Sputtering process of BN based ceramic by the flows of noncompensatied charge plasma

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Abstract: In traditional procedures of sputtering simulation it is used mono energetic ion beams neutralized by electrons adding. But simulating the sputtering process of ceramic in conditions closed to operational real process in the SPT, it is necessary to take into account the influence of the electron component. In this work the investigation of plasma electron component influence on to sputtering process of dielectric surface are presented. The obtained results show that there is no big difference in sputtering process up to the surface potential + 30V in the boundaries of the experimental error.

Nomenclature

E_i = ion energy
$S(E_i)$ = sputtering yield
Δm = sample mass loss
τ = sputtering time
U_d = discharge voltage
I = current
U_Π = probe voltage

I. Introduction

During simulation of the ceramic sputtering process in conditions closed to operational real ones in the stationary plasma thruster (SPT) channel, it is necessary to take into account the influence of electron component[1]. In traditional procedures of simulation it is used mono energetic ion beams neutralized by electrons adding. But in real conditions of SPT operation the ceramic walls of the acceleration channel are bombarded by ions of different energies, so, to our mind it is reasonable to use poly energetic ion flows.

In our work we investigated how plasma electron component influenced on to dielectric surface sputtering process caused by Xe plasma flows. Ceramic sample made of Si_3N_4+BN different composition was used as a tested material.

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In order to recognize clearly how just the electron plasma component influenced on to sputtering process, the electron concentration in plasma beam was changed by the account of thermo-cathode emitter temperature that leaded to ion component undercompensation in the beam hitting to the sample surface.

II. Experimental procedure, results and discussion

In fig.1 one can see a block scheme of the experiment. Under number 5 – radiated sample is presented. On its place it is possible to set (without chamber re-vacuuming) a probe located on a rotating device. The probe is intended for ion current density measurement.

In fig.2 one can see a block scheme of probe connection. The probe is intended for ion current density measurement in the plasma beam bombarding the surface. In this figure it is also represented the volt-ampere performance obtained during ion current determination.

When negative potential is supplied to the probe, the electrons can not reach the surface and already under U_Π in the range -6 to 8 V the ampere meter recording the current coming to the probe shows its value const. The typical probe characteristic is presented in fig.3.

In fig.4 one can see a block – scheme of probe connection under varying "floating" potential at the probe. In this case the probe is not grounded as far as the measuring voltmeter is electrostatic one. In fig.4 one can see how a potential recorded by electro static voltmeter depends on cathode temperature. With filament current decreases less than 20 A, a positive potential is installed on the sample's surface as a result of electrons deficit in the beam bombarding a surface. It is necessary to say that with further cathode temperature decreasing, the discharge disruption is occurred. Due to this fact we can't conduct experiment under surface high positive potentials.
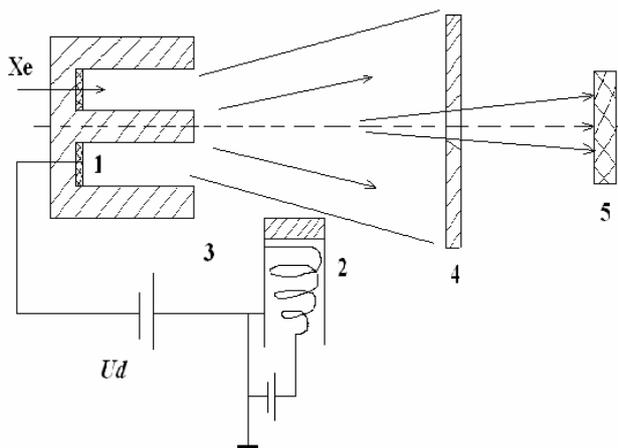

Figure 1. Experimental facility.
1 – anode; 2 – cathode – compensator; 3 – heating tablet LaB_6 – thermo-electrons emitter; 4 cutting diaphragm; 5 – radiating sample or probe.
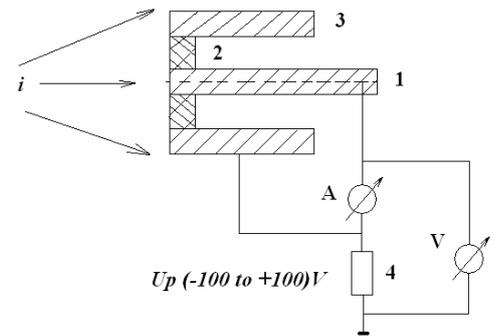

Figure 2. Probe diagram.
1 – metal stick; 2 – ceramic plate;
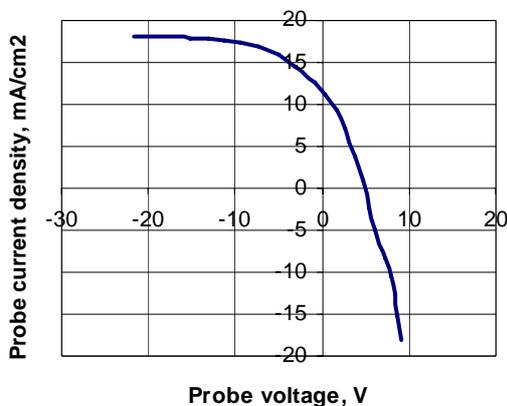3 – securing metal ring; 4 – power supply.
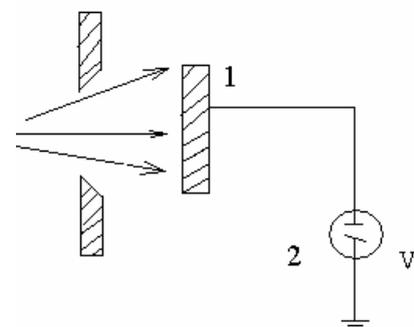

Figure 3. Probe characteristics.

Figure 4. Electrostatic probe.
1 – metallic probe simulating the sample; 2 – electrostatic voltmeter.

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Positive potential on samples surface appears as a result of ion under-compensation in the beam under low heating of thermo cathode. In this case it is necessary to take into account that energy of the ions radiating the surface decreases on the value determining by positive potential of the surface $\left(\Delta E_i = \bar{e} U_\Pi\right)$.

The experiments were carried out according to the following procedure:

– To measure ion current under probe potential U_Π=-10V (see fig.2) under cathode filament 21 A (fig.5). Then to introduce the sample into the flow and to carry out the sputtering experiment under prescribed energy - $\Delta E_i = \bar{e} U_d$, U_d – discharge potential. The amount of sputtered atoms was determined according to target weight change during sputtering $S = \dfrac{\Delta m}{I \tau}$;

– To determine the potential on the probe (fig.4), keeping the cathode filament floating current securing needed positive potential U_Π. To introduce the sample in to the flow. In this case the energy of incidental ions was determined as $E_i = e(U_d - U_{\Pi})$. The value of the discharge anode – cathode potential is equal to its value in the previous item. To measure sputtering coefficients and to compare them with the value obtained in previous item. The possible difference can be explained by electron deficit in the beam bombarding the surface in the second case.
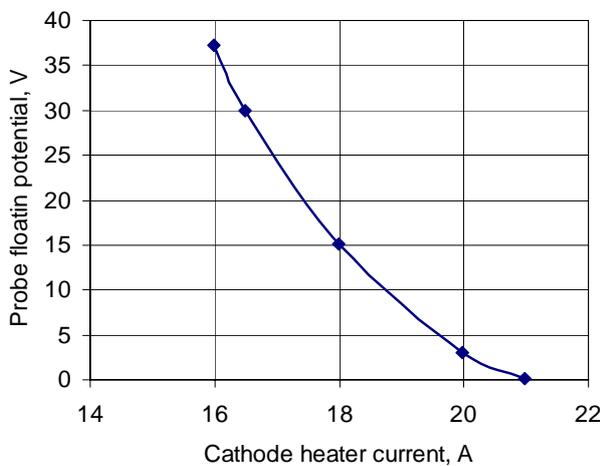

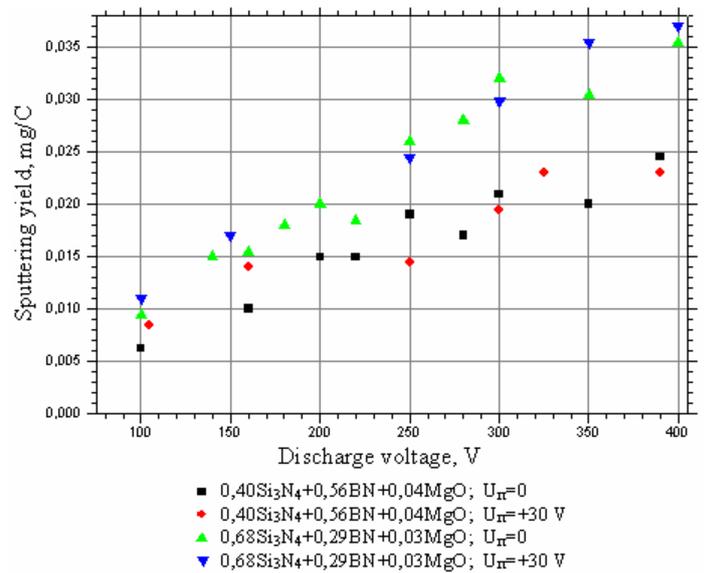Figure 5. Probe "floating" potential dependence on cathode filament current.

Figure 6. Sputtering yield

The obtained results for sputtering yield *S(E_i)* are represented in fig.6. This data was obtained under cathode filament current equal *I*~21A securing zero value of surface floating potential. The surface positive potential occurs due to lack of electrons in the beam when the cathode current was maintained on the 16.6 A. In the second case one can keep in mined that ion energy decreases by the surface potential.

III. Conclusion

The investigations of influence of ion component undercompensation in the beam hitting to the ceramic sample surface show that, in the boundaries of the experiment error, we can not find the difference for sputtering yield *S(E_i)* values up to surface potential +30V.

Acknowledgments

References

Books
[1]Morozov A.I. Introduction into Plasma Dynamic. Moscow: PhIZMATLIT, 2006 (in Russian).