# THE INVESTIGATION OF DRY ETCHING PROCESSES OF REFRACTORY MATERIALS IN A BEAM-PLASMA DISCHARGE

V.M.Atamanov, A.A.Ivanov, G.B.Levadnyi,
Yu.F.Nasedkin, Yu.V.Sereda, A.A.Serov
I.V.Kurchatov Institute of Atomic Energy,
Moscow, USSR
S.Klagge
Sektion Physik Electronik, E.M.A.Universität,
Greifswald, DDR
M.Maass
Zentralinstitut fur Electronenphysik-V, AdW,
Greifswald, DDR

## ABSTRACT

The processes of dry etching of refractory materials in a beam-plasma discharge in the atmosphere of $SF_6$ were investigated. It has been shown that active neutral radicals of $F$ and negatively charges ions $F^-$ play the main role in the etching. Positive ions do not participate in the etching. The etching rate increases almost linearly with the gas pressure increase and at the pressure $P=8.10^{2}$ torr amount to 6,5 $\mu m$/min.

## 1. INTRODUCTION

Refractory materials such as Mo, Ta interacting with atomic fluorine form gaseous fluorides easily pumped off that is why their dry etching is observed in the plasma of fluorine-containing gases. Customarily refractory materials etching is carried out in the plasma of HF and UHF discharges /1/. In the present work the authors carried out the investigation of molybdenum dry etching in the beam-plasma discharge /2,3/ which, compared to the HF and UHF discharges permits to obtain a greater concentration of plasma electrons and a greater degree of dissociation.

## 2. THE DESCRIPTION OF THE EXPERIMENT

Fig.1 gives the scheme of the experiment on refractory materials etching in a plasma-beam discharge.

The pipe-like electron beam having in the middle plane of the reaction chamber the diameter $D$ =80 mm and the thickness $\delta \simeq 2$ mm when working gas flows through the chamber gives rise to a beam-plasma discharge which has the form of a pipe with the thickness $\Delta \simeq 2\delta \sim 4 mm$ /4/. Diameter and thickness of the electron beam and plasma were defined according to the diameter and thickness of the ring-like groove burnt through in the thin foil in vacuum and when the discharge has been ignited.

The plasma pipe is nothing more than the plasma curtain. When flowing the molecular gas from the nozzle through this curtain the loading of the oscillatory molecular levels with their subsequent dissociation takes place under the influence of plasma electrons. By choosing correspondingly such parameters as beam current, accelerating voltage, gas pressure, gas expenditure, it is possible to control electron gas density and temperature in the curtain and thereby control the degree of gas dissociation and ionization. At the properly chosen parameters the degree of ionization in the discharge constitutes $10^{-3} \div 10^{-4}$ at the dissociation degree of the molecular flow $\sim 1$.

Due to the presence of the longitudinal magnetic field, mostly the active radical neutral component flows out of the discharge region.

The present work investigated the etching of Mo samples depending on the discharge regime and the potentials applied to the samples. Different potentials were applied to four similar Mo samples. The samples were placed at the distance of $\sim 2{,}5$cm from the beam-plasma discharge surface in the medium of $SF_6$ and were held under the given conditions for some time. The discharge burning regimes and the potentials applied to the samples are given in Table 1.

Simultaneously with the etching measurements were taken with the help of a single Langmuir probe situated in the immediate vicinity of the samples (while reading the probe characteristics no potentials were applied to the samples). As a result the dependence of the etching rate on the potentials applied to the samples (See fig.2 and also probe curves of fig.3) was obtained.

## 3. EXPERIMENTAL RESULTS

From analysing the etching rate curves it follows that positive ions do not participate in the etching. It follows from the fact that when applying a negative potential to the samples the etching rate decreases. A slight decrease in the Mo etching rate at the negative potential applied to the samples shows that etching is mostly effected by the neutral component, i.e. atomic fluorine. At the same time negatively charged ions $F^-$ also participate in the process of Mo etching (about 20%).

Measurements of the etching rate taken at various pressures shows that the Mo etching rate being approximately proportional to the $SF_6$ pressure in the working chamber. At the $SF_6$ pressure $8.10^{-2}$ torr Mo etching rate is 6,5 $\mu$m/min, if there is no potential applied to the sample.

Probe curves of fig.3 give additional information on the plasma composition of the beam-plasma discharge in the electrically negative gas $SF_6$ in the places of sample location. A very weakly expressed branch of negatively charged particle on the probe characteristic practically points to the absence of electrons in the location zone of the samples. The electrons are captured by atomic fluorine forming negatively charged fluorine atoms $F^-$. This explains the anomalously small branch of negatively charged particles.

For comparison Fig.3 gives probe characteristics for the discharge in the air atmosphere. The electron branch is well shown in this characteristic.

References

1. Daniel L Flam 4th Int.Symp. on Plasma Chemistry, Zurich, aug. 1979, p.466.
2. Ivanov A.A., Sov. Zh. "Fizika plazmi", 1, (1), 147 (1975).
3. Ivanov A.A., Nikiforov V.A. "Chimia plazmi" Smirnov B.M.(ed.), 5, Moscow, Atomizdat, p.148, 1978.
4. Alecseev A.M., Atamanov V.M. et al. 4th Int. Symp. on Plasma Chemistry, Zurich, aug.1979, p.427.

Table 1

| No.of exper. | Chamber pressure $P_k$, torr | Electron Beam Current A | Voltage kV | Potentials on the Samples V N1 | N2 | N3 | N4 | Floating potential V |
|---|---|---|---|---|---|---|---|---|
| 1 | $2,5.10^{-2}$ | 1,7 | 2 | -20 | 0 | -60 | -40 | 10 |
| 2 | $8.10^{-2}$ | 1,7 | 2 | 0 | | -40 | -80 | 4 |

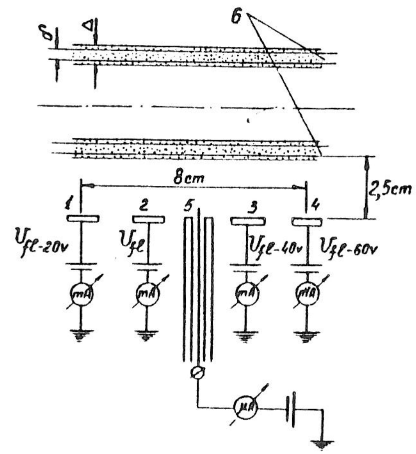


Fig.1 Scheme of the experiment
1,2,3,4 - samples; 5 - probe; 6 - electron beam

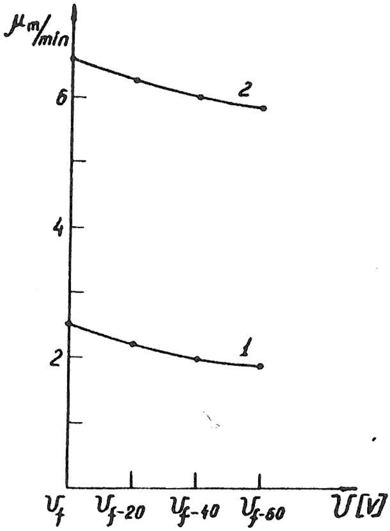


Fig.2 Dependence of dry etching rate on the applied potentail

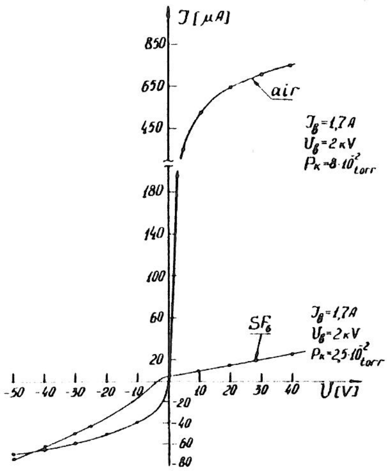


Fig.3 Probe characteristic