DYNAMIC OF WALL CURRENTS IN PULSE PLASMA DIODE IN TIN VAPOR

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In the paper the level of high-current pulse discharge plasma influence on the chamber wall is carried out, that is important for position choosing of the nanolithographer first collecting mirror with gas-discharge radiation source. In the high-current pulse discharge in tin vapor the dynamic of wall currents space distribution and power of wall effect were experimentally investigated. It has been shown, that the ring area in anode flat is undergone by main influence. It was detected the rapid decreasing of energetic wall effect at distance from discharge axis increasing from 8 to 12 cm.
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4. INTRODUCTION

Creation of commercial nanolithographer demands the high level of radiation power, which assumes using dense high-temperature plasma as a radiation source. As against laser-plasma radiation sources the gas-discharges ones are less power-consuming, that is especially important when nanolithographer supply power could be come up hundreds and thousands kW [1]. For effective conversion of supplying energy in radiation energy with the wave length of 13.4 nm it is perspective to apply plasma with 7 – 12-fold ionized tin atoms. However using the powerful discharges produces the problem of optical tract contamination. In the most difficult conditions the first mirror is situated. Set close to discharge it undergone by intensive influence of charged beam particles and plasma. Besides contamination it leads to heightened energy load on the surface, which could perturb the structure of reflecting layer.

In this paper the dynamic of space distribution wall currents and power of their influence on the wall in high-current pulse plasma diode in tin vapor are investigated.

2. EXPERIMENTAL SETUP

The discharge gap and diagnostic units were set in vacuum chamber, which pumped up to 10^{-6} Tor. The scheme of experiment is shown in Fig. 1. The discharge gap consists a cathode *C* and a needle anode *A*. For radiation withdrawal along discharge the cathode has a tube configuration. The outer cathode diameter was 1.1 cm, the inner one was 0.7 cm. The diameter of needle anode *A* was varied from 0.15 to 0.5 cm. For anode current concentration on the butt-end the anode side was covered by tube ceramic insulator. The sides of cathode and anode were covered with pure tin layer. The distance between cathode and anode was 5 cm.

The cathode and anode through the coaxial system of current-supply were attached immediately to capacitor with capacity of 2 μF, which charged up to voltages of 4…15 kV. At low pressure the discharge were ignited after discharge gap filling by initial plasma due to surface disruption on the cathode due to 3 additive ignitor rods (V_{ign}= 0.5…5.0 kV).

For dynamic investigations of space current distribution the system *CS* with 16 collector units was used. The collector unit is the flat disk electrode with the area of 0.25 cm^2 loaded on resistor of 0.1 Ω. The back side of disk electrode and the resistor were protected with copper shield. The signals from resistor of each collector unit were send with coaxial cable through airtight vacuum feed-through and fed on 4[th] channel digital oscillographes Tektronix TDC 2014 with bandwidth of 100 MHz.

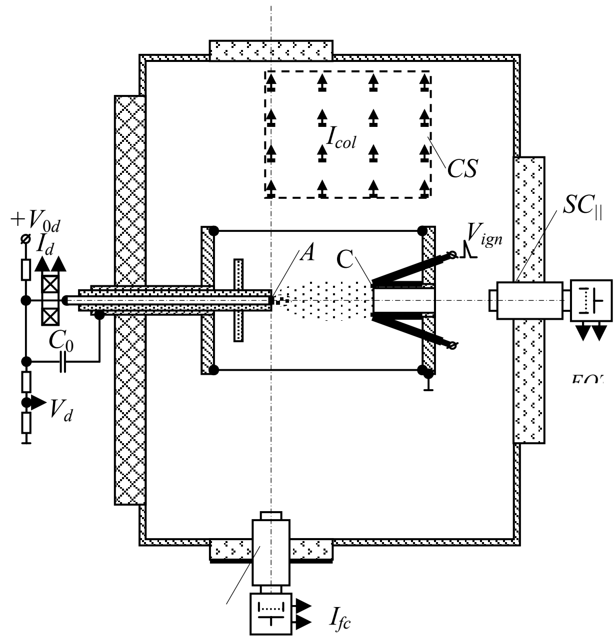

Fig. 1. The scheme of the experiment

The particles energy was estimated by method of retarding field. For this the disk electrodes were switched off from the load resistors, and firstly the dynamic of floating potential was investigated, then different voltage of correspondent polarity was supplied on electrodes.

Additionally the measurements of photo-current in longitudinal and in transverse direction were carried out in experiments by sensor $SC_{\parallel}$ and $SC_{\perp}$. The photo-current sensors were disk electrodes supplied with negative voltage of 85 V, set behind grid at ground potential. Radiation to the sensors was fed through the channels placed in long transverse magnetic field. It protected the sensors from influence of charged beam particles and plasma.

3. RESULTS AND DISCUSSION

In carried out investigations the sufficient current was observed in inductive mode of discharge evolution. In the first half-cycle of discharge current the current pulse of positive polarity was fixed, in the second one the current pulse of negative polarity was fixed. The duration of the pulses was compared with half-cycle durations. The experiments on particle energy measurement shown that the main current transfer the particles with the energy of ~ 50 eV as at positive and at negative collector current as well. It should be pointed out, that the particles groups with the energy to 1000 eV were observed, but their contribution in collector current was small. (The particles surge of such an energy took place, as a rule, in the moment of discharge transition from high-voltage mode to high-current one.)

At data treatment the averaged positive and negative current on a collector were calculated. Averaging was done by numerical integration separately of positive and negative components of signal with the following dividing on the duration of correspondent current part.

The space distribution of positive current measured with collectors system and photo-current are shown in Fig. 2. The space distribution of negative current observed at second half-cycle is presented in Fig. 3. It should be pointed out, that the measurements had not carried out on the distance closer than 8 cm from the discharge axis due to rising of discharge current reconnection on collectors and measuring system elements.

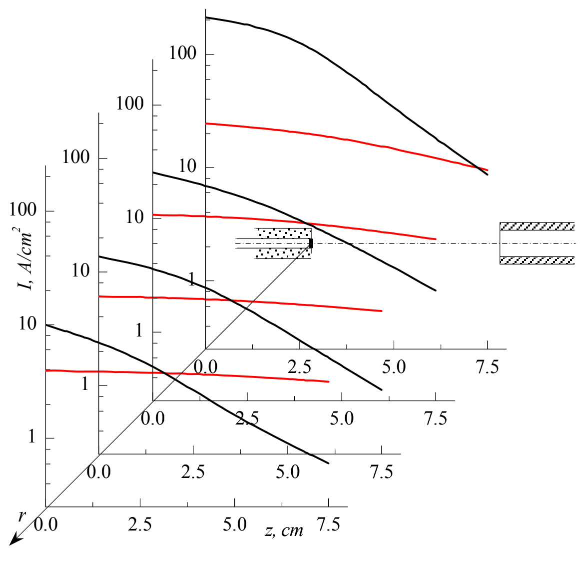

Fig. 2. Space distribution of positive current densities (black) and photo-current one (red) in first half-cycle of discharge current for V_{dis}= 12 kV

One can see from the mentioned space distributions that maximum current fits to ring area ~ 2,5 cm in wide in anode flat. Then toward the cathode the magnitude of wall current strongly decreases. The maximum positive current densities were observed at the level of 100… 250 A/cm^2, the negative ones were observed at the level up to 100 A/cm^2 on the distance of ~ 8 cm from the system axis. As moving off from the axis the current value drastically decreases and on the distance of ~ 12 cm it already falls on the order of magnitude. According to Fig. 2 as moving off from the discharge area it is observed the uniform reducing of photo-current value.

The calculations results of power space distribution are shown in Fig. 4. One can see that time-averaged power in discharge pulse loaded on the wall could come up to 20 kW/cm^2. The Fig. 5 demonstrates the dependence of power value loaded on the wall in anode flat on the discharge voltage and distance from the discharge axis. The investigated range of discharge voltage was chosen subject to paper results [2], where it had been shown, that in the present voltage range it is observed the intensive peak of EUV radiation.

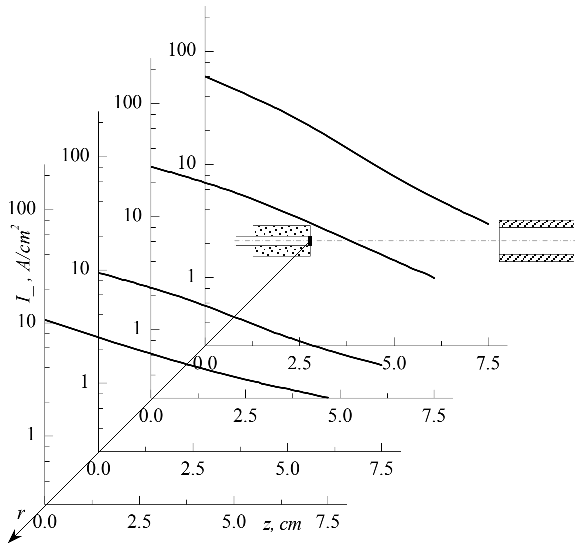

Fig. 3. Space distribution of negative current densities in second half-cycle of discharge current for V_{dis}= 12 kV

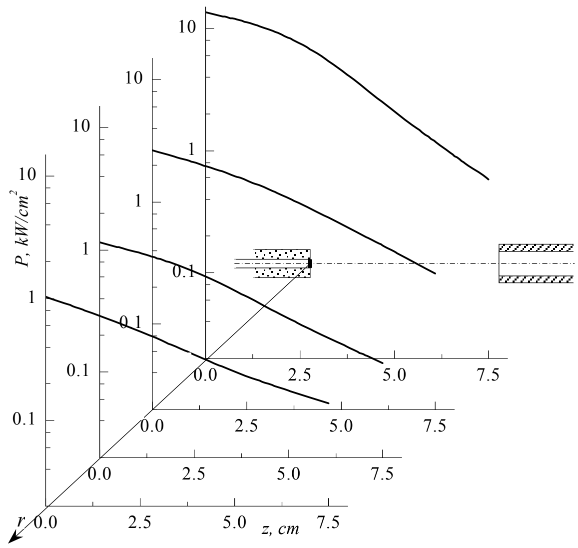

Fig. 4. Space distribution of power loaded on the wall for V_{dis}= 12 kV

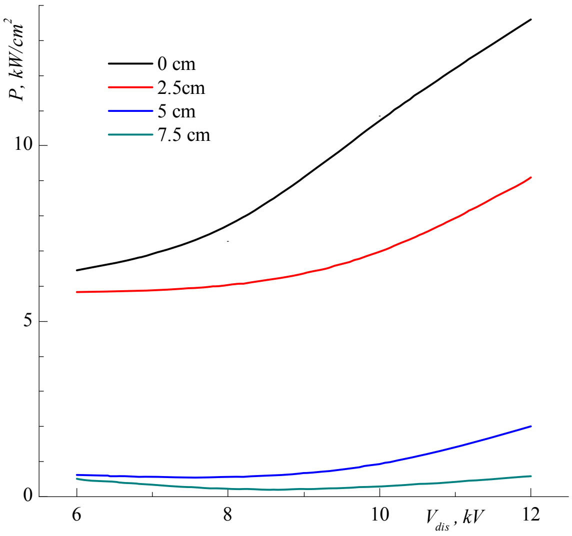

Fig. 5. The dependence of power value loaded on the wall in anode flat on the discharge voltage and distance to the discharge axis

4. CONCLUSIONS

Basing on obtained current space distribution for discharge voltage from 6 up to 12 kV it was established that the most intensive current had been observed in ring area of ~2.5 cm in length in the anode flat. In the radial direction the current intensity fell on a order of magnitude at distance increasing from 8 to 12 cm. At that in the first half-cycle of discharge current the positive current on collectors was observed, but in the second one – negative.

Thus, it has been established that at using high-current discharges in metal vapor as radiation source even at ultra low pressure there is fairly significant range of increased energy loads on a collecting mirror. But the positive moment is its sharp spatial confining. Therefore at lithography system with plasma emission source creating it should be taken into account the spatial distribution of high energy loads zone in the every specific case to choose the set of the mirror out of this region.

REFERENCES

1. R. Seisyan. Nanolithography GSI in EUV (Review) // *Journal of Tech. Phys.* 2005, v. 75, N 5, p. 1-13 (in Russian).
2. A.F. Tseluyko, V.T. Lazurik, D.L. Ryabchikov, I.N. Sereda, D.V. Zinov'ev, I.V. Borgun. The direction of super-radiation from plasma of high-current pulse plasma diode // *Problems of Atomic Science and Techn. Series "Plasma Electronics and New Acceleration Methods"(68)*. 2010, v. 4, p. 66-69 (in Russian).

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ДИНАМИКА ПРИСТЕНОЧНЫХ ТОКОВ В СИЛЬНОТОЧНОМ ИМПУЛЬСНОМ ПЛАЗМЕННОМ ДИОДЕ В ПАРАХ ОЛОВА

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Исследуется уровень воздействия плазмы сильноточного импульсного разряда на стенку камеры, что важно для выбора месторасположения первого собирающего зеркала нанолитографа с газоразрядным источником излучения. В сильноточном импульсном разряде в парах олова экспериментально изучена динамика пространственного распределения пристеночных токов и мощности воздействия на стенку. Показано, что наибольшему воздействию подвергается кольцевая область в плоскости анода. Обнаружено резкое спадение энергетического воздействия на стенку при увеличении расстояния от оси разряда с 8 до 12 см.

ДИНАМІКА ПРИСТІНОЧНИХ СТРУМІВ В СИЛЬНОСТРУМОВОМУ ІМПУЛЬСНОМУ ПЛАЗМОВОМУ ДІОДІ В ПАРАХ ОЛОВА

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Досліджується рівень впливу плазми сильнострумового імпульсного розряду на стінку камери, що важливо для вибору місця розташування першого дзеркала нанолітографу, що збирає з газорозрядним джерелом випромінювання. В сильнострумовому імпульсному розряді в парах олова експериментально вивчена динаміка просторового розподілення пристінних струмів та потужності впливу на стінку. Показано, що найбільшому впливу підлягає кільцева область в площині аноду. Виявлено різкий спад енергетичного впливу на стінку при збільшені відстані від осі розряду з 8 до 12 см.