Thin Film Stress Measurement at NUFAB

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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

PVD coating: ZrO$_2$ Y$_2$O$_3$
$\sigma_r = -270$ MPa

Radius

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

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

$E_s, \nu_s$: 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

$\delta(x) = a + bx + cx^2$
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
Control of the stress

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

- Thermal relaxation
  - Crystalline slip

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