BIOMEMS PHOTOMASK ALIGNER

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Abstract

Microelectromechanical Systems (MEMS) are devices with components generally measuring less than 100µm which 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 underlying layer. 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 low-cost materials with simple machining in addition to modification of standard hardware. The design uses a simple wafer locking method by applying tension to a lock bar which is compatible with 3in and 6in wafers. Alignment holes are cut into the photomask transparency using a laser cutter. Testing of the prototype found achieved accuracy of 238.2 ± 10.55µm (n=5) for the alignment technique.

Background

Motivation

- Biological MicroElectroMechanical Systems (BioMEMS)
  - The science of very small biomedical devices
  - 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[2]
- 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 10-200µm

Existing Technology

- Photomask Aligners
  - Market-available aligners
    - Karl Suss MA-6 Mask Aligner[3]
      - Accuracy ~ 0.5 microns
      - Expensive ($30,000, used)
  - Microscope assisted aligning (Dr. Williams' method)
    - Uses former microscope stage (See Fig. 2)
    - Accuracy ~ 50-200 microns
  - Manual alignment by eye (Dr. Puccinelli's method)
    - Naked eye uses alignment marks (See Fig. 1)
    - Accuracy ~200-300 microns

Figure 1: Photomask alignment marks used for manual alignment by eye [4].

Figure 2: Microscope assisted aligner as seen in Professor Williams' photolithography lab.

Cost Analysis

Table 1: Projected costs of materials used for the fabrication of the final prototype (does not include tooling).

Item	Cost
100% Acrylic Cutting Board Base	$9.99
Hardware Supplies	$3.47
0.030" Delrin with 3M 300LSE Adhesive	$0 (exp. cost: $27.20 for 24"x48" sheet)
TOTAL	$13.46 ($40.66 if purchasing Delrin)

Design Requirements

Create a photomask aligner that is:

- less than $200 to fabricate
- accurate between 10µm and 100µm
- relatively simple to use
- reproducible by other labs
- intended for teaching purposes

Prototype

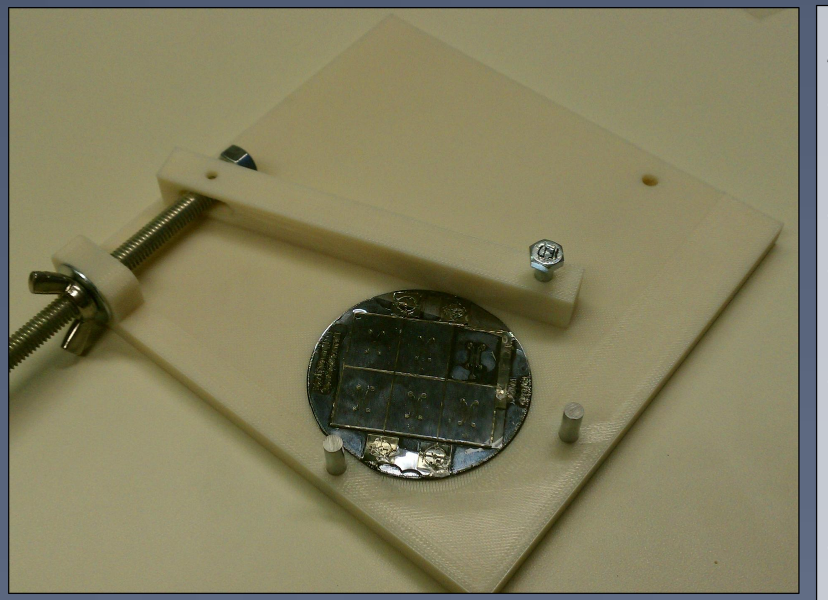

Figure 3: Initial prototype made via rapid prototype assembly as well as modified hardware. The threaded lock bar shown constrains the locked 3in. wafer.

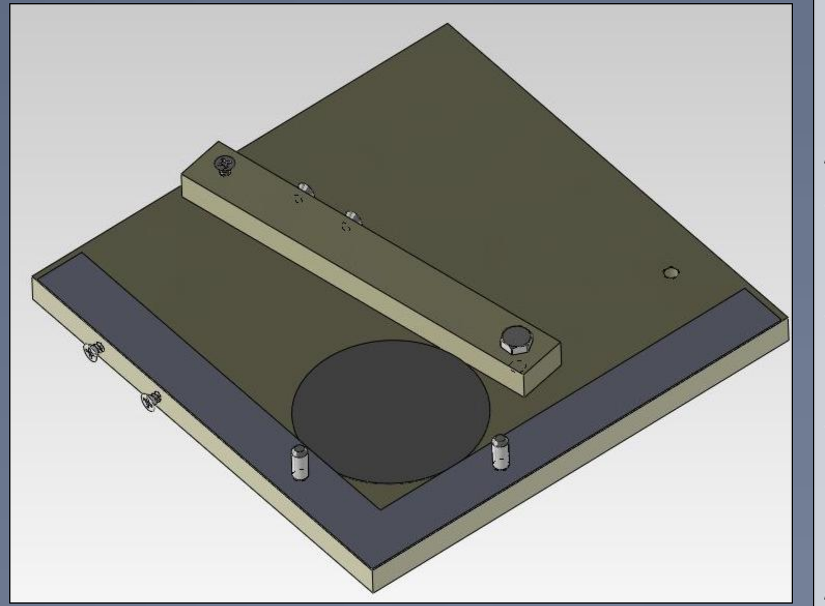

Figure 4: CAD assembly model of all parts with 3in. wafer (shown in gray) in locked position. Note: tension band not shown.

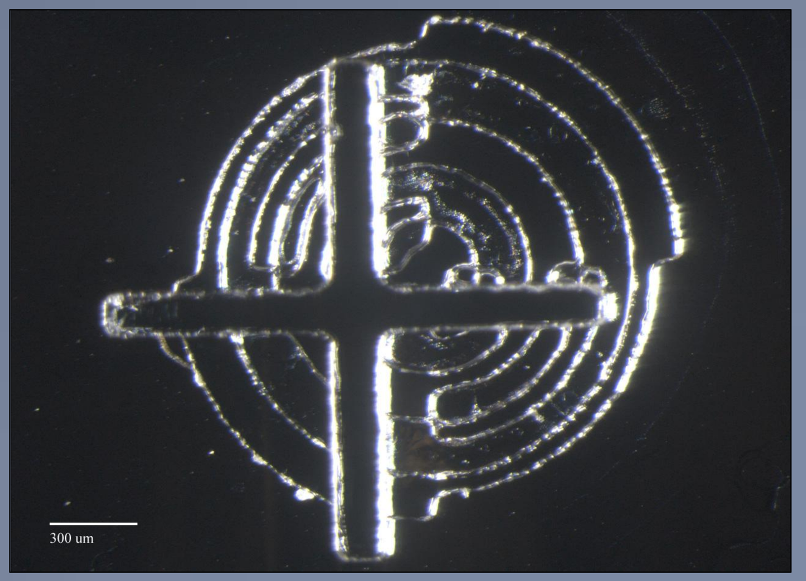

Figure 5: Image obtained from stereo microscope showing 2nd layer crosshairs on 1st layer target used to evaluate accuracy of prototype.

Design

- Compatible with both 3in and 6in wafer sizes
- Light-weight and easily transportable
- Simple to change between 3in and 6in prototype setup
- Entire alignment process is done without microscopes or digital technology
- Material finish allows for easy cleaning when conducting photolithography
- Photomasks are cut with laser cutter to fit over alignment rods
- CorelDRAW® is used to generate cut template

Initial prototype (Fig. 3)

- Base and wafer lock bar were made using rapid prototyping
- Alignment rods and other components are modified standard hardware
- Lock method = threaded rod and wing nut (no loading control)

Final prototype (Fig. 4)

- Base and wafer lock bar made from 100% acrylic cutting board
- Modular lip is 0.030in Delrin
- Alignment rods and other components are modified standard hardware
- Taper added to alignment rods
- Lock method = rubber band-adjustable tension (loading control)

Two Layer Alignment Results

Method:

- Used a stereo microscope to take photographs of the master wafer

Results:

- With master wafer, accuracy was 238.2 ± 10.55µm (n=5) (see Fig. 5)

Future Work

- Advance techniques to further improve accuracy
- Develop hole cutting method that does not require use of a laser cutter
- Implement aligner in BME teaching lab and courses

Testing

Laser Cutter Machine Testing

Method:

- Used a 40 Watt Epson Laser Cutter in BME Teaching Lab to determine "best" settings for cutting of transparency
- Checked for alignment accuracy of cutting platform

Results:

- 50% speed and 20% power showed least amount of variance (Fig. 6)
- Variance was approximately 0.1% off square when testing for alignment of cutting platform
- Determined ideal hole size setting with laser cutter to be 0.230in with center spacing of 2.800in between alignment hole centers

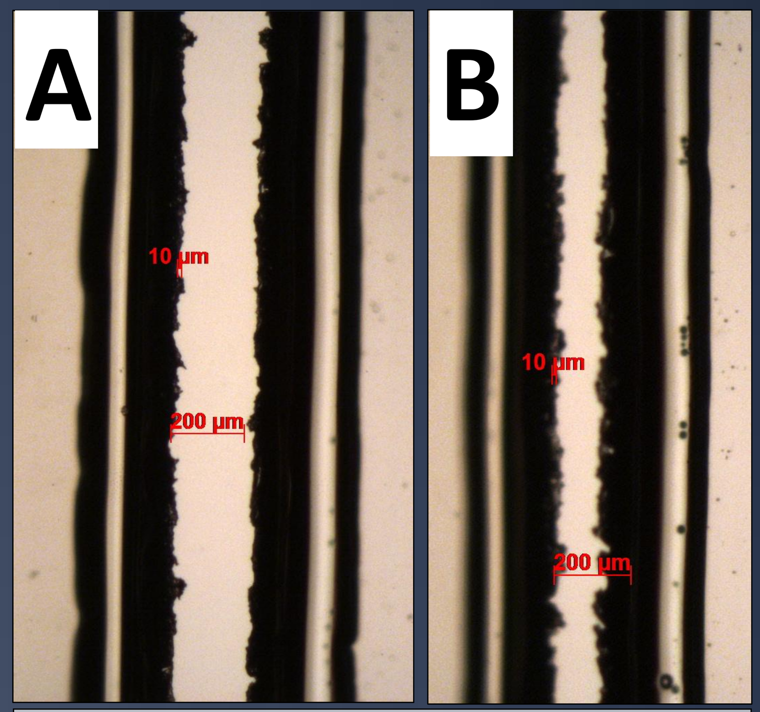

Figure 6: Transparency laser cuts with settings at (A) 50% speed/20% power (B) 50% speed/10% power. (A) shows optimal settings to reduce cut variance.

Alignment Hole Wear Testing

Method:

- Tested repeated use of mask by placing mask over tapered alignment pins 5, 25 and 100 times

Results:

- Minimal wear seen after 100 uses (see Fig. 8)

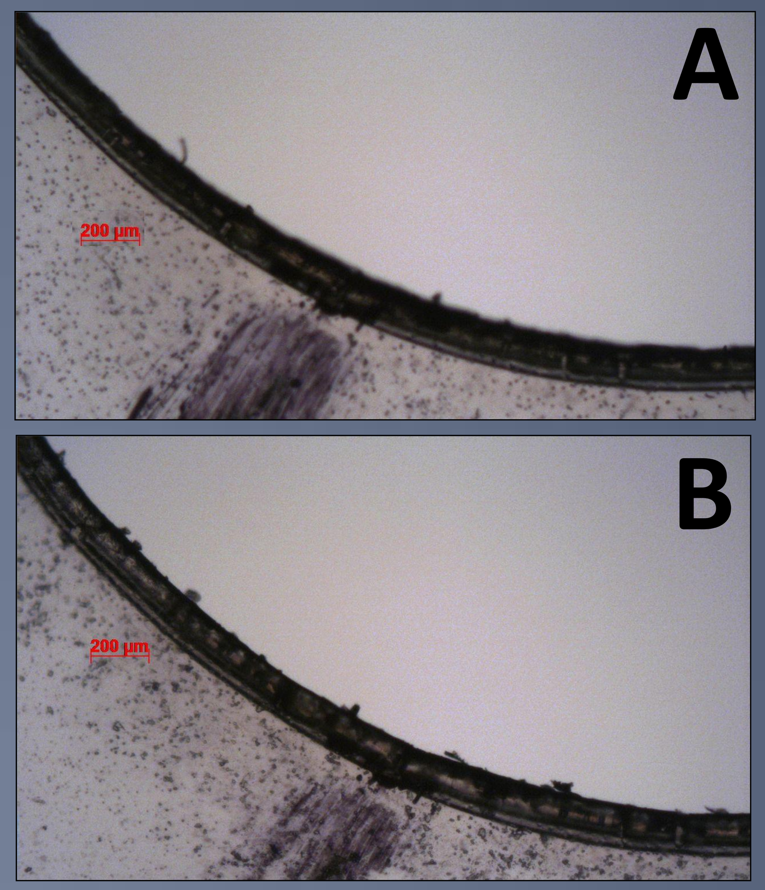

Figure 8: (A) Microscopic image of photomask alignment hole before use. (B) Microscopic image of same alignment hole after placement over rods 100 times.

Rubber Band Spring Constant Testing

Method:

- Calculated spring constant of rubber band to ensure the rubber band force would never snap silicon wafer (k=21.556 N/m)

Results:

- Safety factor range of 23.33 to 1290.32 depending on Si data used (Fig. 7 and stress SF calculations)
- For 3" wafer, max rubber band stretch is 18.4cm which applies 3.06N

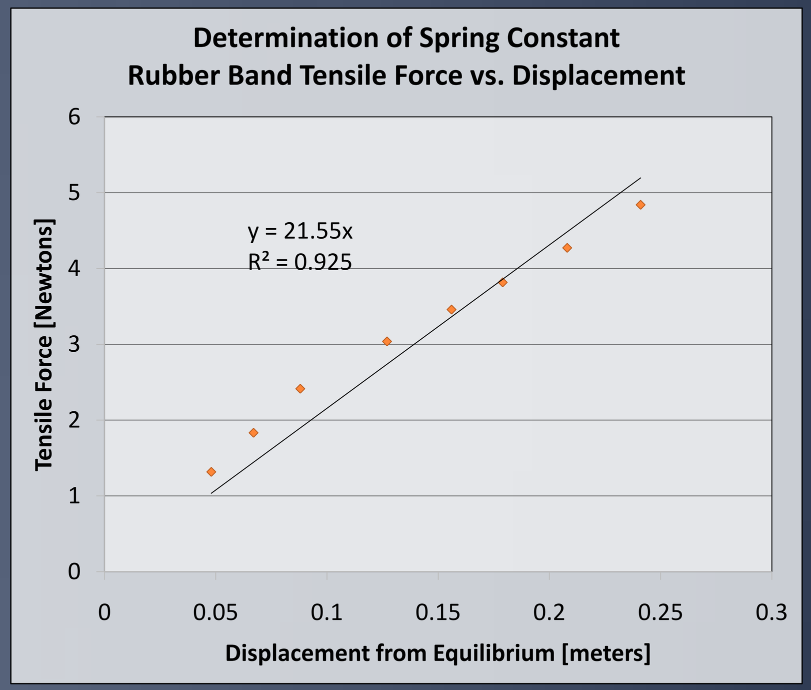

Figure 7: Derivation of the tension band spring constant testing.

$$SF = \frac{\sigma_{ult}}{\frac{F}{A}}$$

A=area of lock bar contact [9.677×10^{-9} m^2]
σ_{ult}=Si wafer fracture limit for 0.015in thickness [400 Mpa] [5]
F=max compressive force from band [3 N]
SF= Safety factor [1290.32]

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