High Aspect Ratio ‘Infinitely’ Long Gold Gratings

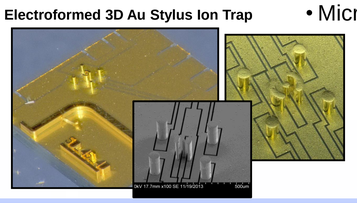
Edward Chakmakian, C. L. Arrington, A. L. Young, A. E. Hollowell
Correspondence: aehollo@sandia.gov (505) 844-8301
Sandia National Laboratories, Albuquerque, NM 87123, USA

Electrochemical Deposition (ECD) offers unique capabilities for new device creation where traditional CMOS is unable to compare. Due to the nature of precise additive processing, as opposed to blanket material deposition, ECD is not hindered by line of sight constraints and keyhole effects inherent in traditional CMOS processes. Additionally, utilizing mold construction methods such as UV lithography, x-ray lithography, and Deep Reactive Ion Etching (DRIE), metal gratings can be realized at high aspect ratios for unique and complex device realization. In this work we’ve combined ECD with unique templates to realize high aspect ratio (as high as 50:1) gold gratings that up to 4 inches in length Metalmichromachining.sandia.gov

Metal Micromachining Team (MMT) Lithography Lab

- Hot Plate
- Wet Bench
- Resist Spinner
- Alignment Tool
- Vacuum Oven
- Microscopy

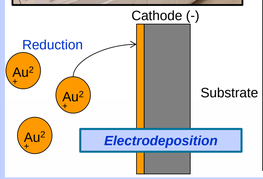
Electroformed 3D Au Stylus Ion Trap

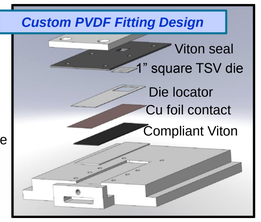


- LIGA
- Ultra thick PR techniques
- Class 100 cleanroom in house
- Access to Sandia Micro Fab Facility & MESA

MMT Electroplating/Electroforming Lab

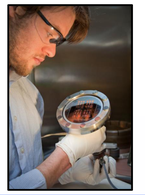
- Hard Gold
- Soft Gold
- Nickel Sulfate
- Copper Sulfate
- Electroless Nickel
- Custom Solutions



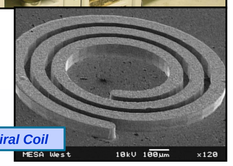


MMT Chemical Mechanical Planarization Lab

- Precision lapping, planarization and polishing capability
- Varying wheel composition to accommodate various material removal needs

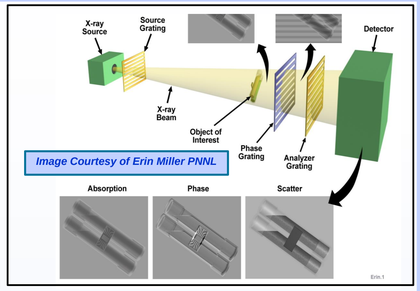


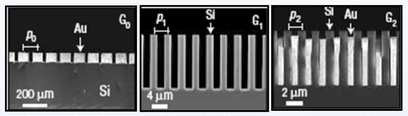
- Controlled wafer, optics and device thinning
- Vacuum fixtures for 4 - 6 inch wafers
- Custom mounting fixtures to secure a multitude of devices



Enabling Technology for Phase Contrast Imaging

- **Source Grating**: Enables use of conventional x-ray source in the lab
- **Phase Grating**: Modulates the phase of the wavefront to form an interference pattern
- **Analyzer Grating**: Converts the interference pattern of the x-rays to an intensity signal that can be recorded with a detector

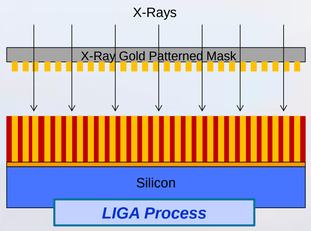




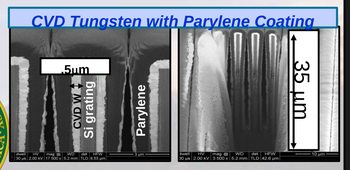
Benefits of XPCI

- No need for a synchrotron
- Higher resolution imaging than absorption based imaging
- Simplified optical arrangement
- Wide Area Imaging

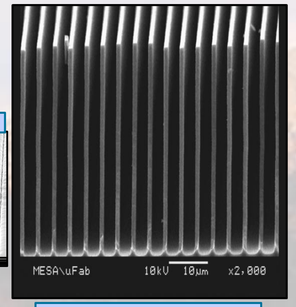
Greater than 25:1 Aspect Ratio Gratings Needed to Increase Absorption and Phase Contrast



- LIGA → resist swelling and structural instability
- CVD Tungsten → high stress (requiring parylene compensation) and non-conformal coatings
- **DRIE Si can achieve > 50:1 aspect ratios and maintain high structural stability**

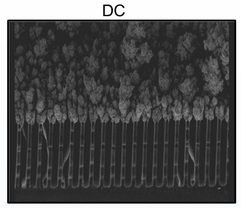


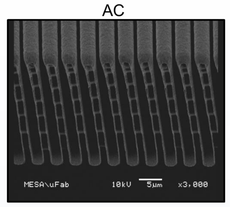
CVD Tungsten with Parylene Coating

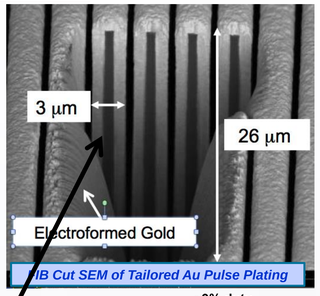


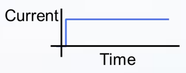
50:1 DRIE Si Gratings

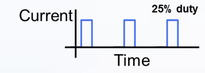
Optimization of the Au Electroplating Process



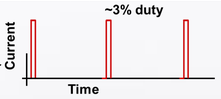


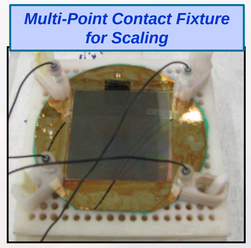


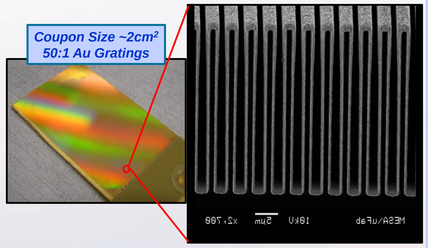




- Atomic Layer Deposition (ALD) of Pt for plating seed layer
- Tailored pulse plating for uniform deposition



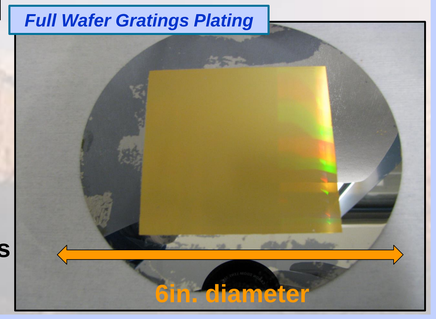




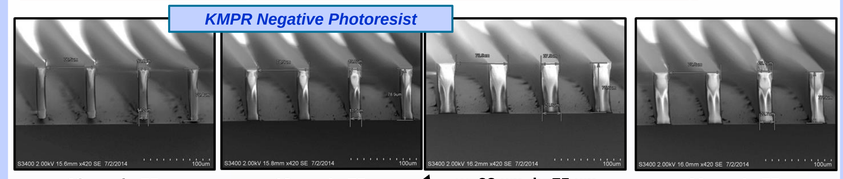
Realizing 16 in.² Grating Area

- Multiple electrical contacts
- Improved chemical flow
- Vibrating sample fixture
- Improved pulse plating regime

4 inch long 1 μm wide Au gratings
100,000:1 Length:Width Ratio!

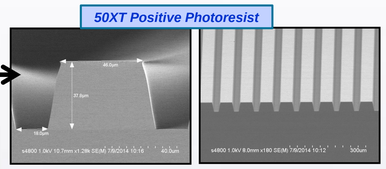


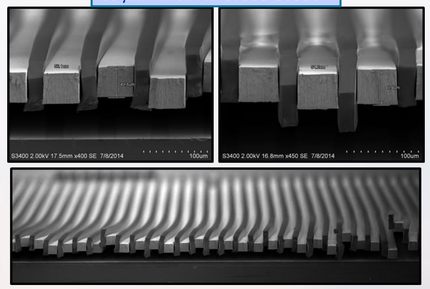
Au Source Gratings via UV Photoresist Trench Filling



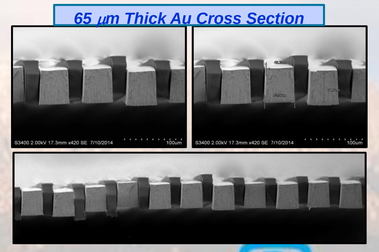
w=13 μm, h=75 μm | w=18 μm, h=75 μm | w=28 μm, h=75 μm | w=23 μm, h=75 μm

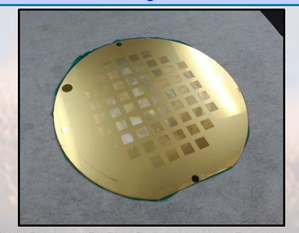
- KMPR produces straight sidewalls with sufficient structural stability
- Conventional positive resists result in insufficient sidewall profiles





- Resist process is dependent on the “lifetime” of the wafer
- Lithography must be performed in a single day
- Plating must occur immediately after resist processing to prevent delamination and resist swelling





Sandia National Laboratories

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.