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PLASMA ETCHING OF POLYSILICON AND SILICON DIOXIDE IN A PARALLEL-PLATE REACTOR[1)]

O. MIKUŠ[2)], Piešťany

A method for highly selective plasma etching of polycrystalline silicon with respect to SiO_2 and photoresist has been developed. The method is based on the eliminating of charged particles bombardment of the etched substrate surface when the substrate is insulated from the electrode by means of a sufficiently thick insulating support. The results are compared with results obtained in a conventional configuration using the same process parameters. Plasma etching of SiO_2 using C_2F_6 as etching gas has also been investigated.

ПЛАЗМЕННОЕ ТРАВЛЕНИЕ ПОЛИКРИСТАЛЛИЧЕСКОГО КРЕМНИЯ И ДВУОКИСИ КРЕМНИЯ В ПАРАЛЛЕЛЬНО-ПЛАСТИНЧАТОМ РЕАКТОРЕ

В работе рассмотрен метод высокоселективного плазменного травления поликристаллического кремния с учетом SiO_2 и фоторезисту. Этот метод основан на устранении бомбардировки травленой поверхности субстрата заряженными частицами, когда субстрат отизолирован от электрода при помощи достаточно толстой изолирующей подложки. Полученные результаты сравниваются с результатами, полученными при обычном расположении с теми же параметрами процесса. Проведено также исследование SiO_2 в случае, когда в качестве газа травления использован C_2F_6.

I. INTRODUCTION

The utilization of low pressure non-equilibrium reactive plasmas represents a key tool for defining precise patterns in the production of semiconductor devices. To transfer fine lithographic patterns into underlying substrate materials, the material to be removed must have a preferential etch rate with respect to other materials. This is especially important when a considerable amount of overetching is required to completely remove the material deposited over a steep step and when other materials not to be etched are also exposed to the plasma. The masking organic resist material should have a low erosion rate during etching, otherwise an unacceptable linewidth change will occur. In the present paper, we will describe how to obtain high selectivities in plasma etching of poly-Si in a parallel-plate reactor and show some results concerning SiO_2 etching.

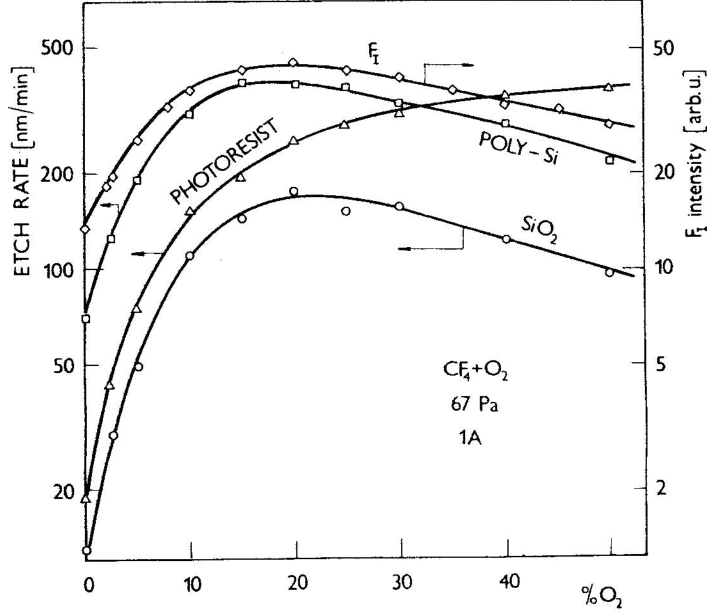

Fig. 1. Etch rates and intensity of the 704 nm line vs. O_2 concentration in the CF_4/O_2 mixture. (Substrate grounded mode).

II. EXPERIMENTAL

The experiments were carried out in a commercial planar etcher. The parallel-plate system consisted essentially of a pair of electrodes (60 cm in diameter, 5 cm apart) which were water-cooled and placed within an aluminium vacuum chamber. The etching table plate with samples to be etched was set on the lower earthed electrode made of stainless steel, which rotated during the etching process. RF power at 360 kHz was supplied to the upper electrode made of anodized aluminium from a standard 6 kW RF power supply. The pumping system consisted of a two-stage rotary pump ($30\ m^3/h$). The etching gases were fed via the rotameters (O_2 and C_2F_6) and a mass-flow controller (CF_4) and introduced into the chamber through the ceramic jet positioned in the centre of the chamber lid.

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[2)] k.p. Tesla Piešťany, Vrbovská cesta, 921 01 PIEŠŤANY, Czechoslovakia.

The main process parameters were the chamber pressure, composition of the gas and the RF power expressed through RF current that was measured (1A corresponds to approximately 600 W). The chamber pressure was measured by means of a capacitance vacuum gauge (BARATRON MKS).

The etching rates were obtained from the etching depths measured with a stylus instrument (DEKTAK).

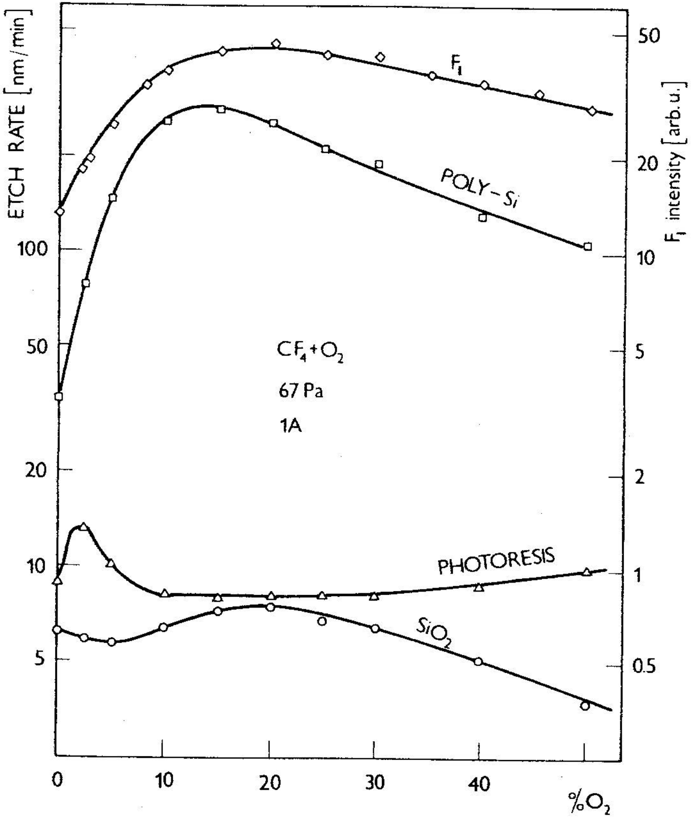

Fig. 2. Etch rates and intensity of the 704 nm line vs. O_2 concentration in the CF_4/O_2 mixture. (Substrate floating mode).

III. RESULTS

III.1. Etching of polysilicon

Experimental runs were performed in two configurations: first, the substrate was placed on the anodized aluminium plate which rested directly on the etching table plate (*substrate grounded*). Later, in order to prevent ion bombardment, the plate with the substrate was electrically insulated from the electrode by means of teflon or fused quartz (2÷4 mm thickness) (*substrate floating*). In the first case the sample creates a part of the electrode, but in the second case, the discharge is essentially confined to the outside of the space between the counter electrode and the substrate. This effect is well observable mainly at higher pressures as a dark space above the substrate.

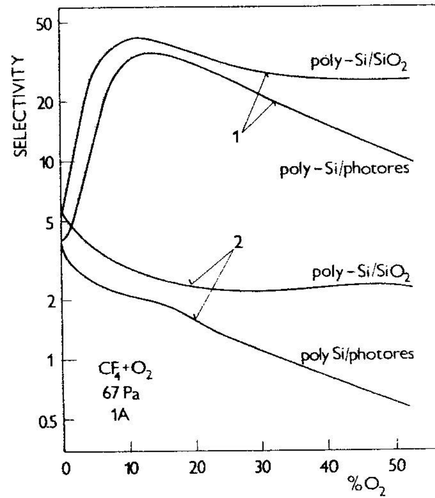

Fig. 3. Etch rate ratios (selectivities) vs. O_2 concentration in the CF_4/O_2 mixture. 1 — substrate floating mode, 2 — substrate grounded mode.

Samples of poly-Si and SiO_2 masked with photoresist HNR-120 were etched in a CF_4/O_2 mixture. The percentage of oxygen was determined from the chamber pressure with and without O_2 as

$$\%\,O_2 = \frac{p(CF_4+O_2) - p(CF_4)}{p(CF_4+O_2)}.$$

The typical etching characteristics at the total pressure 67 Pa and RF current 1A obtained with both above mentioned configurations (with an aluminium etching plate) are shown in Fig. 1 and Fig. 2. These figures also illustrate the relationship between the etch rates and the emission intensity from excited F atoms (F_I line, 704 nm).

It is interesting that in the case of a grounded substrate both the etch rates of poly-Si and SiO_2 peak approximately at the same O_2 percentage as the F_I line does. On the other hand when the substrate is floating, the poly-Si etch rate peaks at a lower O_2 concentration. It is in agreement with conclusions of [1]. In that case, there is also some indication of the SiO_2 etch rate maximum at the F_I line peak, but etch rates of SiO_2 and photoresist are much smaller.

In Fig. 3, dependences of the etching rate ratios (selectivities) derived from Fig. 1 and Fig. 2 are shown. Surprisingly high etch rate ratios are obtained in the floating substrate mode. There is a very interesting result in that the individual selectivities for both configurations are practically the same when using clean CF_4.

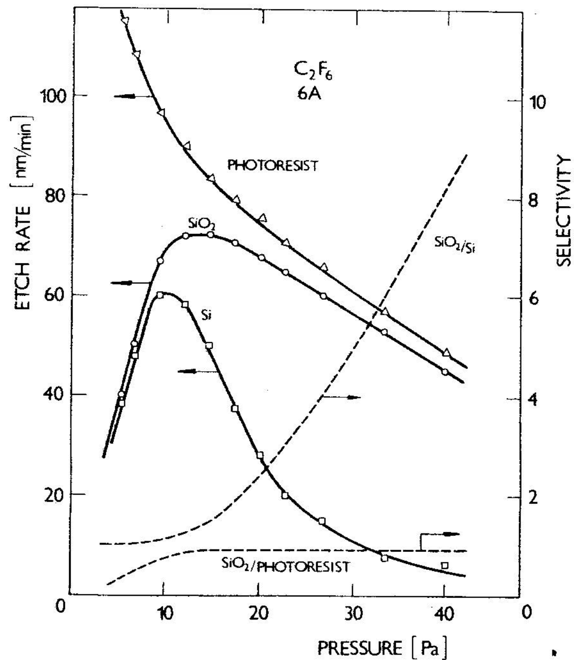

Fig. 4. Etch rates and selectivities dependence on the chamber pressure.

It must be mentioned here that with the decrease of the total chamber pressure the difference between selectivities obtained for both configurations diminishes in the whole extent of the O_2 percentage. Also, in the case of a stainless steel etching table all the etch rates decrease but selectivities do not change. It indicates the importance of surface reactions and possible catalytic effects in the etching process.

III.2. Silicon dioxide etching

C_2F_6 is the suitable gas for etching of silicon dioxide selective with respect to silicon because of its large carbon/fluorine ratio [2].

We investigated the dependence of the etching rate on the chamber pressure and the RF current using C_2F_6 as the etching gas. It was found that both SiO_2 and Si etch rates increase linearly with an increasing RF current. Basic characteristics of

etching with C_2F_6 are shown in Fig. 4. In that case the etching table plate was made of aluminium. The etching selectivity of SiO_2 to Si increases with chamber pressure, but above the pressure of approximately 25 Pa undesirable polymerization effects occur. The influence of the electrode material was examined using aluminium, stainless steel and teflon etching tables. Results are shown in Fig. 5. A teflon table was used to confine the RF current to substrate plates (30% of the electrode area), but the increase in the SiO_2 etch rate does not correspond to an up to threefold increase in the RF current density.

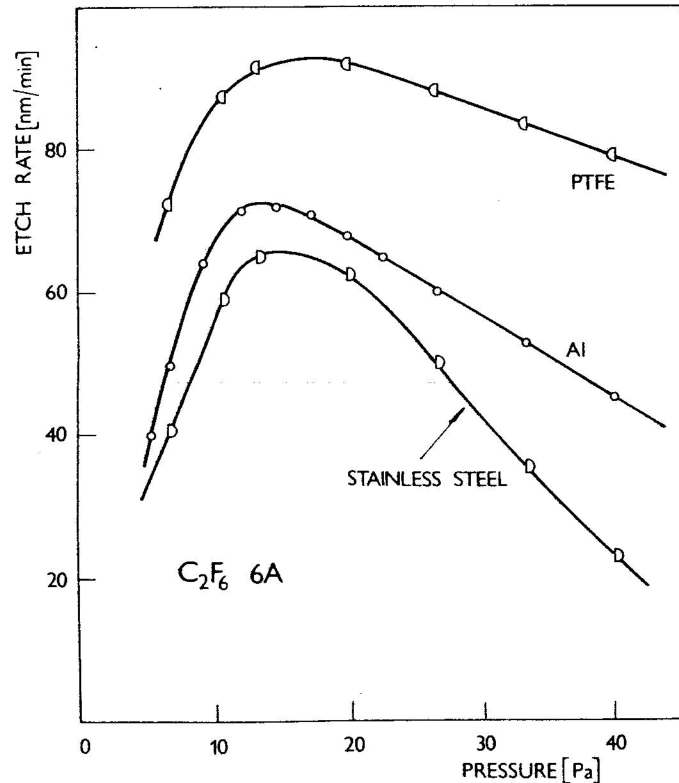

Fig. 5. Electrode material influence on the SiO_2 etch rate.

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