WET CHEMICAL ETCHING FOR GLASS MICRO-MACHINING

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Abstract: *In this paper, wet etching of Pyrex Glass using different chemicals is presented. The advantages as well as disadvantages of each method are presented and discussed in light of the experiments. The etch rates of Glass in different dilutions of HF (Hydrofluoric Acid) and BHF (Buffered Hydrofluoric Acid) are reported. Different agitation techniques are applied during process and results are compared. The improvement in the etching uniformity is achieved by string the solution continuously during etching time. Etch rate of Glass in HF solution is much higher than BHF solution and can be controlled based on concentration. Samples are characterized using Universal Length Measurement (ULM) system and optical profiler.*

Keywords: *Wet Etching, MEMS, Glass, Etch Rate*

1. INTRODUCTION

In micro fabrication process, the etch rate of each material to be etched must be known. Due to the unique material properties of glass like its dielectric properties, transparency and mechanical robustness, the glass has been widely used for MEMS (Micro-electro-mechanical systems). Glass wafer/ substrate are mainly having the application in micro-fluidic device development.

The glass substrate can be boned to a silicon or glass substrate via the wafer bonding processes like Anodic bonding, Adhesive bonding or Fusion bonding based on application requirement. Glass can be bonded to Silicon wafer using anodic bonding process without any additional adhesive, whereas these bond seals show good hermetic vacuum and high bonding strength. However the precise micro-machining of glass is not easy and is less investigated. Glass etching is very important step for micro-system packaging and fabrication of MEMS devices.

The components of Pyrex glass consist of approximately 80.6% SiO_2, 4% Na_2O, 13.0% B_2O_3, and 2.3% Al_2O_3. Hence it is not pure SiO_2, but other compositions that have a different etch rate in the etching processes are added to it. Oxides, such as CaO, MgO or Al_2O_3 which give insoluble products in SiO2 etchants: These insoluble products are deposited on the generated surfaces and act as masking layers. As a result, the surface becomes rough and, in time, the etching rate decreases. In the composition of Corning 7740 the amount of insoluble products is only 2% (Al2O3). For this reason deep wet etching of glass is recommended to be performed on glasses with low concentration of oxides that give insoluble products in HF. Thus, low aspect ratio, low etching rate, limited mask selectivity, and high surface roughness are still current problems in glass micromachining.

Drilling, milling and laser techniques are used for glass micromachining when the patterns are large in size. Another technique which can be used for small features is sandblast technique but it leads to a rough etching surface and has difficulty in the fabrication of small patterns below 100 µm.

For feature sizes below 100 µm, mainly wet etching and dry etching techniques are applicable. The advantages of wet etching method are its simplicity, high etching rate, high mask selectivity, low surface roughness, etc. However, due to its isotropic etching behaviour, the aspect ratio is limited. The wet etching of deep glass etching can be achieved with smooth sidewalls. Wet etching is very cost effective as compare to dry etching.

The objective of this proposed work is to select the suitable etchant for a given application requirement based on etch rate, uniformity and surface finish.

2. EXPERIMENT DETAILS

Since glass contains SiO2, The chemical reaction of the glass in the HF Solution is as follows:

$SiO_2 + 4HF = SiF_4 + 2H_2O$

The wet etching process starts from a 500 µm thick bare glass substrate. The thickness of the glass wafer is measured using ULM before etching.

Firstly the etching of glass is performed in Buffered Hydrofluoric solution which is the mixture of NH4F and HF (49 %) in the ratio of 1:5. Different glass samples of approximately same thickness are etched out without any stirring, with magnetic stirring and with ultrasonic agitation using ultrasonic cleaner by keeping the etching time equal for all three methods. Since etching of Pyrex glass is performed without any mask material, the glass will be etched out from both sides. For calculating the etch rate, the thickness of etched glass is measured using again ULM system and compared with glass thickness before etching. Thicknesses of the glass pieces are measured on 8 locations to get the average etch rate and etch uniformity. The surface roughness is measured using Optical Profiler.

Glass etching is also performed in Hydrofluoric acid (HF) of different concentration with magnetic stirring for calculating the etch rate of glass and to analyse the effect of concentration variation of HF on etch rate.

3. RESULTS AND DISCUSSION

Etch rate for Pyrex glass in BHF solution has been found out and compared the results with magnetic stirring and ultrasonic bath process.

It can be observed from Table 1 that glass etch rate is highest in case of etching with ultrasonic agitation while etch quality is poor. However this method is not recommended to be use for safety reasons and the resistance of masking layer in the wet etchant will be reduced drastically. Magnetic String will give lesser etch rate as compare to etching with ultrasonic agitation but etch quality in terms of uniformity and surface finish is very good.

Table 1: Non-Uniformity and Etch Rate Comparison for BHF

Method	Etch rate (nm/min)	Non-Uniformity (in %)
Without Stirring	26.4	13.35
With Magnetic stirring	21.5	4.73
With Ultrasonic agitation	146.2	7.33

Table 2: Etch Rate Comparison for BHF and HF with Magnetic Stirring

With Magnetic Stirring	Etch rate (in nm/min)
HF 49%	9460.0
HF 30%	2015.0
HF 20%	1172.1
BHF	21.5

In Microsystems, Sometime there is a requirement of deep glass etching, Hence HF is preferred in place of BHF, because HF provides very high etch rate as compare to BHF. The etching uniformity is improved by doing magnetic stirring of HF during Process. Further the etch rate can be controlled by varying the concentration of HF as mentioned in Table2..

A trend graph based on results mentioned in table 1 for extrapolating the value of etch rate for a given HF concentration is shown in Figure1.

The etch rate for a given HF concentration can be calculated by following trend equation:

*Etch rate=0.251*exp(0.073*HF concentration);*

The experimental and calculated values of etch rate for a given HF concentration are compared and difference is within 12%.

In table 2, the etch rate and non-uniformity of

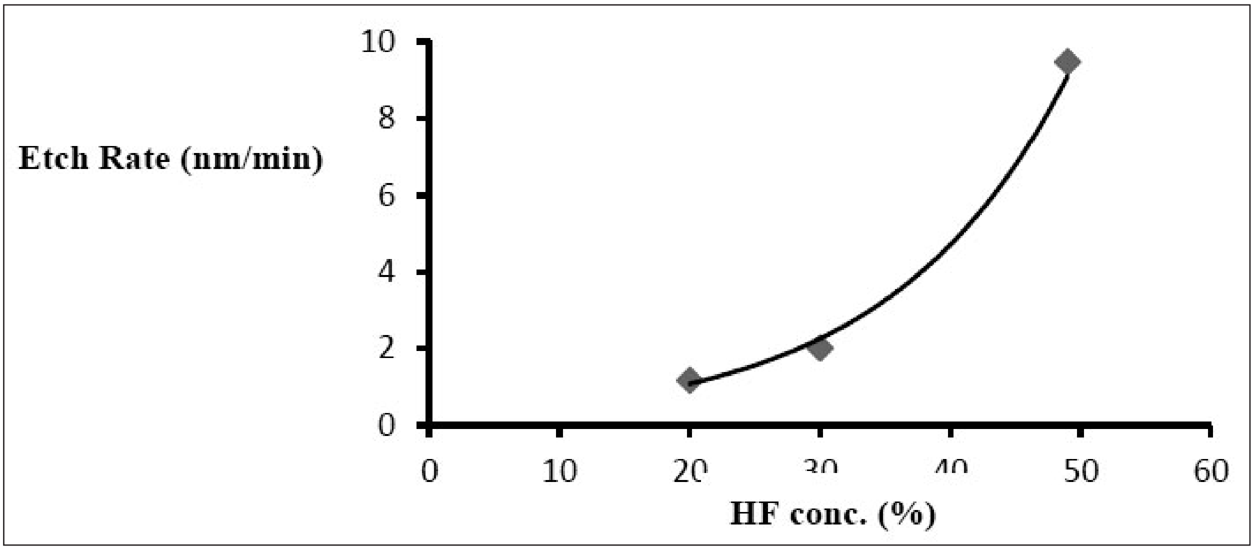

Fig 1. Effect of HF Concentration on Etch Rate for Glass

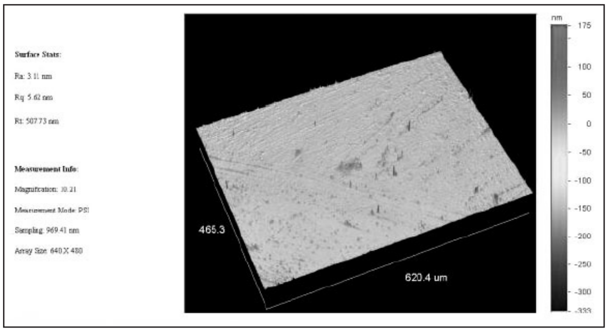

Fig 2. Surface Profile of Glass Sample Etched in BHF Solution

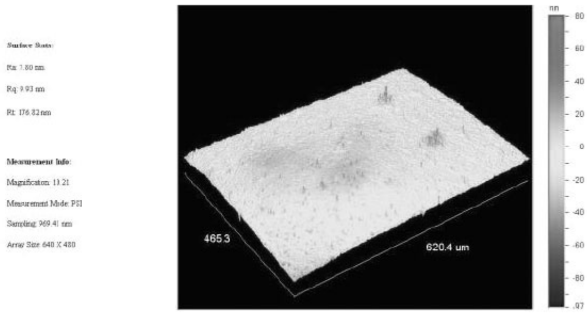

Fig 3. Surface Profile of Glass Sample Etched in HF (49%) Solution

glass in BHF and HF (with different concentration) are summarized. It can be observed from table 1 and 2 that surface roughness is more in case of HF in comparison to BHF. The surface roughness of etched glass in BHF and HF (49%) are 3.11nm and 7.80nm respectively as shown in the figure 2 and figure3, which have been measured using Optical profiler.

4. CONCLUSION

BHF can be used for glass etching with magnetic stirring for less etch rate and good surface finish requirement. Deep glass etching can be achieved by using HF, which provides significantly high etch rate as compare to BHF. The etch rate of glass in HF solution can be controlled by changing the concentration of HF.

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