THE INVESTIGATION OF SiO_2 AND Si DRY ETCHING IN A BEAM - PLASMA DISCHARGE

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ABSTRACT

We studied the dry etching of SiO_2 films and of crystalline Si in a beam-plasma discharge in the atmosphere of CF_4 and SF_6. We obtained the SiO_2 film etching rate of 0,2 μm/min at the CF_4 pressure 2.10^{-2} torr and in the case of crystalline silicon - 30 μm/min at the SF_6 pressure 0,5 torr.

1. INTRODUCTION

Lately intensive research of the Si and SiO_2 dry etching under the influence of fluorine active radicals created with the help of HF and UHF discharges /1/.

Intensive fluxes of fluorine active radicals may also be generated with the help of a beam-plasma discharge in molecular gases containing fluorine. The beam-plasma discharge makes it possible to obtain strongly inequillibrium plasma with great difference between electron temperature and temperature of ions and neutral gas ($T_e \gg T_i$, T_o) /2,3/. By correspondingly changing the power, the accelerating voltage, the electron beam current, the pressure in the chamber and the gas pumping rate, it is possible to adjust the electron temperature, the ionization and the dissociation degree.

The beam-plasma discharge in molecular gases is steadily ignited in the vast range of pressures ($5 \cdot 10^{-5}$)torr; the ionization degree in the beam-plasma discharge depending on the regime may be 10^{-4}÷1; the dissociation degree 0,1÷1. The longitudinal magnetic field directed along the electron beam permits in certain regimes to carry on the separation of the charged and neutral components, that is rather difficult in the case HF and UHF discharges.

2. THE DESCRIPTION OF THE DEVICE

Fig.1 gives the scheme of the device /4/ for initiating the beam-plasma discharge with the help of a stationary beam of accelerated electrons. The device consists of electron gun 1, reaction chamber 2, differential pumping chamber 3, collector 4.

The gun cathode "K" is of the circular form of the diameter Ø=70 mm made of tungsten wire 1,5 mm in diameter; the anode

"A" has a ring-shape slot for emitting the beam. The gun chamber is pumped out by the diffusion pump. To provide the pressure diffence between working chamber 2 and the gun vacuum resistances are installed in chamber 3, between which differetial pumping with the help of a booster pump is provided. Between the working chamber and the collector vacuum resistance 7 is installed. Collector 4 serves to collect the electron beam. Through the electron collector nozzle 5 completed in the form of pipe with an orifice for the gas input into the reaction chamber is inserted. The nozzle is located inside the tubular electron beam. Inside the chamber there is support 9 for fixing of the specimen. Magnetic coils 8 produce the magnetic field of the mirror configuration. The magnetic field strength in the mirrors is 2000 e ; in the centre of the working chamber is 500 e .

3. EXPERIMENTAL RESULTS

When applying the accelerating voltage to the electron gun, the tubular electron beam penetrates the plasma through the circular vacuum resistances and gets to the receiver. If the pressure in the chamber is less than 2.10^{-5} torr the discharge in it is not initiated and the electron beam power fully reaches the collector, where it is resistered calorimetrically. When feeding molecular gases (CF_4, SF_6) through the nossle the beam plasma discharge in the form of a plasma tube is ignited, that has the effective wall thickness approximately twice that of the electron beam.

At the discharge ignition the amount of energy passing to the collector is reduced, that testifies to the energy transfer from the beam to the plasma. The efficiency of the energy transfer to the plasma is defined calorimetrically $\eta = 1 - Q/W_b$, where Q is the power coming to the collector; W_b is the electron beam power, J_b is the beam current, V_b is the accelerating voltage. Fig.2 gives the dependences of the energy transfer efficiency from the electron beam to the plasma on the current for various voltages. From Fig.2 it follows that increasing the accelerate beam electron density brings about the increase in the efficiency of the energy transfer from the beam to the plasma. If the accelerating voltage is enlarged the efficiency becomes less, which is conditioned by the decrease of n_b. The maximun efficiency corresponding to the beam current $J_b \sim 3,8$ A and the beam voltage $V_b=1,8$ kV constitutes 75%.

3.1. Silicon Oxide Film Etching

Silicon oxide film etching was carried out with florine active radicals formed at the freon CF_4 dissociation in the discharge. Fig.3 gives the dependence of the SiO_2 film etching rate on the distance R to the chamber axis. The figure also gives the distance from the samples to the beam surface $\Delta = R - D/2$ where D=60mm is the electron beam diameter in the middle plane. The etching was carried out in the regime $P=2.10^{-2}$ torr, $J_b=2$A, $V_b=1,5$ kw. From Fig.2 it follows that the etching rate decreases with the increase in distance and at the distance of 2,6 cm from the beam surface is 0,2 μm/min. Power density evaluated according the solid angle at the place of the target location is then approximately 1 W/cm^2.

3.2. Crystalline Silicon Plate Etching

Crystalline silicon plates 0,4 mm thick were installed in various places in the chamber. Each plate was partly covered by a screen of stainless steel to leave an unetched part of it for comparison. The etched layer thickness proportional to the active radical flow density and to the exposure in the discharge was measured by a micrometer. The etching was carried out at the SF_6 pressure P=0,6 torr, J_e=3A, V_b=2,5 kw. The etching rate of the silicon specimen located at the distance of 2,5 mm from the electron beam was 20 μm/min. The dependence of the etching rate on the sample location is analogous to Fig.3. The current density of active fluorine radicals evaluated according to this etching rate is no less than 10^{19} part/cm^2.sec.

References

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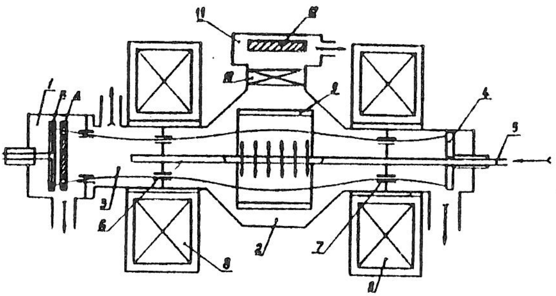

Fig.1 Device scheme

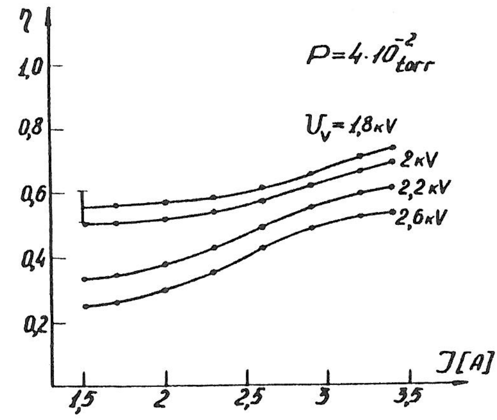

Fig.2 Efficiency dependence on current at different voltages

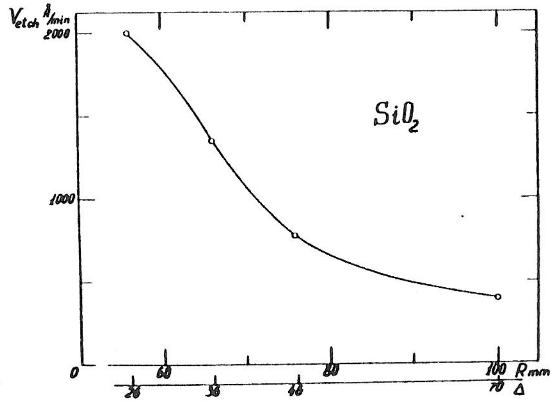

Fig.3 SiO_2 etching rate dependence on the radius