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WET ETCHING OF SILICON

Anisothropic etch

The etch of monocrystalline silicon wafers along preferential directions is a typical process step in the fabrication of micromechanical devices. Reviews of the possibilities given by the anisothropic etch of silicon are contained in the following classic papers:

- K.E. Bean: "Anisotropic etching of silicon", IEEE trans. on EL. Dev., ED-25, p. 1185 (1978).
- E. Bassous: "Fabrication of novel three-dimensional microstructures by the anisotropic etching of (100) and (110) silicon", IEEE trans. on EL. DEV., ED-25, p. 1178 (1978).
- S.Sriram and E.P. Supertzi: "Novel V-groove structures on silicon", Appl. Optics, 24, p. 1784 (1985).

The anisotropy is obtained through the different etch rates that selected chemicals exhibit against different crystalline planes (for an introduction to crystal plans and directions see : C.Kittel, "Introduction to solid state physics", Wiley).

In silicon, the atoms laying on (111) planes appear more densely packed than those on the (110) and (100) planes. As a consequence, certain etching formulations are favoured in removing atoms from (110) and (100) planes. This result in the possibility of making V- or U-shaped structures, through an etch resistant mask layer. This is usually made of silicon dioxide or nitride.

A popular anisotropic wet etching bath is obtained with a solution of 40% in weigth of potassium hydroxide (KOH) in isopropyl-alchol (this acts as a "moderator", i.e. slows down the etch). In the literature etch speeds of 6000 Å/min at 80°C for (100) planes, 1000 Å/min for (110) planes and 60 Å/min for (111) planes are reported (see : S.M.Sze, "Semiconductor Devices: Physics and Technology", p.456, Wiley, 1985).

Actually, the practical use of the mix described above may result difficult. KOH and isopropyl-alcohol tend to remain split in two liquid phases, which are difficult to mix even through an energic stirring. Hence, the etching speed may depend on the position of the material in the bath, where KOH or alcohol rich areas can appear. As an alternative, a different mix is proposed here: simply replace isopropyl-alcohol with methyl-alcohol, which can be much better mixed with KOH.

In order to minimize alcohol evaporation, the bath temperature can be reduced to 50 - 60 °C. Eventually, the final recepy is:

50g KOH in 100g H_2O + 40 g (30 ml) of methyl alcohol.

This can be used with a slow magnetic stirring, in a "reflow" system: the alcohol vapours reach a cold surface, where they condense and are driven back to the etch solution. In this way, the alcohol/solution volumetric ratio is kept constant.

Special care should be devoted to keeping the bath active for a long time (hours may be needed for etching several tens of microns). To this purpose it is necessary to avoid that the back side of the wafer gets etched. This is usually just ground polished and for this reason it offers a huge surface to the bath. Hence, the back surface of the wafer should be previously coated with a water-insoluble protective lacquer.

During the etch in KOH small hydrogen bubbles appear on the areas not protected with oxide. If bubbles are observed in areas that should be covered with oxide this would indicate a damage in the oxide mask.

The etching rate for the above formulation is around 0.7 m/min for (100) planes and 0.035m/min for (111) planes. For (110) planes the etching speed is roughly 4 times that of the (111) direction.

The KOH solution has also a weak effect on the masking film, if this is SiO2. A mask etch rate around 15 Å / min is reported in the literature, against 1 micron/min for silicon. By assuming a safe 500:1 ratio between the etching speeds of silicon and oxide, the maximum achievable silicon etch depth can be calculated for given oxide thickness. For example, a 2000 Å thick oxide film can be used for obtaining a 100 micron deep structure on silicon. However, for larger depths a more resistant mask layer must be used, such as silicon nitride.
