

# Introduction to the LIGA Microfabrication Process

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Fundamentals of Microfabrication

## Outline

- What is LIGA?
- The LIGA Process
  - Lithography Techniques
  - Electroforming
  - Mold Fabrication
- Analyzing Processing Problems

## What is LIGA ?

**L**ithographie → *Lithography*

**G**alvanoformung → *Electroforming*

**A**bformung → *Moulding*

## The LIGA Process

### • Lithography

In general terms lithography is an image transfer process using .....

Visible and UV Light

Electron Beam

Ion Beam

Laser

Machining

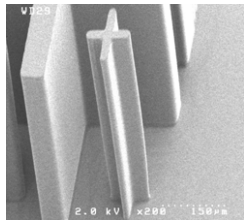
X-ray

### • For LIGA

The key consideration is high aspect ratio structures are required

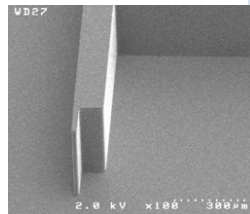
# High Aspect Ratio Patterning

## Specialized Optical Lithography Processes



SU-8 Resist

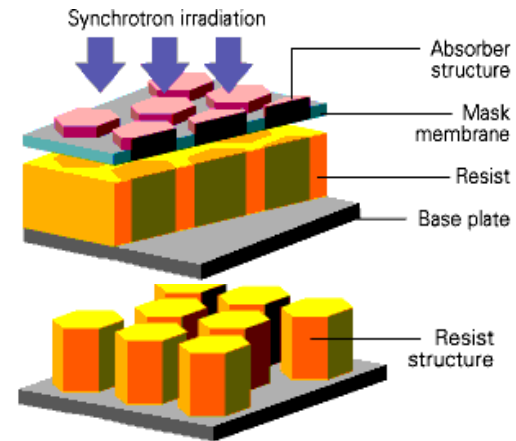
Height: ~360µm  
Width: ~14 µm



Height: ~250µm  
Width: ~14 µm

# X-ray Lithography

## Shadow Printing Using X-rays



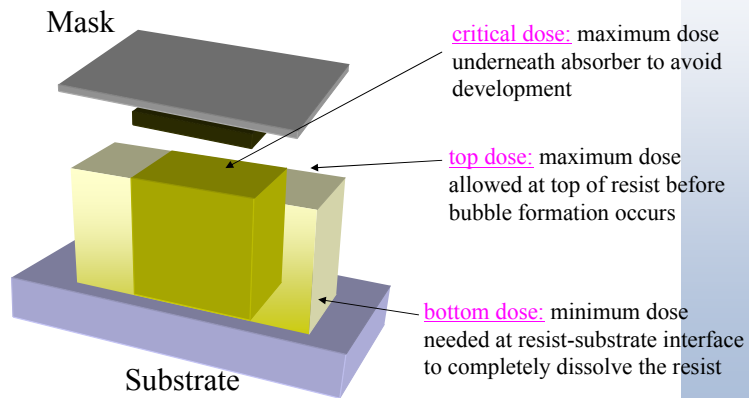
• X-ray mask

• Resist

• Substrate

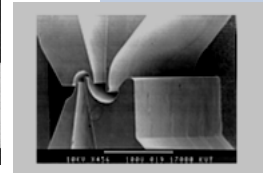
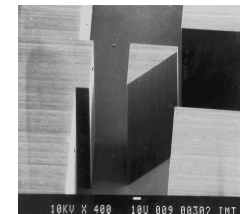
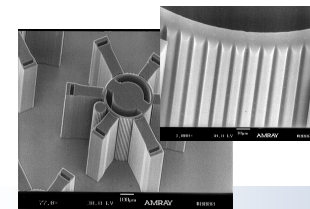
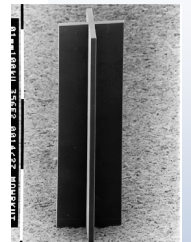
• Development

# Critical Parameters in DXRL Exposures



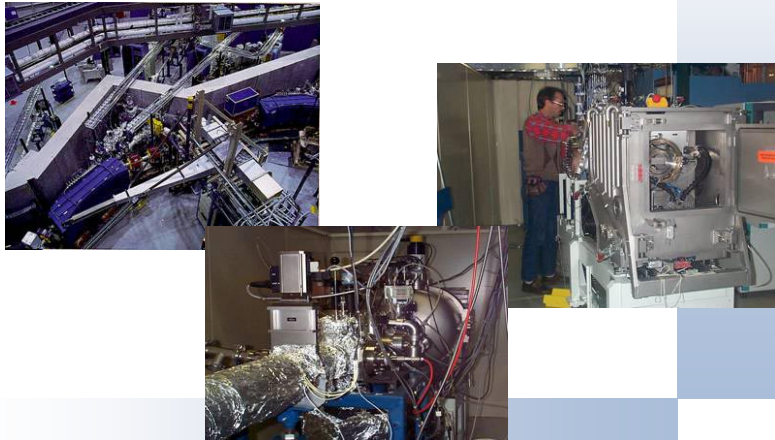
# Key Features of DXRL Microstructures

- Arbitrary Shape
- Structure Height up to Several Millimeters
- Minimum Feature Sizes in the Order of Micrometers
- Sub-micrometer Topographical Details
- Vertical Sidewall Profile
- Smooth Sidewalls

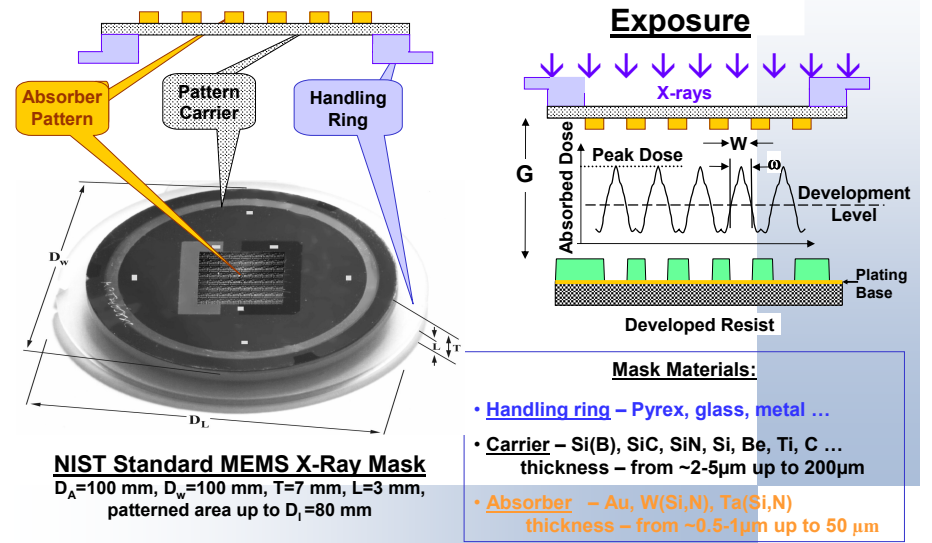


# Deep X-ray Lithography at CAMD

## Two Beam Transport Lines and Scanners for Deep X-ray Lithography



# X-Ray Mask



# X-ray Mask Membranes for DXRL

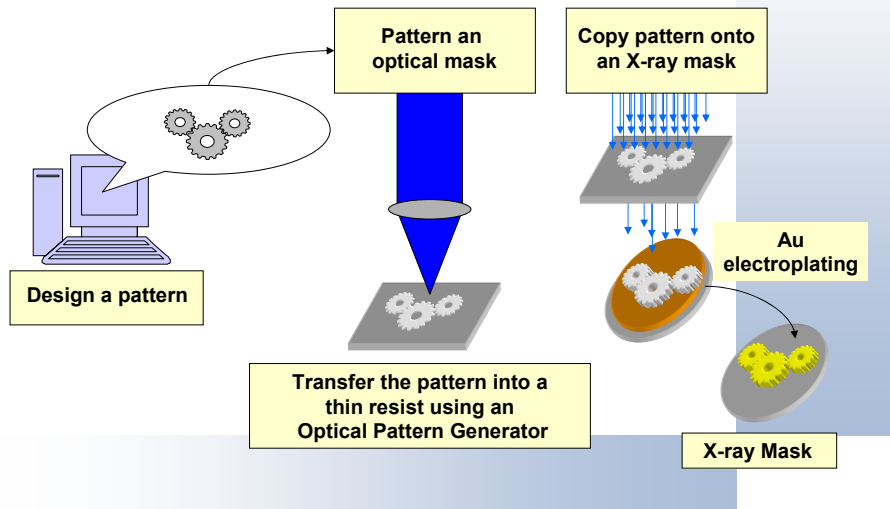
- Silicon Based (Si, SiC, Si<sub>3</sub>N<sub>4</sub>)
  - => Acceptable X-Ray Transmission, Mechanically Stiff, Reasonable Optical Transparency(SiC, Si<sub>3</sub>N<sub>4</sub>), Widely Used Material
  - but:** Thin Membrane of 1-3 Micrometers Thickness, Reduced Thermal Conduction Characteristics
- Titanium
  - => Acceptable X-Ray Transmission and Stiffness
  - but:** Thin Membrane of 2-3 Micrometers Thickness, Poor Thermal Conduction, no Optical Transparency

# X-ray Mask Membranes for DXRL

- Beryllium
  - => Excellent X-Ray Transmission, Mechanically Stable Substrate, Good Thermal Conduction for Mask Cooling
  - but:** Potentially Toxic, not Optically Transparent, High Cost
- Diamond
  - => Reasonable X-Ray Transmission, Mechanically Stable, Good Thermal Conduction, Optically Transparent
  - but:** Free Standing Membrane in Required Size Range Difficult to Fabricate, High Cost
- Rigid Graphite
  - => Reasonable X-Ray Transmission, Rigid, Mechanically Stable Substrate, Good Thermal Conduction, Off-the-Shelf
  - but:** Bulk Porosity, Surface Roughness, not Optically Transparent

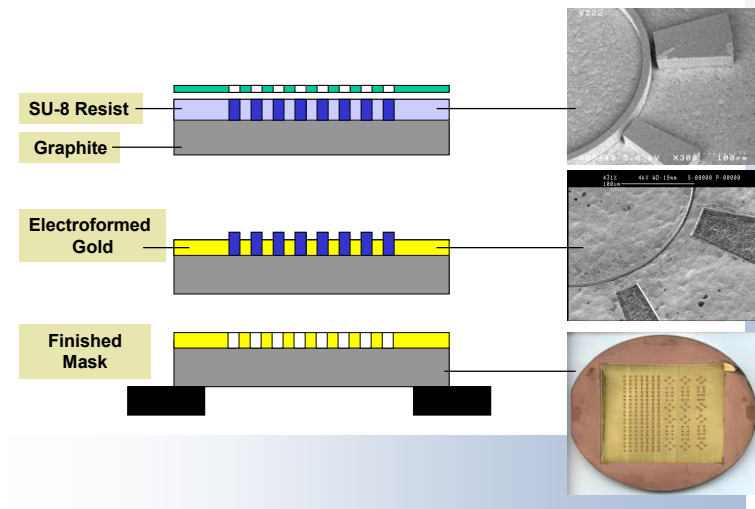
# X-ray Mask Fabrication

## Intermediate Mask Technique



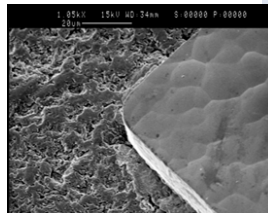
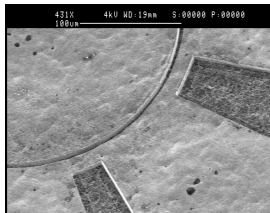
# X-ray Mask Fabrication

## Optical Lithography



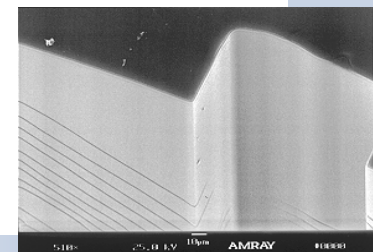
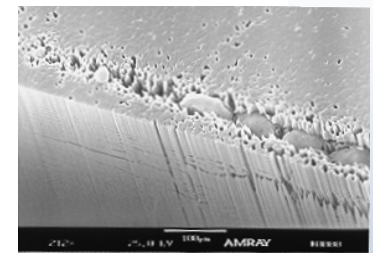
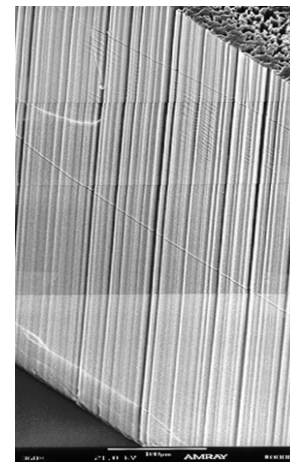
# X-ray Mask Process Development

## Graphite as the Mask Membrane



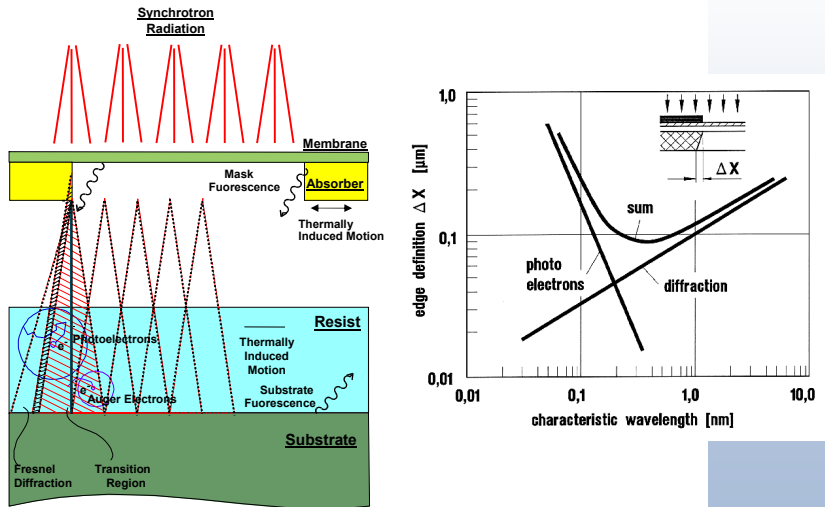
Electrodeposited Gold Absorber

# Exposed Pattern Analysis

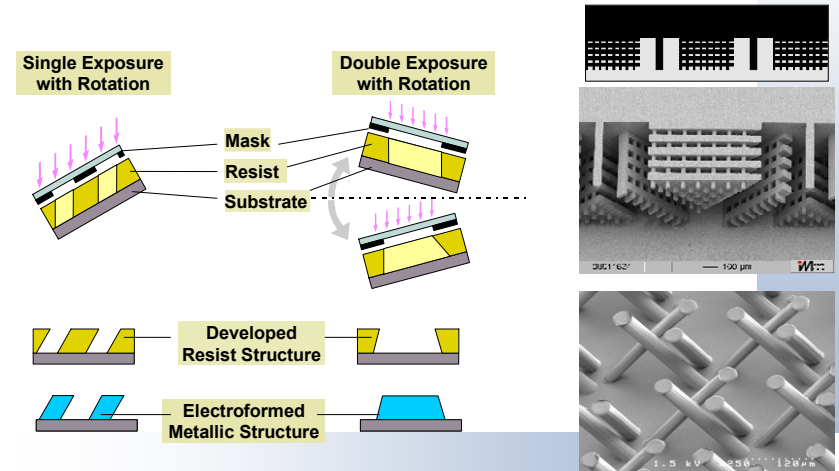


Sidewall Roughness

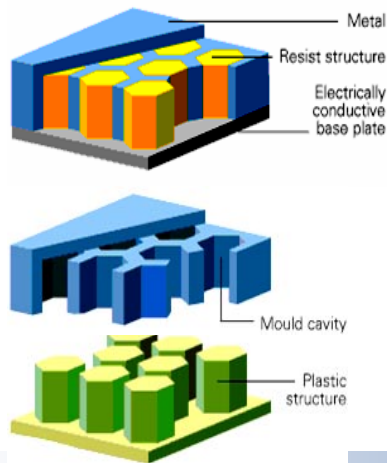
## Secondary Effects in DXRL



## 3-D X-Ray Lithography



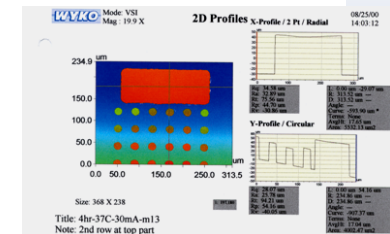
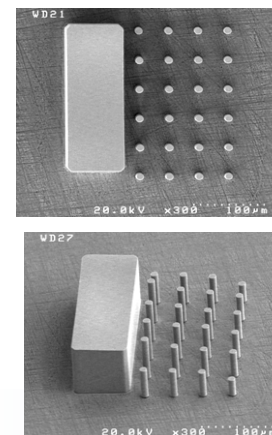
## Electroforming and Molding



**Electroplating of metal structures and mold inserts**

**Replication by molding (hot embossing, injection molding)**

## Electroplating in High Aspect Ratio Structures - Uniformity

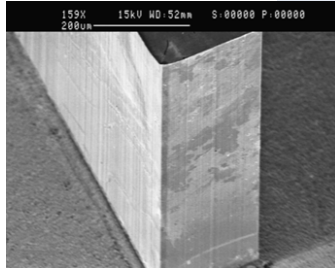
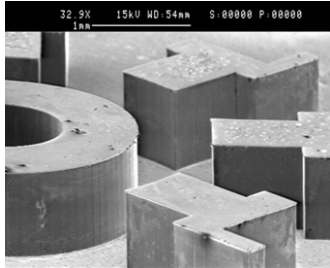


**Optimized Plating Conditions Results in more Uniform Deposition of Structures with Different Dimensions.**



# Mold Fabrication

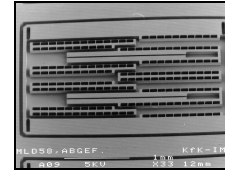
## Nickel Electroplating



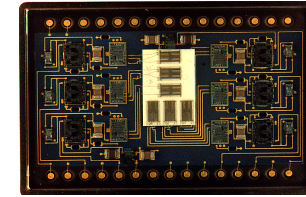
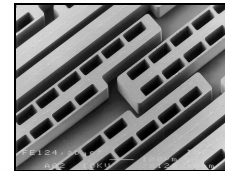
# Application of Aligned Molding

## LIGA Acceleration Sensor

PMMA structure



Detail



Redundant Sensor System

Ni - structures 120  $\mu$ m high

