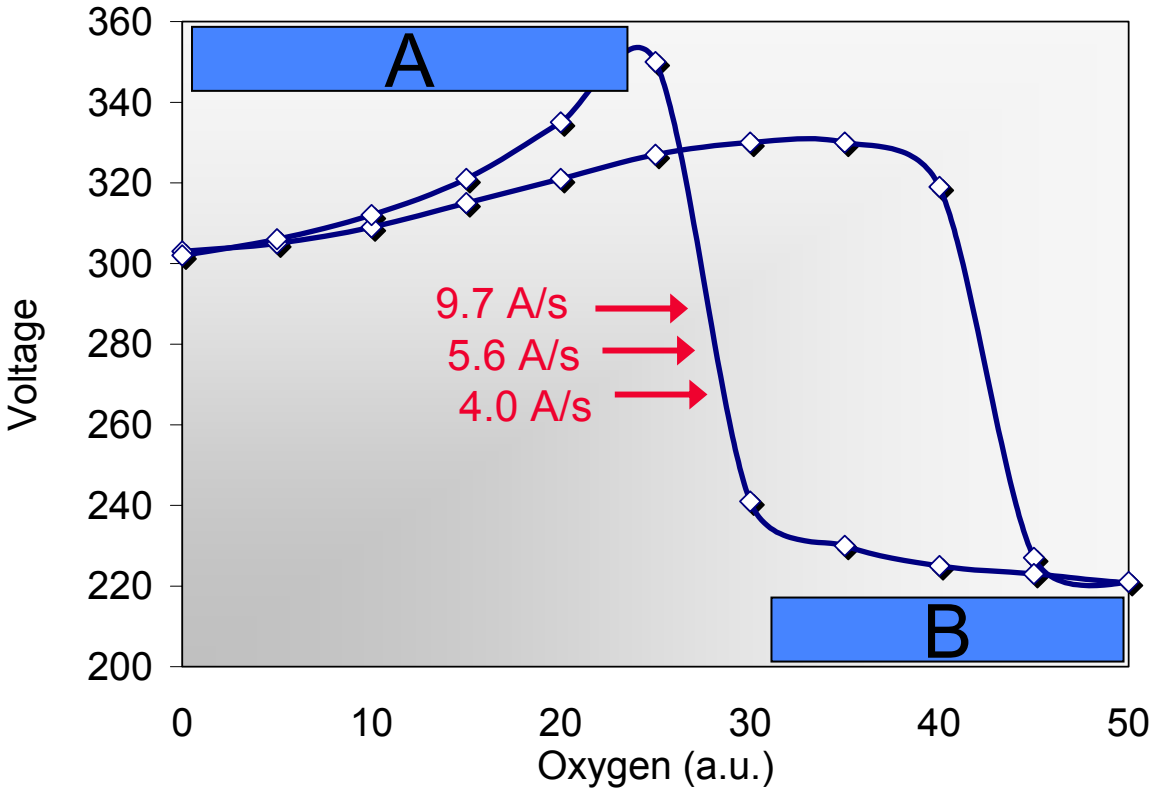
BUT: In plane texture broadens >1˚ from Y_2O_3 to YSZ

YSZ deposition restricted within ± 5V on hysteresis curve: failure %(111)

Homogenous YSZ layer on moving web – loss in in-plane texture, small parameter space

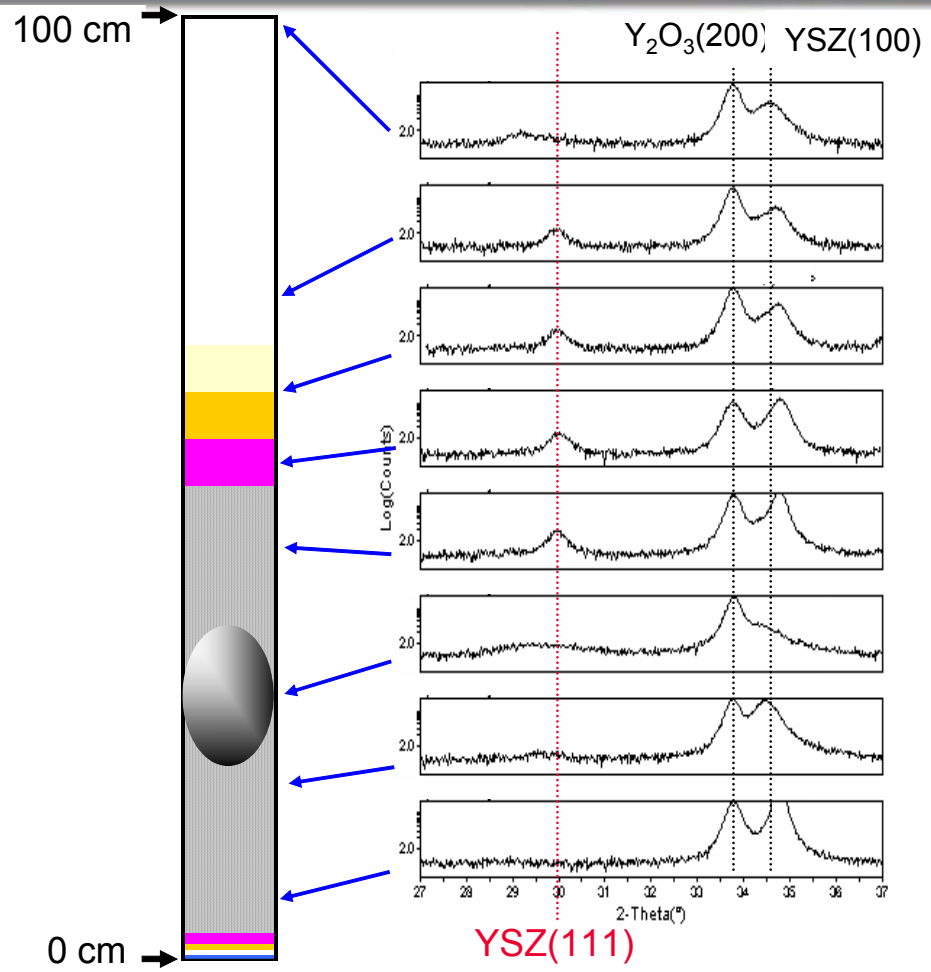
Reactive Sputtering: Typical Hysteresis Curve of YSZ

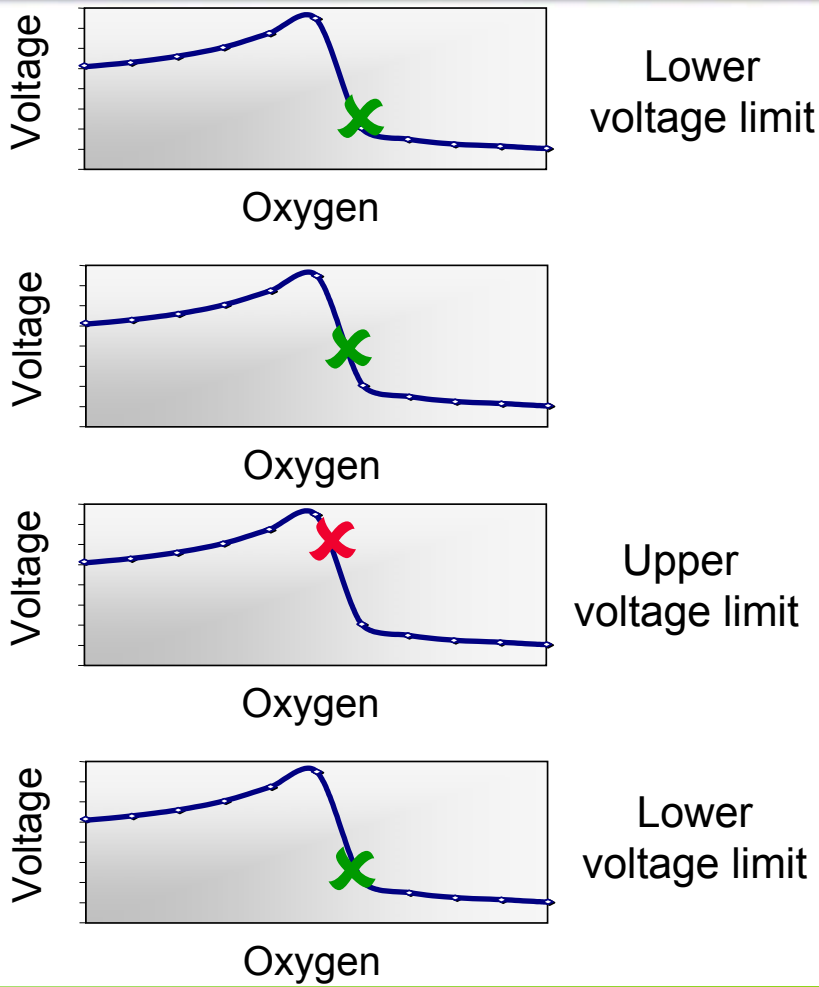
- Metal mode A – high rate, metallic film
- Poison mode B – low rate, oxide film
- Control process in transition region for high rate deposition of oxide film



- Rate increase is linear with Voltage over range of transition regime
- Rate = f (plasma power, magnetic field, Ar pressure, pumping speed, …)

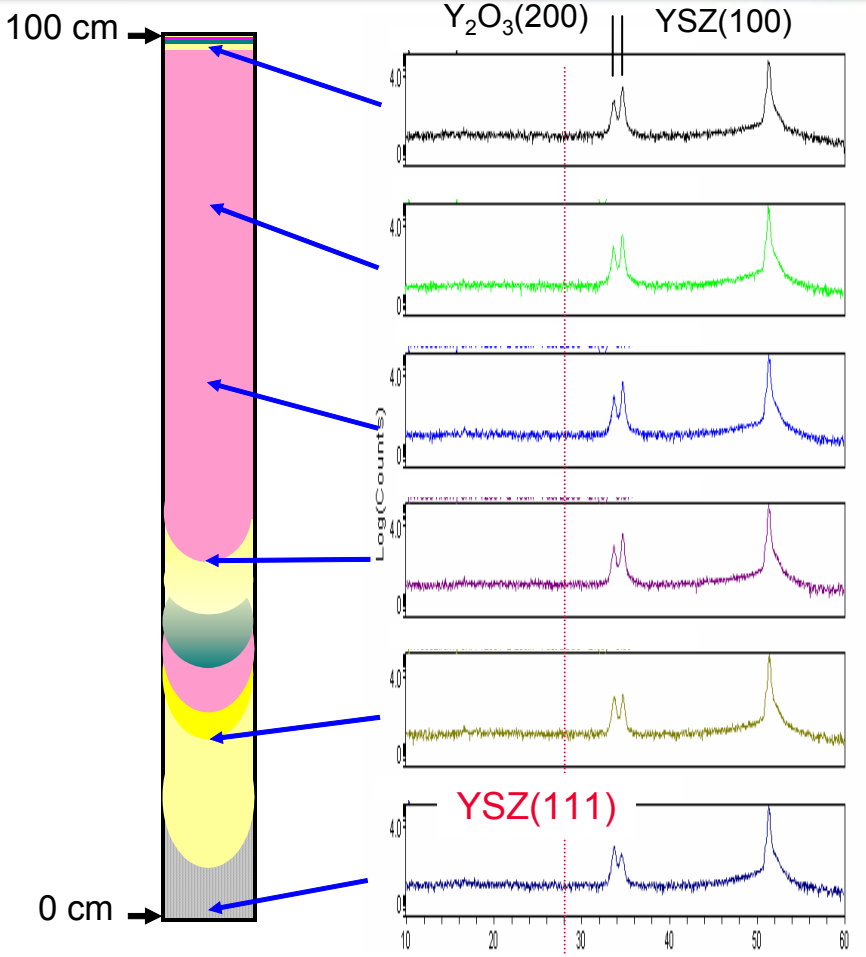
Local YSZ Growth Conditions – Static Run **Outside** Parameter Space

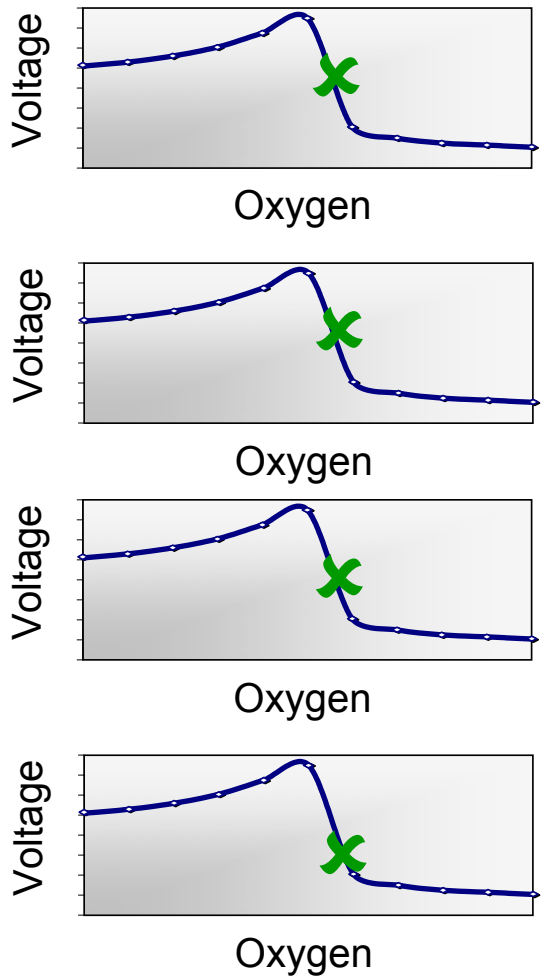




Inhomogeneous Dep zone restricts parameter space & produces bad film quality

Improved Homogeneity in Dep Zone – Static Run





Improved Condition produces 0%(111) over wide range of parameter space

Results of Optimized YSZ Deposition Conditions

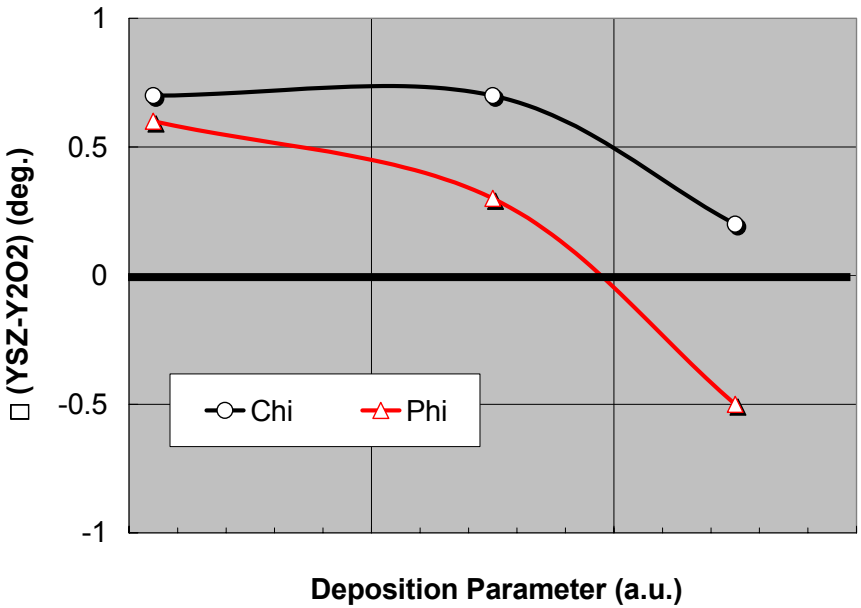
- Homogenous deposition zone (rate, oxidation stoichiometry, texture)
- Higher film quality on moving web

- Parameter window not limited by “hot spots” in deposition zone
- Broad parameter window provides higher yield
  - Control within ±20 V compared to ±5 V
- Allows to optimize conditions for layer quality and cost
  - In-plane texture
  - Barrier properties
  - Rates

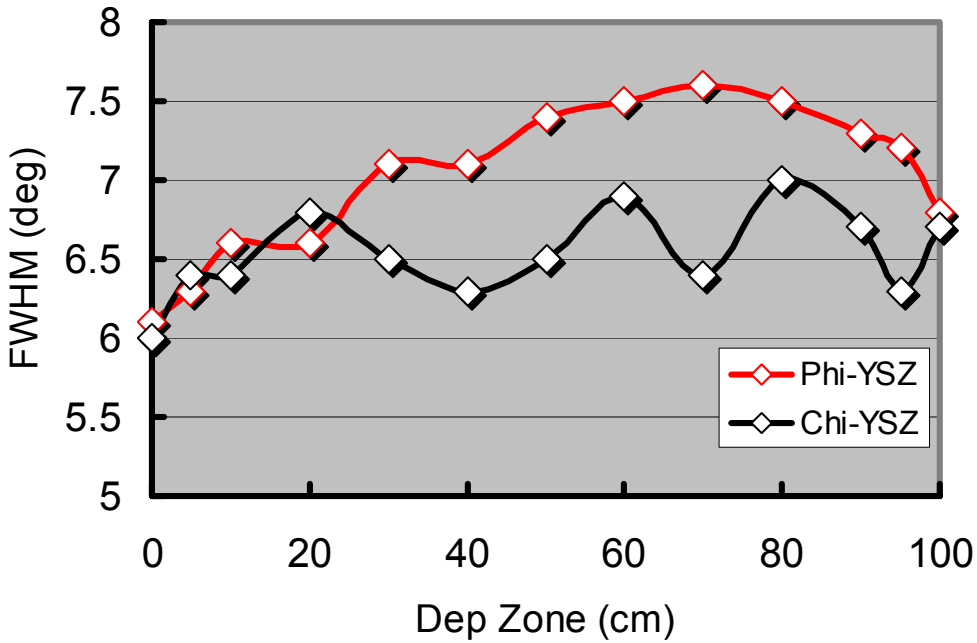
Result: High quality buffer layers with broader process window

In-Plane Texture of Buffer Layers depend on Process Conditions

Study texture development of Y_2O_3



(Phi values not corrected)



In plane texture copies / improves that of the seed layer – further improvement possible

Transform 2G into a Commercial Product

- Meet customer specs
  - Performance
  - Conductor design
- High yield process
  - Process Development
  - Process Integration
  - Manufacturing Infrastructure
- Low cost process
  - Wide Web Processing
  - Line Speed (residence time, equipment scale)

Establish Manufacturing Infrastructure

Standard Procedures and Data Management

- SPC
- Databases
- Process / Equipment Documentation
- Materials / Product flow
- Product storage, handling
- Sampling & Testing

Integrate with existing 1G manufacturing infrastructure at AMSC

Summary

- Capable process required for scale up
  - *Process can be controlled to deliver product quality*
- Key Input Variables sufficiently define process
- Thorough process understanding is basis for successful & cost effective scale up
- Understanding of full deposition zone (length / width) allows:
  - Optimize film quality – in-plane texture, barrier properties
  - Develop robust process with broad parameter space
- In depth characterization of product to understand process space and for failure analysis – rely on collaborations and external capabilities