BIOMEMS PHOTOMASK ALIGNER

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Abstract

Microelectricromechanical Systems (MEMS) are devices with components generally measuring less than 100 µm are often used to study biological interactions such as cell activity monitoring or biocompatibility testing. These devices are created using photolithography to transfer an image onto a photoresist substrate that can be cross linked with UV light. Consecutive layers of photoresist are added to create a three dimensional structure, and a typical device has two to three layers. When creating a new layer the image mask must be precisely aligned with the layer underneath. There are many high fidelity aligners on the market, however these are extremely expensive and impractical for an educational setting. A prototype was built using rapid prototyping and simple machining. The design uses a simple drop-in method for the wafer and the corresponding photomasks. Alignment holes are cut into the photomask transparency using a laser cutter. Basic testing has been completed with the laser cutter showing an estimated accuracy of 180µm.

Background

Motivation

- Biological MicroElectroMechanical Systems (BioMEMS)
  - The science of very small biomedical devices
  - Subset of MEMS
  - At least one dimension from 100nm to 200µm [1]
- Photolithography
  - Process of using optical means to transfer a pattern onto a substrate
  - Second and third layers are increasingly difficult to align
- Industrial/Academic Applications
  - Significantly lower cost aligner desired for teaching purposes
  - Depending on the intended use of the PDMS final product, accuracy desired can range from 1-200µm

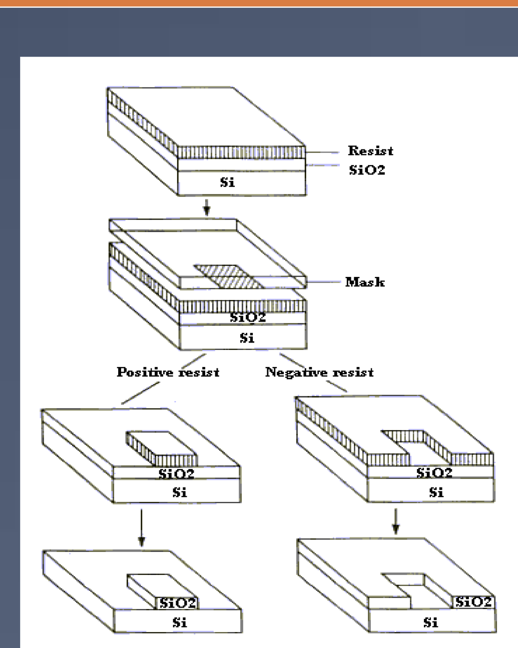

Figure1: Diagram of steps to positive and negative photoresist for photolithography [2]

Existing Technology

- Photomask Aligners
  - Karl Suss MA-6 Mask Aligner
    - Accuracy ~ 0.5 microns
    - Expensive ($30,000 used)
  - Microscope assisted aligning (Dr. Justin Williams' method)
    - Utilizes former microscope stage
    - Accuracy ~ 50-200 microns
  - Manual alignment by eye (Dr. John Puccinelli's method)
    - Aligned manually (naked eye)
    - Accuracy ~200-300 microns

Figure 1: Karl Suss MA-6 used mask aligner [3]

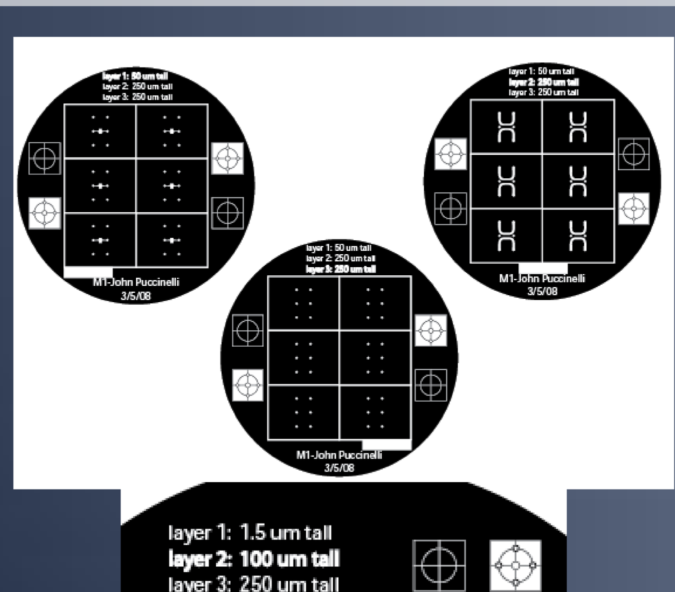

Figure 2: Photomasks used for manual alignment by eye with alignment marks [4]

Figure 3: Microscope assisted aligner

Design Requirements

- Create a photomask aligner that is:
  - accurate between 10µm and 100µm
  - less than $200 to fabricate
  - relatively simple to use
  - reproducible by other labs

Prototype

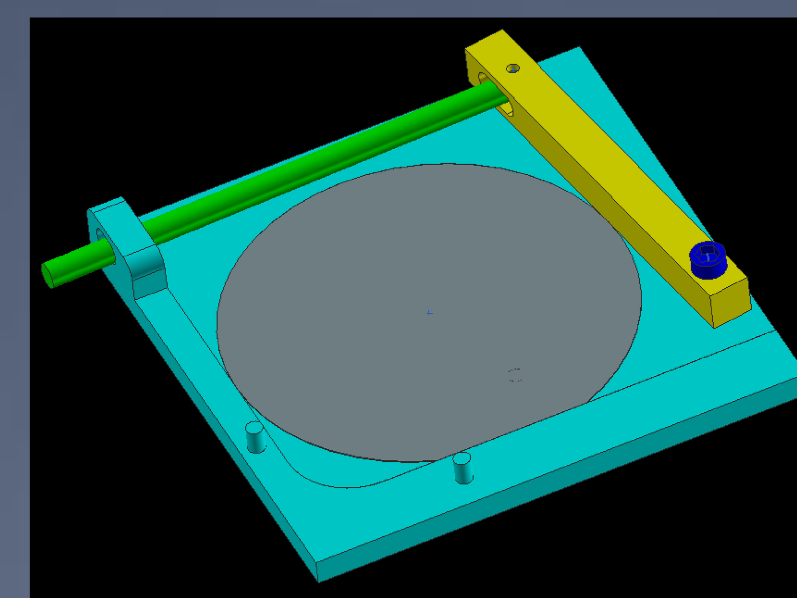

Figure 4: Unigraphics NX 7.5 assembly of all parts with 6in. wafer (shown in gray) in correct placement

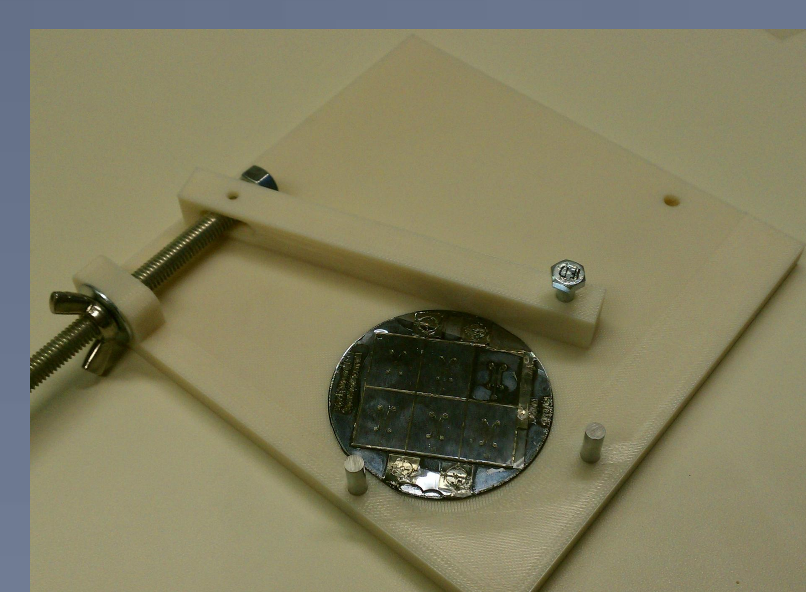

Figure 5: Initial prototype made with rapid prototype assembly as well as store-bought hardware

Design:
- Compatible with both 3in and 6in wafer sizes
- Light-weight and easily transportable
- Simple to use and change between 3in and 6in settings
- All alignment is done without microscopes or digital technology
- Plastic/Metallic finish allows for easy cleaning when conducting photolithography
- Photomasks are to be cut with laser cutter to fit onto alignment rods
  - Corel draw is used to generate cut template
- In prototype:
  - Base and wafer lock bar were made using rapid prototyping
  - Alignment rods, and other components are modified standard hardware

Specifications:
- Overall size of assembly is 7.5in x 7.5in x 1.0in
- Overall weight of assembly is 1.76lb (well below max weight of 10lb)

Cost Analysis

Table 1: Specific costs of materials used for the fabrication of the initial prototype

Item	Cost
Rapid Prototyped Assembly	$152
Parts from Hardware store	$6.47
TOTAL	$158.47
Budget	$200

Testing

Laser Cutter Machine Testing

Method:
- Used a 40 Watt Epson Laser Cutter in BME Teaching Lab to determine "best" settings for cutting of plastic transparency
- Checked for alignment accuracy of cutting platform
- Tested two separate "photomask-like" transparencies to determine accuracy of two "layers"

Results:
- 50% speed and 20% power determined to have least amount of variance
- Variance was approximately 0.1% off square when testing for alignment of cutting platform
- "Two photomask layers test" yielded a difference of 180µm
- Determined ideal size with laser cutter to be 0.235in with center spacing of 3.009in between alignment pins

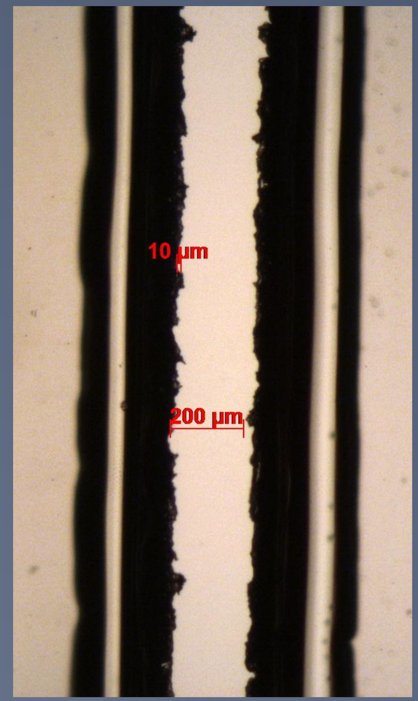

Figure 6: Settings at 50%speed and 20% power determined to have least amount of variance

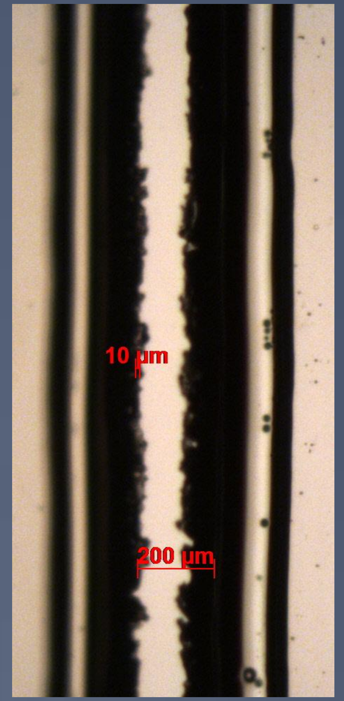

Figure 7: Settings at 50%speed and 10% power determined to have least amount of variance

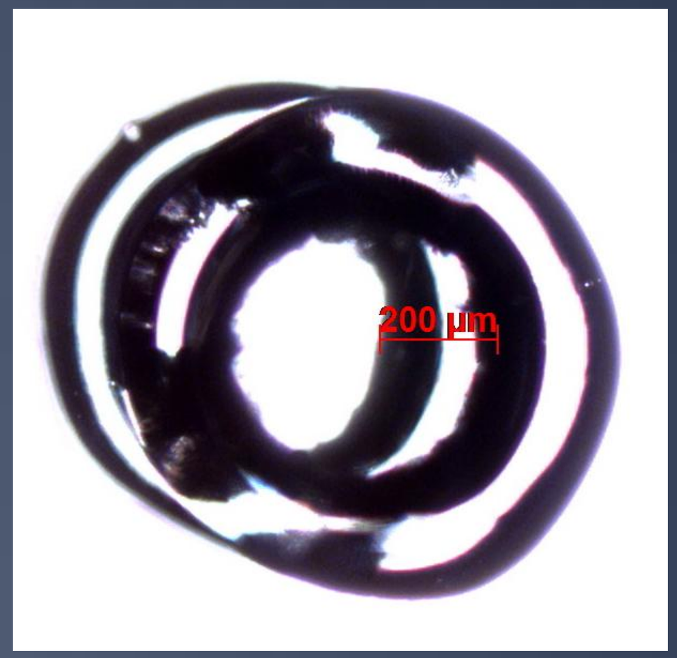

Figure 8: Results from the "two photomask layers test"

Future Work

- Adjust current prototype for better performance (increase wafer lip depth)
- Testing
  - Confirm initial accuracy from "two photomask layer test"
  - Acquire alignment accuracy (testing with 2 and 3 layers)
  - Comparative analysis to current alignment techniques
- Streamline production of aligner to use most efficient and cost-effective materials and process
- Consider alternatives to produce aligner without use of laser cutting or rapid prototyping
- Do-it-yourself manual for construction and use of low-cost aligner

Acknowledgements/References

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- Justin Williams, PhD, Associate Professor BME (BioMEMS instructor)

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