Vapor Deposition and Structure

3.044 April 29, 2005

Mechanics:
■ PS7 #3d: qualitative answer only
■ PS 8 handed out on Monday, shorter than planned
■ Final exam Monday May 16 1:30-4:30

Today’s lecture:
■ Vapor phase transport
■ Film structure formation

Vapor Phase Transport

By Knudsen number:
■ >10: Molecular Beam Epitaxy (MBE)
■ 0.1-1: E-Beam evaporation, sputtering
■ <0.01: Chemical vapor deposition, OMVPE, etc.
Vapor Phase Transport

For many vapor processes, both line-of-sight and continuum approaches fail!


Deviation from Cosine Distribution

At high power density, evaporant flux follows cosine squared or cubed distribution.

Deviation from Cosine Distribution

Hypothesis 2 results:

- Calculated flux distributions are very similar to observed
- Background gas has almost no effect on distribution
- Plot cosine power n and return ratio vs. "local" inverse Knudsen number, outstanding fit!

![Graphs showing deviation from cosine distribution](image1)


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Deviation from Cosine Distribution

DSMC simulation results reframed:

![Graph showing deviation from cosine distribution](image2)

Structure Zone Model

Thornton, 1977; competing effects:

- Quickly arriving atoms
- Shadowing
- Crystal faceting
- Surface diffusion
- Bulk diffusion
- Ion bombardment

Oriented grains, platelet or whisker
Normal grains, like bulk material

Fibrous, columnar, low density
Lots of surface & bulk diffusion

Little energetic bombardment, low mobility
Energetic neutral, & ion bombardment
Greater mobility

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Structure Zone Model

More detail: Ohring 1992
"The Materials Science of Thin Films"

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Source:
Fig 1b from Thornton, J. "High Rate Thick Film Growth." *Ann Rev Mater Sci* 7 (1977): 239-60.
Figure by MIT OCW.