Characterization of XeF_2 Etching for Release of Piezoelectric Micro-Robots

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Abstract and Introduction:

Thin-film piezoelectric micro-robots could potentially help save human lives with their ability to do reconnaissance in hazardous places, or help avoid costly demolition processes during infrastructure maintenance by utilizing images provided from inconvenient and/or unreachable locations. In order to achieve these goals, there should be an optimized fabrication process for these micro-robots using microelectromechanical systems (MEMS) technology.

A critical fabrication step in MEMS technology is the safe release of these micro-robots using xenon difluoride (XeF_2) etching, which etches only silicon in an isotropic manner. Due to the nature of isotropic etching, the etching results depend on the amount and location of the silicon's open surface area. Micro-robots can also be designed with trenches such that XeF_2 gas flows through the trenches and undercuts piezoelectric actuators, allowing free movement. Thus, the geometry and location of the trenches is important to successfully release micro-robots.

In this work, XeF_2 etching of several piezoelectric micro-robot designs have been characterized, which can be used to modify the design of the micro-robots for a faster and safer release. Additionally, the etching of C_4F_8 polymer, which was deposited on the side wall of the trenches in deep reactive ion etching (DRIE), was characterized after the polymer was observed to protect silicon from being etched.

Experimental Procedure:

Characterization of Fluorocarbon Polymer. Polymer etching was tested using modules containing dummy micro-robotic devices fabricated from silicon oxide and gold. Images were taken of each module using the scanning electron microscope (SEM). Then, tape was placed on the module to prevent the fluorocarbon polymer from being deposited at certain locations. Next, a fluorocarbon polymer was deposited on the module. Afterword, the tape was removed confirming the polymers presence. Subsequently images were taken using the SEM to further verify the presence of the fluorocarbon polymer. The SEM also provided the thickness of the polymer where the tap was. Later the fluorocarbon polymer was removed using an oxygen based recipe. This recipe was then confirmed to remove the fluorocarbon polymer after SEM images showed no fluorocarbon polymer on the module.

Releasing Micro-Robotic Devices. XeF_2 etching was completed on silicon wafer modules containing between one and fifteen micro-robotic devices of various shapes. First, the module was mounted with the backside exposed on a six-inch silicon wafer with crystal bond. Then the sample was etched with reactive ion etching (RIE), removing the oxide layer. Next the module was etched using deep reactive ion etching (DRIE) process to etch away the silicon until there was visible etching on the module. Subsequently the module was removed from the silicon wafer and the photoresist (PR) material was removed from the module. The cleaned module was mounted with the topside exposed on a silicon wafer and then placed in the STS Pegasus to remove the residual Teflon® using the oxygen-based cleaning recipe. Later, the module was detached from the silicon wafer and cleaned. Thereafter the module was mounted with the backside exposed on a silicon wafer and the DRIE process was continued until the oxide layer was visible.

The wafer was then placed in hot water until the module released from the wafer. To prepare for XeF_2 etching, the module was placed on a glass slide and taped along the edges to prevent XeF_2 from etching the sidewalls of the module. The module was etched with XeF_2 until the sample was released from the wafer as it was designed to do. Finally the top side's protective oxide layer was removed from the module.

Results:

Two patterns were observed after completing the XeF_2 etching process on the modules. The first pattern was that micro-robotic devices designed with the same geometry would have similar etch rates and releasing times. This pattern emerged regardless of where the micro-robotic devices were located on the module. Some samples observed were located as far as 1000 microns from each other.

The second pattern demonstrated how the amount of time needed to release the micro-robotic devices was heavily dependent upon the geometry of the backside etching area. It was found that a greater etching area on the backside led to a significantly faster release of the micro-robot.

Conclusion and Future Works:

Through the releasing of different micro-robots, we were able to determine that the etch rate is dependent upon the number of micro-robotic devices on a module and the geometry of those devices. However, the most significant factor is the geometry of the backside etching area. Therefore, if a module has devices with different geometry and/or backside etching areas, they will be released at different times. This results in over-etching of the faster-releasing devices, making them unusable. Accordingly, we suggested alterations for the area of the backside etching on devices that have more geometric features, in order to reduce the etching time and release all of the micro-robotic devices at the same time. With these changes in place it would be possible to increase the yield of adequately released micro-robots.

In the future, the group would be able to test this theory with more fabricated micro-robotic devices using these design changes. Also the group would be able to characterize the micro-robotic devices to find the optimum design and integrate them in the final micro-robot.

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