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Electrochemical Etch-Stop

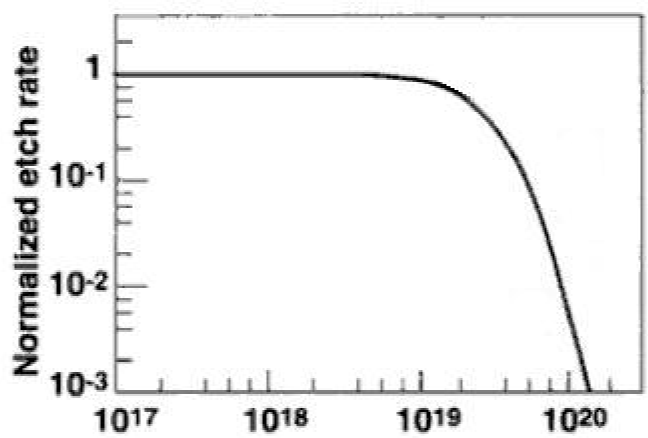
In microfabrication, it is often the case that a precise control over the etching process is desired. This means control over the direction and depth of the etch is critical. The most important characteristic of an etch stop is its selectivity. Etch stop would not be possible if there was no difference in etch rates. Selectivity is defined as the etch rate of the fast etching material divided by the etch rate of the etch stop. Also, the roughness of the respected layers are correlated to their etch rates. Various etch stop techniques used to achieve this end are timing, boron or p+, and electrochemical etch stop techniques.

Timing technique

The simplest type of etch stop is the timing technique. With this technique, the etch rate must approximated as a function of certain variables, such as temperature and concentration of etchant. The etch stop 'mechanism' is that the etching process is interrupted by rinsing away the etchant after an amount of time determined by the etch rate [4]. There are a couple key disadvantages of this technique. One is accuracy. For some processes the etch rate may vary considerably with a small change in temperature, so it may be very difficult to produce structures when the sizes are very small. Another disadvantage is reliability and reproducibility. The variables that affect the etch rate are very difficult to keep constant, so the result may be different each time.

Boron etch-stop

Last is the boron etch stop. This is one of the most widely used techniques due to its relative simplicity. The technique relies on the fact that anisotropic etchants, such as KOH and EDP, do not etch heavily boron-doped silicon very quickly (Fig. 1). In fact, a silicon substrate with a dopant concentration of 10^20 boron atoms/cm^3 only has the etch rate of 1% of that of intrinsic silicon [5]. Another etch stop method is called 'buried etch stop'. This method, like before, relies on heavy boron doping, but instead of doping the surface of the substrate, boron ions are bombarded with high energy. Since penetration depends on the kinetic energy of the ions, controlling the energy of the ions can control the depth of the doped layer. Which then results in an etch stop layer buried in undoped, etchable silicon.



Boron Concentration
Fig. 1 EDP at 100°C

Electrochemical etch-stop

The electrochemical etch-stop technique is essentially how it sounds, an etch stop achieved by a voltage potential (electro) and the use of different chemicals (chemical). Two of the electrochemical etch-stop techniques, used today, involve electrodes and one doesn't. An electrode is the contact to either the silicon wafer or the doped wells, where electrons are either released or accepted. In addition to the contact electrodes a reference electrode is often used as seen in figure 2.

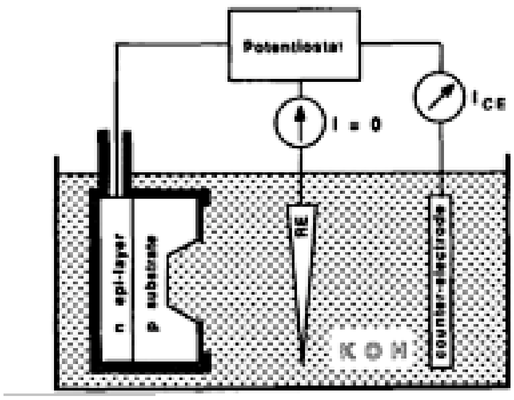


Fig. 2 p-n junction etch stop

The p-n junction etch stop "was first proposed by Waggener in 1970 and has since been successfully applied to the fabrication of several different micro sensor structures [3]." A p-n junction etch-stop is created by reverse biasing the junction and applying a positive voltage to the n-type, which is greater than the passivation potential. The passivation potential is the potential at which the n-type material becomes an etch-stop. The p-type material is held at the open circuit potential (OCP), where there is very little current, and completely etched away [4]. In figure 1 a three-electrode system is used, a four-electrode is the same configuration with an additional electrode on the p-type, with a negative voltage, to create a larger potential difference between the junction. The three-electrode system has a higher current density at the corners due to the increase of the electric field, which may create a passivation of the p-type material. As a result, the four-electrode system can be used to obtain greater precision because the negative potential applied to the p-type decreases the current effect and allows for thinner bulk silicon lines [5].

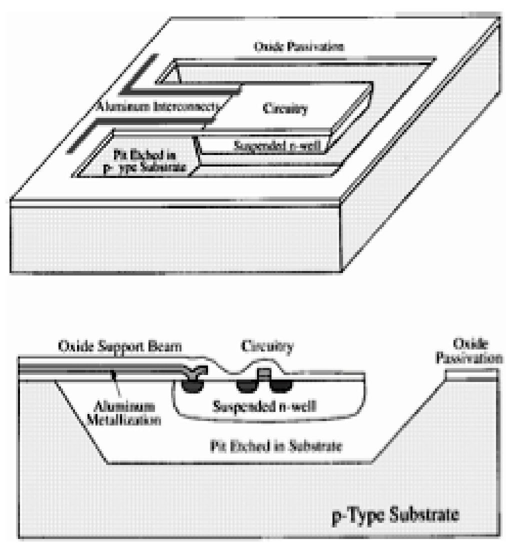


Fig. 3 Suspended silicon n-well

Electrochemical etch rate modulation is possible for either p- or n-type doping. A voltage potential is applied between the silicon wafer and the etch solution, the etch rate is proportional to the voltage potential. As the voltage is increased more holes are placed near the silicon surface, the passivation potential is eventually reached and silicon dioxide is formed, which creates a temporary etch stop but if KOH or TMAH is used the silicon dioxide can be etched off. Porous silicon can be created if a highly concentrated HF solution is used with the absence of OH^- and an anodic bias [4]. In figure 3 electrochemical TMAH etch modulation was used.

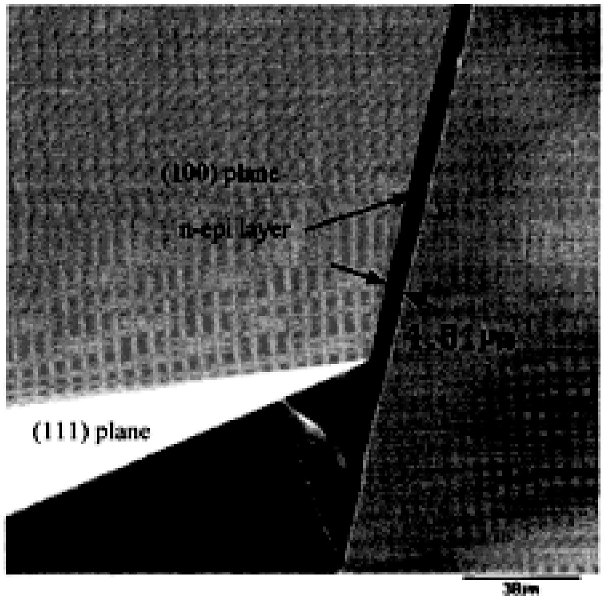


Fig. 4 Electrodless etch-stop

Electrodless electrochemical etch stops are more desirable because batch fabrication is easier and there is less stress on the wafer. A Au/Cr/n-Si/TMAH cell is deposited on the wafer using evaporation of a gold/chrome layer on the silicon. The cell creates a passivation voltage internally, which creates an anodic oxide on the surface of the silicon wafer. The process needs to take place below a critical value for the oxide to implemented as a etch stop. An example of the electrodless electrochemical etch stop can be seen in figure 4.

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