Fabrication techniques for Al and Al alloy optical coatings for the GIMM

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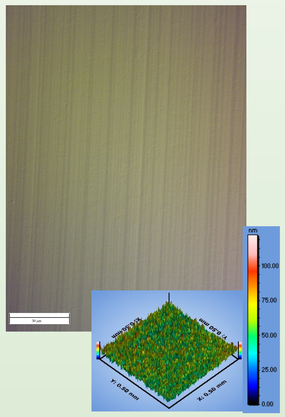
Baseline Fabrication:

- Pure Al
- Electroplated thick film
- Smoothed by single point diamond turning (SPDT)

Too soft:

- Plastic failure under laser testing
- No mechanical polishing
- "gummy" during machining



Potential Solutions:

- Advanced polishing
- Smoother deposition
- Harder alloy

Chemical Mechanical Polishing beats Single Point Diamond Turning

Better prototype:

- Smoother surface with CMP
- SPDT must cut deep; needs more deposition
- No hardness requirement for CMP

Better production:

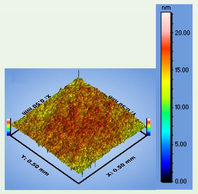
- One wobble in diamond point spoils a whole mirror
- Time for CMP scales as depth removed; for SPDT, as area
- CMP has history of semiconductor-level QC

Preliminary results:

- Good smoothness, but some trapped abrasive.
- Poor initial performance attributed to slurry particles.

Work with Cabot

- SPDT first chosen for want of vendor to polish pure Al.
- Cabot Mircoelectronics has produced samples, and is improving the process.
- Can scale up to production-sized mirrors

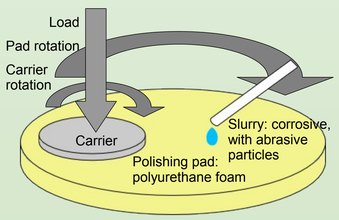


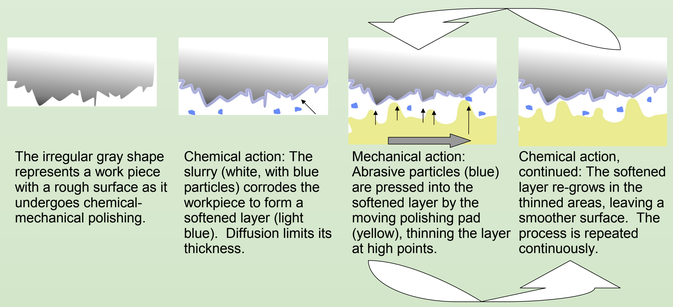
Introduction to CMP:

- Porous polishing pad (yellow, below)
- Slurry, with abrasive particles in a corrosive liquid
- Mirror (or wafer) held against polishing pad by carrier (gray).
- Control of pressure, rotation rates, slurry flow

Ideally,

2. Passivation limits material removal until surface layer is thinned by abrasion
3. Particles never break through passivating layer
4. Relative speed between pad & carrier is approximately equal at any point on the mirror





The irregular gray shape represents a work piece with a rough surface as it undergoes chemical-mechanical polishing.

Chemical action: The slurry (white, with blue particles) corrodes the workpiece to form a softened layer (light blue). Diffusion limits its thickness.

Mechanical action: Abrasive particles (blue) are pressed into the softened layer by the moving polishing pad (yellow), thinning the layer at high points.

Chemical action, continued: The softened layer re-grows in the thinned areas, leaving a smoother surface. The process is repeated continuously.

Versatility of Magnetron Sputtering

New options vs. electroplating

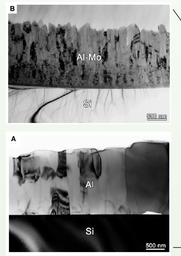
- Use alloy target or co-sputter
- Rate control
- Layers & gradients

Why not sooner?

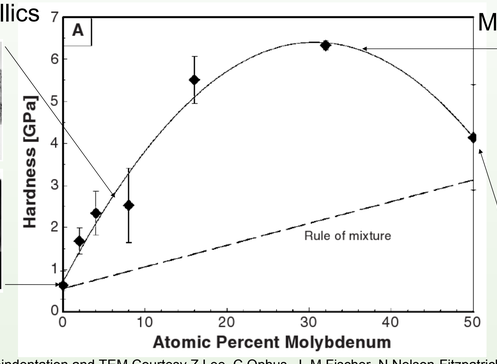
- Other deposition too thin
- Plating still gives best resutls

Al/Mo co-sputtering:

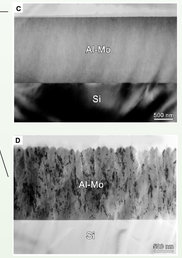
Al & Intermetallics



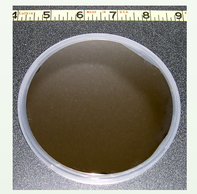
Pure



Mostly amorphous



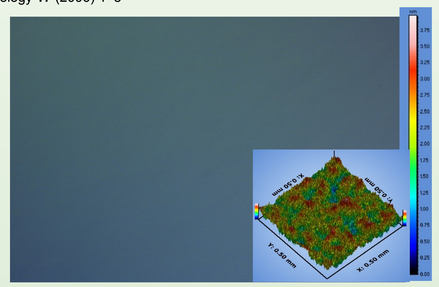
Intermetallics



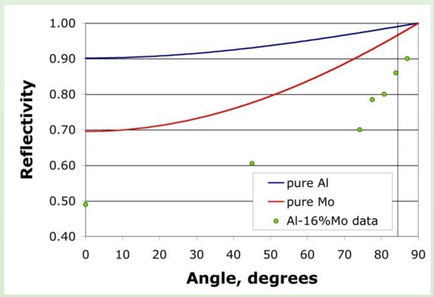
Nanoindentation and TEM Courtesy Z Lee, C Ophus , L M Fischer, N Nelson-Fitzpatrick, K L Westra, S Evoy, V Radmilovic, U Dahmen and D Mitlin. Nanotechnology **17** (2006) 1–8

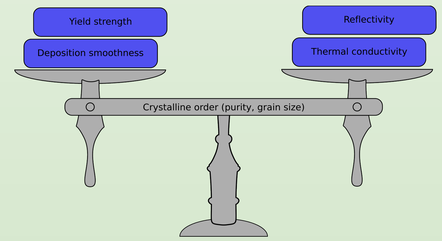
Results:

- Fine grains → no polishing! (right)
- Disappointing reflectivity (below)
- Poor performance vs. baseline (see poster: "Laser-induced damage testing of metal mirrors: fluence-life data and surface analysis")



Optical micrograph & surface profile (inset) for Al/16 at.% Mo





Escaping the tradeoff:

Gradient coating in progress. We expect:

- Reflectivity near pure Al
- Smoothness near amorphous alloy
- Intermediate strength & thermal conductivity