Quantitative characterization of Ni MEMS

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What is our role?

• We provide experimental support for the mechanical properties simulations
  • Atomistics
  • Dislocation dynamics

• Quantitative microstructural characterization lead by simulation needs
  • Grain size and orientation
  • Dislocation and defect density
  • Interfacial chemistry
SEM Device overview
SEM: confirms a uniform structure
Focused ion beam (FIB) images
FIB images (x-section near middle)

Ion images show ‘indications’ of competitive grain growth.

Useful, but TEM is better at revealing these features.
TEM results (FIB-prepped x-section)

SEM image of FIB-prepped x-section

Bright Field TEM image
Quantifying grain size and texture
TEM results (FIB-prepped x-section)

E-beam evaporated Ni

Ni: fcc
Ti: hcp

Sputtered Ti

More on this layer later...

March 3rd, 2008
Ni is \{200\}- and \{111\}-textured
Ni is {100}- and {111}-textured
Texture as function of film thickness
Texture as function of film thickness
Texture as function of film thickness
Texture as function of film thickness

1 µm

1  2  3  4

1  2  3  4
DF + measurements

Average In-Plane Grain Size $\langle d \rangle$

Film Thickness ($h$)

- 100 nm
- 125 ± 60 nm
- 61 ± 47 nm
- 35 ± 26 nm
- 28 ± 17 nm
- 20 ± 8 nm

0-200 nm

200-600 nm

600 nm - 1 µm

1 µm - 1.6 µm

1.6 µm - 2.8 µm

Film Thickness ($h$)
This is ‘schematic’: we are working to get these distributions (along with texture variation) from the PRISM device.

**Hunter, Koslowski**

1. **In-plane grain size, \( d \)**
2. **Out-of-plane grain size**
3. **Simulation**
4. **Actual**

\[ h = 0 \]

\[ h = \text{film thickness} \]
Measurements + schematic

![Schematic diagram of V-shaped microstructure](image)

- **Film Thickness (h)**
  - 100 nm
- **Average In-Plane Grain Size ⟨d⟩**
  - 125 ± 60 nm
  - 61 ± 47 nm
  - 35 ± 26 nm
  - 28 ± 17 nm
  - 20 ± 8 nm

**Film Thickness**

- **In-plane grain size, d**
- **Out-of-plane grain size**
Grain Size Quantification

“Average Grain”
Grain Size Quantification


“Average Grain”
Quantification of texture.


Bright field

Dark field

Annular dark field

\[ \lambda = 2d_{\text{m}} \sin(\theta) \]
Example: Texture in SiC MEMS films

Texture in SiC MEMS films

Plan view texture map

Quantifying interfacial chemistry
Oxygen distribution at bottom of Ti layer

Inform Atomistics

Kim, Strachan

HRTEM image showing bottom of Ti layer

Oxygen distribution at bottom of Ti layer
Overview Images

BF TEM @ 7600x

FIB thinning direction

0.5 μm

Zero Loss EFTEM @ 72 kX

Ni

Ti

FIB redeposition

50 nm
Energy Filtered TEM

Zero Loss EFTEM Image
Energy Filtered TEM Images @ 410 kX
Bottom of Ti layer

Zero Loss EFTEM Image

Ti

FIB redeposition

10 nm

Ti map

10 nm

O map

~5 nm of TiO$_x$

10 nm
Energy Filtered TEM Images @ 155 kX

Zero Loss EFTEM Image

Ni
Ti

FIB redeposition

20 nm

O map

20 nm
Energy Filtered TEM Images @ 530 kX

Zero Loss EFTEM Image

TiO$_x$ redeposition

~5 nm of TiO$_x$

5 nm scale bar

5 nm scale bar

PRISM
NMSA Center for Prediction of Reliability, Integrity and Survivability of Microsystems