Surface Roughness and XRD Studies of Electron Beam Evaporated Mo and Er Films: correlation to substrate and process conditions

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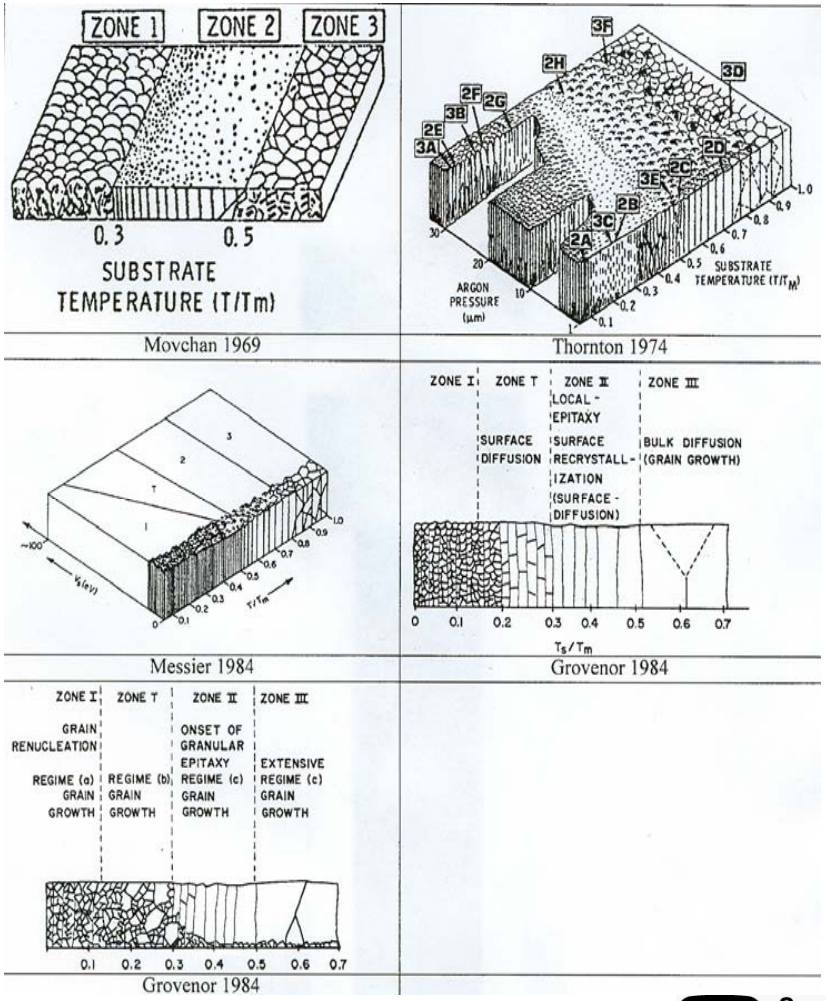
What do we measure

Grain Size orientation - Texture

Surface Roughness

Growth of Thin Films

- **Zone I -** Ts/Tm < 0.3 (low mobility; ad-molecules stick where they land: the results is a fine-grained porous real structure).
- **Zone II -** 0.3<Ts/Tm<0.5 (surface diffusion occurs with activation energies of 0.1-0.3 eV; a columnar real structure is obtained).
- **Zone III -** Ts/Tm > 0.5 (bulk diffusion occurs with activation energies above 0.3 eV, resulting in a rough equiaxed grained real structure).



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Importance of Process Conditions

- Deposition Conditions
  - Temperature, rate, atoms, energy, residual gases
- Substrate surface Morphology
  - Material Real Structure
    - Grain size, orientation, defect density
- Film Properties
  - Electronic, Magnetic, Optical, Mechanical

Process Conditions

Substrate	Texture	Surface Finish
Si	(100)	smooth
Al_2O_3	[1-102]	smooth
Rolled Mo	Rolled	rough

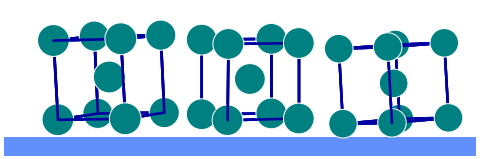
Deposition Temperature	RT 250°C 450°C
Deposition Rate	1.0 Å/s 10 Å/s

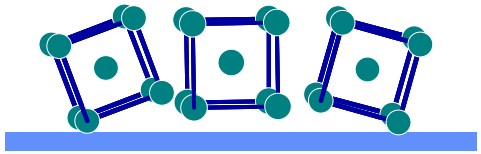
Summary of Samples

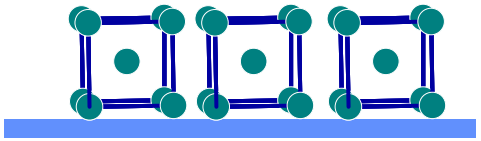
Substrate	Film	Thickness (Å)	Temperature °C	Deposition Rate (Å/s)
[1-102] Al_2O_3	Mo	1000	250	1
Mo/[1-102] Al_2O_3	Er	5000	450	10
No-Etched Mo	Er	5000	450	10
Etched Mo	Er	5000	450	10
Si(100)	Mo	1000	RT	1

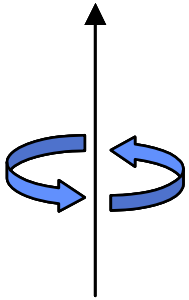
Texture Definitions

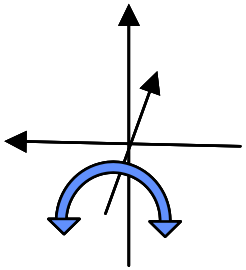
Fiber	Rolling Texture	Bi-Axial
out-of-plane (YES) in-plane (NO)	out-of-plane (YES) in-plane: 1-dimension of freedom, other fixed	out-of-plane (YES) in-plane (YES)

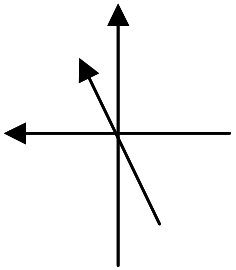






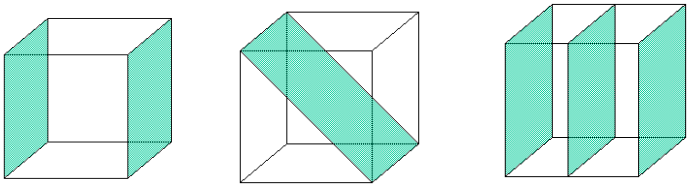




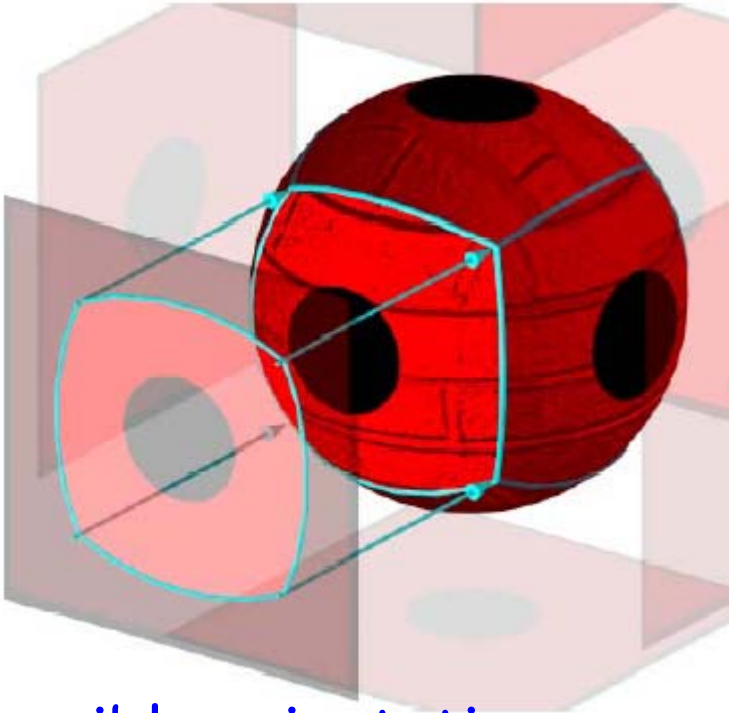


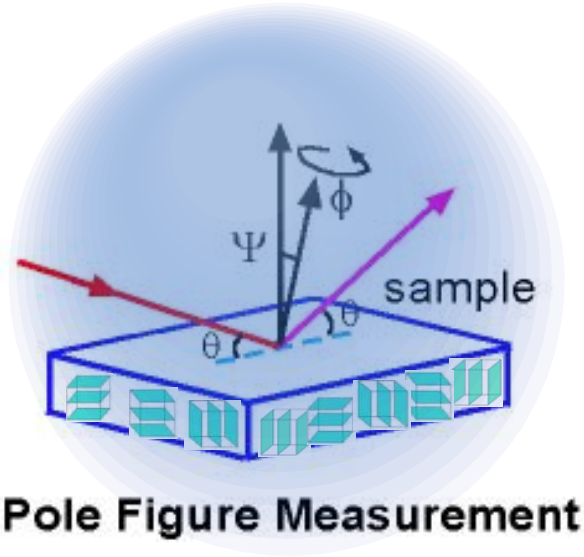
Courtesy of Mark Rodriguez

Pole figure represents a distribution in space of a given set of lattice planes (hkl)



(100) (110) (200)





Pole Figure Measurement

All possible orientations of the given hkl are plotted on a hemisphere which is projected onto a planar surface

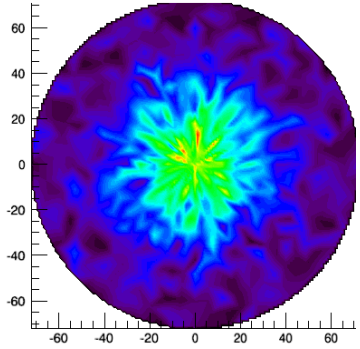
http://www.mrl.ucsb.edu/mrl/centralfacilities/xray/xray-basics/Xray-basics.html#x4

http://www.ashlar.com/tutorial/textures_tutorial.pdf

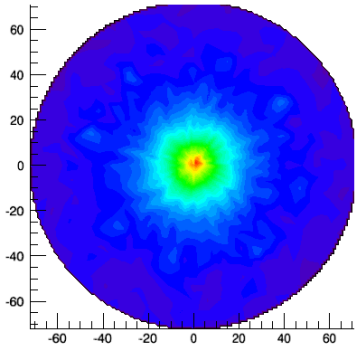
The Influence of Substrate Texture on Mo Films Grain Orientation

RT, 1000 Å, 1 Å/s

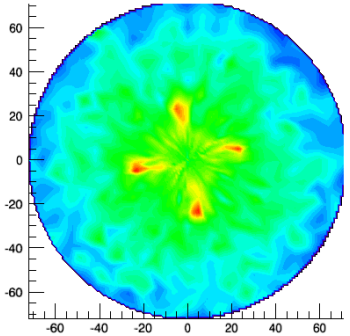
110



211

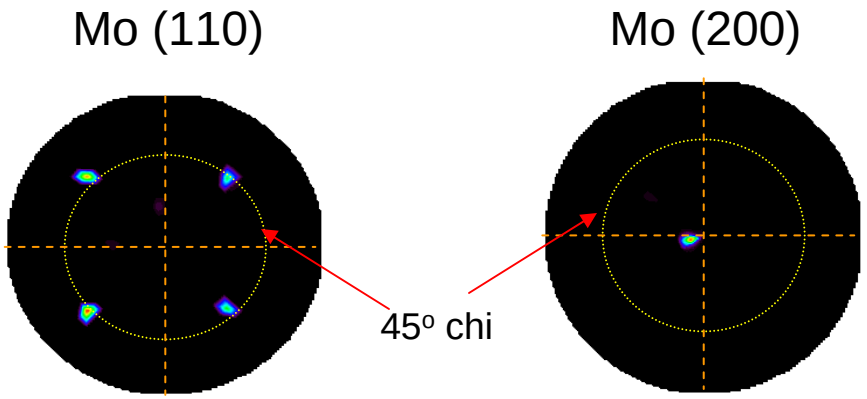


200



- Pole figure data complicated by Si signal. Mo (211) has Si (400) at center of pole figure.
- Mo deposited on Si(100) at room temperature might have bi-axial (110) out-of-plane texture.
  Mo (200) pole is complicated by Si. What we see is only the Si (311) artifact intensity.

Mo on [1-102] Al_2O_3

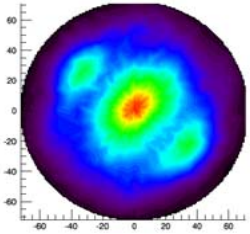


250°C, 1000 Å, 1 Å/s

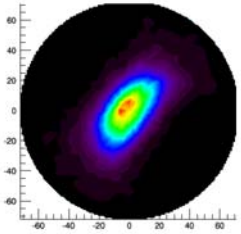
- Mo film deposited on sapphire has out-of-plane (200) texture.
- Four fold spots at 45° chi for Mo (110) indicate (200) out of plane texture and in-plane bi-axial texture for film. Note that spots are not perfectly aligned to the 45° chi ring (yellow dotted line).
- Bi-axial Mo film on Al_2O_3 [1-102]

Er deposited on rolled Mo no-etched

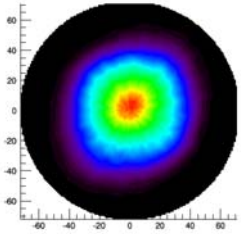
450°C, 5000 Å, 10 Å/s



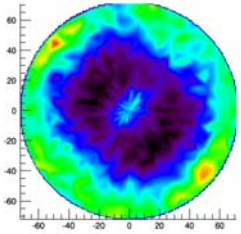
Mo (110)



Mo (200)



Er (002)

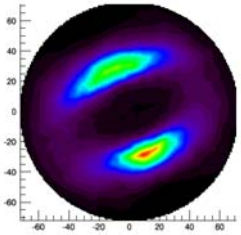


Er (100)

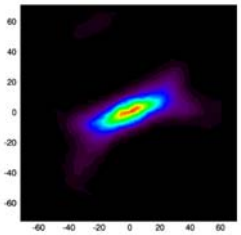
- No etched Mo substrate shows both (110) out of plane and (200) out of plane rolling texture.
- Er (002) out of plane with hint of rolling texture

Er deposited on Mo etched

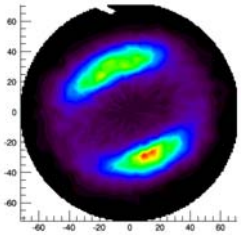
450°C, 5000 Å, 10 Å/s



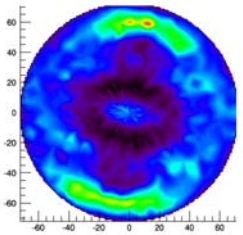
Mo (110)



Mo (200)



Er (002)

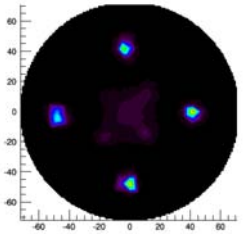


Er (100)

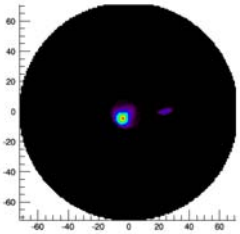
- Mo-etched substrate has (200) out of plane rolling texture. Er (002) shows rolling texture. Is Er (002) growing epitaxial on Mo (110) ? Maybe
- Mo film has clear out-of plane (200) bi-axial texture.

Er on Mo on Sapphire [1-102]

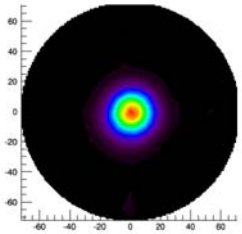
450°C, 5000 Å, 10 Å/s



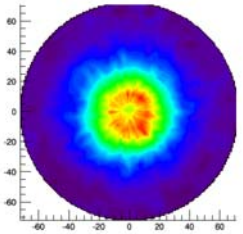
Mo (110)



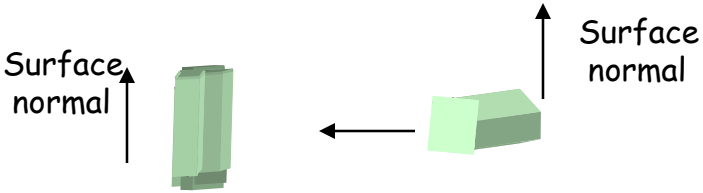
Mo (200)



Er (002)



Er (100)

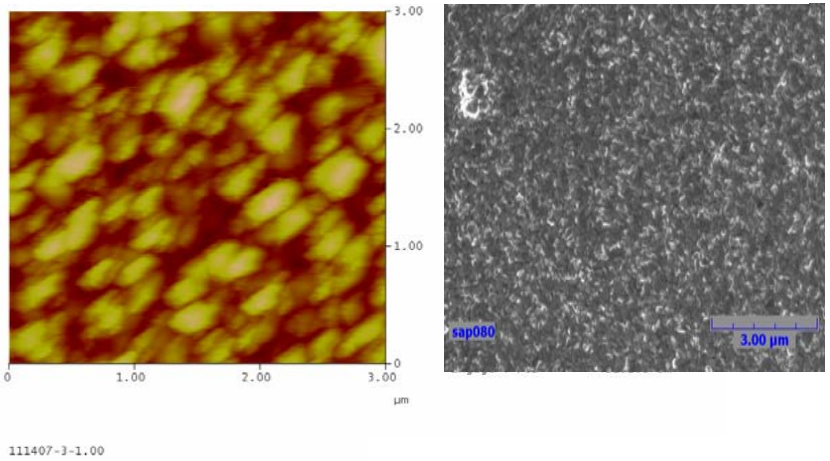


- Er film appears to have bi-modal texture with the (002) and (100) nearby out of plane.
- The Er (002) does not appear to be growing epitaxially on Mo(110) this time perhaps because of the presence Er_2O_3? The (100) is nerby epi on Moly.

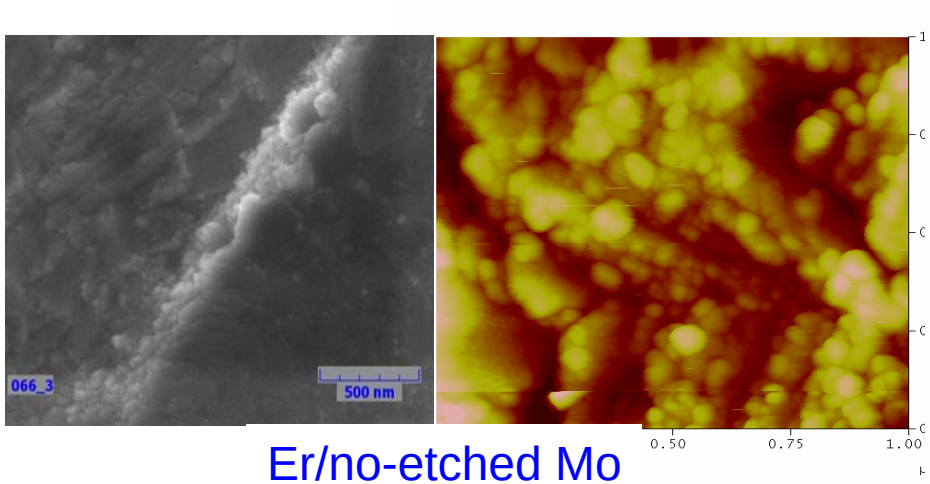
Er deposited onto various Mo substrates

Er/Mo/[1-102] Al_2O_3

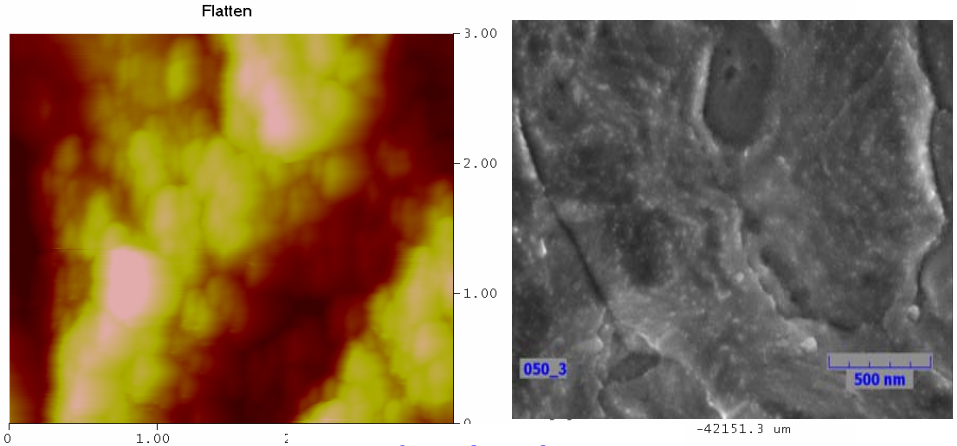
450 °C, 10 Å/s



Films RMS = 10.32 nm



Er/no-etched Mo



Er/etched Mo

092107-6-2_f.000

111407-2-1.000

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Summary of the influence of substrate roughness and deposition parameters on the film surface quality

- The Mo films were prepared at low deposition temperatures (Ts/T_m=0.02-0.32) they consist of small round grains as observed by SEM. At low temperatures the surface mobility is reduced.
- The surface roughness measured using AFM shows that the surface roughness varies with substrate and deposition rate. A facetted film is observed when deposited at 10 Å/s on sapphire.
- AES shows that the Mo samples has a surface oxide layer ~ 29.5 at/% and 18 at/% in the bulk

Questions/Future Work

- A systematic study to parameterize the growth mode as a function of substrate texture and growth conditions and how that influence hydride structure

- Study the role of impurities (i.e. O_2) on film texture and residual stress