INFLUENCE OF A CONSTANT MAGNETIC FIELD ON THE UNIFORMITY OF PLASMA GENERATED BY PLANAR ICP SOURCE

A. Yasunas, D. Kotov

Belarusian State University of Informatics and Radioelectronics, P.Brovky 6, Minsk, 220013, Republic of Belarus, alex.yasunas@gmail.com

Inductively coupled plasma (ICP) sources are widely used in the technologies of plasma chemical etching and deposition for low-temperature high-density plasma generation at pressures of 0.05-10 Pa. It is possible to improve plasma treatment uniformity by simultaneous decrease in the operating pressure and increase in the surface being treated by means of ICP source's antenna system geometry, constant gas supply into plasma generation area, and also by means of an external constant magnetic field in a process reactor. In this work it is introduced a research of the influence of a constant magnetic field distribution in a plasma treatment process reactor on the basis of a flat ICP source 200 mm in diameter with a four-spiral helical antenna system, having a discharge gap 55 cm in length, on plasma concentration distribution; a magnetic trap configuration wherein plasma uniformity improves from ±37% to ±24% at a distance of 120 mm from a plasma source was determined.

As was shown in the work /1/ a constant magnetic field has an influence on the operating pressure and the ICP source's plasma concentration. To determine the influence of a constant magnetic field on the ICP source's plasma concentration distribution in a vacuum plant «UVN-630» a stand for measuring plasma concentration distribution over the ICP source's surface at different distances to a plasma source and different magnetic trap configurations was assembled. The measuring stand design is shown in Fig. 1. To measure plasma parameters a single cylindrical Langmuir probe with RF compensation of space charge oscillations was used, a detailed description of this measuring technique is introduced in the work /2/. The measuring probe was fixed on a scanning system, which ensured its movement parallel to the surface of plasma source antenna system. The distance from the plasma source surface to the probe cone scanning surface was: 120 mm, 75 mm and 25 mm, scanning amplitude – 115 mm from the source's axis. A negative bias of 30 V was applied to the probe, ion saturation current was recorded by a micro-ammeter.

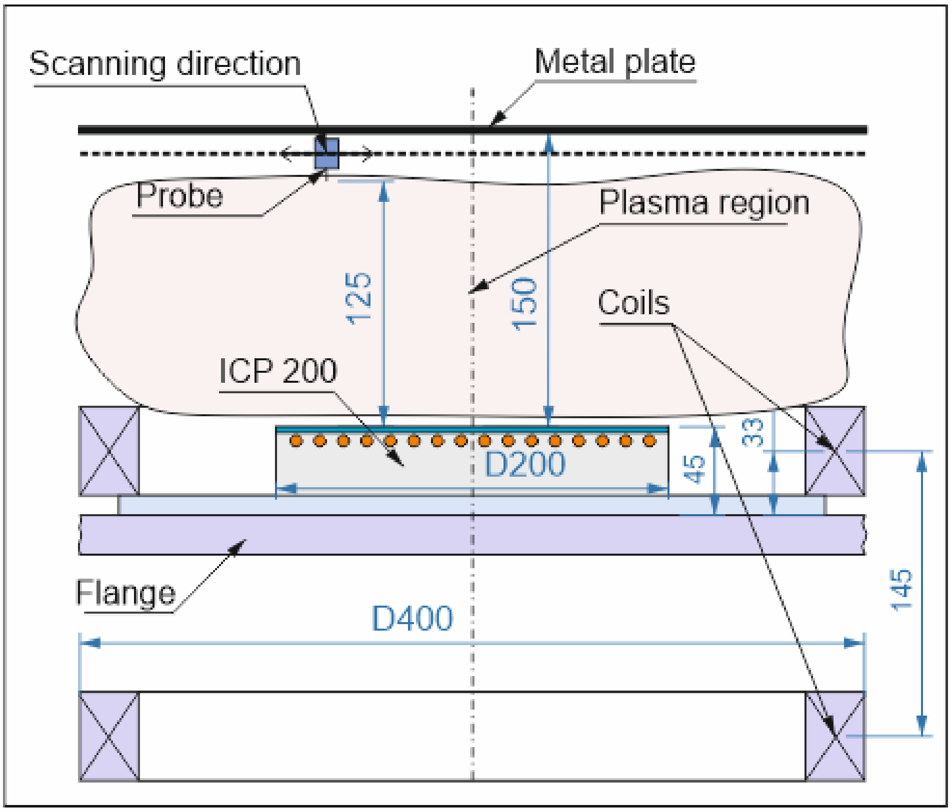


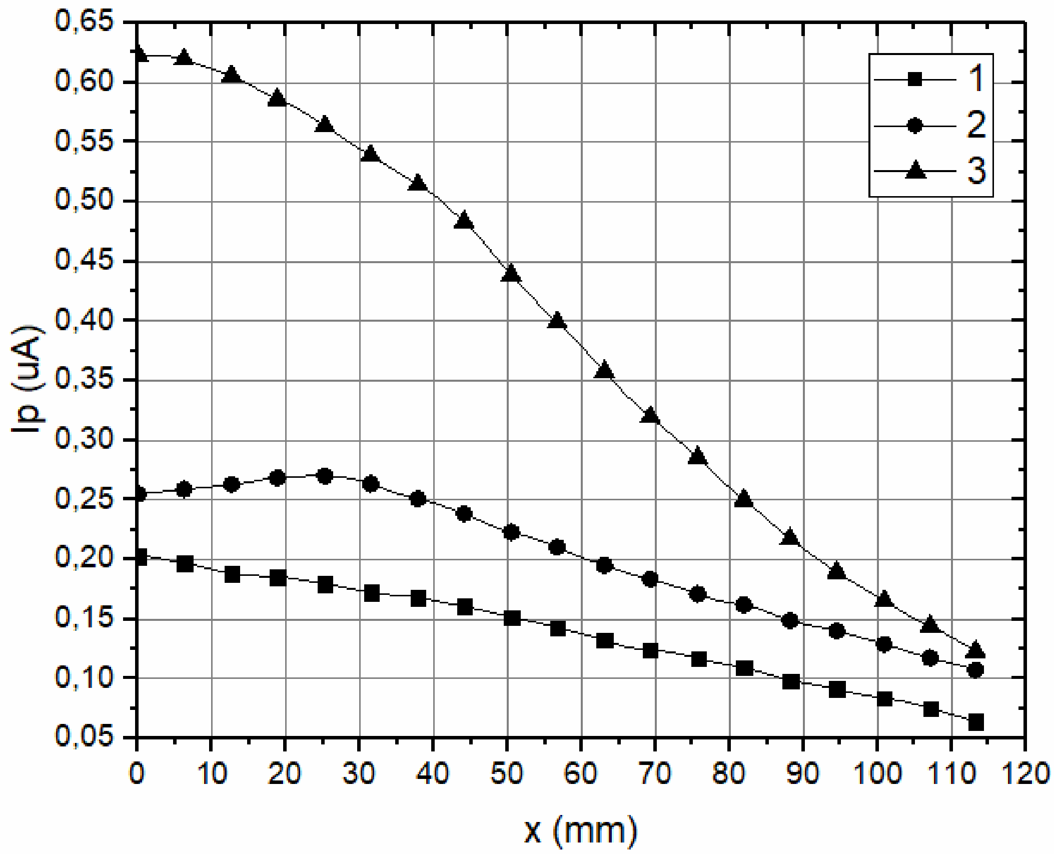
Fig. 1 – Allocation scheme of the devices in the chamber of the vacuum plant «UVN-630»

Fig. 2 represents distribution of ion saturation current on a measuring probe depending on the distance to the process reactor axis – the distance from the ICP source antenna system surface to the probe: 120 mm, 75 mm, 25 mm, pressure – 6 Pa, RF power – 600 W, solenoids are disabled. The graph was constructed from the central axis of the ion source.

All the graphs represent maximum ion saturation current, and, consequently, plasma concentration locates on the source's axis and falls to its edge, what is caused by the diffusion of charged particles from the plasma formation area as a result of their chaotic motion. In order to reduce this effect, it is possible to use magnetic traps of different configurations. In the considered case for the magnetic field formation two solenoids situated behind the ICP source were used (see Fig. 1). Such an arrangement was chosen due to the necessity to use the obtained results in a vacuum plant of the chosen type.

Magnetic field distribution was calculated by finite elements method with the help of program complex COMSOL Multiphysics. Fig. 3 represents a magnetic trap at the current of the lower solenoid equal to 1568 A×turns, and at the current of the upper solenoid - 700 A×turns. We can see an area with zero magnetic field induction on the source's axis, the distance of which from the antenna system surface will be used to describe a magnetic trap and indicated by

H (H=0 mm for this particular case). Table 1 represents main traps configurations where plasma concentration was measured.



1 – 120 mm; 2 –75 mm; 3 –25 mm

Fig. 2 – Distribution of ion saturation current on a measuring probe for different distances from the ICP source antenna system surface to the probe

Table 1 – Experimental results

	Ion saturation current uniformity, ± %			Distance probe-plasma source, mm	Magnetic trap
№	D220	D200	D150		
1	43	37	24	120	without a magnetic field
2	30	26	14	75	without a magnetic field
3	56	48	26	25	without a magnetic field
4	70	61	34	120	B=0,1-0,3 mT; H = ∞ (2)
5	58	55	42	120	B=0,05-0,2 mT; H = 50 mm (5)
6	35	28	16	120	B=0,2-0,5 mT; H = 25 mm (6)
7	44	38	23	120	B=0,2-0,8 mT; H = -30 mm (11)
8	42	38	24	120	B=0,2-0,4 mT; H = 80-120 mm (12)
9	31	24	12	120	B=0,5-1,5 mT; H = 0 mm (21)

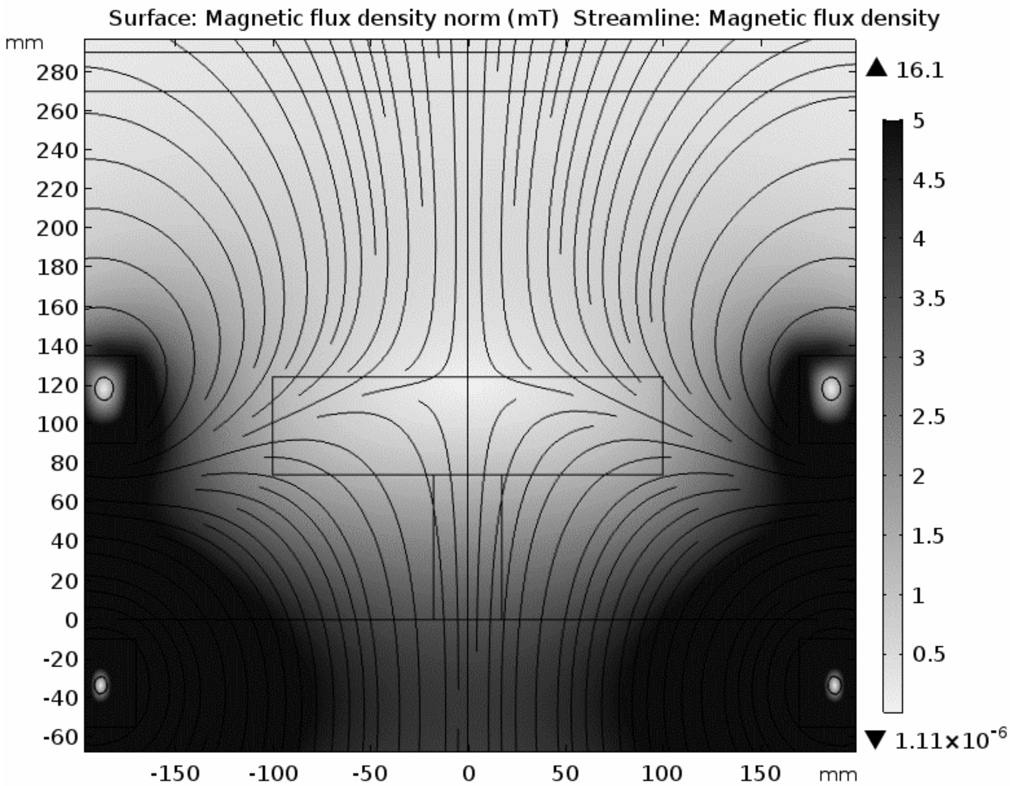
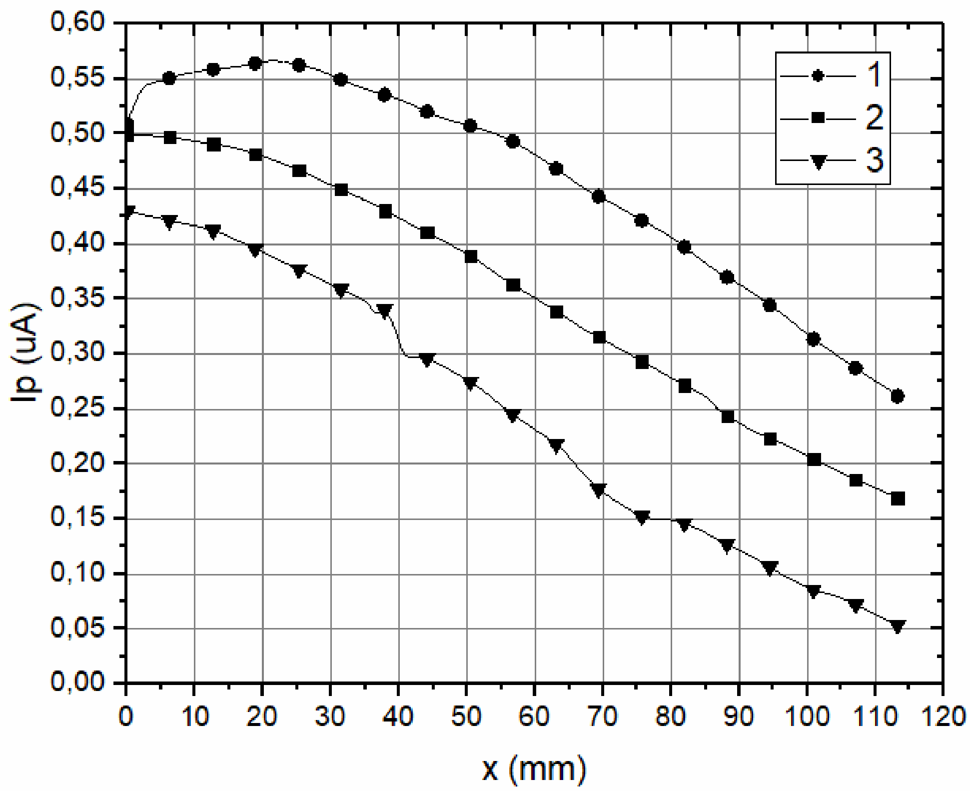


Fig. 3 – Magnetic field distribution in the chamber. Experiment 9 in the table



1 – line 9, 2 –line 7, 3 – line 4, in the table 1
Fig. 4 – Ion saturation current distribution on the probe

From the obtained dependencies of the probe ion saturation current density distribution we can see that the maximum plasma concentration locates over the center of the ICP source's antenna system. The most uniform is plasma distribution situated at the distance approximate to the middle distance between the antenna system and the process reactor wall parallel to it.

An introduction of an additional constant magnetic field allows to control the size of the uniform plasma distribution area. So the creation of the magnetic field gradient, where magnetic induction has minimum on the antenna system axis and increases to its edges, allows to increase the uniformity of plasma concentration distribution from 43 % to 31-35 % (experiments 6, 9 in the table 1). The best uniformity is obtained when a magnetic field increases at a distance from plasma source antenna system surface to the measuring plane with 0,01-0,05 mT до 0,7-0,9 mT (experiment 9 in the table 1). And if the gradient change is of the opposite character the plasma concentration distribution uniformity goes down (experiment 5 in the table 1).

A uniform distribution of a magnetic field with the induction lower than 0,8 mT doesn't make significant changes in the distribution of plasma concentration generated by the ICP source, the change in plasma concentration distribution doesn't exceed 1% (experiments 7,8 in the table 1). Fields with the induction higher than 0,1 mT have a significant influence over plasma concentration distribution - deterioration of uniformity from 43% to 70 % in the experiment 4, table 1.

References

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2. **Yasunas, A.A.** The influence of antenna system configuration on the parameters of the inductively coupled plasma / A. Yasunas, D. Kotov. VII International Conference, Plasma Physic and Plasma Technology, Minsk, Belarus, September 17 –21, 2012., 2012. – 639-642 p.