MICROTECH SYSTEMS, INC.

Alkaline Etching of Silicon

Introduction

Alkaline etching of crystalline using KOH (potassium hydroxide), TMAH (tetramethyl ammonium hydroxide), or EDP (ethylenediamene pyrocatecol) is performed for creating various feature definition in MEMS (micro electrical mechanical structures, solar cells, and integrated circuit manufacturing. KOH will be discussed in this section.
The alkaline chemistries have the ability to preferentially etch silicon along the crystal orientation. This makes it possible to create geometries difficult to produce with other micromachining techniques (for example V-grooves).
The etching rate is dependent on the orientation of the silicon's crystal planes, orientations of <100> and <110> etch differently than <111> due to the arrangement of atoms at these orientations. Silicon <100> etches anisotropically along the <111> crystal plane, with a 54.74° angle from the <100> plane. Silicon <100> that is masked etches as shown in Figure 1.

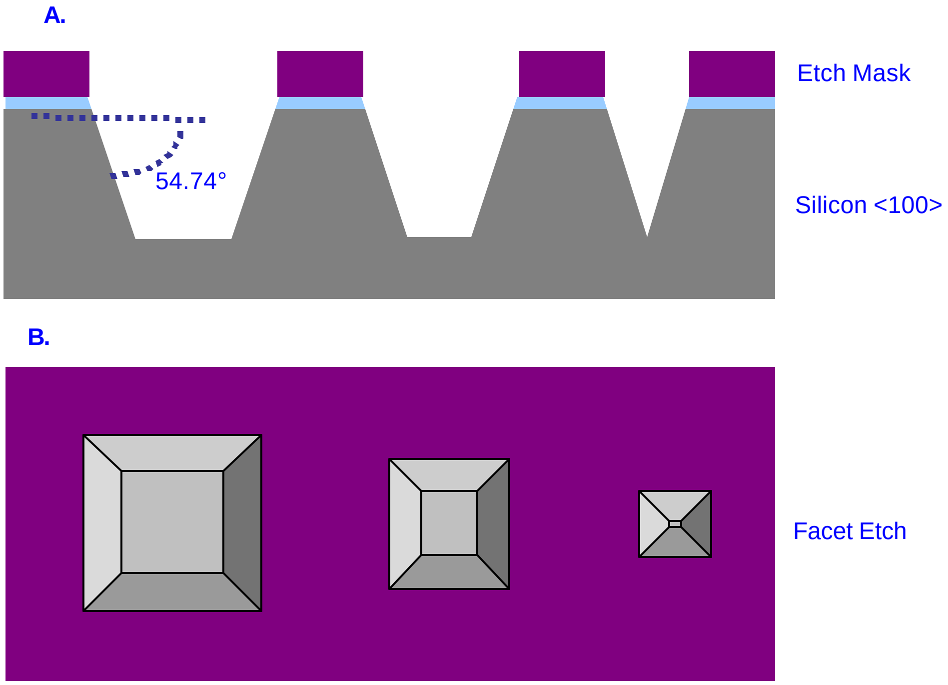

Figure 1. Silicon <100> etching using KOH. The crystal facet etches at an angle of 54.74º

Process Technology

KOH solutions are prepared by dissolving KOH pellets in deionized ultra pure wafer (DI H_2O). Various concentrations for the etching solutions are proposed and additives are sometimes used to decrease the surface roughness; the etching rate of silicon is dependent on the concentration of the KOH solution. KOH etching rates are also dependent on temperature. Batch immersion tanks, which control the temperature and have the ability to spike the KOH solution with water, are the preferred method of processing. Additives are usually organic in nature, such as isopropyl alcohol (IPA) and are added to smooth the surface during the etching process.

Bubbles in the solution must be avoided as these can mask the etching. Masking material is typically silicon nitride (Si_3N_4) or SiO_2. Gold or other metals also may be used as masking materials. Wafers should not have any organic material (such as photoresist) on them, as this will contaminate the KOH solution, as the photoresist will etch. The selectivity of silicon to silicon nitride is very high and for production, the assumption can be used that silicon nitride does not etch at all. However, KOH etching of silicon dioxide is observed; the etch rates are considerably slower (1-2 orders of magnitude) than that of silicon but should be considered when deep etching is being performed. The selectivity is dependent on the temperature and the concentration. Slow etching rate processes, as obtained by adjusting concentrations and temperatures, are used to maximize silicon to silicon dioxide selectivity. The silicon etching rate is independent of the doping for N-type materials; for example P and As, however, for P-type doping, such as B, the <110> etching rate decreases at higher doping concentrations [1] [2].

Etching rates approaching 20 µm/hour are obtained for silicon <100> at a concentration of 20 weight % KOH in 80% DI water at a temperature of approximately 60°C. Etching rates for silicon, silicon nitride, and silicon dioxide in varying concentrations and temperatures of KOH are shown in reference [3] [4]. Figure 2 shown the relationship of temperature to etching rate for a 20 weight % KOH solution. At lower concentration, ~20 to 30 %, a smoother surface is obtained than at higher concentration, in addition to a higher strip rate being obtained. The maximum concentration used is ~60 %, as the etch rate decrease rapidly with higher concentrations. Additionally, lower concentrations are more easily controlled and give the optimum results for facet etching. Figure 3 shows the relationships of concentration and temperature on the etch rates of various orientations of silicon. Heating of the solution accelerates the etching rate. However, a solution that is above 60°C evaporates water at a faster rate and has etching rates that are greater than what is reasonable to obtain repeatable results. Optimization of the KOH immersion tank process to the needed device results will result in a wide process window.

The potassium (K^+) is an alkali metal ion and like sodium (Na^+) an extremely fast-diffusing, lifetime-killer for MOS (metal oxide semiconductor) devices or any device that relies on long lifetimes, such as solar cells. Thus, KOH etching solution must be effectively cleaned off the surface of the silicon after the etching is complete. A RCA-type clean using SC-1 is suggested after the KOH process. Proper procedures must be observed to avoid contaminating any metal-ion sensitive processes and equipment elsewhere in the lab. Additionally, KOH is a caustic solution and must be handled with safety precautions.

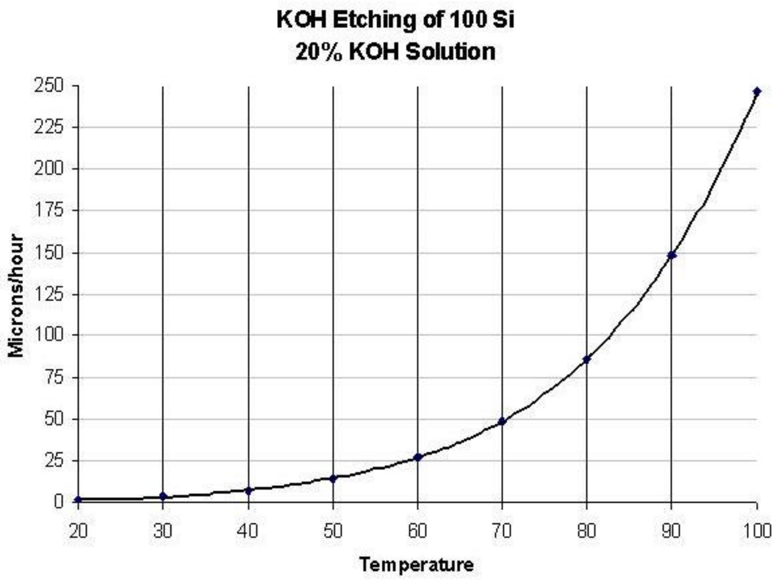

Figure 2. The graphic relationship of temperature to etching rate for a 20 weight % KOH solution.

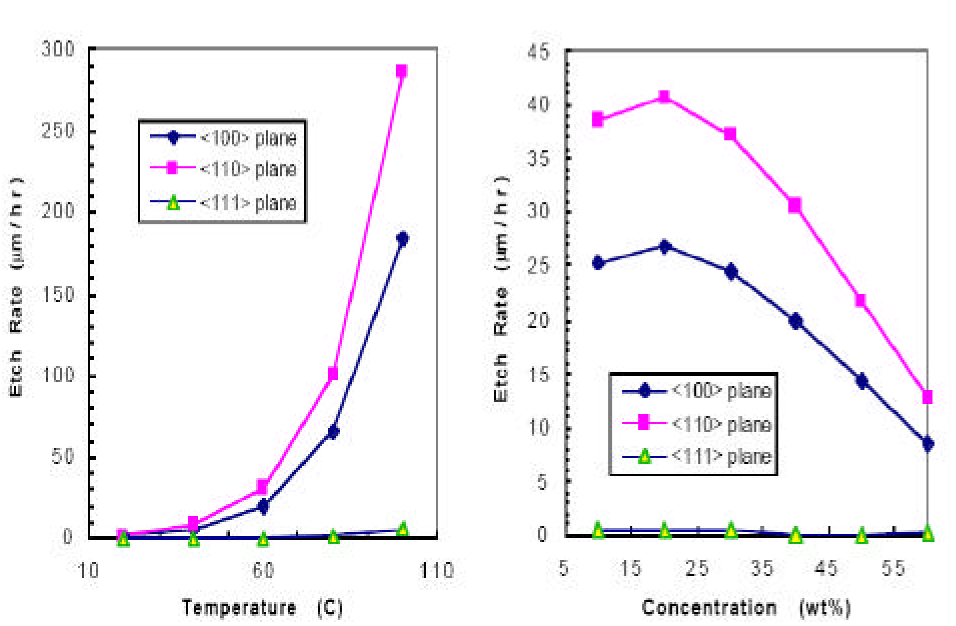

Figure 3. The relationships of concentration and temperature on the etch rates of various orientations of silicon.

Applications

Solar Cells

Solar cells (photovoltaic devices) chemical etch the mono or multicrystaline silicon to controllably roughen the silicon with random texture, which provides more surface area for light absorption thus increasing the efficiencies of the solar cells [5] [6].

Another application of chemical etching with KOH or other alkaline solution is removing the edge doping called shunts. The efficiency of the solar cells is electrically affected by leakage due to a poorly defined interface between the P and N junctions. The edge, unprotected from the silicon nitride surfaces is preferentially etched to improve electrical performance [7].

MEMS

Example of use of anisotropic silicon etch is the formation of microphone structures for the acoustic MEMS. The microphone is a membrane supported by small fingers of material on the top surface of the silicon-based device and behind the microphone the silicon substrate is completely removed. Etching the hole is much more economical using KOH solutions versus a dry plasma process. Other MEMS sensors also use this technique.

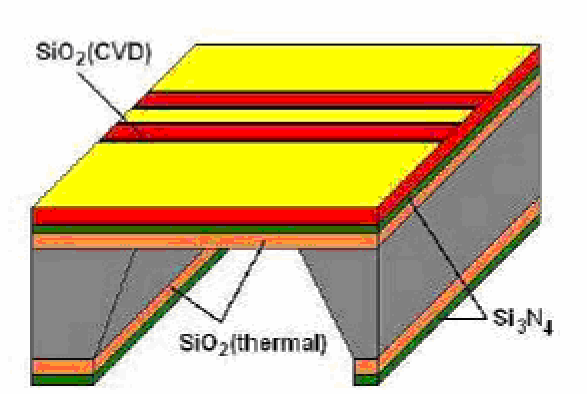

Figure 4. An example of the etching of a deep trench silicon structure for MEMS.

SOI

The potential exists for using KOH to etch deep trenches to form island for SOI materials such as sapphire or silicon on silicon dioxide insulator.

Reclaim

A KOH bath is used to strip the polycrystalline silicon prior to lap and polish step. Some monocrystalline silicon is also removed during this process.

Wet Cleaning Tool Configuration

The configuration for KOH baths, with automatic wet bench configuration and a SC-1 post-KOH process, is shown in figure 5. Various alternatives to this configuration are available depending on the process goals. Spiking and temperature control are also available.

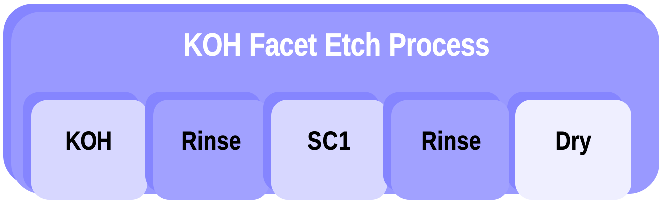

Figure 5. Example of a KOH facet etching configuration for a wet bench.

References

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