DIAGNOSTIC SYSTEM FOR EUV RADIATION MEASUREMENTS FROM DENSE XENON PLASMA GENERATED BY MPC

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Magnetoplasma compressor (MPC) of compact geometry has been designed and tested as a source of EUV radiation. In present paper diagnostic system for registration of EUV radiation is described. It was applied for radiation measurements in different operation modes of MPC. The registration system was designed on the base of combination of different types of AXUV photodiodes. Possibility to minimize the influence of electrons and ions flows from dense plasma stream on AXUV detector performance and results of the measurements has been discussed.
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1. INTRODUCTION

Development of powerful high-stable source of vacuum ultraviolet radiation (EUV, λ~13.5 nm) is important from the point of view further technological progress in production of microelectronic components by photolithographic method. There are several advanced types of the devises for solution of this problem: laser plasma systems with solid target (tin, lead, lithium), different kinds of plasma discharge devices (z-pinches, plasma foci and MPC systems with xenon plasma, capillary discharges etc), plasma devices with metal powder and tin vapour [1-3]. All these devices have some advantages and disadvantages, but there is general important diagnostic task for development and improvement these facilities as light sources –registration and measurement of EUV radiation in different wave-length ranges with high temporal and spatial resolution.

2. SCHEME OF EUV REGISTRATION SYSTEM

One of the most universal methods of EUV radiation registration is based on application of semiconductor photodiodes. The photodiodes for registration of EUV spectral range must be installed in vacuum chamber, because EUV radiation is strongly attenuated in atmosphere. The semiconductor detectors can be used with different kind of filters for selection of necessary wavelength range. Applying filters result in reduce of the radiation intensity and measured signal amplitude. Thereby, the photodiodes must have sufficient sensitivity in this range. Another important detector parameter is amplitude-frequency characteristic, since a majority of EUV sources have pulsed regime of operation. Typical pulse duration lies from several nanoseconds to some microseconds. In this work, absolutely calibrated AXUV diodes manufactured by IRD inc. were used to measure the radiation intensity and radiation energy in required wavelength ranges [4]. From these measurements efficiency of radiation source can be evaluated.

The AXUVE based diagnostic system for selection and registration of EUV radiation from plasma stream was designed, manufactured and tested in plasma experiments. The block scheme of registration equipment is shown in Fig. 1. This system consists from duralumin corps with 20 cm in diameter, height of 6 cm and connection tube from stainless steel with maximum diameter of 26 mm and 10 cm in length. Connection tube consists from two coaxial tubes. Outer tube is used for connection of diagnostic system with vacuum chamber of plasma source [5, 6] and for vacuum pumping of corps.

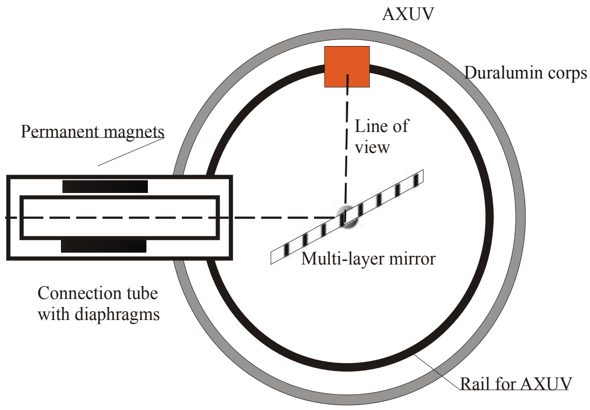

Fig. 1. Block diagram of the registration system

The inner tube with diameter of 12 mm has two diaphragms (input and output). The diaphragms determine line of view and spatial resolution for measurements of EUV radiation. Typical spatial resolution in near axis region is below 1 cm. Two permanent magnets were installed between walls of inner and outer tubes in order to provide deflecting magnetic field with strength up to 0.5 T inside inner tube. This field prevents charged particles penetration into the registration tract.

In central part of diagnostic system the multi-layer mirror has been installed. The mirror has a possibility for rotation around the centre of corps providing variation of reflection angle from the mirror surface. The multilayer mirror [7, 8] in registration system was adjusted for radiation in 13.5 nm wavelength, but radiation in visible wave range could be reflected from mirror too. Possible influence of visible radiation on results of AXUV measurements has been checked. The detector in special holding system was mounted on rail in registration system and had possibility of moving around the centre of corps and measuring visible and EUV radiation. Different types of AXUV diodes were applied for EUV radiation measurements.

Output part of the inner tube has holding ring for installation of different kinds of filters [9]. It made possible changing the range of wavelengths, which measured by AXUV (without additional internal filter). Aluminium foil with different thickness and quartz was also used as filters in our experiments. Multi-layer Mo/Si mirror was applied in first stage of experiments as selective element.

3. INFLUENCE OF CHARGED PARTICLES

The flow of particles from plasma stream through the connection tube to AXUV surface is one of possible obstacles for accurate measurements of EUV. Copper collector (with size corresponding to AXUV dimension) was applied for measurements of particles current. The collector was installed into AXUV holder with line of view directly to the plasma stream through varied number of diaphragms. The flow of electrons and ions along the connection tube to the collector surface was registered. The current of ions measured by collector was up to (0.1…0.3) A if no diaphragms applied. A typical signal of particles current to the collector is presented in Fig 2.

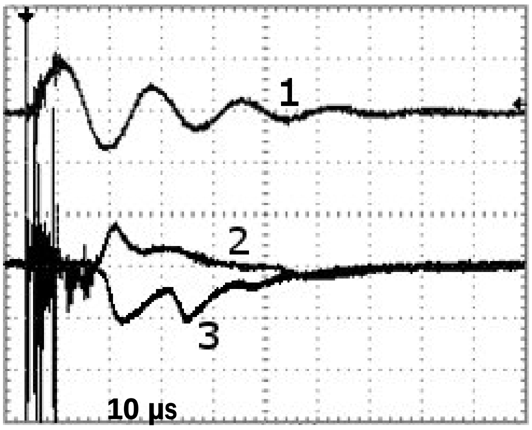

Fig. 2. Wave forms of discharge current at U_c=20 kV (1), particles current to the collector (2) and radiation in visible wave range, measured by photodiode(3)

As it is shown in this figure, the currents of electrons and ions were clearly observed. The current of electrons appears first and it starts earlier than signal from photodiode. Duration the electron current signal is about 6...8 µs. The current of ions starts after 10...12 µs from the discharge ignition and in the same time moment with photodiode signal. The duration of ion current is about 30-35 µs and it corresponds to duration of radiation in visible wave range. The maximum value of ion current in this figure is about 0.1 A. The values of electron and ion currents were decreased by several times using input and output diaphragms with diameter of 1 and 1.2 mm correspondingly, but it still has essential level up to (1...3)×10^{-3}A. Time evolution of electron and ion currents remains without changes. Two permanent magnets were installed between walls of outer and inner connection tubes for more effective suppression of electron and ion currents. The magnets provided magnetic field across particles flow direction with strength up to 0.5 T. In this perpendicular magnetic field most of particles were deflected to the wall. Thus electron and ion currents to the collector decrease drastically. The detected current falls down (1...2)×10^{-6} A. Thereby, the negative influence of particle current on EUV measurements was reduced below the level of sensitivity in diagnostic equipment.

4. TESTS OF REGISTRATION SYSTEM AND FIRST RESULTS

First experimental tests of registration system were made to check the influence of high power visible radiation from the compression zone to our EUV detector. The AXUV-20 photodiode with Mo/Si film on the surface was used for EUV measurements in narrow bandwidth of 12.2…15.8 nm. Detector was installed to the holder of registration system. A quartz glass was applied as the filter for visible light selection. It was installed in front of AXUV-20 Mo/Si. Radiation measurements from the plasma stream showed that radiation with wave length more than 200 nm and, in particular, in visible wave range did not registered by the detector. The level of signal was less than 1 mV (noise-level). Thus, the radiation in visible wave range doesn't make influence on measurements in EUV region.

Typical signals from AXUV (in EUV region), the radiation intensity of visible xenon lines (observed by photoelectronic multiplier with spectral selector) and the discharge current are shown in Fig. 3. From this data follows that with reduction of wavelength the start time of light emission shifts to the moment of discharge ignition.

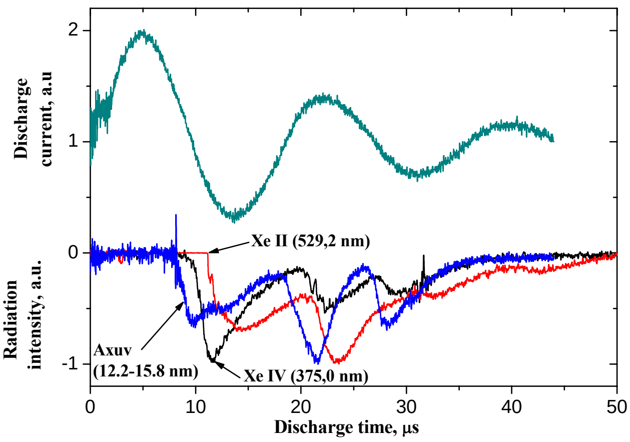

Fig. 3. Waveforms of discharge current and radiation intensity in visible and EUV region

Thus, the experiments show that the electromagnetic radiation from plasma discharge, and also the particles flux from the plasma stream to AXUV through connection tube, doesn't make any influence on performed EUV measurements.

It was found that radiation peak from the compression zone, measured in half width, is about 3…5 µs. The intensity of EUV radiation rises with increase of discharge current and this increasing is faster than registered grow of visible radiation intensity.

EUV radiation depends on operation modes of magnetoplasma compressor. It was discovered that most important parameter in this case is time delay between the gas injection start and the moment of discharge ignition. In present experiments the time delay was varied between 400 to 600 µs. The maximum intensity of EUV radiation was measured when time delay is 450 µs. The intensity of EUV radiation is reduced with increasing of the time delay up to 600 µs.

5. SUMMARY

Diagnostic system for EUV measurements based on AXUV detectors was designed, manufactured and tested. Permanent magnets were applied to decrease the influence of particles flux from plasma stream to AXUV surface. It was achieved, that the influence of particles on AXUV detector became less than sensitivity of equipment. Therefore, it doesn't have any influence on the EUV measurements. It was shown, that electromagnetic radiation from the plasma discharge, does not affect results of measurements.

The EUV radiation in 5…13 nm wave range was monitored. The region of measured wavelengths was selected by film filter and type of AXUV detector.

The intensity of EUV radiation rises with increase of discharge current and this increasing is faster than grow of visible radiation intensity. It was found that radiation peak from the compression zone, measured in half width, is about 3…5 µs.

It is shown that the maximum level of EUV radiation depends on operation modes of magnetoplasma compressor. The most important parameter, which determines the variation of operation mode, is time delay between the gas injection start and the moment of discharge ignition.

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СИСТЕМА РЕГИСТРАЦИИ ВУФ- ИЗЛУЧЕНИЯ ИЗ КСЕНОНОВОЙ ПЛАЗМЫ ВЫСОКОЙ ПЛОТНОСТИ, ГЕНЕРИРУЕМОЙ МПК

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Магнитоплазменный компрессор (МПК) компактной геометрии был разработан и испытан в качестве источника излучения ВУФ. В настоящей работе описана диагностическая система для регистрации излучения ВУФ. Проведены измерения ВУФ-излучения в различных режимах работы МПК. Система регистрации построена на основе сочетания различных типов фотодиодов AXUV. Было исследовано влияние потока электронов и ионов из плазмы на поверхность детектора, а также видимого излучения на результаты измерений.

СИСТЕМА РЕЄСТРАЦІЇ ВУФ ВИПРОМІНЮВАННЯ З КСЕНОНОВОЇ ПЛАЗМИ ВИСОКОЇ ГУСТИНИ, ЯКА ГЕНЕРИРУЄТЬСЯ МПК

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Магнітоплазмовий компресор (МПК) компактної геометрії було розроблено і випробувано у якості джерела випромінювання ВУФ. У цій роботі описана діагностична система для реєстрації ВУФ-випромінювання. Проведено вимірювання ВУФ- випромінювання в різних режимах роботи МПК. Система реєстрації побудована на основі поєднання різних типів фотодіодів AXUV. Було досліджено вплив потоку електронів та іонів з плазми на поверхню детектора, а також видимого випромінювання на результати вимірювань.