

Figure 1: Schematic of TETRA-30

TETRA-30 operates in two different modes. In automatic mode, a program consists of different processes is created through process parameters. A program can be built by sub-programs and consists of upto 10 sub-programs. The program parameters can be saved. A sub-program consists of:-

- Pumping down
- Gas supply
- Plasma process
- Flushing period
- Venting period

Pumping down is used to create vacuum in the chamber and the maximum pumping down time is set. If this time exceeds, an error message is generated, entry in alarm list appears and display field of the switch is red. As soon as pumping down starts, display switch turns green. Gas supply input is made in sccm. Different MFC (mass flow controller) are connected to the system. Plasma process duration defines the duration for which plasma is created in the chamber. During this time dissociation, ionization, excitation all the processes take place. Plasma process time in hour, minutes, seconds is set. It also depends upon the material to be etched. For some material plasma process duration is kept in hours but for some it is kept even in minutes. The set power and maximum absolute deviation is entered. If the value exceeds, entry in alarm list appears. The minimum and maximum temperature must be entered. The process starts if the minimum temperature is reached. Flushing period is entered and during this time all the gases are flush out. Flushing time is set in minutes. Venting is done in order to set the chamber pressure equals to atmospheric pressure so that the door of chamber can easily be opened. Venting period should be chosen such that atmospheric pressure is reached in vessel and display field of switch turns yellow.

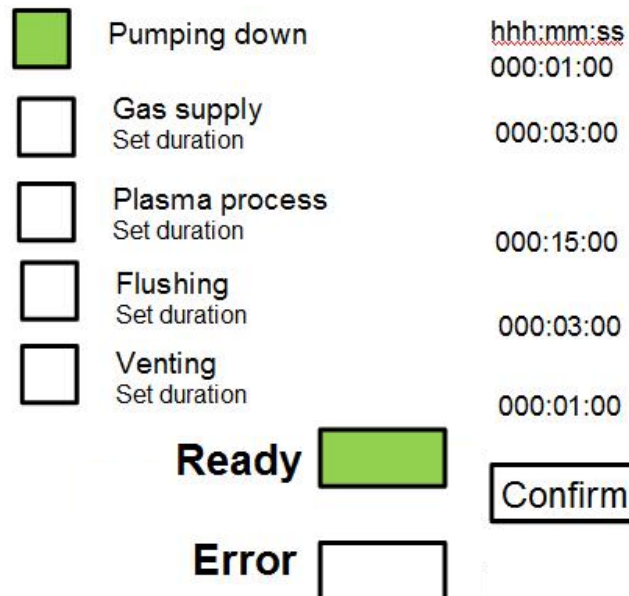


Figure 2: Sub program run in TETRA-30

2.1 Development of RIE processes for Si

<100> oriented, n type Si wafers were used as substrate and piranha cleaning was done. Positive photo-resist S-1818 was deposited using spin on method at 2000rpm, soft baking at 90°C. Photo resist of 2.8 μm thickness was deposited on wafer. Then the pattern was defined by UV exposure. The pattern was recovered using photo resist developer CD-26. After development, the wafer was hard baked in oven at 120°C. Then wafer was placed in tetra-30. Reactive ion etching at LF was done using suitable recipe.

The gases used for this purpose were SF₆ and O₂. Dry etching has been performed in TETRA-30. The etch rates were measured using Surface Profiler and Zeta. The etch rates were found to be dependent upon the power and pressure. Etch rates at two different pressure .15mbar, 0.1mbar were found 0.344μ/min and 0.304μ/min respectively.

2.2 Development of RIE processes for SiO₂

<111> oriented p-type wafers were used as substrate and piranha cleaning was done. PECVD oxide of .8micron was deposited. Positive photo-resist S-1818 of 2.8 micron thickness was deposited using spin on method at 2000 rpm rate. Soft baking at 90°C and a pattern was defined by UV exposure. Then pattern was recovered using photo resist developer CD-26. After development, the wafer was hard baked in oven at 120°C. Then wafer was placed in tetra-30. Reactive ion etching at LF was done using suitable recipe.

CF₄/O₂ gas mixture was used for this purpose. Different etch rates of 0.3.16μm/min at 0.1mbar and 0.23μm/min at 0.3 mbar were obtained. The etch rates were found dependent on pressure in side the chamber and power.

3. Results and Discussion

Different recipes were developed for different wafers. Nine wafers of silicon and nine wafers of silicon dioxide were

taken. On three wafers, same recipe was run. Then the recipe was changed. Then the modified recipe was run on other three wafers. In this way the different etch rates were obtained by changing the power and pressure. For first three samples, when the pressure is 0.5mbar then at different power i.e. 400W, 600W, 800W, different etch rates were obtained. Similarly same process was carried out for 0.1mbar and 0.15mbar pressure. But for silicon dioxide, for first three samples when the pressure is 0.1mbar and next three samples when pressure is 0.15mbar, the power is kept 400W, 500W, 600W but for last three samples when pressure is 0.3mbar power values are kept 600W, 700W and 800W. By varying the power, different etch rates were obtained. Etch rates also depends upon the duration of plasma process.

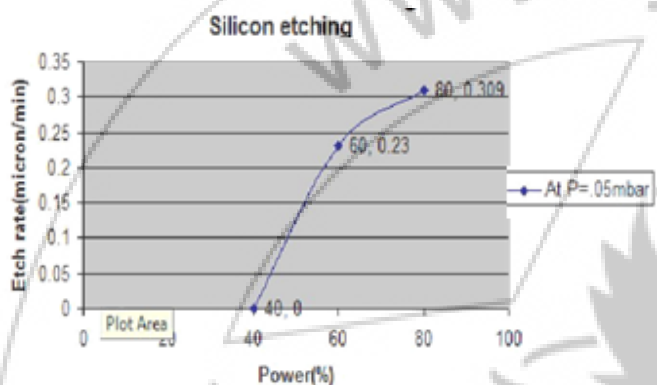


Figure 3 Etch rates of samples at 0.5mbar

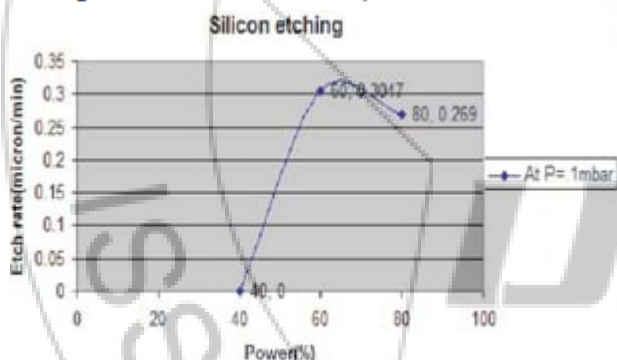


Figure 4 Etch rates of samples at 0.1mbar

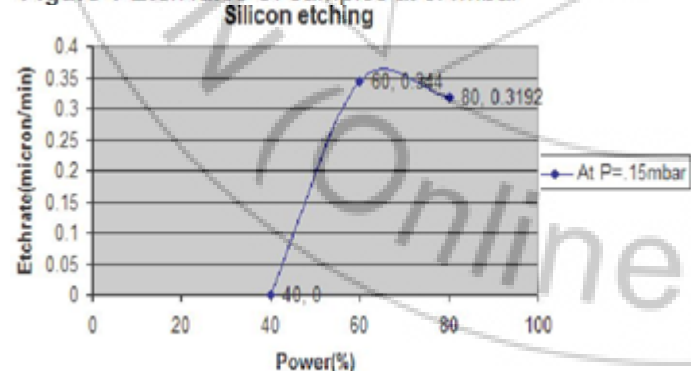


Figure 5: Etch rates of samples at 0.15mbar

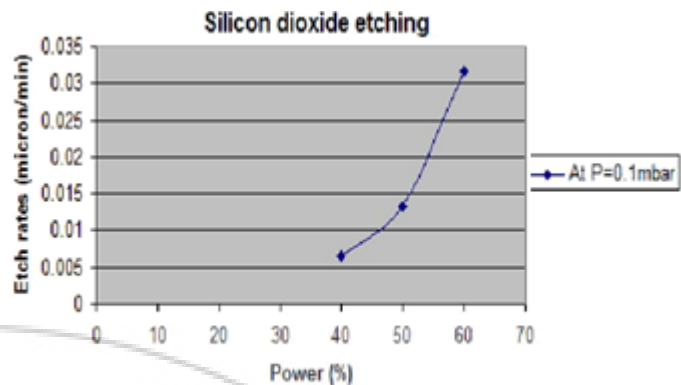


Figure 6 Etch rates of samples at 0.1mbar

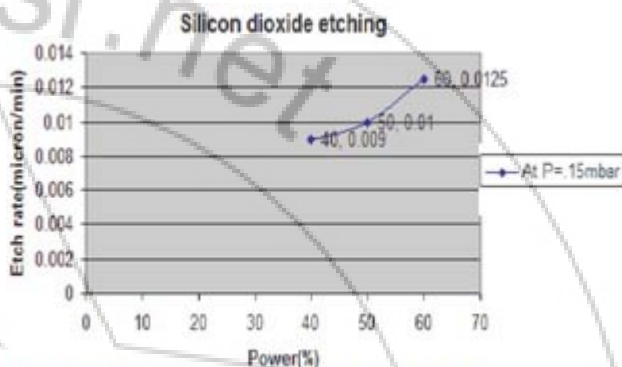


Figure 7 Etch rates of samples at 0.15mbar

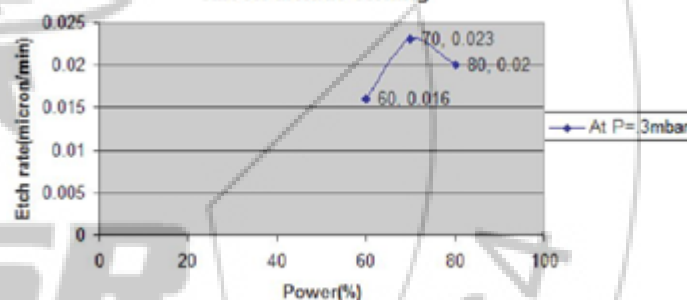


Figure 8: Etch rates of samples at 0.3mbar

For these experiments, etch rates were evaluated as the function of pressure of the chamber and power. As power increases, etch rate increases but as pressure increases, etch rates decreases. For Si, when the pressure increases, the etch rate increases and achieves the maximum value of 0.344 μ m/min and after a certain pressure value i.e. 0.1mbar, etch rate decreases. For SiO₂, etch rates increases initially and achieves the maximum value of 0.0316 μ m/min but after 0.3mbar pressure etch rates decreases. When power increases beyond 70%, the etch rate decreases because the pressure is goes on increasing simultaneously. For 40% of power no etch rates were observed independent of pressure values.

4. Conclusion

For better etch rates, the pressure for Si should be kept 0.1 mbar and also power should be greater than 40%. For SiO₂, the pressure should be kept 0.3mbar and then the power should be increased. The increase in power leads to increases in ionization that leads to more number of free radicals and more etching takes place. But increase in pressure, decreases the mean free path of radicals. So, the ions collide with each other rather than collision with the

surface. Ions crowding take place just above the surface that decreases the etch rate.

References

- [1] Muhammad M. Morshed and Stephen M. Daniels, "effect of positive photo resist on silicon etching by reactive ion etching process" IEEE transactions on plasma science, Vol. 38, No.6 JUNE 2010
- [2] Siti Azlina Rosli, Azlan Abdul Aziz and Haslinda Abdul Hamid "Highly Chemical Reactive Ion Etching of Silicon in CF₄ Containing Plasmas" ICSE2006 Proc. 2006, Kuala Lumpur, Malaysia
- [3] E. Gogolides, C. Boukouras, G. Kokkoris, O. Brani, A. Tserepi, and V. Constantoudis, "Si etching in high-density SF₆ plasmas for microfabrication: Surface roughness formation," *Microelectron. Eng.*, vol. 73/74, pp. 312–318, Jun. 2004.
- [4] C. Caillat et. al, *Solid State Electronics*, 46 (2002).
- [5] Tohno, M. Saito, K. Omiya, and Y. Kataoka, "Structural changes in a resist resulting from plasma exposure during the reactive ion etching process," *Jpn. J. Appl. Phys.*, vol. 40, pt. 1, no. 2A, pp. 798–802, Feb. 2001.
- [6] Min Tae Kimz "Kinetics of etching of silicon dioxide in a CF₄ plasma" *Journal of The Electrochemical Society*, 147 (3) 1204-1209 (2000)
- [8] J. M. Bustillo, R. T. Howe, and R. S. Muller, "Surface micromachining for microelectromechanical systems," *Proc. IEEE*, vol. 86, no. 8, pp. 1552–1574, Aug. 1998.
- [9] Gottlieb S. Oehrlein and Young H. Lee Reactive ion etching related Si surface residues and subsurface damage: Their relationship to fundamental etching mechanisms G. T. A. Kovacs, N. I. Maluf, and K. E. Petersen, "Bulk micromachining of silicon," *Proc. IEEE*, vol. 86, no. 8, pp. 1536–1551, Aug. 1998
- [10] Henri Janseny, Han Gardeniers, Meint de Boer, Miko Elwenspoek and Jan Fluitman "A survey on reactive ion etching of silicon in micro technology" *J. Micromech. Microeng.* 6 (1996) 14–28.
- [11] F. Laermer and A. Schilp, "Method of anisotropically etching silicon," U.S. Patent 5 501 893, Mar. 26, 1996
- [12] Fonash, "An Overview of Dry Etching Damage and Contamination Effects", *J. Electrochem. Soc.* vol 137, p 3885 (1990)
- [13] Rob Legtenberg, Henri Jansen, Meint de Boer, and Miko Elwenspoek "Anisotropic reactive ion etching of Silicon using SF₆/O₂/CHF₃ gas mixtures" MESA Research Institute, University of Twente, 7500 AE Enschede, The Netherlands
- [14] Picard, G. Turban, and B. Grolleau, "Plasma diagnostics of a SF₆ radiofrequency discharge used for the etching of silicon," *J. Phys. D, Appl. Phys.*, vol. 19, no. 6, pp. 991–1005, Jun. 1986.
- [15] L.M. Ephrath "Selective etching of silicon dioxide using reactive ion etching with CF₄-H₂