# Replicate Mirrors

**M. P. Ulmer*, S. Vaynman**, M. E. Graham**,**
**S. Ehlert*, A. Davis****

**Northwestern University**
***Department of Physics and Astronomy**
****Department of Materials Science and Engineering**

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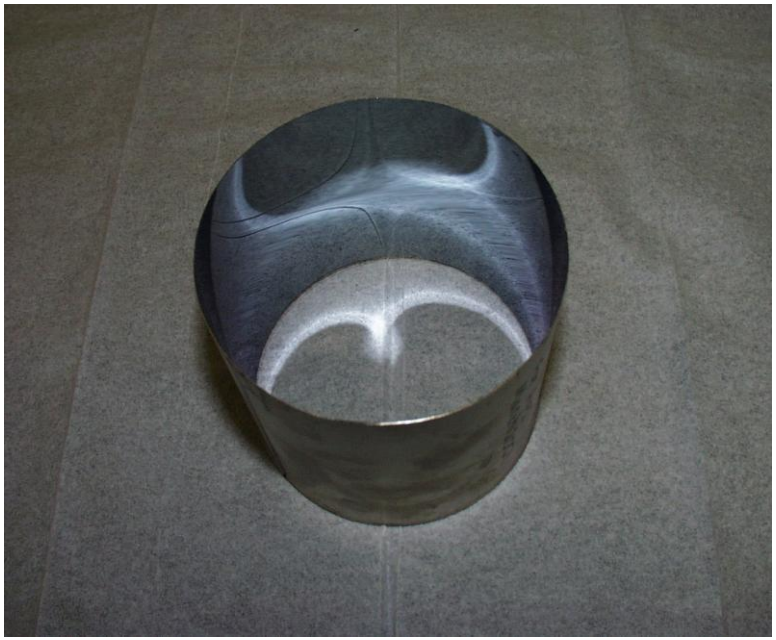
# Prior Northwestern Experience in Optics Replication

- More than 25 years experience of optics replication by Ni electroforming
- Have facilities:
  - Electroforming
  - Physical vapor deposition/coating
  - Characterization



# Traditional Replication Technology

- Advantages:
  - Many mirrors can be produced using one master mirror;
  - No polishing is required;
  - Low cost and short production time
- Disadvantage
  - High weight if Ni is used

# Objective

Develop replication technology to produce large-scale lightweight mirrors by combining newly designed lightweight high-strength composites with a thin nickel layer

# Important Issues

- Adhesion between substrate and electroformed mirror
- Differences in thermal expansion of substrate, mirror, adhesive

# Approaches Explored

Three methods of Ni-surface-composite-substrate-mirrors fabrication were explored at Northwestern University; the first two are not replication methods --- they require surface polishing

# Method 1

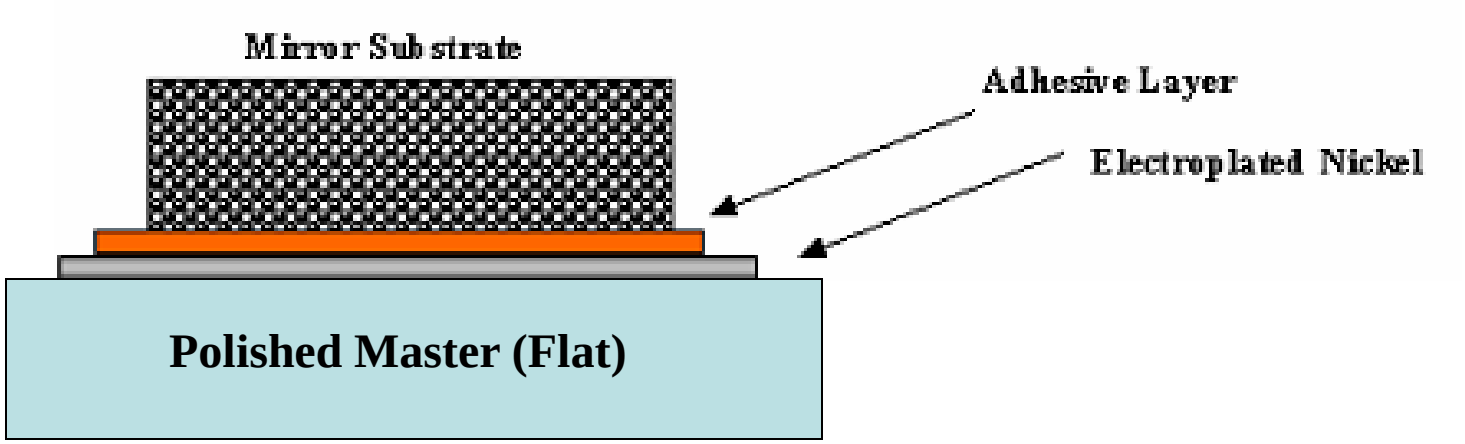
- seal the surface of the substrate (to fill the pores and to prevent the interaction with electrolyte in the plating bath);
- grind/polish the filled surface to flatten it;
- deposit  the conductive layer(s) on that surface;
- electroplate (or electroless deposit) nickel on conductive layer;
- polish nickel to mirror finish

# Method 2

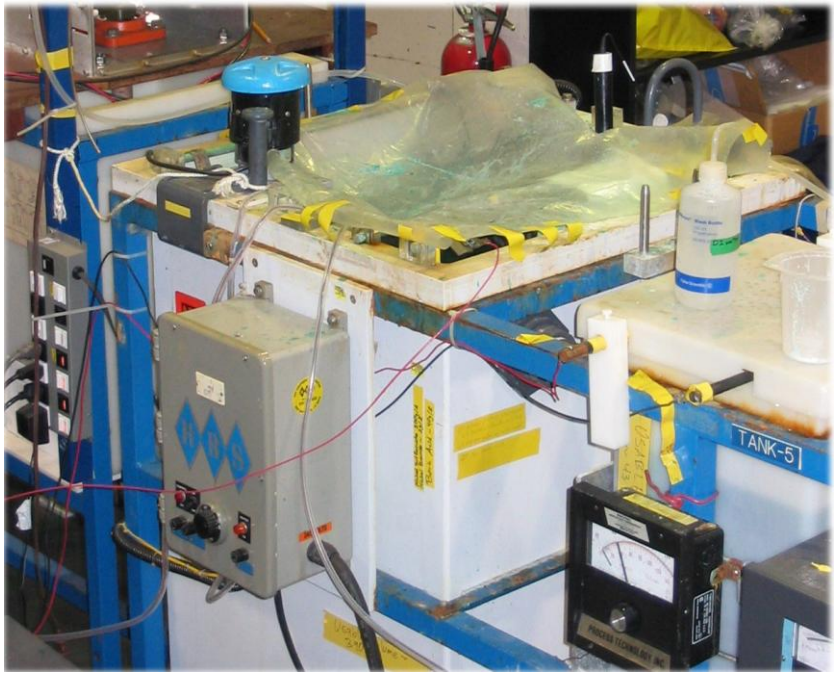
- deposit release/conductive layer(s) on the glass surface;
- attach the substrate to the release/conductive layer(s) with an adhesive;
- remove assembly from the glass;
- electroplate nickel on the coated surface of the substrate;
- polish nickel surface to mirror finish

# Method 3

- electroplate nickel on the polished master;
- attach substrate to the nickel surface with an adhesive;
- remove mirror from the flat;
- trim mirror; no polishing is required



# Electroforming Facility at Northwestern University




**Small Bath – 100 gallons**

**up to 18-inch mirror**

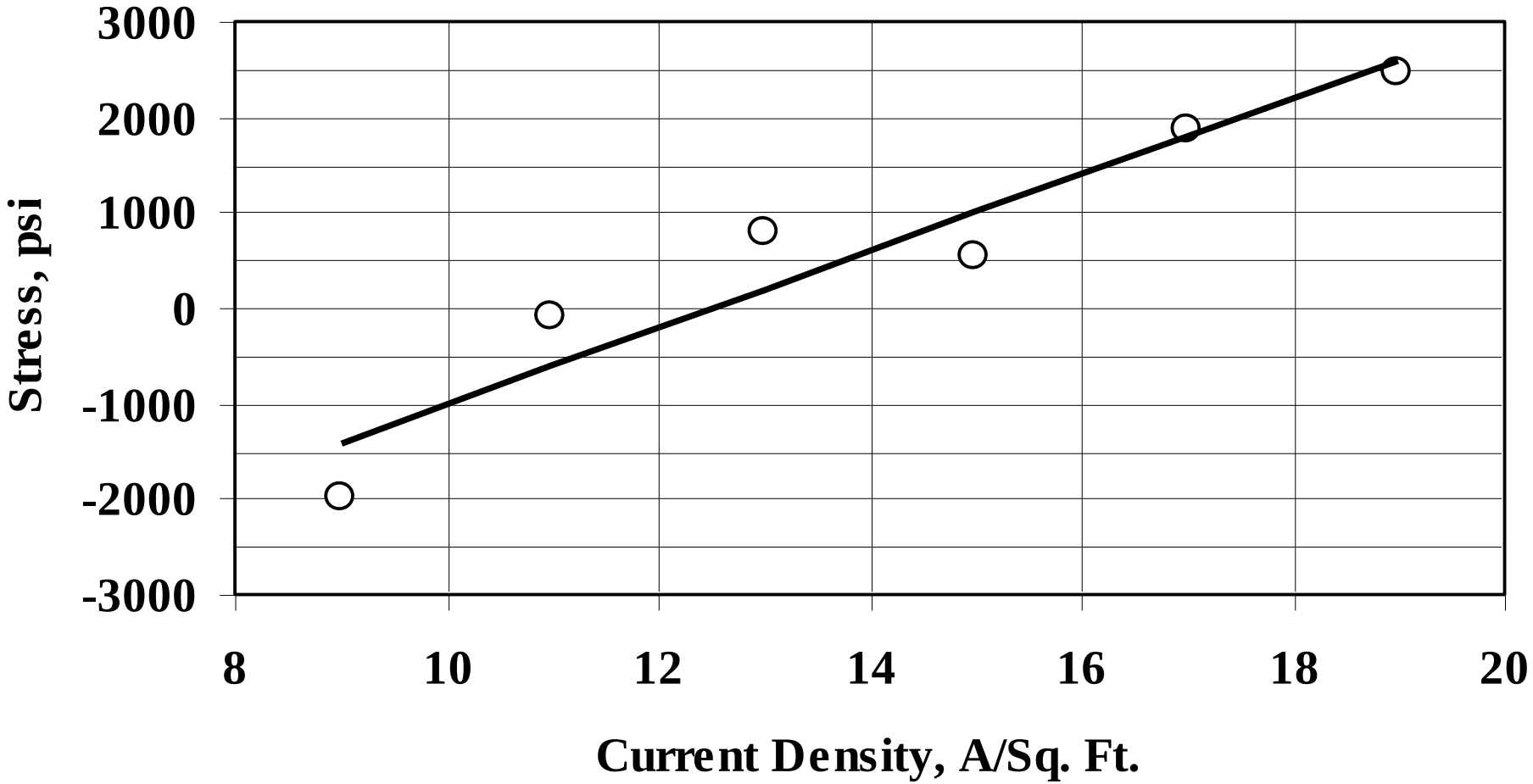
**Big Bath – 700 gallons**

**up to 50-inch mirror**

# Ni Electroforming Conditions

- Aqueous/Nickel sulfamate electrolyte
- Temperature --- 40 C
- pH --- 3.5-4.5
- Four anodes (in small bath) - location of anodes is fixed
- Continuous agitation/filtration

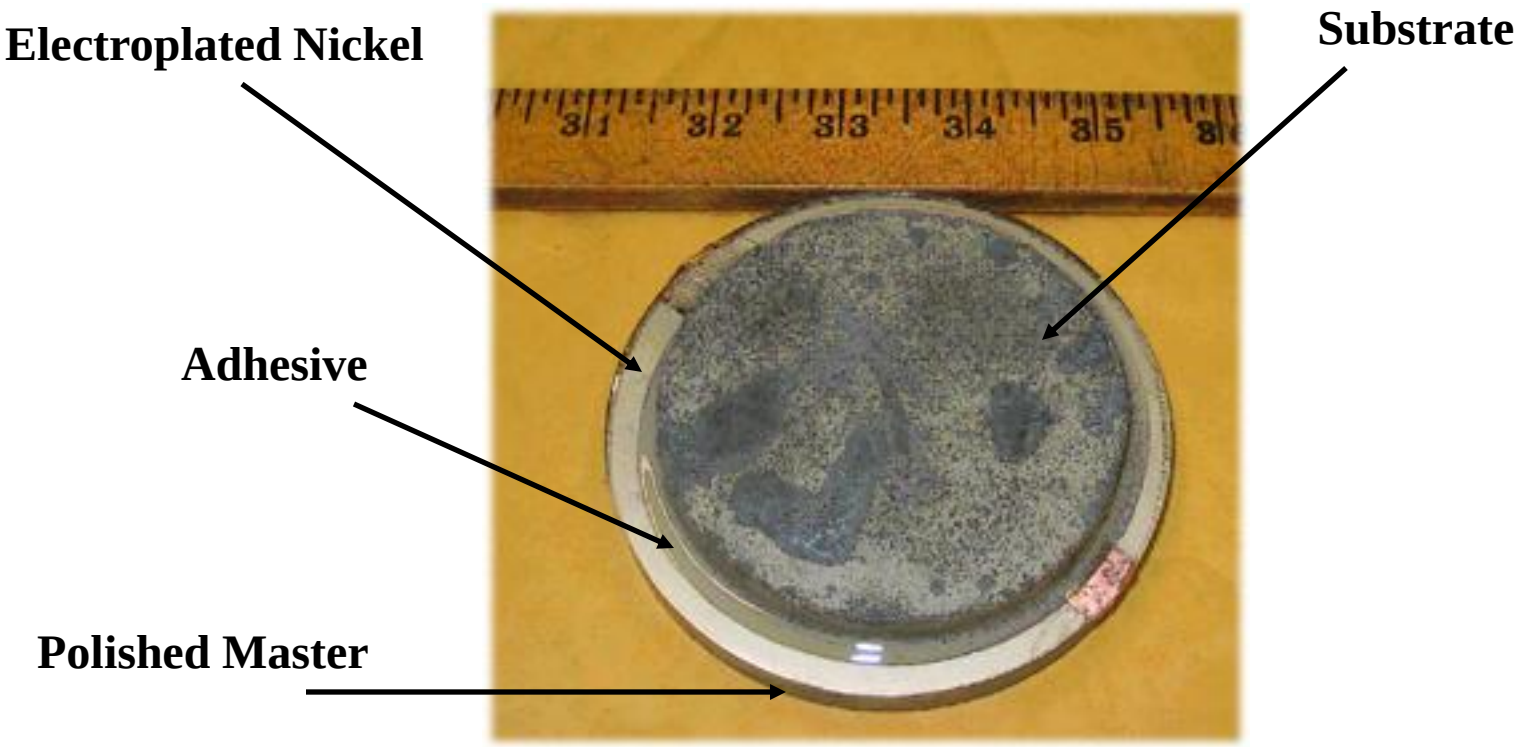
# Stress Control in Electroplated Ni



# Polishing of Flat Master Mirror

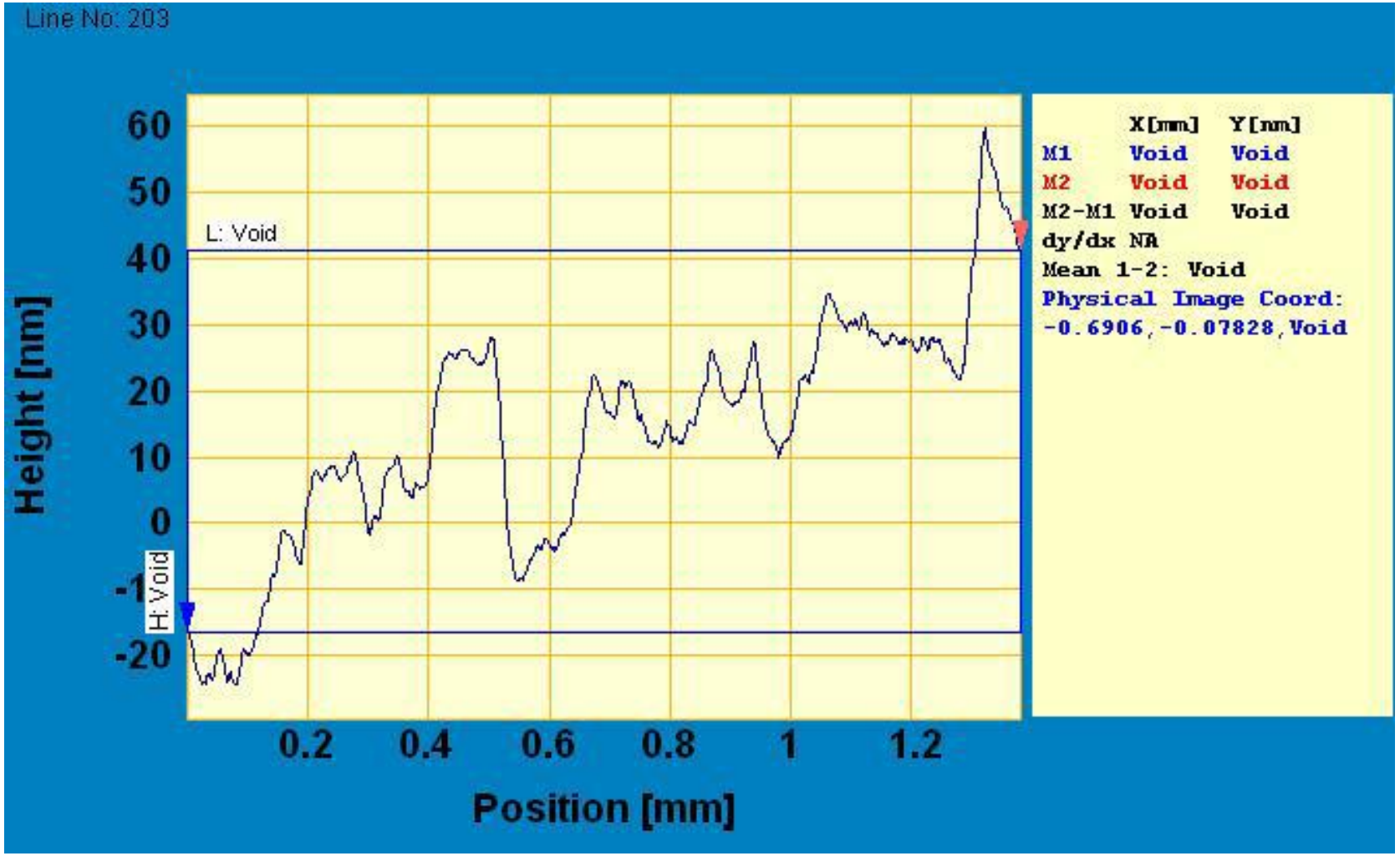
# Master (Flat) in Fixture Before Plating

# Substrate Attached to Electroformed Nickel



# Finished Electroformed Mirror

# Mirror Surface Profile Analysis



# Mirror Surface Profile Analysis

# Density of the Mirrors

Areal density of 0.45-0.65 mm-thick mirrors is in 9.2 to 11.0 $kg/m^2$ range

# Summary

Flat lightweight mirrors (4-inch diameter) are produced by replication technology by combining lightweight high-strength composites with a thin nickel layer

# Future Work (Phase 2)

- Scale up the technology
- Further focus on adhesion between composite substrate and nickel mirror
  - different adhesives
  - CTE matching
- Fabricate concave/convex mirrors
- Perform thorough characterization of the mirrors