All-Glass Gray Scale PhotoMasks Enable New Technologies

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Overview

All-Glass Gray Scale Photomask technologies include:

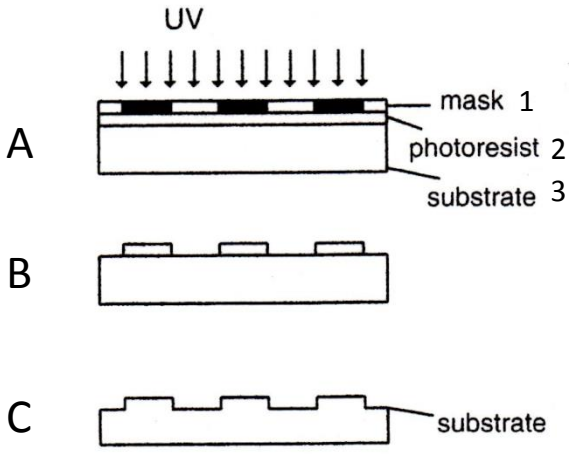
- HEBS-glasses and LDW-glasses
- HEBS-glass gray scale photomasks and LDW-glass gray scale photomasks
- Method of making 3D microstructures using an All-glass gray scale photomask
- Examplary Utility of the 3D microstructures

Chrome on Glass Photomasks have been the Economic Driving Force of the Integrated Circuit (IC) Industry

1. IC industry grows very fast since inception in 1960.
2. One of the driving forces for the growth is the fact that IC chips can be mass produced economically through the use of photomasks
3. IC chips are built with many (e.g. 20-30) layers of binary (i.e. 2D) microstructures
4. Each layer requires a chrome on glass photomask to define the IC pattern in that layer

A Common Process Step in IC Chip Fabrication

Chrome Mask Lithography



A1. Chrome on glass mask

A2. A layer of photoresist coated on a substrate

A3. The substrate is chosen to have correct material properties, e.g. an Si wafer

B. The areas exposed to UV become soluble and are removed

C. Transfer the micro-structure into substrate via RIE process

IC patterns produced in photoresist have a rectangular cross section

1. Chrome mask lithography can only produce two dimensional (2D) structures
2. This is because areas in a chrome mask can only be totally opaque or totally transparent
3. There cannot be gray areas in a chrome photomask

How to make 3D microstructures of continuously varying surface height profile?

- In other words, how to make microstructures having cross sections other than  or  rectangles

- For example: 

  or 

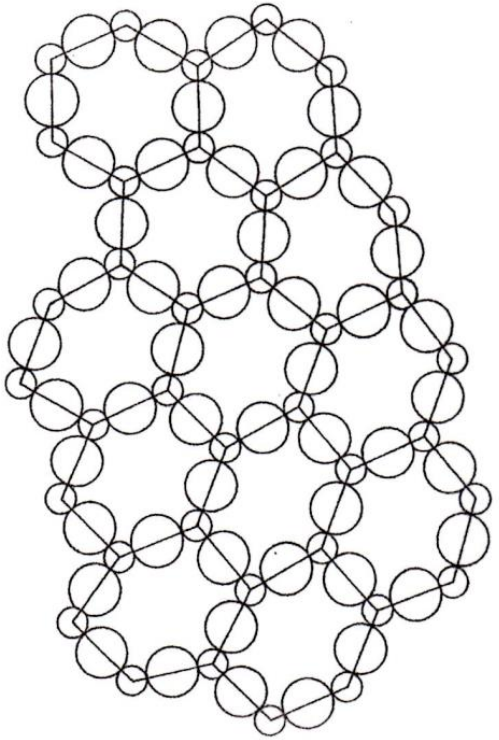
any arbitrary surface

Envisioning a Gray Scale Photomask

- In a chrome on glass mask, each pixel has only two choices; either totally transparent (100% T) or totally opaque (0% T)
- My question was:
  1. Can one build a 3D microstructure via changing %T continuously from one pixel to the next and next pixels?
- The invention of an All-Glass Gray Scale Photomask turns imagination into reality

A Two Dimensional Representation of

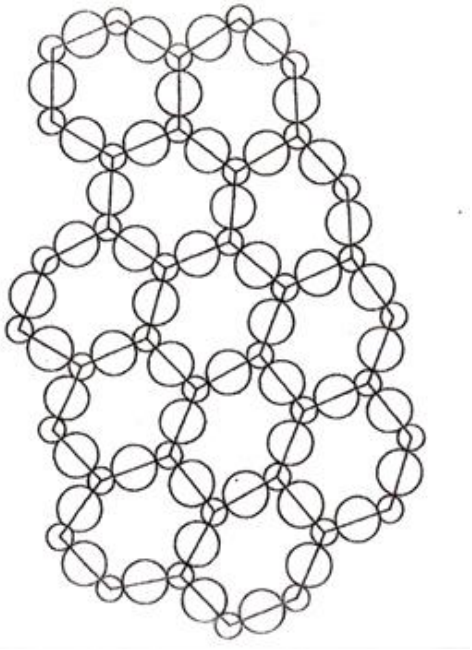
FUSED SILICA $(SiO_2)_n$ Glass



A $(SiO_2)_n$ net work forms thee dimensional cavities of 4 to 8 nanometer in size.

By Growing Nano-particles, in these Nanometer sized cavities, HEBS-glasses and LDW glasses are created.

Process of Making HEBS-glass & LDW-glass



Base silicate glass compositions are so formulated that upon a surface chemical treatment on the base glass, nanoparticles having the following properties are created in the nanometer size cavitities.

Clear nanoparticles → (E-beam > 10kev) → Dark nanoparticles

Dark nanoparticles → (Focused laser beam) → Clear nanoparticles

HEBS-glass gray scale photomask having gray images in clear background is made via E-beam exposures having a range of electron dosage levels

LDW-glass gray scale photomask having gray images in dark background is made via exposures to focused laser beam using a heat erasure mode of recording.

Photomasks for mass production of microstructures

Product type	Phototools for mass fabrication
2D microstructures, eg. IC Chips	Chrome on glass photomask
3D microstructures, eg. Microoptics	HEBS-glass and LDW glass gray scale photomasks*

*7 U.S. Patents having 458 patent claims related to HEBS and LDW-glasses were granted to Che-Kuang Wu and assigned to CMI

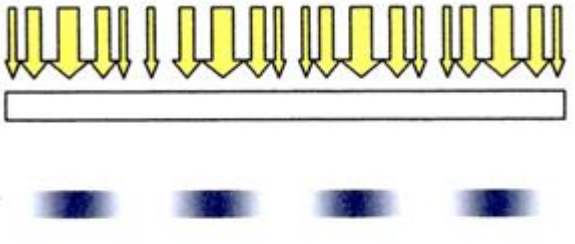
Method of Making 3D Microstructures

Step 1:
Fabricate e.g. a HEBS-glass gray scale photomask

E-beam

HEBS-glass (unexposed)

HEBS-glass (exposed)

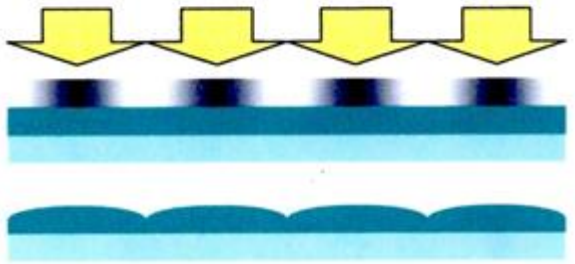


Step 2:
Photolithography

UV

Photomask
Photoresist
Substrate

Developed photoresist on substrate

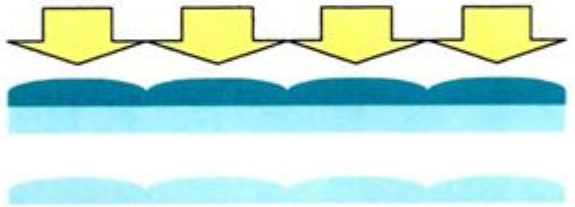


Step 3:
Reactive ion etching (RIE)

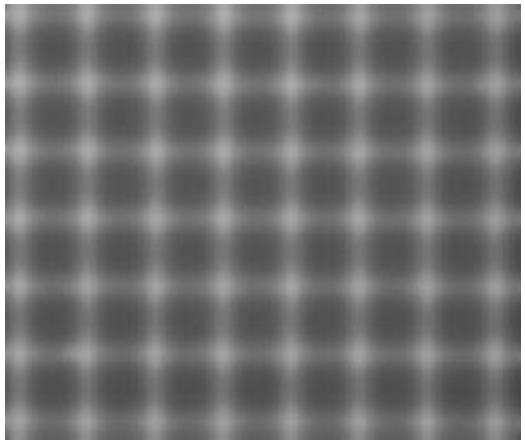
Reactive ionic species

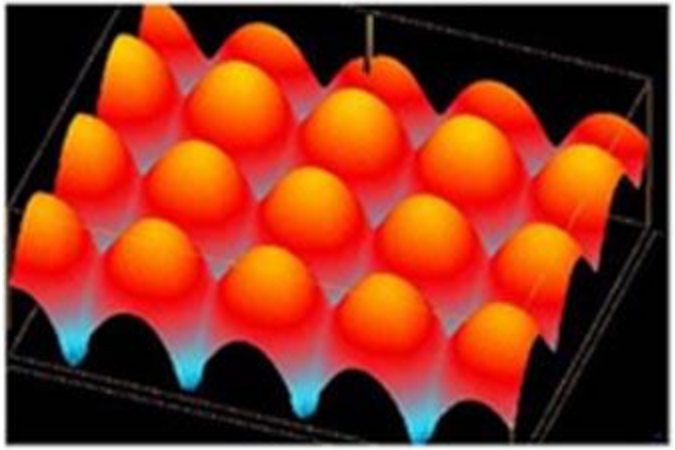
Photoresist
Substrate

Miro-optical element in substrate



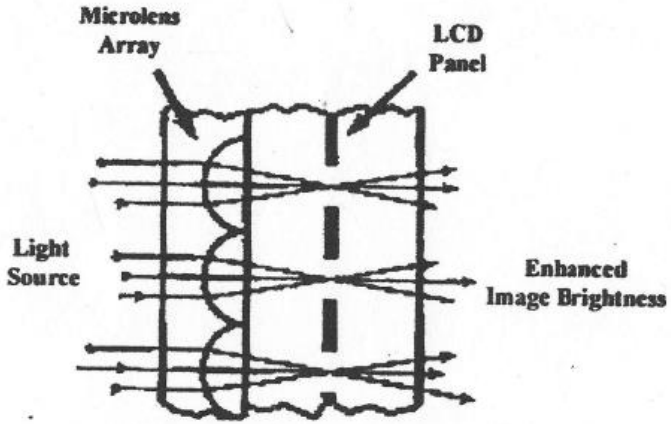
True Grayscale Photomask, A, is Essential to economic Mass Fabrication of 3D Microstructures, B

A 

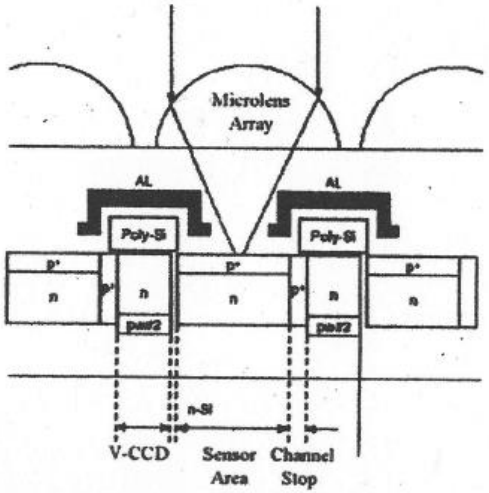
B 

1. HBES-glass and LDW-glass photomasks enable mass production of 3D microstructures by spatially various exposure on photoresist
2. Convert optical density D(x,y) in a mask into designed height h(x,y) in a 3D microstructure
3. The microlens array shown here has many applications; see following slides

Fill Factor Enhancement of LCD's and Image Sensors



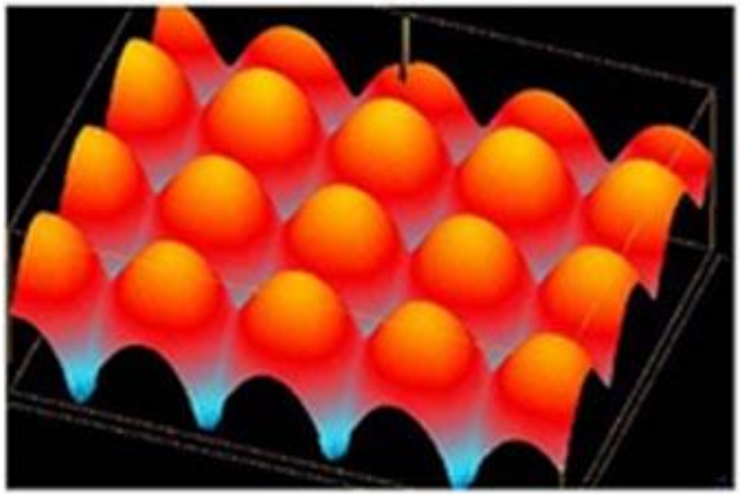
Microlens Array for LCD



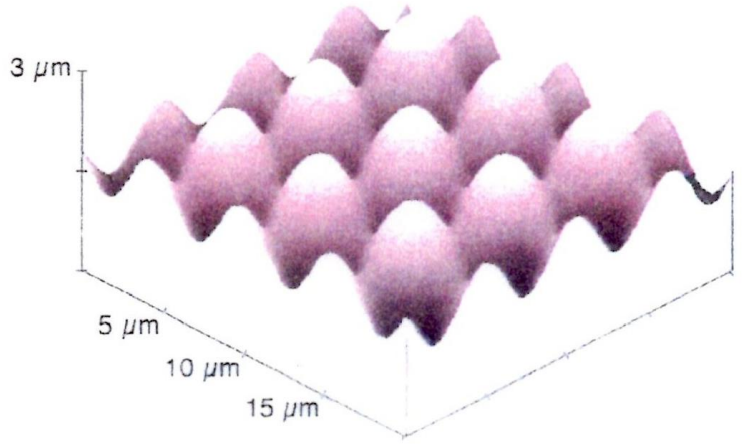
Microlens Array for Image Sensors such as CCD

- In LCD displays, 70% of display area is blocked by TFT transistor circuit, microlens array is used to funnel light through each TFT transistor.
- In a detector array of an Image Sensor, 80% of a detector cell is blocked by electronic circuit, microlens array is used to focus light onto each detector cell

Microlens Array for Image Sensors

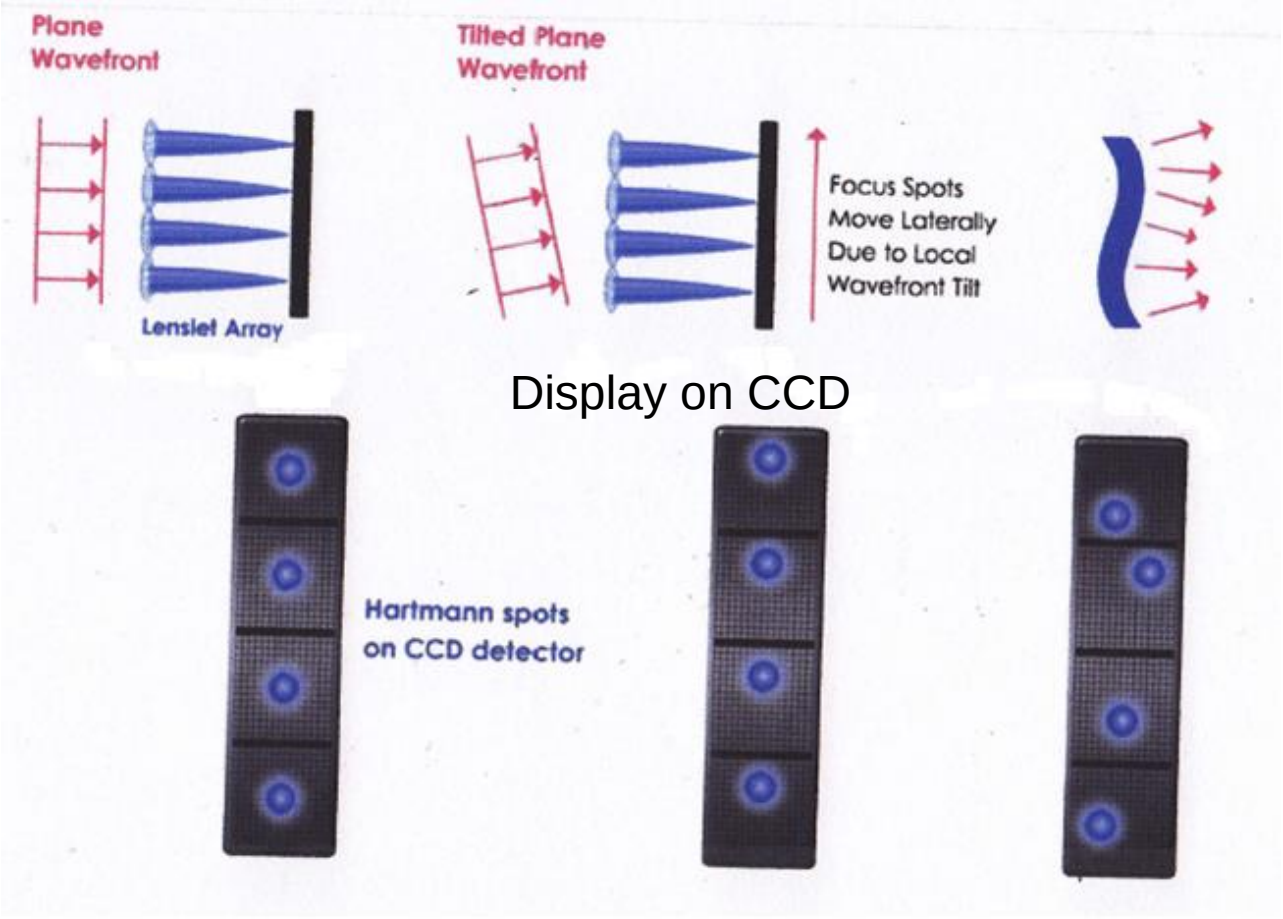


SEM Micrograph of 60 micron lenslet array



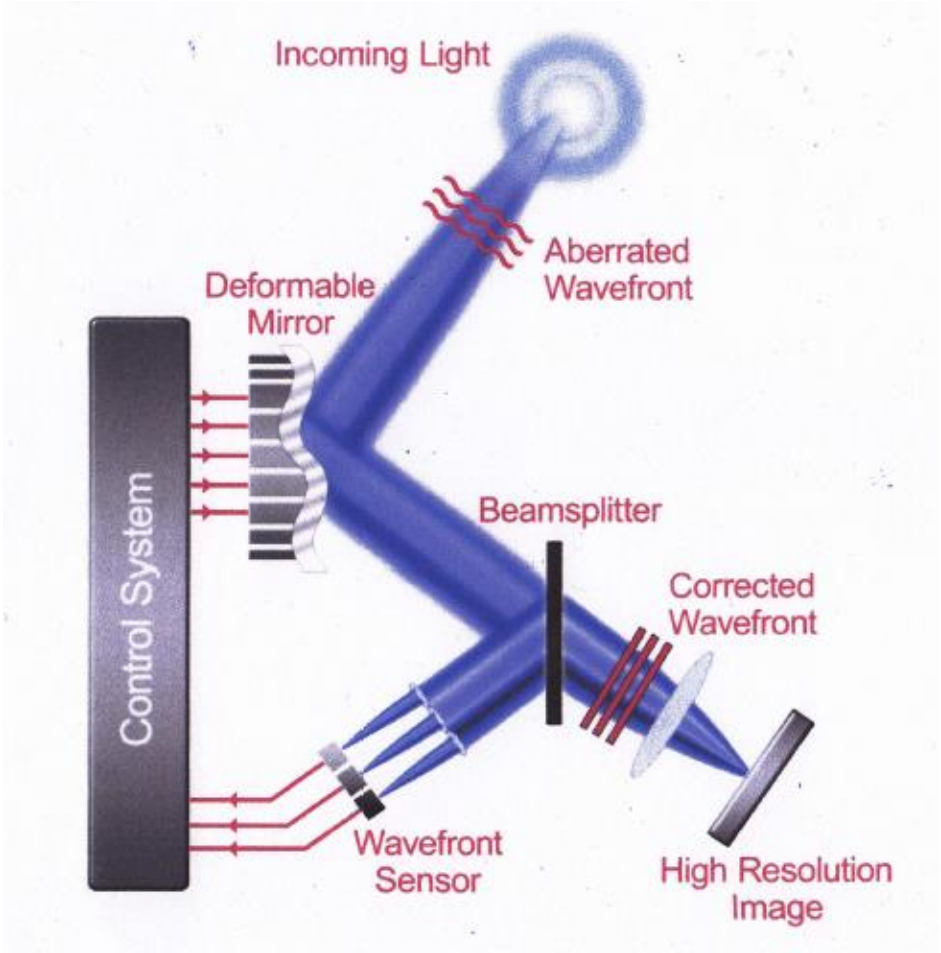
Atomic Force Micrograph of 5.5 micron Lenslet Array

Microlens Array for Wavefront Sensor

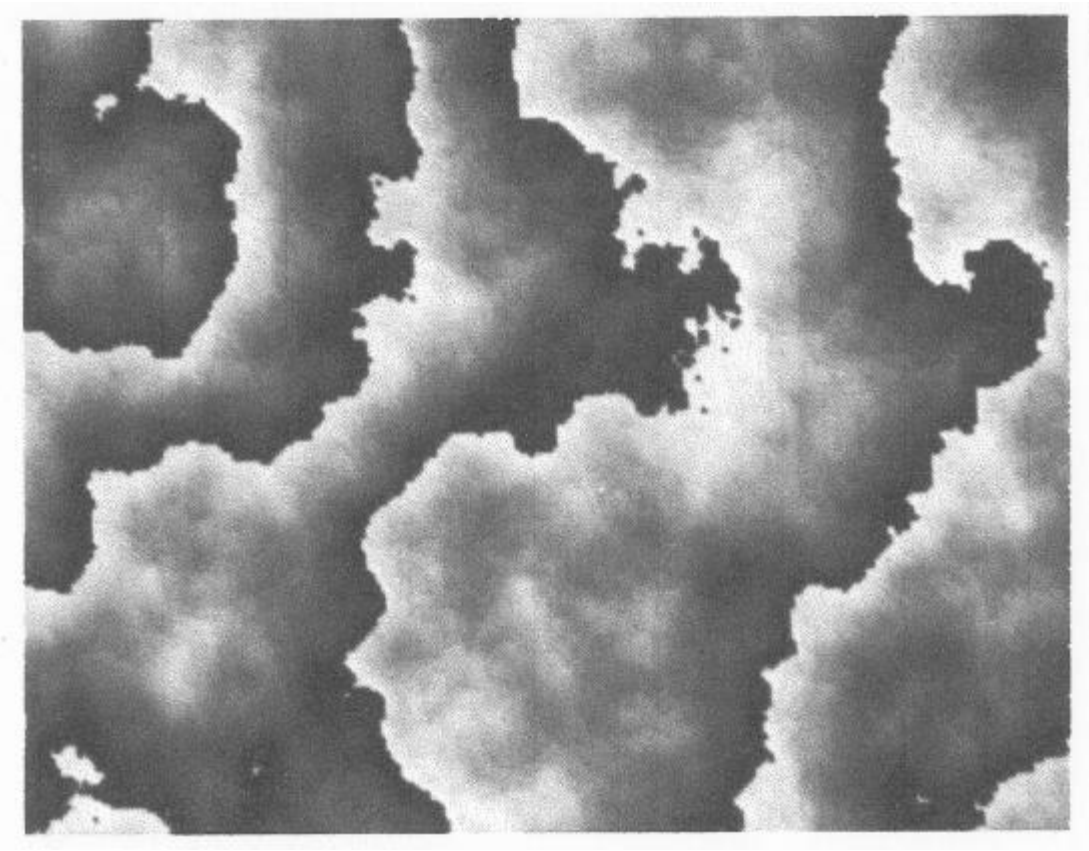


Wavefront Sensor in Adaptive Optics

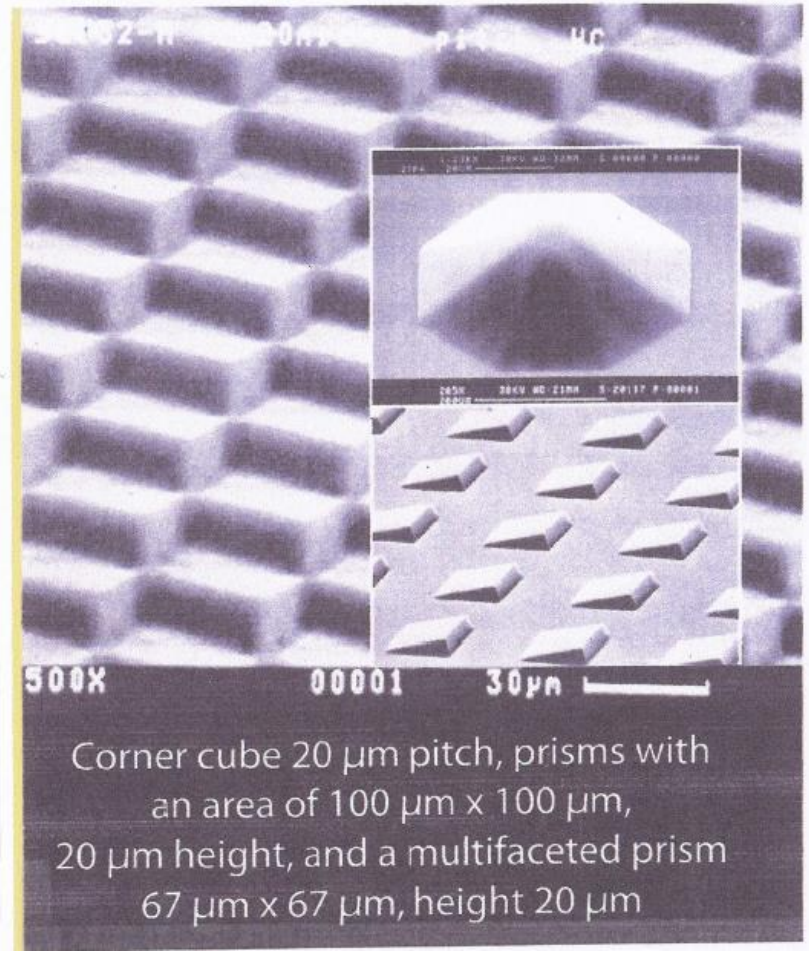
For Real Time Wavefront Correction



Random Phase Plate for Real Time Atmospheric Aberration Correction



Grayscale Micro Elements for Micro-Electro-Mechanical Systems (MEMS), and for Micro-Opto-Electro-Mechanical (MOEM) Devices



An Example: Slider for Magnetic Hard Disc Drive

All-Glass Grayscale Photomasks Enable

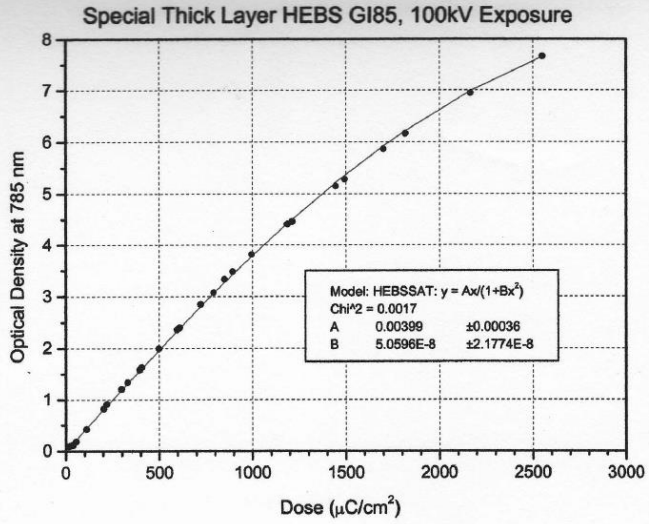
Mass production in quality of Grayscale Diffractive Optics , i.e. DOE

- shape error < 10nm
- diffraction efficiency 85%

Having no coating of any kind, there exist no scattering from line edges, grayscale optical density patterns in an all-glass grayscale mask are faithfully and reproducibly converted into pre-designed gray scale height profiles in photoresists.

AS AN EXAMPLE:
The Technology Improved the Signal Quality of Optical Disc Drives by
- Increasing the Diffraction Efficiency of the Diffractive Optic, and
- Brought Significnnt Reduction in Cost per Drive

As a Result:
The Technology made Panasonic Optical Drive Very Competitive in
- Technology, and
- Cost



Optical density of thick sensitive layer HEBS GI85 glass at 785 nm as a function of electron-beam dose. The data was fit with the ad hoc saturating function $y = Ax/(1 + Bx^2)$ for use in E-beam pattern preparation.

APODIZATION: CIRCULAR GAUSSIAN

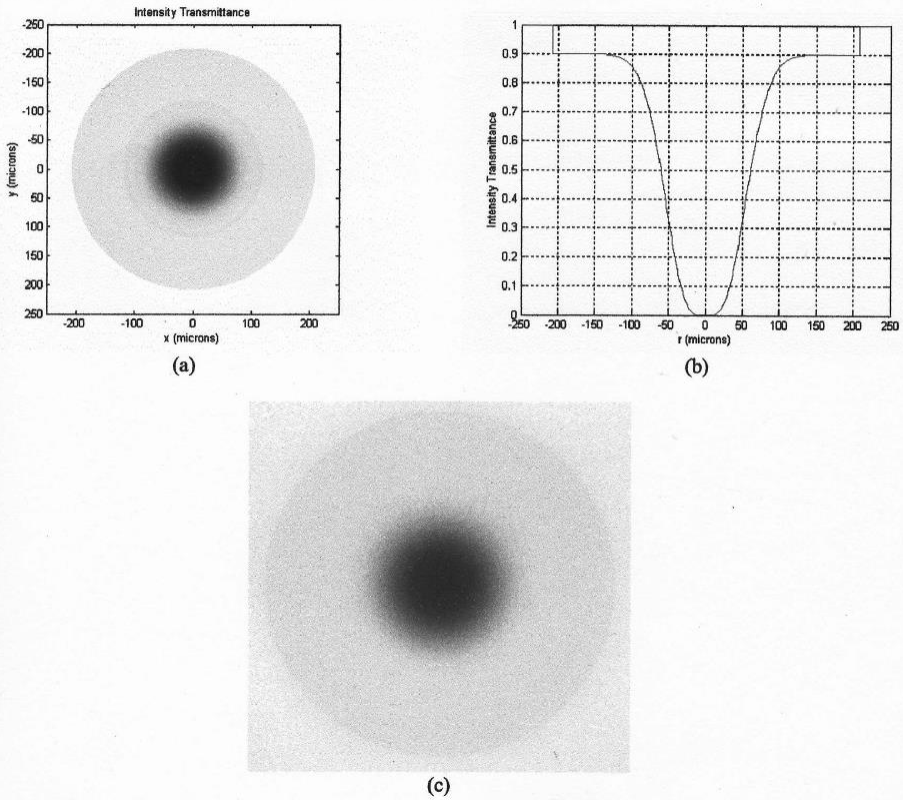


Figure 6. (a) Gray-scale representation of the designed intensity transmittance, (b) cross-section of the design intensity transmittance, (c) transmission microscope image of the E-beam fabricated spot (broadband illumination).

NASA Project Success to Look for Earth-like Planets Relies on HEBS-glass

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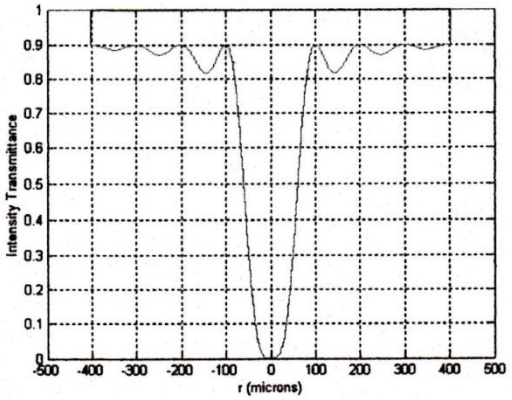
Attach: nature cover_vol446_070412.pdf; Nature_Trauger_Traub_070412.pdf; Nature_Supplementary Article.pdf
Subject: Nature article by John Trauger and Wes Traub

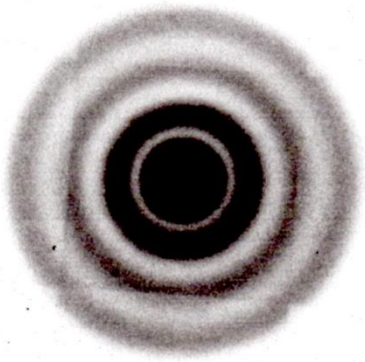
Chuck,

I thought you might be interested in reading the attached article.
JPL couldn't have done this work without your HEBS glass.

Regards,
Peggy

HEBS-glass is the filter material of choice to look for an earth-like planet which is buried in the one billion time higher intensity background





ALL-Glass Gray Scale Photomasks Enable New Technologies

- A large number of publications exist world-wide including publications in technical journals, PhD dissertations, MS thesis, and patents by authors/inventors/companies/university professors/National labs throughout the world who rely on the use of HEBS-glass and/or LDW-glass grayscale photomasks to develop their new technologies