Automated unit of the chemical wet etching

Yu V Sukhoroslova¹, D S Veselov¹ and Yu A Voronov¹
¹National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, 115409 Moscow, Russian Federation

Corresponding author’s e-mail address: ASBakerenkov@mephi.ru

Abstract. This paper is devoted to the development of wet etching unit and its control system. The experimental model represents the reaction chamber, equipped with the stirrer and steam-gas condenser, located inside the heated chamber. The unit is also equipped with heat-insulated reservoirs for preheating of etchants and water. The control system provides automated supplying of liquids into the reaction chamber. This allows realizing multistage etching in single technological cycle with etchants replacement and substrate washing, without its extraction from the reaction chamber. With using the unit was studied deep anisotropic etching of silicon in various alkaline etchants. Was revealed, that unit provides the uniformity of etched surface on the level of about 1 μm.

1. Introduction
Currently, for the technology of integrated circuits, along with the plasma chemical etching techniques are increasingly applied the liquid silicon etching. It differs with its simplicity, implementation and low cost, also ensures high reproducibility and uniformity of the surface etching. However, it is difficult to stabilize the temperature and concentration of the etchant when the wet etching. This complicates the manufacturing process of sensing elements based on dielectric membrane structures for the gas concentration sensors. A typical construction of such sensing elements is shown in Figure 1.

![Figure 1. Sensor element based on a dielectric membrane structure: 1 - silicon substrate; 2 - dielectric membrane; 3 - structural elements (resistive heater, a resistive temperature sensor contacts to the sensitive layer); 4 - the sensitive layer; 5 - cavity under the membrane; 6 - a layer of thermal silicon oxide.](image-url)

In the manufacturing process of such sensing elements cavity is formed under the membrane deep anisotropic etching of silicon in alkaline solutions etchants. Formation of cavities is made in two
stages. On the first step is formed the cavity mordants through anisotropic silicon etching to a depth of 80-90% of the substrate thickness. Then carried out the steps of forming the structural elements and the sensitive layer. After that, the final stage is carried through anisotropic etching of silicon substrate with a protection of the front side against contact with the etchant. Depending on the size of the substrate, it is required to provide one-time mordants of cavity under membrane to a depth of 0.3 to 0.8 mm. In the process of the deep etching solution loses its etching properties. This lowers the etching rate and uniformity, which requires periodic replacement of the etchant. Stages of the etchant solution replacement significantly complicate the manufacturing process and reduce the yields of devices, which adversely affects the final cost of the product.

While forming the sensing elements based on dielectric membrane structure is extremely important to obtain simultaneously the entire membrane area of the substrate. This requires providing a high level of silicon etching uniformity. More information about etching process can be found in following article [11]. Otherwise, the etchant can etch one of the membranes and to come under the protective device, resulting in the poisoning of the sensitive layers on a substrate. Furthermore, it is required to provide uniform access of the etchant to the etching surface. Also, in order to avoid destruction of the substrate fixed in the protection device when it is immersed in the etchant is necessary to ensure smooth heating and cooling.

The existing equipment for the wet etching process, as a rule, is designed for the individual process steps for the group of substrates. There is no special technological equipment for the group of technological operations of etching a substrate, which is represented on the market. Therefore, the authors had a task to develop the stable wet etching equipment with an automatic control.

2. The construction

To automate the anisotropic etching process the structural design was made in various modifications, and it was empirically determined the optimal device design for the temperature stabilization and the concentration of the etchant shown in Fig. 2 (hereinafter referred to as indicated by Fig. 2). It consists of the following main parts: a heat-resistant heat-insulating casing 6, the outer contour 8 warms up with coolant; inside etching chamber 10 for loading protection device with the one-sided etched 14 (3,4 Picture) with the substrate; condensing the vapor-gas suspension system 25; storage tank 38 with deionized water.

Thermostat performs latitudinal load control with a period of 2.56 seconds and sets the current limit load in a range from 0 to 100% in 1% increments. Empirically were found, that the equipment of heated loop keeps the etchant temperature in the etching chamber with an accuracy of ± 1 ° C, the control of which is held by a thermocouple TCA 13, located in the etch chamber. It is also equipped with an external circuit, which heats the channel 20 for draining the coolant from the built-in water valve 18 and the electric coolant channel 5 for the Gulf.
**Figure 2.** The device construction.

**Figure 3.** The protection device for the one-sided etching:
1 - the Teflon basis; 2 - Teflon ring; 3 - substrate; 4 - Teflon screw; 5 - chemical and heat-resistant O-ring; 6 - channel for removal of excess pressure; 7 - LED.
Figure 4. A substrate at the security device for the sided etching.

Access to the etching chamber is made through an insulated door 4, and the control of the final stage of the etching process is performed visually through a transparent and sealed door 2, provided with a valve to drain the over-pressure from the etching chamber, at which is the drive of 3 blades for stirring the etchant. Also, the chamber for etching is provided with a channel 19 for the drain of the etchant with built-in water with an electric valve 16 and initially filled with deionized water, which is gradually heated to the temperature of etching. The device is equipped with a capacity of 33 with an opening 21 for filling the etchant, which is heated to a temperature etching using coiled heater 32, the operation of which is controlled by a thermocouple temperature controller TCA 31.

Upon reaching the desired temperature of the etchant solution, the water is drained from the etching chamber and the etchant is then supplied to the chamber through the channel 34, equipped with an electric valve. The deionized water is supplied through the channel 39 to the capacity storage 38. The water temperature is maintained throughout the etching process at a temperature equal to the temperature in the etching chamber with spiral heater 40, the operation of which is controlled by a second thermostat Warta TP410-1 by a thermocouple 36 TCA.

After the etching process, deionized water is supplied through a valve 15 by water pump 41 to the etching chamber. The water supply is controlled by a float liquid level sensor 12. There is a similar water valve 35 on the back side of the camera, through which the etchant is pumped out (washed out) by the pump 30 and the channel 37. The process is controlled by an analog linear float liquid level gauge 11.

The steam-gas suspension is given into the condensation system from the etching chamber through the channel 22. In the condensation system the vapor condenses, and the liquid returns to the etching chamber through the channel 27, and the gas is discharged from the device through the channel 24, equipped with an air check valve 26.

A condensation cooler is fed to the channel 28 (the easiest way is to connect to the cold water) and output through the channel 23. When placing the protective device for one-sided etching in the etching chamber 14, channel 42 is connected to the channel 29 for discharging the excess pressure in the installation. Protection device 14 is equipped with LEDs. On completion of step etching with a residual silicon layer (less than 10 microns) in the cavity for the membrane formation, the membrane LEDs change color, as shown in Figure 5, to stop the etching process. This method of stopping etching is used at the non-applicability of other methods within the framework of the developed technology. The control equipment is placed on a single dashboard 7 for the convenience of work.
3. Conclusion

There was developed an automated system for carrying out multi-step process cycles of wet etching with the replacement of solutions and washing the substrate without its removal from the etch chamber. It was revealed that the designed setting provides the etching temperature stability with an accuracy of less than ± 1 °C in the etching temperature range (50-100) °C. Also, the installation provides stability of the solution concentration in the etching process with an accuracy of less than ± 1% of the mass fraction of each component of the solution. The unit provides uniform access of etchant to the substrate, as well as a smooth substrate heating and cooling. Experimentally was found that by etching to a depth of several hundred micrometers the unit provides silicon etch uniformity across the substrate area at the level of 1 micron. The installation price is only about 5 thousand dollars. This makes it particularly attractive in the market of technological equipment.

4. References

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