

13.56 MHz Inductively Coupled Plasma Source ICP-P 200



Fig. 1: ICP-P 200

Etching of Si and SiO₂

Deep anisotropic dry etching in silicon has become an important technology for the development of bulk micromachines and micromechanical systems (MEMS). Using this technique the lateral dimension can be made extremely small while keeping the large vertical size due to the high anisotropy.

The actual requirements for the bulk etching technologies are: a high aspect ratio (dept/width > 30), a maximal etch rate (several $\mu\text{m}/\text{min}$), superior dimension (width) and profile (anisotropy) and high selectivity.

The etch rate, which is defined as the thickness of material removed per unit time, increases with increasing the RF power, temperature and varies with changes in chamber pressure.

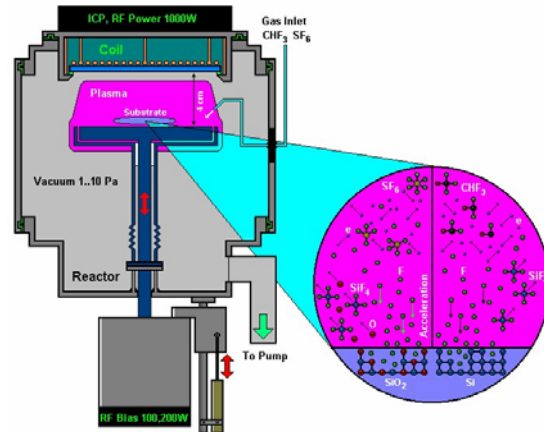


Fig. 2: Mechanism of the plasma etching for silicon and silicon dioxide and two gases CHF₃ and SF₆

Chemistry of etching

Halogen atom etchants like F, Cl or Br are almost always used for selective and anisotropic removal of patterned silicon or polysilicon films. Fluorine atoms are known to spontaneously attack silicon and silicon dioxide in the absence of ion bombardment. One can obtain negative fluorine ions in the plasma by using gases like CHF₃ or more efficient SF₆.

The etch rate can be increased by factor of 5-10 for sufficiently high fluxes and energies of bombarding ions. A single ion can cause the removal of as many as 25 silicon atoms from the surface. This ion energy driven etching mechanism is very useful in case of etching more durable materials like silicon dioxide.

Oxygen gas is often added to the feedstock gas and gives a variation of the silicon etch rate and the fluorine atom concentration versus %O₂.

Experiments

The etching experiments have been performed in a reactor equipped with an additional RF driven substrate holder (RBS 150/100) which offers the possibility of vertical movement. The RBS is simultaneous an additional plasma source which provides RF bias for the etching of SiO₂. The Si was etched in a pure chemical reaction between Si and F atoms. The distance between the quartz plate of the ICP and the surface of the substrate holder was 4 cm. Etching was done with two gas mixtures: CHF₃:O₂ and SF₆:O₂ (O₂ max 30%) for two substrate materials, pure Si and SiO₂. CHF₃ was used because of its better selectivity compared to SF₆. The RF power was fixed at 1000 W while the gas flow was in the range from 10 to 50 sccm for pressures of 5 and 10 Pa. The etching time for pure silicon and the gas mixture CHF₃ : O₂ was 10 minutes whereas for SF₆ : O₂ was 5 minutes. The etching time for silicon dioxide and the gas mixtures CHF₃ : O₂ and SF₆ : O₂ was 15 seconds only, since just a thin layer of SiO₂ (200 nm) was deposited on a Si substrate.

The etch rate was determined by using a Dektak profilometer. For pure CHF₃ the maximal Si etch rate was observed at a pressure of 10 Pa (0,37 µm/min). When the partial pressure of oxygen was increased to 20%, the etch rate decreased to 0,25 µm/min. According to the theory [3], the etch rate should increase with O₂ addition, but in this and in other cases we did observe that the addition of oxygen caused a decrease of the etch rate. Probably this is caused by a too low gas flow rate (max. 50 sccm). For SF₆ the maximum Si etch rate was also observed at a pressure of 10 Pa (>12 µm/min). The exact rate could not be determined due to the limited measurement range of the Dektak profilometer (60 µm).

In case of silicon dioxide the maximal etch rate was observed at a pressure of 10 Pa and a RF bias of 200 W (>0,6 µm/min) for the gas mixture SF₆:O₂. The etch rate increased with increasing the RF bias and pressure.

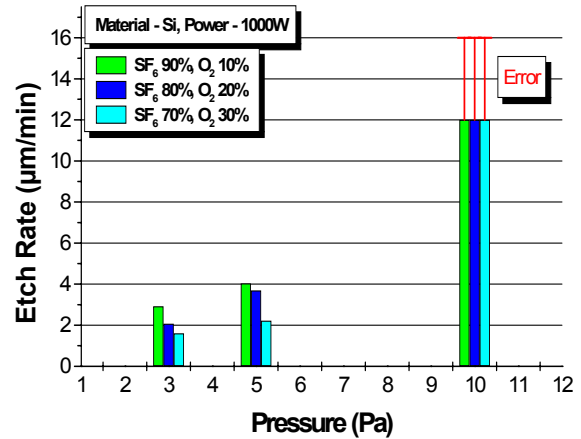


Fig. 3: Si etch rate as a function of pressure for different SF₆:O₂ mixtures, ICP RF input power 1000 W (no RF bias).

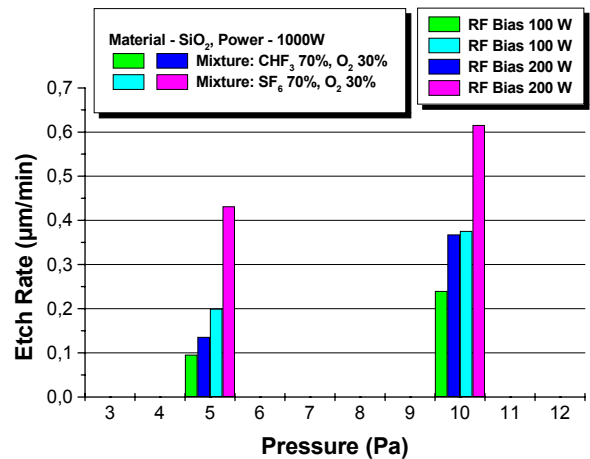


Fig. 4: SiO₂ etch rate as a function of pressure for different CHF₃:O₂ and SF₆:O₂ mixtures, ICP RF input power 1000 W, different RF bias.

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