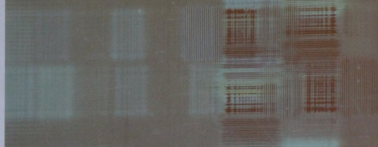




Holographic Photomasks for "Green" Microlithography

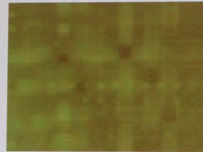


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Outline of this Talk

- Who/Where: Introduce our company (CMC)
- Why: Microlithography for Microelectronics
 - Ablation Patterning = "Green" manufacturing process
 - Holographic Masks = Lens-less Projection Lithography
- How: Fabrication and Application of Holographic Masks
- Summary



Holographic Mask patterns seen in microscope 500X

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Creative MicroSystems Corporation (CMC)

Business Model

- Leverage knowledge/skills in Optics, Holography and Microfabrication.
- Formerly part of Diffraction LTD – founded by Julie Parker (Walker)
- **Invent/Innovate—Develop: Ready for Production—Technology Transfer**
- Flexible Business Model based on Collaborations and Partnerships

- CMC also develops unique products and is an engineering resource for:
 - Holographic technology and materials
 - Displays – HUD's, HWD's, Near-to-Eye Displays
 - Masters for security holograms and DOE's/HOE's
 - Micro/nano systems, MEMS, microfluidics, ablation masks
 - Low light imaging and night vision systems



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CMC Technical Focus Areas

Microsystems

Microfluidics/MEMS
Miniaturization
Custom Device+Process
Calibration structures



Advanced Optics

Electro-Optics/SLM's
CGH/Gratings/DOE's
Planar optics
Holographic Systems



Applications

3-D micropatterns
2D/3D Displays
Biomedical Devices
High Energy Masks



Lithography Mask + High Power Laser Sources

- Industrial manufacturing processes use lasers effectively and profitably via ablation of thin films and solid materials. +++
- Ablation patterning speed is often limited by mechanical scanning of a single beam (*serial processing*). ---

A photomask process can yield higher production rates:

- Laser peak and average power are now very substantial >1000W CW.
- Laser Ablation can produce patterns quickly by directing laser light to more points on the workpiece simultaneously. (parallel processing)

Metal ablation mask

Lithography Mask + High Power Laser Sources

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 - Can ablation be more efficient?
Many systems waste >90% of illumination



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- Key Questions for Holographic Lithography:
- **Can ablation be more efficient?**
Many systems waste >90% of illumination
- **Can photomasks withstand higher energy and power?**

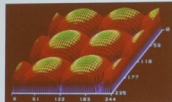


Ablation Lithography Applications

- Microelectronic packaging
- MEMS and 3-D devices
- Displays, ink jet nozzles
- Microfluidic and medical devices
- Sensors and detectors
- Photovoltaic cells



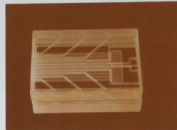
Thin film microfluidic sensors



Micro-lens array in polymer



Micro-nozzle array by ablation



Microfluidic reactor in glass

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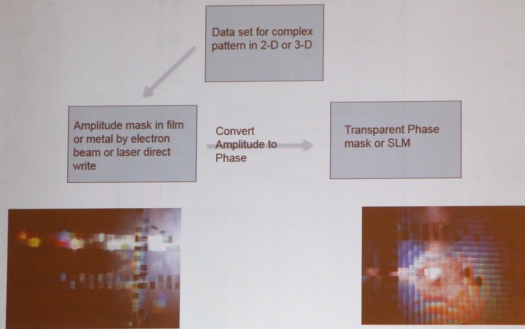
Microlithography in a Global Context

- Critical to microelectronics manufacturing
 - Mask projection is ideal for high throughput requirements
 - Only way for “massive” patterns with $>10^9$ features
- “Green” manufacturing with laser ablation
 - Lowers energy usage in the tool and support facilities
 - Reduces pollution and water usage, now approx. 40 liters per IC
 - Cuts waste stream from process steps in litho and etch
 - Increase throughput and profits

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- Holo-lithography Complements “mask-less” lithography:
 - Direct Write Laser (patterning without a mask)
 - Spatial Light Modulator and DLP pattern generators

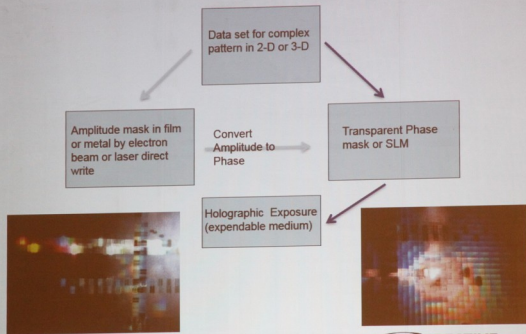
Holographic Masks: Hybrid Approach



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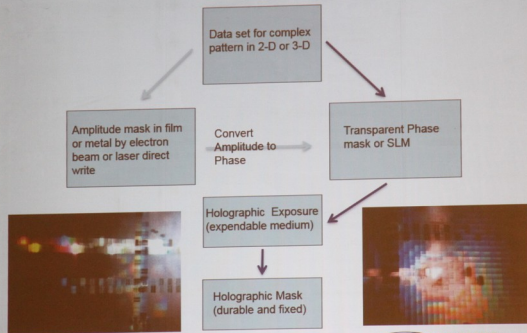
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Holographic Masks: Hybrid Approach



Holographic Exposure
(expendable medium)

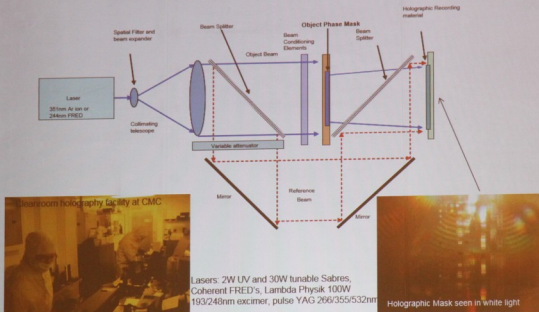
Holographic Mask
(durable and fixed)



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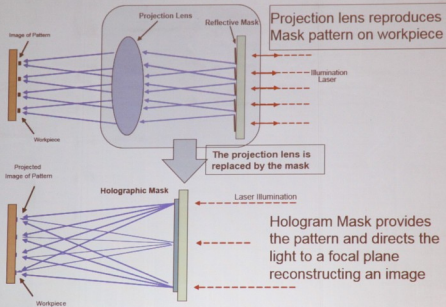
Holographic Mask Fabrication



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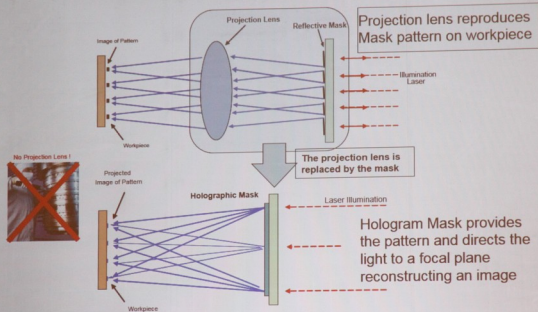
Holographic Projection Mask Compared to a Projection Lens system



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Holographic Projection Mask Compared to a Projection Lens system



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Holographic Mask Advantages

Lensless Projection: a holographic mask projects a real image that is focused on the workpiece [Resolution and DOF follow N.A.]

- Less expensive system – saves the cost of a projection lens
- Less maintenance – no lens to maintain, align or replace
- Not off-axis (i.e. Stetson/Phillips/Holtronics) a true “in-line” system

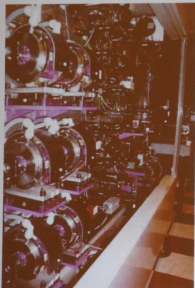
Redundancy: pattern data is distributed on the holographic mask

- In-line recording of the image
- Hologram masks are highly resistant to damage and debris
- Inherent security – can not be modified or copied

3 Dimensional: one hologram can have multiple patterns/foci

- Images recorded on the mask can be addressed with multiple wavelengths simultaneously – one for each material or energy/depth
- Images can be replayed sequentially for different features or simultaneously at several distances

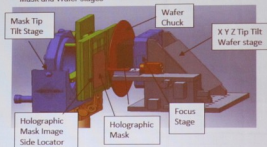
CMC Holographic Lithography Testbed



Laser System at 355nm – 120W, 400ps, 300Hz

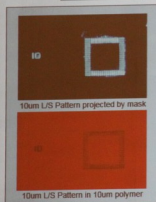
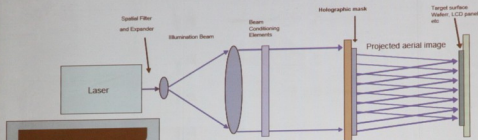


Mask and Wafer stages



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Lithographic Image with Lensless Projection

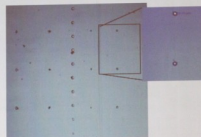


Laser with good quality ($M^2 < 1.4$) is shaped, homogenized and expanded.

Tests using 193nm, 248nm, 365nm, 532nm and 1064nm, and broadband UV sources @365nm, 405nm, 436nm

Materials patterned to date:

- Polymers
- Metal films (Al, Cu, W, Ni)
- Transparent conductors
- Glasses
- Silicon
- ZnSe
- CdTe



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Answers the Questions: Efficiency and Power Handling



Features on Mask



Mask's phase modulating surface relief



5, 20 and 40um holes ablated in Kapton film



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Answers the Questions: Efficiency and Power Handling

Illumination "Gain": the hologram collects light and focuses it on the substrate

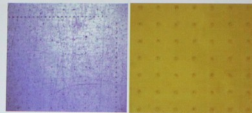
- Illumination is not reflected or absorbed (vs traditional mask)
- More efficient use of expensive laser light: up to 12X better
- Ideal for use with non-linear materials: 15-40X background level



Features on Mask



Mask's phase modulating surface relief



5, 20 and 40um holes ablated in Kapton film

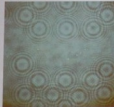
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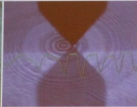
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Higher power: illumination energy can be 10-20X that used with metal or dielectric ablation masks

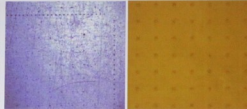
- Higher power means higher throughput from one tool
- Higher gain means more features per pulse – less wasted light
- Over a 4 million holes a minute from one laser (2009)



Features on Mask



Mask's phase modulating surface relief



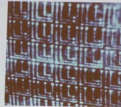
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Conclusion

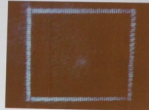
- Laser lithography using holographic projection masks is a low cost "Green" alternative to lens-based lithographic systems.
- Parallel process yields high production rates using short pulse high power lasers to pattern large areas with many features
- "Green" micro/nano manufacturing for microelectronic and MEMS devices or any precise microsystem component. No water or chemicals involved.
- Redundancy of pattern information on the mask increases yield and 3-D structures enabled with one mask



Holographic Mask in white light



Projected images with 0.5um resolution





Thank You for your attention!

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