**Introduction**

Porous silicon structures can be formed by etching silicon wafers under a constant current density in HF solutions. These silicon structures offer much greater surface area than the unetched silicon wafers, which can be taken advantage of in various applications.

The anodic etching process is explained briefly: oxidation begins to occur on the surface of the silicon wafer, forming silicon dioxide. HF then effectively eats away at the silicon dioxide formations, creating pores in the remaining silicon layers and drastically increasing the surface area of the wafer.

These porous structures have a variety of uses in the semiconductor industry— as efficient gas sensors, for example. Metal particles can be deposited on the increased surface area of the wafers; these metals will react with gases to change the resistivities of the wafer. Because specific gases will react with the metals on the wafers at differing sensitivities, the presence and identity of gases can be determined by the level of response from the sensor.

Filters can also be created from porous silicon structures etched in HF-DMF solution. The process is essentially the same, though in these etches, a thick white foam forms on the surface of the wafer and separates the etched region from the intact silicon wafer.

**Procedure**

P-type boron doped wafers are used to create porous silicon structures. Resistivities of the wafers were generally chosen to be within 14 to 22 $\Omega$ cm. However, wafers with resistivities between 70 to 130 $\Omega$ cm were also acceptable when first coated with nickel to lower the resistivities.

Two kinds of organic solutions were prepared. The first is prepared using 49% aqueous HF in acetonitrile (MeCN) with tetra-n-butylammonium perchlorate (TBAP) as the supporting electrolyte; the second is a solution containing HF (aq) in dimethylformamide (DMF).

To etch the silicon wafer, the wafer was clamped to an electrochemical cell (made of polyethylene) containing the solution, and a constant current density was delivered to the resulting setup. A piece of platinum glued to the cell served as the cathode, while the wafer itself was the anode. The current density was kept constant anywhere between 3 mA/cm$^2$ and 50 mA/cm$^2$ for each individual run and later adjusted for the next etch if electropolishing is observed. The duration of the etches was also varied between 10 minutes and 2 hours, with adjustments made in accordance with the results of the previous etch.

A sample is presumed to be etched when a matte dark gray area is present on the surface of the wafer, rather than the shiny gloss indicative of electropolishing. The wafer is then rinsed with deionized water and methanol and finally soaked in a dilute HF solution. Once the HF solution has evaporated, the final mass of the wafer can be subtracted from its initial mass to determine the approximate amount of silicon that has been etched.

**Results and Discussion**

The etched wafer is commonly either shiny and streaked with color or has a dull gray region on the surface of the wafer in contact with the solution. A color-streaked surface is indicative of electropolishing, which occurs when pores are first created, but due to too long a duration, are later destroyed by over-etching. The etch procedure is time sensitive, and the etch interval is adjusted in subsequent etches. On the other hand, the production of a dull gray area suggests that porous silicon structures have been created, and the existence of these pores can be confirmed by SEM photographs of the etched areas. Figure 1 shows the side and top views of wafers etched in the HF-MeCN-TBAP solution.

Figure 1. (Left) Side View; (Right) Top View

The silicon wafers etched with HF-DMF solution displayed potential for the etched film to be lifted off with a razor blade. These films are often accompanied by a white foam, which separates the etched region from silicon wafer. Figure 2 below shows the porous structures created from a DMF etch.

Figure 2. Two side views of filters.

Pore sizes depend on the etch conditions and on the type of solution used, though they are typically found to be within a few micrometers. It is not uncommon for wafers to lose approximately 0.02 grams in mass to the anodic etching process and in the subsequent formation of these pores.

**Conclusion**

Porous silicon structures were successfully created in a number of ways for uses in the semiconductor industry. Continuing research would focus on metal deposition on the surface of the wafer for gas sensor applications. Using porous silicon to create gas sensors is highly efficient and practical, as these sensors are relatively inexpensive to make and are operational under standard conditions. Further explorations could be in determining how parameters (such as HF concentration and current density) affect the porosity and pore diameters of these structures.