RECX

Thin film metrology
**XRR**
- Film thickness
- Roughness
- Density

**GIXRD**
- Enhance material probed
- Phase
- Stress
- Depth profiling

**HRXRD / RSM**
- Texture
- Strain
- Orientation

**Phi-scan**
- In plane orientation

**Rocking curve**
- Miscut
- Orientation

**Polar plot**
- Texture
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XRR (X-ray reflectometry)

Reflectivity as function of angle to obtain information on:
- Film thickness
- Surface roughness
- Density
Scattering from surfaces and interfaces at low angles, \( \sim 0-8^\circ \)

Variations in electron density arise from film thickness, roughness and density which can be determined for each layer.

Scattering occurs from variations in electron density

\[
I(q_z) = \frac{1}{q_z^3} \int\! d\rho(z) \exp(iq_zz)dz
\]

Refined parameters:
- LaNiO\(_3\) Thickness 48.98nm
- Roughness 0.30 nm
- Density 7.05 g/cm\(^3\)

A surface layer of 1.4nm is also required to fully explain the results.
Layered thin films of Eu$_2$O$_3$ and TiO$_2$ grown by ALD as conversion material with the aim of controlling the Eu-Eu distance.
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The double layer thicknesses:
- 10N = 7.5 Å
- 20N = 15.9 Å
- 50N = 29.1 Å

Half the double layer thickness of the 10N sample, 3.8 Å, is approx the same as the shortest Eu – Eu distance in cubic Eu$_2$O$_3$, 3.6 Å.
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**GIXRD (Grazing incident x-ray diffraction)**

Increase the pathway through the sample

Conventional $\theta$-$2\theta$
GIXRD (Grazing incident x-ray diffraction)

Increase the pathway through the sample
GIXRD (Grazing incident x-ray diffraction)

A ZnO film of 200 nm deposited by ALD
An example of depth probing on a CIGS solar structure, showing the different layers exposed to the parallel X-ray beam in a sequential mode by varying the incident angle. Top pattern is from the conductive oxide layer only, with CIGS coming in (middle, highlighted) and next the Mo metal contact layer appearing (bottom diagram, Mo peaks highlighted).
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HRXRD (High-resolution x-ray diffraction)

Increase the pathway through the sample
HRXRD (High-resolution x-ray diffraction)

Map the reciprocal space to obtain information on:
- Orientation
- Strain
- Texture … and a lot more…

single crystal poly crystal
HRXRD (High-resolution x-ray diffraction)

$q = k_h - k_i$

$|q| = 2\pi/d$

Courtesy P. Kidd, PANalytical Research, Sussex, GB
HRXRD (High-resolution x-ray diffraction)

- Spread due to finite size effects
- Layer thickness
- Range of tilts
- In-plane
HRXRD (High-resolution x-ray diffraction)

A reciprocal space map (RSM) of a GaAs based epitaxial solar cell structure

A rocking curve diagram (RC) of an epitaxial solar cell structure around the (004) reflection of the GaAs substrate
HRXRD (High-resolution x-ray diffraction)

Film of NaNbO$_3$ on LaAlO$_3$
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