Thin Film Stress Measurement at NUFAB

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NUANCE
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Northwestern
EXPLORING INNER SPACE

Quick Survey

Did you ever consider film stress in film deposition process or device fabrication or film characterization?

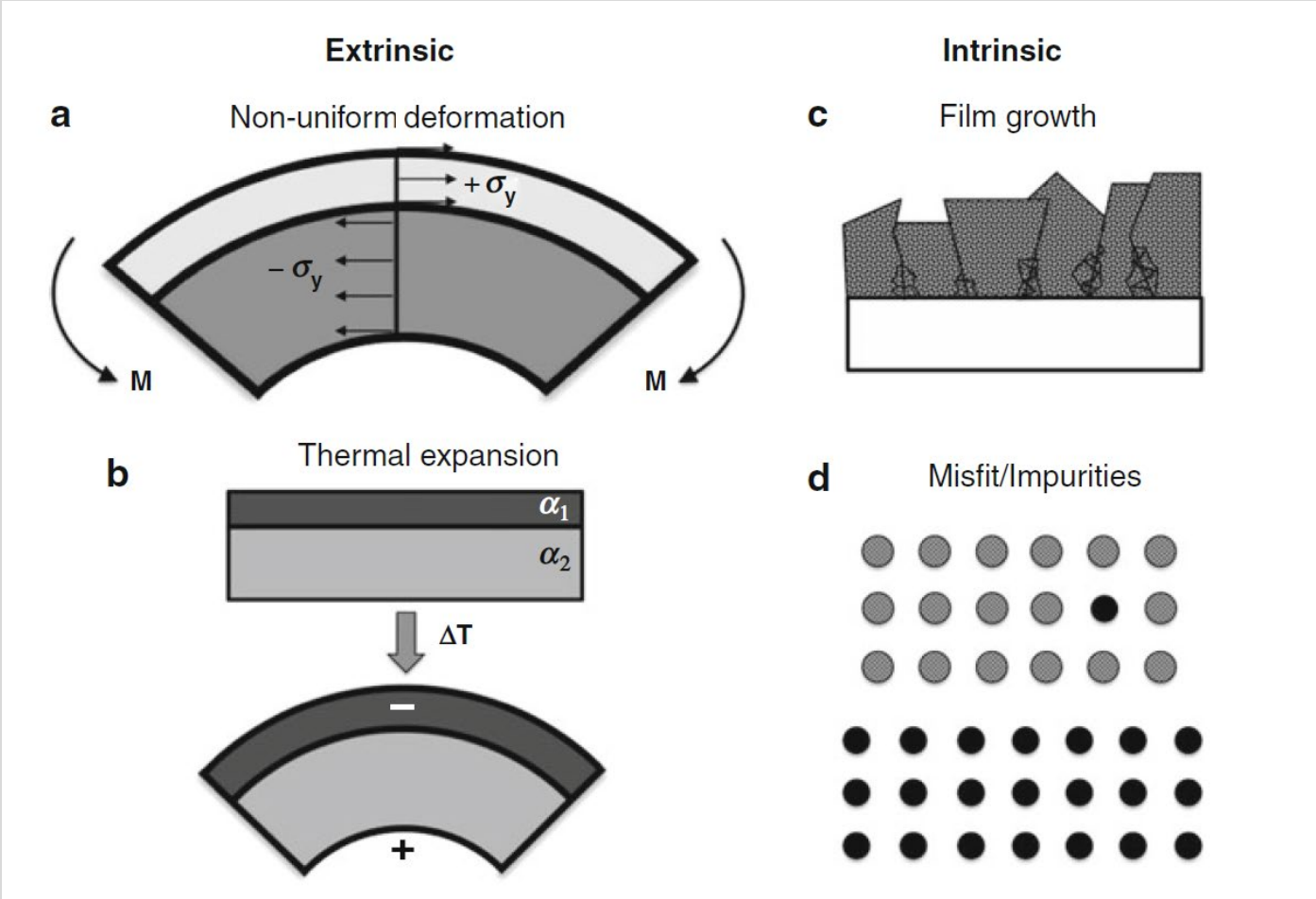
Yes/No in chat

Outline

- Where does the film stress come from?
- Why should you care about the stress?
- How to measure the stress?
- The Toho-FLX 2320-S thin film stress measurement system
- Control of the stress

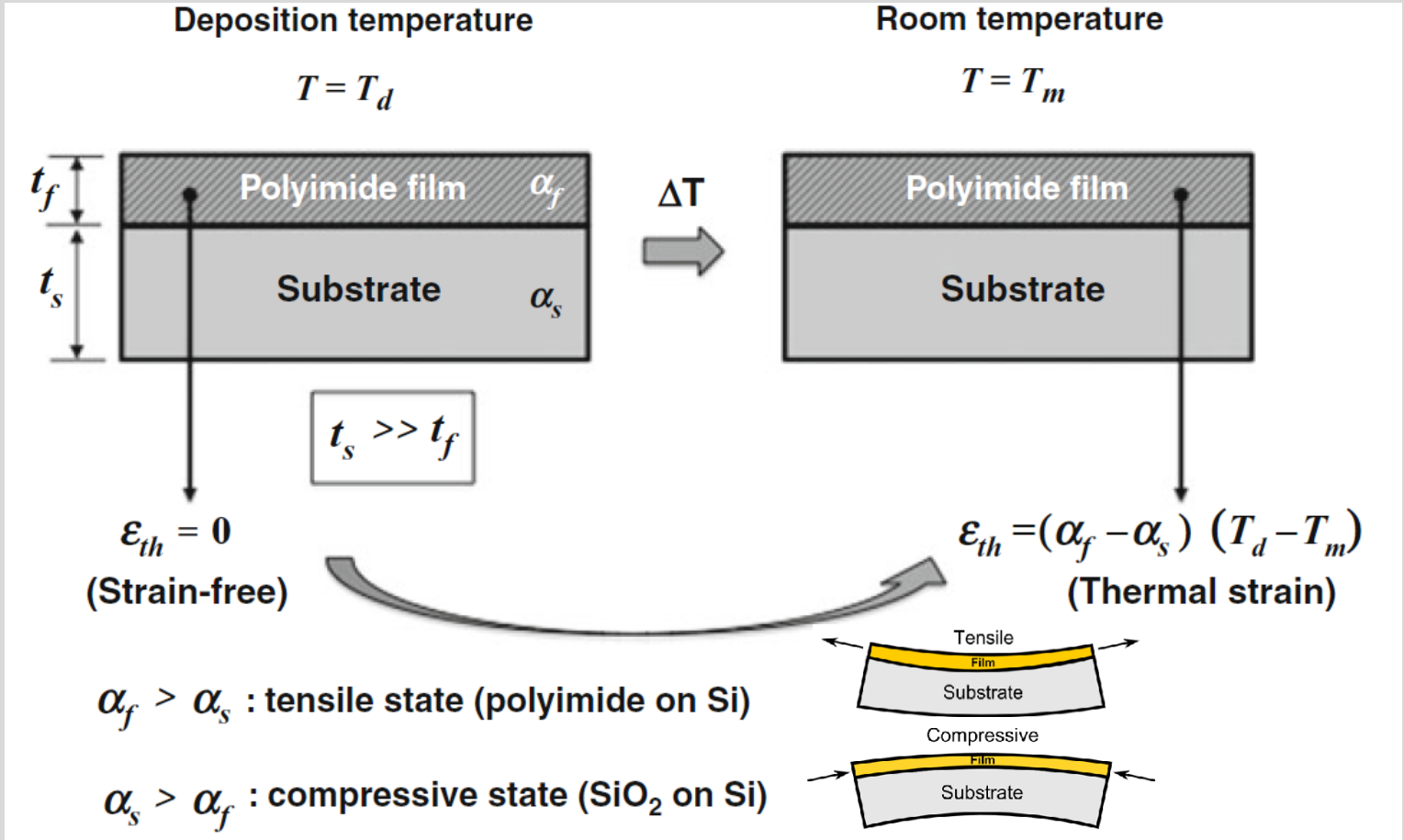
Where does the stress come from?

- Induced during film deposition
- Intrinsic stress:
  - Non-equilibrium nature of deposition
  - Lattice mismatch, impurities etc.
- Extrinsic stress:
  - Environment change
  - Thermal expansion coefficients mismatch
  - Nonuniform plastic deformation



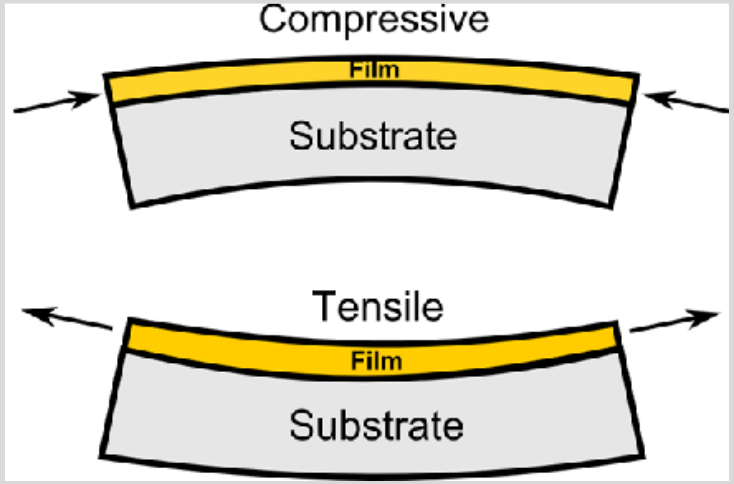
Thermal stresses

- In a structure with inhomogeneous thermal expansion coefficients subjected to a uniform temperature variation
- In a homogeneous material exposed to a thermal gradient

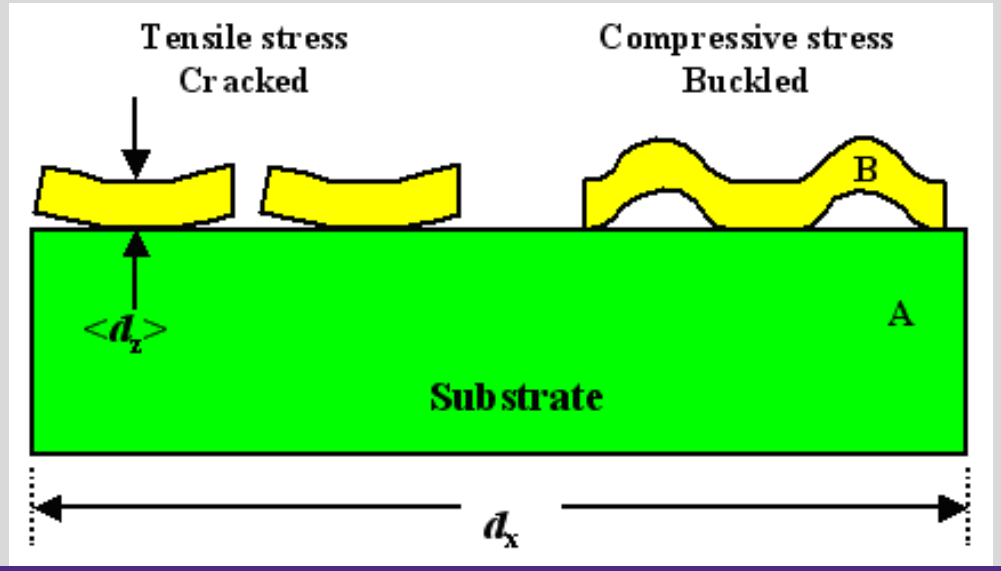


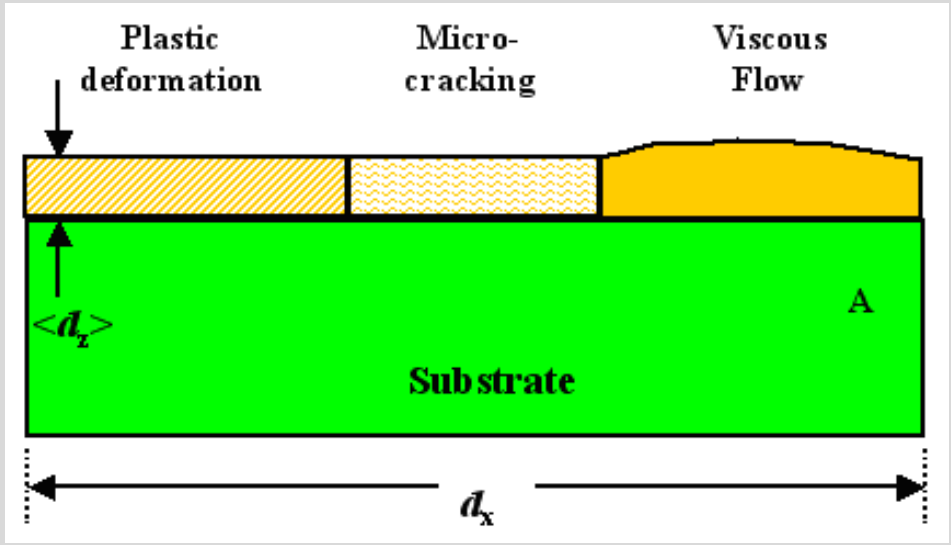
Consequences of high stresses

The adhesion is not very good



The adhesion is very good

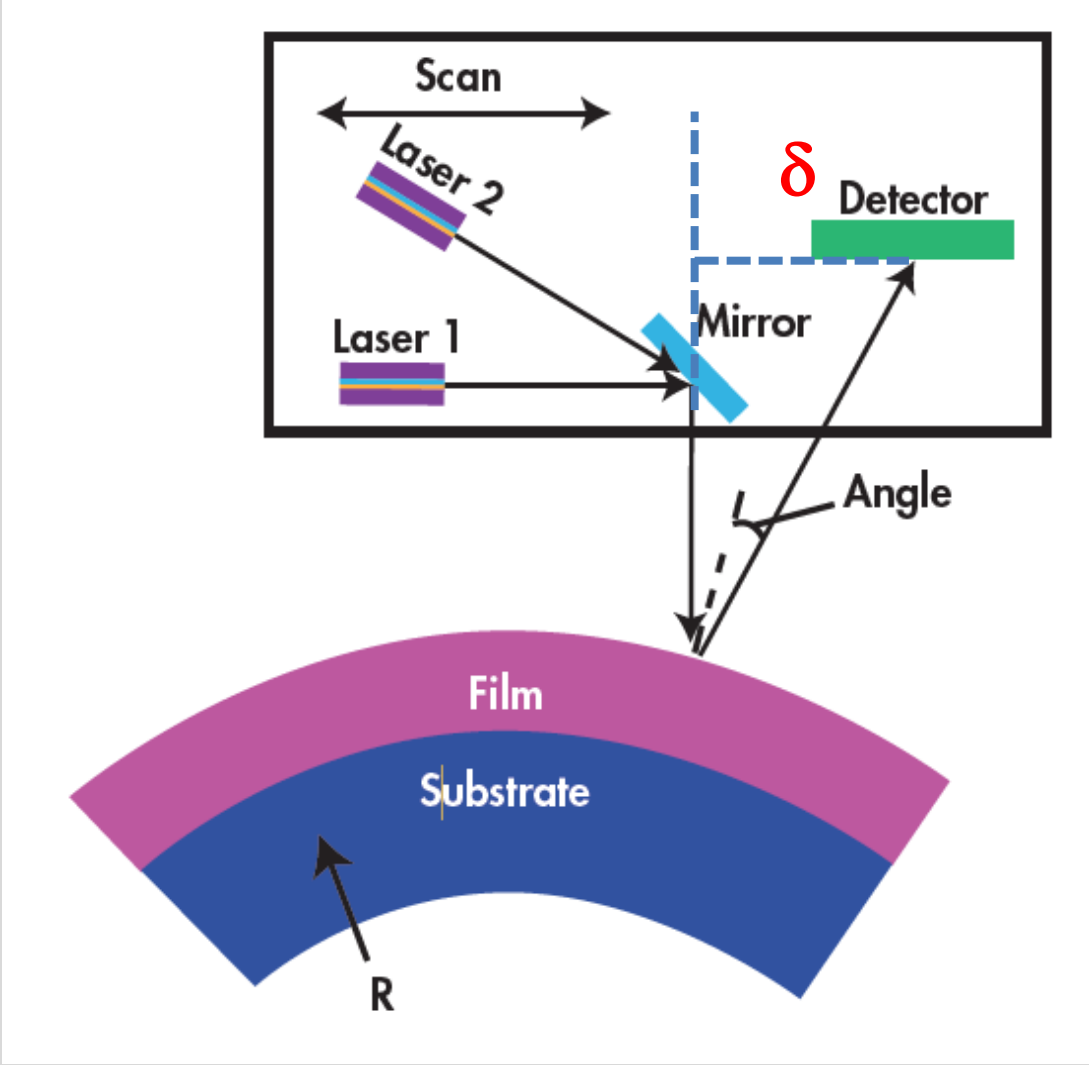




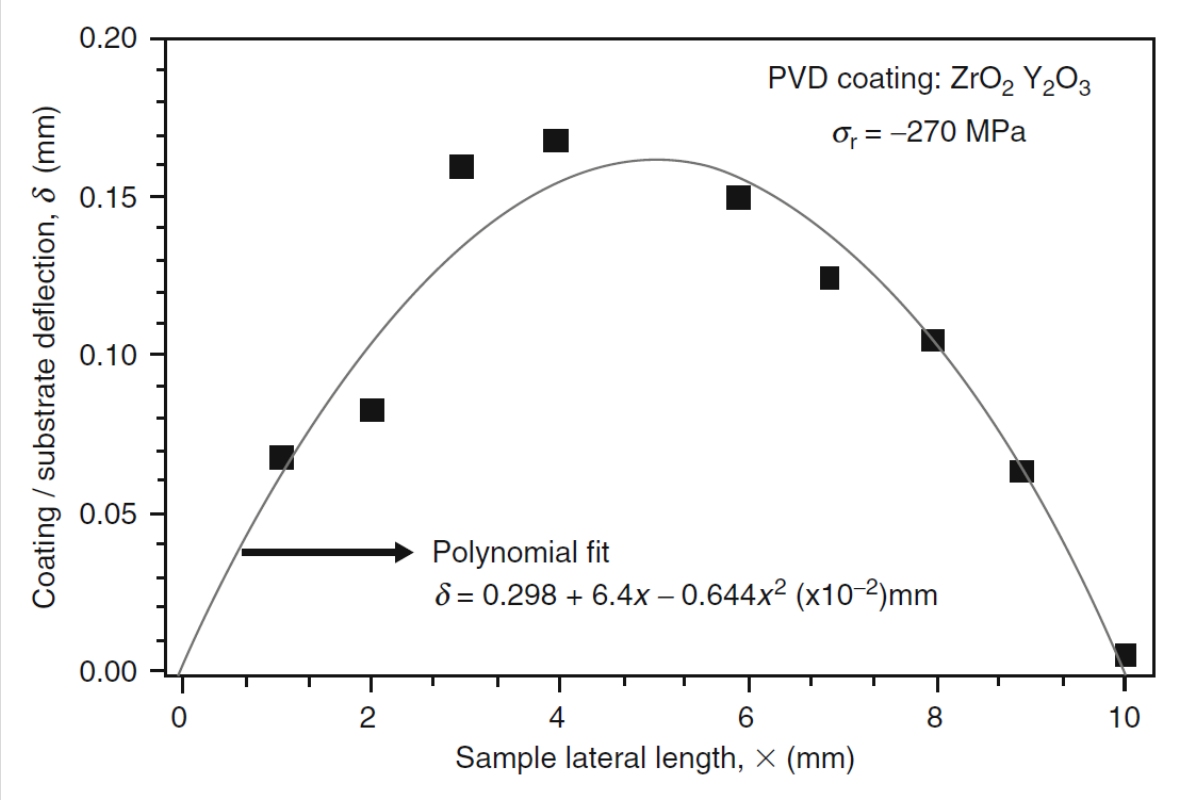
Stress measuring techniques

The deflection technique

- A stressed thin film will bend a moderate thick substrate by a measurable degree
- Measure the curvature or deflection of the substrate before and after coating
- Simple and fast



Calculate stress



$$\delta(x) = a + bx + cx^2$$

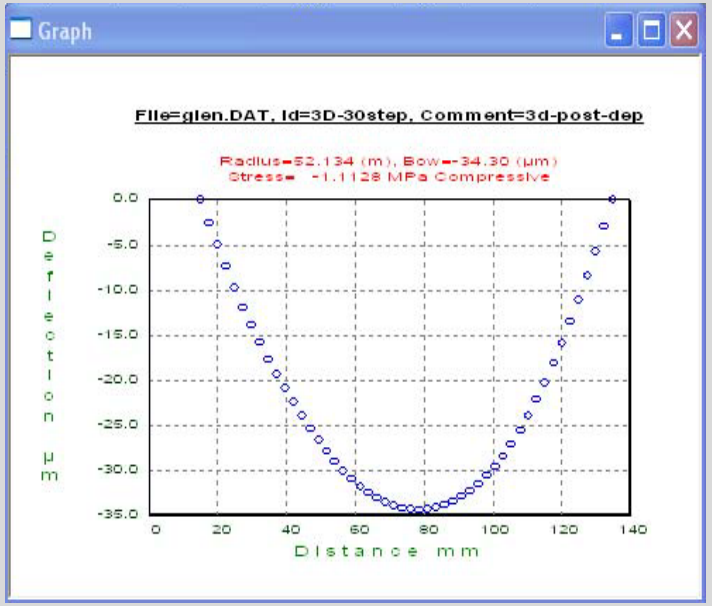
Radius $$R = \frac{1}{2c}$$

$$\sigma_r = \frac{E_s}{(1-\nu_s)} \frac{t_s^2}{t_f} \left(\frac{1}{R_a} - \frac{1}{R_b}\right)$$

E_s, V_s: Young's modulus, Poisson ratio of substrate
t_s, t_f : thickness of substrate and film
R_a, R_b: radius before and after coating

Film stress measurement at NUFAB

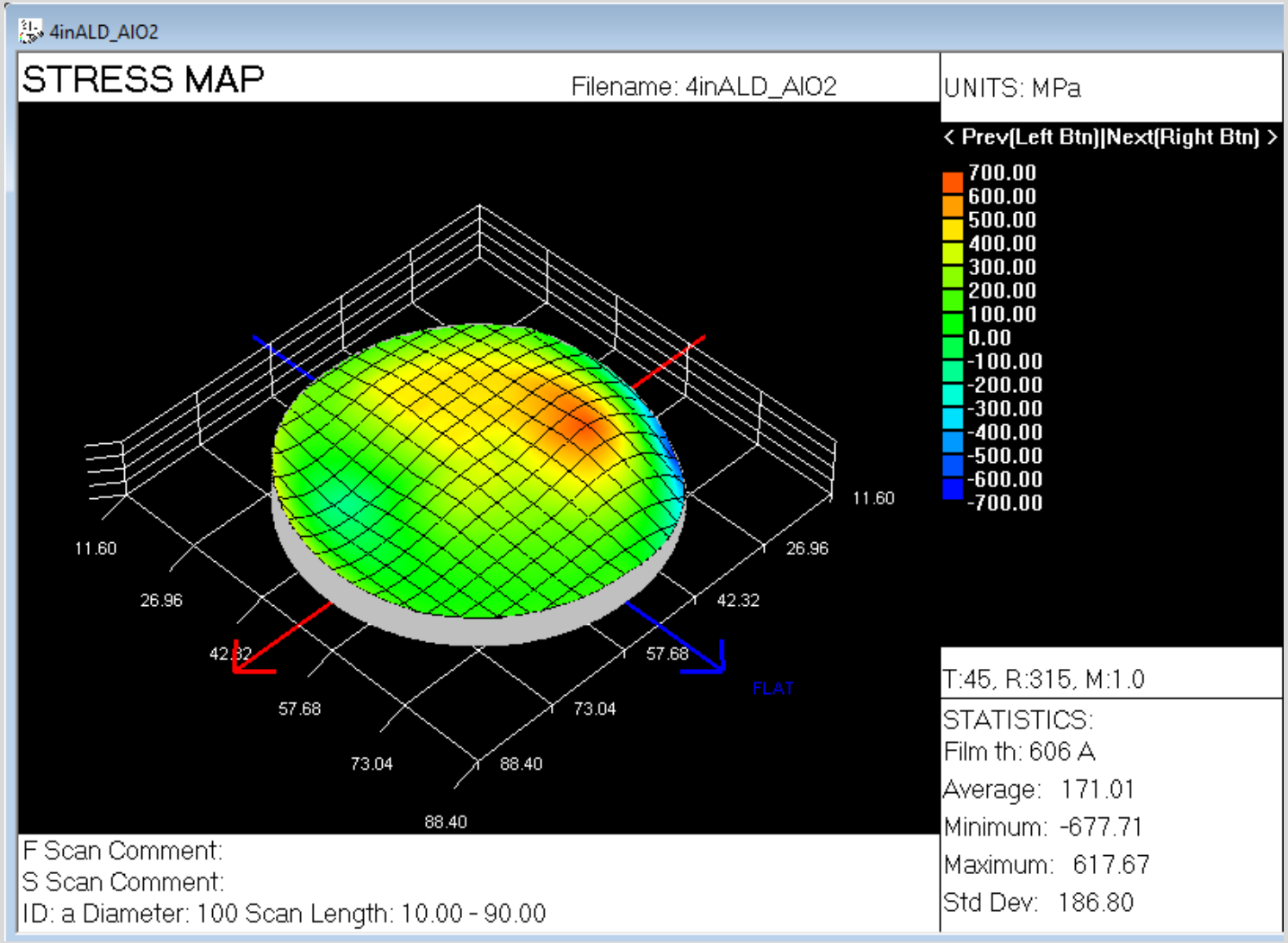
Toho FLX 2320-S



- Two laser (670 nm and 785 nm) to resolve the possible destructive interference
- Measurement Range 1 MPa to 4 GPa
- Accuracy Less than 2.5% or 1 MPa (whichever is larger)
- Scan range programmable up to 200mm
- Minimum scan step 0.02 mm
- 3D mapping
- In-situ stress measurements from room temperature to 500°C

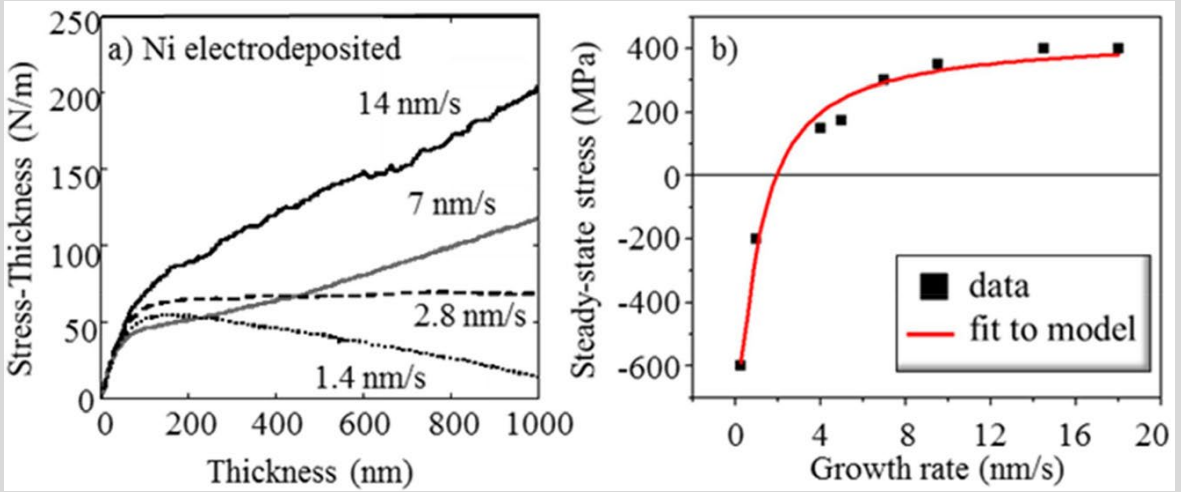
Limitations:
1. Not local stress
2. Too much roughness, low reflectivity
3. Transparent substrate – use Dektak

3D mapping


4inALD_AlO2
STRESS MAP
Filename: 4inALD_AlO2
UNITS: MPa
< Prev(Left Btn)|Next(Right Btn) >
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
-100.00
-200.00
-300.00
-400.00
-500.00
-600.00
-700.00
11.60
26.96
42.32
57.68
73.04
88.40
FLAT
T:45, R:315, M:1.0
STATISTICS:
Film th: 606 A
Average: 171.01
Minimum: -677.71
Maximum: 617.67
Std Dev: 186.80
F Scan Comment:
S Scan Comment:
ID: a Diameter: 100 Scan Length: 10.00 - 90.00

Control of the stress

- Adjust coating process parameters
  Film thickness
  Deposition temperatures
  Deposition rate
  Substrate etc..



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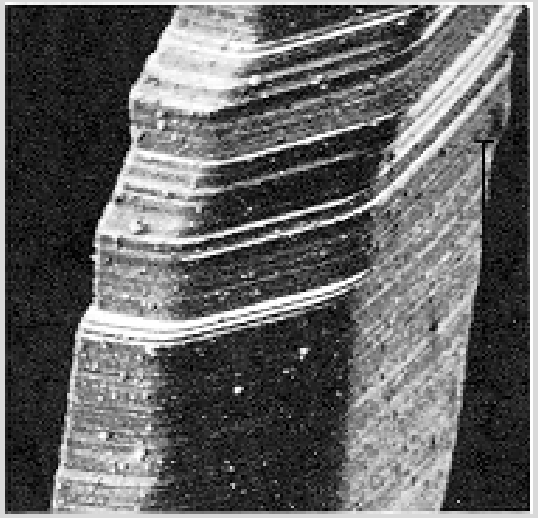
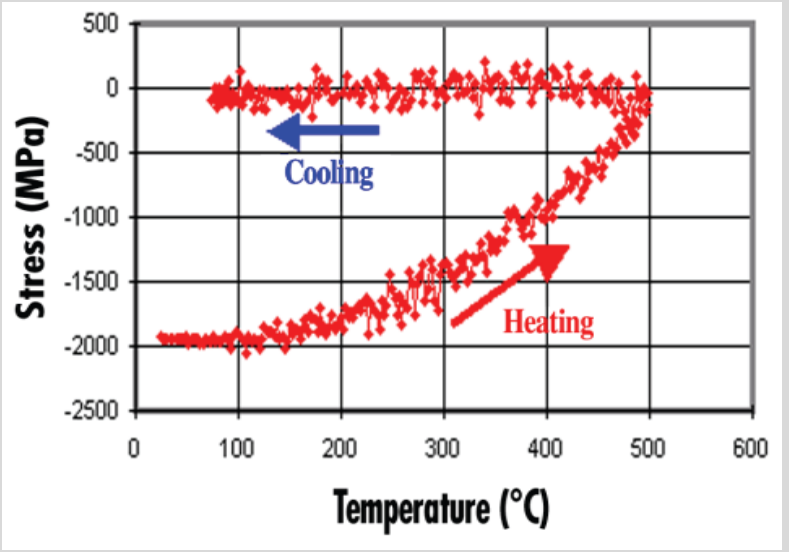
- Thermal relaxation
  Crystalline slip

Toho FLX 2320-S
In-situ stress measurements from room temperature to 500°C





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