International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-3, Issue-6)

Research Article

June
2014

Experimental investigation and optimization of etching process parameters for machining of glass

Manish Chopra[1], Charanjit Singh Kalra[2], and Gurdeep Singh Deol[3]
[1]*M-Tech Student, SUSCET, Tangori, Mohali, Punjab*
[2]*Assistant Professor, SUSCET, Tangori, Mohali, Punjab*
[3]*Assistant Professor, SUSCET, Tangori, Mohali, Punjab*

Abstract-

Glass is become more prevalent in recent years due to their high brittle and optically transparent properties. Glass is used for architecture application, illumination, electrical transmission, instruments for scientific research, optical instruments, domestic tools and even textiles. The classical processing of glass includes drilling with diamond bits, ultrasonic drilling, powder blasting and laser machining. However, they tend to generate micro cracks on surface, poor surface roughness and generation of taper effect. Laser and plasma technique are costly and produce the thermal cracks. Wet etching is one of the most commonly and easiest ways for machining of glass and any shape is to be machined. In this paper, study the wet etching of glass by using hydro fluoric acid (HF) as an etchant. The highest material removal rate is noted at 20% wt of HF, 80^{0}C temperature, and 15 min time. Also, these tests indicated that the etching rate is highest in the first 15 minutes, and after that it decreases with exposure time. MRR is increased by increasing percentage of HF up to a certain limit after that MRR is decreased due to formation of hydrogen bubbles. MRR is increased by increasing the temperature, due to at higher temperature erosion rate is increase. MRR is decreased by increasing exposure time because erosion action is occurred in initial stage after those only gases are generated. For higher MRR, the optimum parameters for etching are 20% concentration of HF, 80^{0}C temperatures and 15 min time.

Keywords: machining of glass, wet etching, hydro fluoric acid, etchant rate.

I. Introduction

Glass is become more prevalent in recent years due to their high brittle and optically transparent properties. Glass is used for architecture application, illumination, electrical transmission, instruments for scientific research, high electrical insulation, optical instruments, domestic tools, MEMS applications and even textiles as explained by E. Belloy et al. (2000) and J. Chae et al. (2002).

The classical processing of glass includes drilling with diamond bits, ultrasonic drilling, powder blasting and laser machining. These methods are commonly used for performing holes through the glass wafers. However, they tend to generate a rough surface. If generation of hole by conventional machining i.e. drilling, there are generation of micro cracks on surface of glass due to its brittleness and diamond bits are too much costly. If use the ultrasonic drilling, then there are poor surface roughness and generation of taper effect. Powder blasting is produces rough surface. Laser and plasma technique are costly and produce the thermal cracks. Wet etching is one of the most commonly and easiest ways for machining of glass and any shape is to be machined.

Wet etching is used mainly for cleaning, shaping, polishing and characterizing structural and compositional features. Hydro fluoric acid (HF) an anisotropic etchant, has many advantages, such as high selectivity to thermal oxide, very smooth etching surface.

Minqiang Bu et al. (2004) reported a new masking technology for wet etching of glass, to a depth of more than 300µm. R. Bhandari et al. (2010) presented a wafer-scale etching method for the UEA. The method offers several advantages, such as substantial reduction in the processing time, higher throughput and lower cost. More importantly, the method increases the geometrical uniformity from electrode to electrode within an array (1.5±0.5% non-uniformity), and from array to array within a wafer (2±0.3% non-uniformity). T. S. Kavetskyy et al. (2013) was subjected to a low energy implantation with 40-keV Cu^+ ions at a dose of 7.5 $\times 10^{16}$ ions/cm^2 and an ionbeam current density of 5 µA/cm^2 through a surface metal wire mask with square holes of ~40 µm on Silica glass.

II. Experimental Work

Cleaning - For removing the dust particles, corrosions and other foreign particles firstly the work piece are cleaned with solvents to insure uniform etching. Specimens are cleaned by acetone. Masking - a maskant (resist, chemically resistant to etchant) is applied to portions of work surface not to be etched. Maskants are generally used to protect parts of the workpiece where chemical dissolution action is not needed. Polymer is used as mask material. Patterning of maskant or Coated and the image of the part is imprinted. Patterning is performed with micro cutting of polymer mask materials on

3D printer. Spray etched to dissolve the unprotected areas or part is immersed in etchant which chemically attacks those portions of work surface that are not masked. However in this case the etching conditions were modulated with time, temperature and concentrations of etchant. It was possible to controllably modulate the etching rate and undercut depth. The mask is removed before the part is finished and leaves the finished part after cleaning of chemical.

Fig1: Process of Chemical Etching

The weight loss experiment was carried out on glass in HF (Hydro Fluoride) solutions with different concentration, different temperature and for different time intervals based on Taguchi design of experiments showing in table below. The weight loss at each interval was determined with the help of electronic balance after drying each specimen. Initial weight of specimen was measured prior to these experimentations.

Table 1: Parameters and their levels for etching

S.No	Input Parameters	Levels		
		1	2	3
1	Concentration (wt %)	10	20	30
2	Temperature (^{0}C)	30	50	80
3	Time (hr)	15	30	45

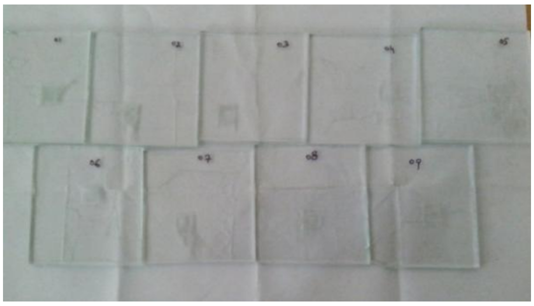


Fig 2: Glass after Machining

III. Results and Discussion

After all the measurements of weight loss and calculations of material removal rate (MRR), it is required to study the effect of different etching parameters for machining of glass.

s**Fig 3: S/N Ratios Graph for MRR**

Fig. 3 exhibits Signal to Noise (S/N) response graph for MRR. It has been observed that the S/N ratio of MRR is increases with increase of concentration of HF. S/N ratio of MRR is sharply raising with increasing temperature. S/N ratio of MRR is continuously decreased with increasing exposure time.

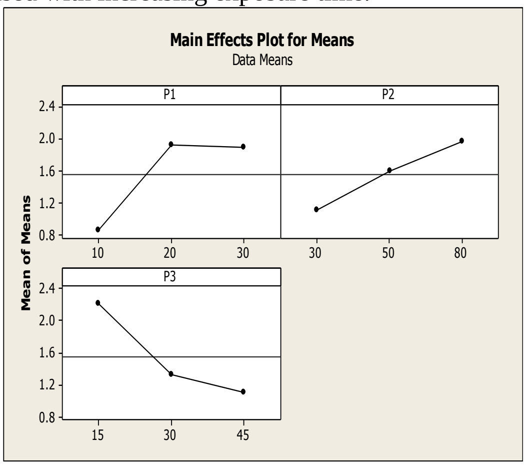
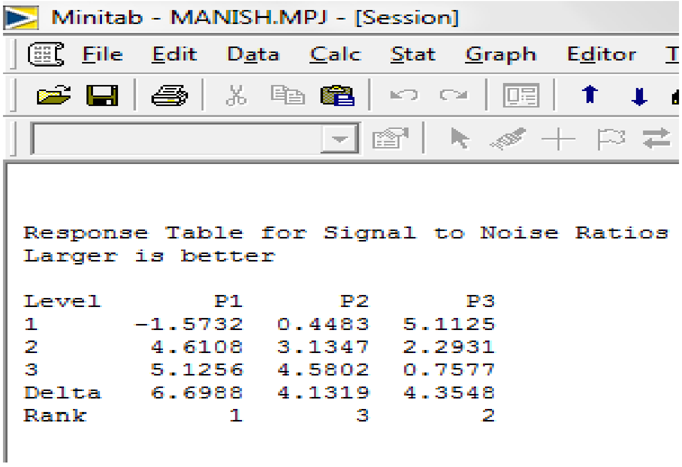


Fig 4: Mean value Graph for MRR

ISSN: 2278-9359 (Volume-3, Issue-6)

Fig 4, shows effect of various etching parameters on the mean of material removal rate plotted utilizing the machining results obtained etching of glass. From the figure, it is observed that the mean value of MRR is increase by increasing the concentration of HF from 10 to 20% and 20 to 30%. The mean of material removal rate rises constantly by increasing the value of temperature from 30 to 50^{0}C and 50 to 80^{0}C. The mean of MRR is decrease by increasing exposure time from 15 to 30 m, and from 30 to 45m.

It can be observed form Fig 5, that percentage of Concentration of HF has the largest effect on the MRR during machining of glass by etching. The temperature has the smallest effect on the MRR.



Response Table for Signal to Noise Ratios
Larger is better

Level	P1	P2	P3
1	-1.5732	0.4483	5.1125
2	4.6108	3.1347	2.2931
3	5.1256	4.5802	0.7577
Delta	6.6988	4.1319	4.3548
Rank	1	3	2

Fig 5: Ranking of Factors according to Effect of Factors for MRR

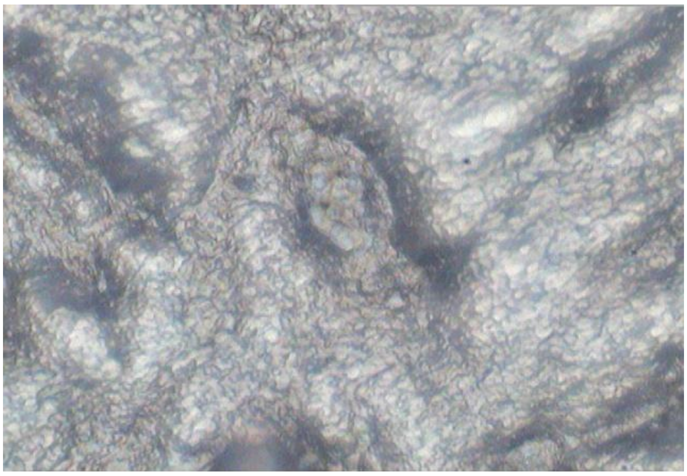


Fig 6: Micro surface structure of experiment no. 1

Figure 6 shows the micro surface structure after etching of glass at 10% concentration of Hydro Fluoride, temperature 30 ^{0}C, and time 15 min. It is observed that there are some pit on surface due to insufficient time for removes glass at this temperature and concentrations.

Figure 7 shows the micro surface structure after etching of glass at 30% concentration of Hydro Fluoride, temperature 30 ^{0}C, and time 45 min. It is observed that the micro surface structure is good because of providing proper time and temperature for etching at 20% concentration.

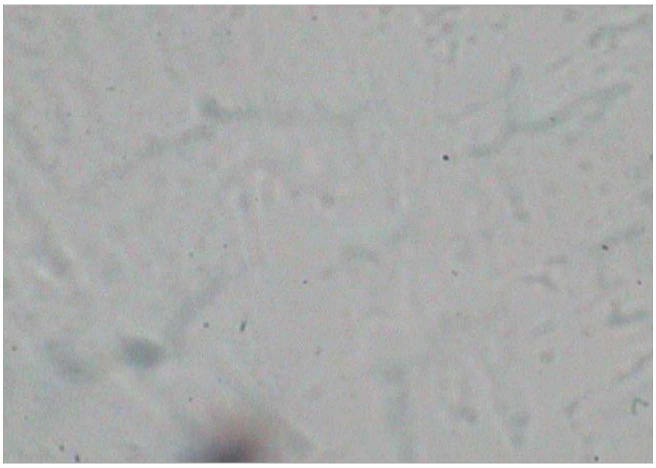


Fig 7: Micro surface structure of experiment no. 7

IV. Conclusions

- The highest material removal rate is noted at 20% wt of HF, 80^0C temperature, and 15 min time. Also, these tests indicated that the etching rate is highest in the first 15 minutes, and after that it decreases with exposure time.
- MRR is increased by increasing percentage of HF up to a certain limit after that MRR is decreased due to formation of hydrogen bubbles.
- MRR is increased by increasing the temperature, due to at higher temperature erosion rate is increase.
- MRR is decreased by increasing exposure time because erosion action is occurred in initial stage after those only gases are generated.
- For higher MRR, the optimum parameters for etching are 20% concentration of HF, 80^0C temperatures and 15 min time.

References

1. E. Belloy, S. Thurre, E. Walckiers, A. Sayah, and M.A.M. Gijs, “The introduction of powder blasting for sensor and microsystem applications”, Sens. Actuatators A, 84, 2000, 330–337.
2. J. Chae, H. Kulah, and K. Najafi, “A hybrid silicon-on-glass (SOG) lateral micro-accelerometer with CMOS readout circuitry”, Proceedings of 15th Annual International Conference on Micro Electro Mechanical Systems (MEMS), Las Vegas, 2002, 623–626.
3. Minqiang Bu, Tracy Melvin, Graham J. Ensell, James S. Wilkinson, and Alan G.R. Evans, “A new masking technology for deep glass etching and its microfluidic application”, Sensors and Actuators A, 115, 2004, 476–482.
4. R. Bhandari, S. Negi, L. Rieth, and F. Solzbacher, “A wafer-scale etching technique for high aspect ratio implantable MEMS structures”, Sensors and Actuators A, 162, 2010, 130–136.
5. T. S. Kavetskyy, M. F. Galyautdinov, V. F. Valeev, V. I. Nuzhdin, Yu. N. Osin, A. B. Evlyukhin, and A. L. Stepanov, “The Formation of Periodic Diffractive Plasmonic Nanostructures with Implanted Copper Nanoparticles by Local Ion Etching of Silica Glass”, Technical Physics Letters, 39, 2013, 591–593.

