DEVELOPING A MOTORIZED ANGULAR ADJUSTMENT HEAD FOR A MECHANICAL POLISHING SYSTEM

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Background

PROBLEM STATEMENT

IOActive is a cybersecurity firm with one team focused on chip security. Analysis of chip structure requires delayering the integrated circuit via mechanical polishing to access circuitry and logic directly. These layers are extremely thin (~5µm) requiring high precision angular adjustments to avoid damaging the circuitry.

This process is currently done with a small handheld jig that takes time to learn how to use proficiently. The goal for our project is to design and fabricate a motorized polishing head that can be integrated into IOActive's Allied High Tech MULTIPREP polishing system and is controlled electronically via a companion GUI to increase reliability and accuracy while shortening training time for new employees.

Future goals include Implementing a touchdown sensor and imaging system to create an almost fully autonomous polishing process.

Design Criteria

Criteria	Metrics
Goniometer	
Force Requirements	• Must be able to withstand a load of 600 grams
Angular Performance	• Angular Adjustment increments must be within 0.003° • Repeatability within 0.003°
Control System	• Must be able to be integrated within GUI for automated use.
Size	• Full System should be no bigger than 6 in. in width or length (within current system's footprint) • No taller than 4 in.
Weight	• Ideally no heavier than current system in place
Cost	• Sponsor has allocated $16,000 for the entirety of the project
GUI Functionality	
	• Intuitive use, little to no instruction needed • Numerical inputs preferred, down to 0.003 increments • Windows based, to integrate within existing software

Methods

GONIOMETER SELECTION

- 10 Goniometers examined
- 3 Final Contenders

ZABER X-GSM-40/60 –E

PROs
- Cheaper than other stages
- Full API Library to draw from with GUI as well
- Readily- Available CAD Models
- Designed for stacking

CONs
- Poorer repeatability in comparison

SMARACT CGO-60.5/77.5

PROs
- Small Size/Weight (140 g)
- High Resolution (<1 µ°)
- High Repeatability (±100 µ°)

CONs
- Maximum Normal Force (5 N)
- Expensive

PI WT-85/100

PROs
- High Repeatability (±69.8µ°)
- High Resolution (2.11 µ°)
- High Normal Force capabilities

CONs
- Not available for purchase

- Chosen Goniometers: Zaber X-GSM-40/60-E

With goniometer selected, design of integration into existing polishing system followed.

Design

LOWER FIXTURE

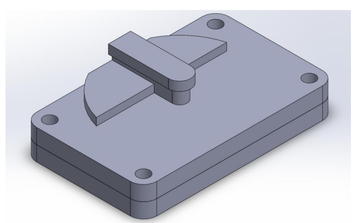

Figure 1. Lower mating fixture that attaches to the goniometer stage. Bottom plates secures to goniometer stages with screws and top plate mates with a metal polishing fixture.

A lower fixture was designed to attach a preexisting polishing fixture to the goniometer stages. The extrusion the polishing fixture mates to was dimensioned in way that allows the polishing fixture to disconnect with moderate effort while maintaining the rigidity of the fixture during polishing.

UPPER FIXTURE

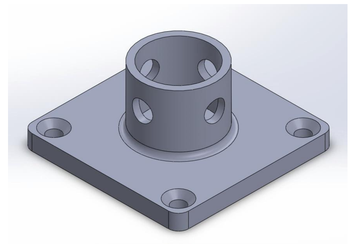

Figure 2. Upper mating fixture that attaches the angular adjustment head to the existing polishing machine.

The upper mating fixture attaches the entire customized adjustment head to the existing polishing machine. This fixture must support the combined weight of the goniometers and the lower fixture while maintaining stability to ensure precise polishing.

GUI DESIGN

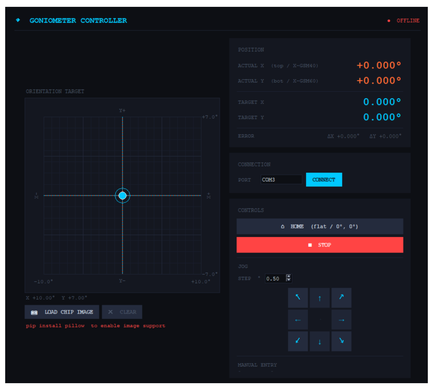

Figure 3. The GUI for goniometer control following Client feedback. To control stages, either the set of axes or the adjustable-step, 8-directional jog arrows in the bottom right can be utilized.

The GUI was coded within python for integration within the client's systems, with numerical and step inputs possible. The Home button serves to reset both stages to the parallel position, and the axes are clickable to immediately go to a set location. The top right has the present tilt of both stages, with error values present as well, although the precision of the stages is high enough that error is usually undetected. Chip images can be uploaded as backgrounds to the axes to best see the next polishing angle.

Final Assembly

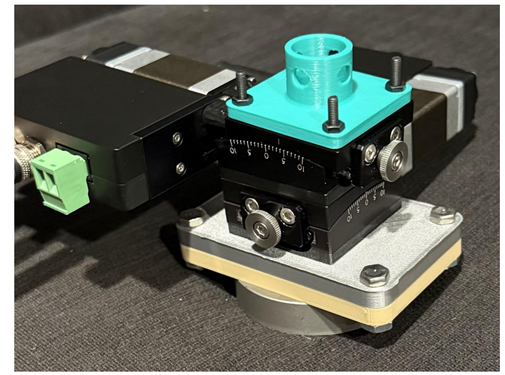

Figure 4. Final Assembly of the Motorized Angular Adjustment Head

Conclusion

- Motorized angular adjustment head was assembled and tested, well within the $16,000 sponsor budget plus $2,000 from MSE Dept.
- Zaber X-GSM40/60-E03 stacked goniometers hit all major targets: ±0.003° angular precision, 600 g force capacity, and fit within the size and weight constraints
- Mating fixtures were CAD-modeled, 3D printed, assembled, and tested, before finally being milled in aluminum to make the stacked goniometer setup work in practice
- GUI is functional and meets the control requirements
- Touchdown sensing fell outside our timeline, but everything built here sets up a future team to take it the rest of the way
- Future improvements could also include integrating an imaging system, allowing the operator to view the layer being polished away in real time, and adjust accordingly

Acknowledgements

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