Design of Methods and Fabrication of MEMS Endoscope
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ABSTRACT
Micro-Electro-Mechanical Systems (MEMS) will play a major role in the future of surgery. An important area of research, and a primary use of MEMS probes, is MEMS endoscopy. The microfabrication of scanning mirrors and actuators in these probes is being used to fabricate a narrow 2mm diameter endoscope. An endoscope of this size allows improved navigability, cost effectiveness, and, more importantly, early detection of precancerous and cancerous conditions of the pancreatic duct and common bile duct. An important property of this particular MEMS endoscope is that it is forward-facing, allowing for a more natural field of vision for the surgeon.

OBJECTIVE
The objective of the research work was to design and engineer the MEMS endoscope with all of its functioning components.

MATERIALS AND METHODS
KOH Etching the Chip:
Etching creates a groove for the future placement of the optic fiber.
1. Heat KOH in beaker to 70°C.
2. Submerge apparatus in KOH.
3. Seal beaker with foil.
4. Insert thermometer.
5. Monitor temperature and etch for ~20 hours.

Sawing the Chip:
Slicing is necessary to isolate the subchips of interest.
1. Hot glue whole chip to microscope slide.
2. Load microscope slide into micrometer arm with rubber band to apply consistent force.
3. Use vernier scale of micrometer to precisely measure distances for sawing.
4. Turn saw on and slowly lower blade.
5. Saw for ~1 hour, then measure chip.
6. After sawing is complete, use heat to separate the subchips from the microscope slide.

Sandblasting the Chip:
The chip’s V-groove must be thinned in order to properly accommodate the optic fiber.
1. Hot glue subchip to microscope slide.
2. Load microscope slide into micrometer arm with rubber band to apply consistent force.
3. Use vernier scale of micrometer to precisely measure distances for sawing.
4. Turn saw on and slowly lower blade.
5. Saw for ~1 hour, then measure chip.
6. After sawing is complete, use heat to separate the subchips from the microscope slide.

Relieving the Mirror with HF:
HF dissolves the oxidized layer over the mirror allowing for operation.
1. Clean chip in acetone.
2. Place chip in curved apparatus and secure with rubber bands.
3. Submerge chip in HF for 25 minutes.
4. Extract chip and place in CO₂ dryer to remove stiction.

RESULTS
KOH Etch Design
<table>
<thead>
<tr>
<th>Materials</th>
<th>Fieldman Design</th>
<th>Outcome</th>
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</thead>
<tbody>
<tr>
<td>PVC Knockout Plug</td>
<td>Floats / Warped at 70°C.</td>
<td></td>
</tr>
<tr>
<td>Rubber Gasket &amp; Vaseline</td>
<td>KOH dissolves Vaseline.</td>
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<tr>
<td>Clear PVC</td>
<td>Warped at 70°C.</td>
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DESIGN OF KOH ETCHING APPARATUS
Clear PVC was chosen as the material to use for the KOH etch apparatus. It allowed a clear view of the patterned side of the chip while etching, as well as the mirror arm break and indentation.

CONCLUSIONS
The most efficient and durable design for a KOH etch apparatus is the clear PVC. To make further progress, more work needs to be done with the Teflon wrapped PVC. This design provides the most resistance to mirror indentation into the PVC. A more efficient design must be developed to conclude the optimal amount of time necessary for the chip to be submerged in HF to produce a successful mirror release. Efforts to resolve these issues are ongoing.

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