Reliable Deep Silicon Etching for High Volume Production Applications

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The MEMS community has embraced the Bosch[1,2] process for deep silicon etching of three dimensional structures. This process utilizes an ICP source and a non-corrosive fluorine chemistry at room temperature to pattern high aspect ratio features. Typical process results include selectivity to photoresist of >75:1, selectivity to silicon dioxide of >150:1, and etch rates of up to 3 um/min.. High aspect ratio features (>100:1) have been demonstrated as a result of this technique, which include through wafer processes.

There is currently a complete list of publications that show how this process can be used to fabricate an endless number of MEMS devices. To supplement this, a study regarding the repeatability and reliability of this process is currently being undertaken by Plasma-Therm and one if it's customers. This study is designed to investigate the individual process parameter repeatability over a large number of runs. Data analysis will be made in the form of SQC plots, which are commonly used for process control in large manufacturing operations.

To obtain the data, a standard silicon etch process was chosen. Parameters were selected which represent typical processing conditions used by our numerous customers. These were then fixed and routinely repeated on a silicon etch system at fixed intervals. Information was collected on etch rate and selectivity values, which are both easily measured and known to be important results.

Although the study is still in process, results from the first eight months of data collection are presented in Figures 1-4. The first two graphs plot etch rate vs. time and the last two figures are for Si:PR etch rate selectivity. Data is included for both 2.0 and 100.0 um spaces, since these two different size features are frequently used on MEMS devices. Lastly, means and control limits are plotted using methods commonly employed in the development of SQC charts. The authors realize that there are not enough data points for rigorous statistical analysis, however by implementing these methods on the initial data, trends are easily observed.

The data from Figures 1 and 2 clearly show an in control situation. Although the data point in month 7 is out of the statistical limits, an assignable cause was found and quickly corrected. Once this issue was resolved and the chamber conditioned, the dependent variables were quickly brought back to acceptable values.

Reviewing the selectivity data in Figures 3 and 4, it is clear that these parameters are well understood and controllable. It is interesting to note that although the component issue observed in month 7 did not adversely affect selectivity to photoresist, it’s presence is observed in the data to a lesser extent. Again, process robustness and repeatability are clearly observed.

Based upon the above, it can be concluded that the Bosch deep silicon etch process is repeatable and controllable for high volume production applications. Repeatability data over 8 months of run time has demonstrated this, with assignable causes being identified for out of control situations. Work in this area is expected to continue, with the goals of future efforts being to further understand the etch process and continually reduce the range of the control limits.

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[1] N. MacDonald, “SCREAM MicroElectroMechanical Systems”, *Microelectronic Engineering*, No. 32, 1996, p. 49.

[2] F. Laermer, et. al., “Method of Anisotropically Etching Silicon”, US Patent #5,501,893, March 26, 1996.