ABOUT INFLUENCE OF ENERGY OF ELECTRONS AND IONS ON SPEED OF ELECTRON- AND ION-STIMULATED PLASMACHEMICAL ETCHING OF SILICON

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The experimental dependence of the etching rate monosilicon of self-bias voltages on the active electrode at other constant conditions in the discharge is shows. With increasing negative bias potential monosilicon etching rate increases, then reaches a maximum at $U_{bias} \approx$ - (140…160 V). Further increasing of negative potential, regardless from method of preparation leads to a decrease in the monosilicon etching rate. This effect can be explained by an increase in dispersion of the active electrode. Application of a positive potential leads to polymer films deposition. Monosilicon etching rate increases with a positive potential bias rise on the active electrode.

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INTRODUCTION

Despite the widespread use of plasma etching (PCTs) in the technological processes of manufacture of microelectronic products, computer and microwave - machinery, electronics and other components. The plasma etching process physics is poorly understood. The effect of electron and ion bombardment on plasma etching processes carried out in different conditions and in different settings. Results presented in reviews [1,2] are insufficient for unambiguous advice on the choice of optimal energy of electrons or ions for optimal etching of many materials, including mono-, poly-, and multi-Si. The latest materials found very wide application in the manufacture of solar cells with high efficiency (18%). For proper insulation between the worker and the other side of the solar cells is necessary to provide good insulation, because leakage currents leads to a decrease in efficiency. This is done using specially developed for JSC «Quasar» plasma-chemical reactor (PHR), developed at the Institute for Nuclear Research [3,5]. Productivity developed PHR in 2,4 times higher than the performance of the best foreign analogues. To further increase productivity and the edge etching duration reduce of the solar cells necessary to carry out further the technological research. One of the most important is the e electrons and ions energy effect on the monosilicon etching rate. As shown in [3-5] results the question was not addressed. The presented works carry out the study such an influence on silicon etching rate.

RESULTS AND DISCUSSION

The studies were conducted in plasma-chemical reactor with a closed electron drift [6]. He is the prototype PHR to create the silicon wafers isolation for solar converters Energy ions in the PHR can be changed by several methods. As shown in [7], the average ion energy approximately corresponds to the particle energy accumulated in an electric field of bias. Bias voltage in the PHR can be changed by several methods. One of them - to change the size and configuration of the magnetic field, from which the self-bias voltage is depended. The etching rate dependence results of monosilicon from the strength of self-bias are shown in Fig. 1.

The self-bias voltage influence investigation on the etch rate were carried out at constant composition of gases, their pressure in the chamber, a discharge current. Area cultivated samples also were chosen the same. As seen in Fig. 1 when the self-bias voltage changes from (-100) to (-250) V, the etching rate increases smoothly.

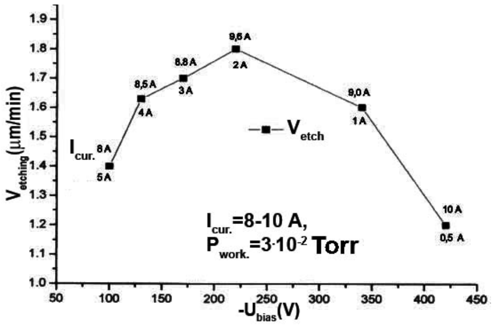

Fig.1. Dependence of the Si etching of self-bias voltage

Further increase in self-bias voltage (even a slight increase in discharge current) leads to a significant decrease in the etching rate of 1.8 up to 1,2 μm/min. As already noted, these results were obtained when adjusting the self-bias voltage by changing the magnetic field configuration. With this the plasma parameters may change,: the degree of dissociation of sulfur hexafluoride and oxygen, as well as the degree of ionization of the working gas. Therefore the result, that is, the dependence of V_{etch} and U_{bias} can be ambiguous in these experiments.

Another U_{bias} variation way may be the ratio change in areas of active and grounded electrode. But there may be redistribution of current in the discharge. It can also lead to mixed results. Therefore, this U_{bias} changes method not used.

But the bias voltage can be changed by the additional power supply with adjustable voltage, connected through a special filter. All other discharge parameters, including size and configuration of the magnetic field in these studies were maintained constant. The velocity dependence studies results from the bias when it is changed from an external source of direct current shown in Fig. 2.

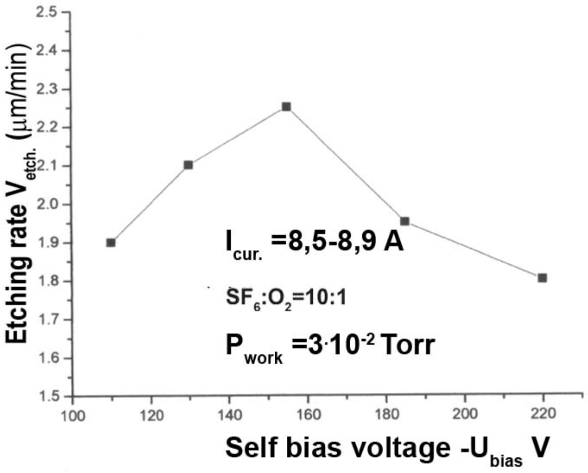

Fig.2. Dependence of the Si etching of self-bias voltage

From this follows that in the beginning with increasing the bias voltage from etching (-110) to (-160) is an increase in the silicon etching rate with a maximum at about (-160) V. Further increase of bias voltage to (-220) V leads to a decrease in the etching rate from 2.3 to 1,8 μm/min at a current in the discharge ~8,5…8,9 A, as well as constant pressure in the PHR of $P = 3 \cdot 10^{-2}$ Torr, the composition of the working gas $SF_6 : O_2 = 10 : 1$, the constant rate of pumping and injection of working gas, as well as a constant magnetic field.

When the current is reduced to 8 A and the pressure increases to $5{\cdot}10^{-2}$ Torr, bias voltage can be increased without breakdown to (-400) V. (Fig. 3). The maximum etching rate is observed at (-110) V, while increasing the bias voltage up to 400 V, the monosilicon etch rate is reduced from 1,6 to 0,8 μm/min. Connecting an additional generator with a frequency of 440 kHz increases the etching rate by 30% at constant other conditions.

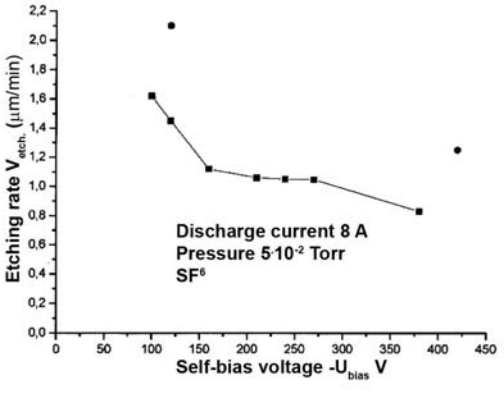

Fig.3. Dependence of the Si etching of self-bias voltage

The effect study of the positive potential and its value at the monosilicon etching rate is interest. The study results of etching rate dependence from the positive potential bias on the active electrode is shown in Fig. 4, i.e. with electronic stimulation of the silicon surface.

The main feature of these measurements was large irreproducibility the etching rate dependence results from polarity positive voltage. In this case, polymer film is also deposited on the surface; this apparently leads to large non-repeatable results.

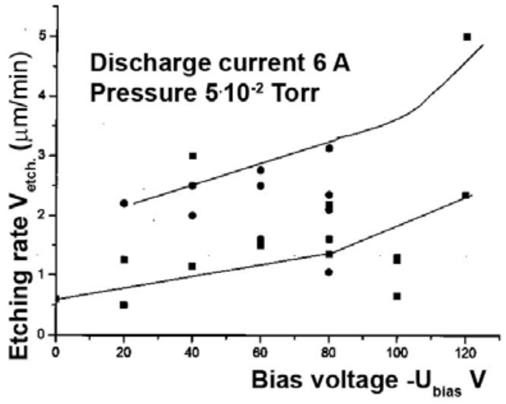

Fig.4. Dependence of the Si etching of bias voltage

But the general trend is an increase of etching rate with increasing positive bias voltage on the sample Fig. 5 shows. The general dependence of the etching rate with the potential variation on the active electrode from (-400) to (+150) eV is shown in Fig. 5.

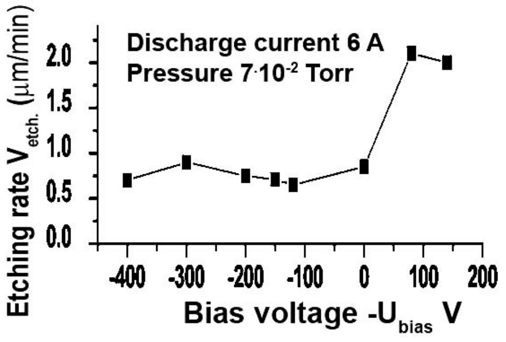

Fig.5. Dependence of the Si etching of bias voltage

Influence additional make power to discharge due to the constant voltage is negligible. The power source current dependence from bias positive voltage as well as the polarity negative is shown in Fig. 6.

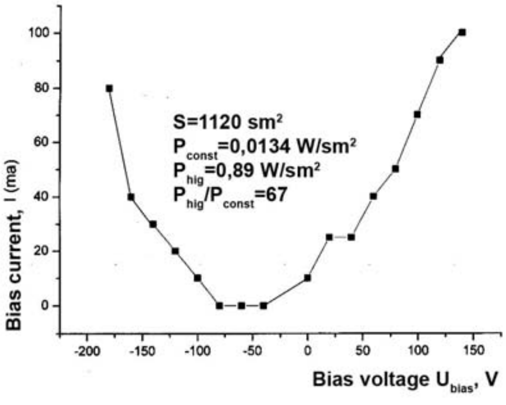

Fig.6. Dependence of the bias current of bias voltage

When the active electrode surface area is equal 1120 cm^2, power density RF discharge is equal 0,89 W/cm^2, on the direct current is equal 0,0134 W/cm^2. The power ratio is equal 67, i.e. a few percent, that should not lead to significant changes in plasma parameters in the PHR.

It is characteristic that during the transition bias through "0" there is no abrupt change in etching rate. I.e. main contribution to the etching is made by free radicals and fluorine atoms, and not fluoride.

In addition, with increasing the negative potential on the active electrode higher - 250-300 the monosilicon etching rate decreases. This effect may be explained by the spraying increase of active electrode and redeposition the of atoms and ions of metals (Fe, Ni, Cr), from which the active electrode is make, on the substrate.

CONCLUSIONS

When the monosilicon etching is carred out by ions stimulation, the dependence of etching rate from the bias voltage is maximum. Increasing the bias voltage (regardless of method of preparation), leads to a decrease in etch rate. This fact can be explained by spraying the active electrode and the deposition of material onto the substrate stimulation When the monosilicon etching is carred out by stimulation electrons, deposition of polymer films is obtained. With increasing positive potential on the active electrode, an increase of etching rate monosilicon is obtained.

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О ВЛИЯНИИ ЭНЕРГИИ ЭЛЕКТРОНОВ И ИОНОВ НА СКОРОСТЬ ЭЛЕКТРОННО- И ИОННО-СТИМУЛИРОВАННОГО ПЛАЗМОХИМИЧЕСКОГО ТРАВЛЕНИЯ КРЕМНИЯ

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Приведены экспериментальные зависимости скорости травления монокремния от напряжений смещения на активном электроде при других неизменных условиях в разряде. При увеличении отрицательного потенциала смещения скорость травления монокремния увеличивается, достигая максимума при $U_{см} \approx -(140\ldots160)$ В. Дальнейшее увеличение отрицательного потенциала, независимо от метода его получения, приводит к уменьшению скорости травления монокремния. Указанный эффект может объясняться увеличением распыления активного электрода. Подача положительного потенциала приводит к осаждению полимерных пленок. Скорость травления монокремния увеличивается с увеличением положительного потенциала смещения на активном электроде.

ПРО ВПЛИВ ЕНЕРГІЇ ЕЛЕКТРОНІВ І ІОНІВ НА ШВИДКІСТЬ ЕЛЕКТРОННО- І ІОННО-СТИМУЛЮВАННОГО ПЛАЗМОХІМІЧНОГО ТРАВЛЕННЯ КРЕМНІЮ

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Наведено експериментальні залежності швидкості травлення монокремнію від напруги зміщення на активному електроді при інших незмінних умовах у розряді. При збільшенні негативного потенціалу зміщення швидкість травлення монокремнію збільшується, досягає максимуму при $U_{зм} \approx -(140\ldots160)$ В. Подальше збільшення негативного потенціалу, незалежно від методу його отримання, призводить до зменшення швидкості травлення монокремнію. Зазначений ефект може пояснюватися збільшенням розпилення активного електрода. Подача позитивного потенціалу призводить до осадження полімерних плівок. Швидкість травлення монокремнію збільшується зі збільшенням позитивного потенціалу зміщення на активному електроді.