Optimization of Magnet System for Magnetron Plasma Source

O.H. Asainov, E.A. Ibragimov, and V.P. Krivobokov

Nuclear Physics Research Institute, 2a, Lenina ave., Tomsk, 635050, Russia
Phone: +8(3822) 41-79-54, Fax: +8(3822) 41-79-56, E-mail: egor83@list.ru

Abstract – The calculations of magnetic field of magnetron plasma source have been done by software ELCUT in order to study the reasons of its constructional element sputtering. It has been found out that it is necessary to change the magnetron configuration to eliminate this disadvantage. For the assumed configuration of magnetron the magnetic inductance values have been calculated as well as the experiment for magnetic inductance value measurement at the surface of its target has been done. The calculation results showed a very good coincidence to the experimental values. This indicates the correctness of the selected software and given boundary conditions. The assumed magnetron configuration allowed avoiding the disadvantages of the previous configuration as well as to obtained coatings of better quality.

At the present moment among a lot of methods of thin film coating generation the vacuum ion plasma methods are the most promising ones. This is mainly connected to their ecological safety, high purity of technological processes and quality of product. But in spite of all advantages of these methods there is a row of disadvantages such as high cost of equipment, heterogeneity of the applied coatings (arc sputtering), small areas of the treated surfaces (laser ablation), low adhesion (thermal evaporation). The magnetron sputtering partially misses these disadvantages. The drift current of electrons in the crossed electric and magnetic fields gives the possibility to get extensive fluxes of rather dense plasma with the characteristics controllable within a wide range.

Working at magnetrons of extended configuration it was noted that the formation and ignition of plasma take place in the periphery zone instead of target-cathode sputtering zone. The sputtering of the construction elements of magnetron took place what in its turn led to the contamination of film deposited to the substrate by the side admixtures.

To eliminate this disadvantage it was offered to create a computer model of magnetic field picture of magnetron. For modeling the software ELCUT was used which is a product of Russian company PC TOP [1]. The software ELCUT is intended for the engineering solution and simulation of two-dimensional electric magnetic, heat and mechanical tasks by final element method. In comparison to other existing software complexes such as Ansys, Maxwell (Ansoft Inc), Flux (Cedrat), MagNet (Infolytica) capable to solve such tasks, the software ELCUT does not require a special training from user for the study of mathematical foundations of algorithms and peculiarities of their realization [2]. The only thing required is to understand physical principles of modeling device operation.

The users of this software complex are a lot of large enterprises, scientific research organizations and universities of Russia and Independent Countries Union [3].

We also would like to note that the universality of ELCUT complex allows flexibly alter the geometrical parameters of the designing model leaving the component properties without changing.

In our case the calculation of magnetic field was done for several real configurations of magnetron. The cross section drawing of one of them is presented in Fig. 1.

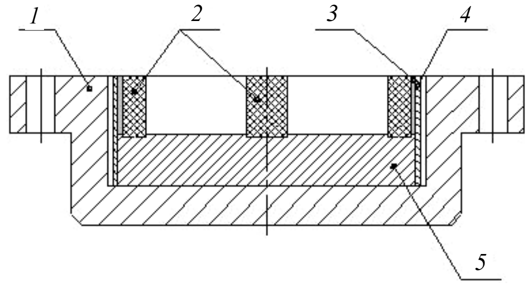

Fig. 1. The magnetron cross section: *1* – magnetron body; *2* – constant magnet system; *3* – dielectric; *4* – screen; *5* – magnetic conductor

This magnetron construction consists of the following materials: aluminum body; steel magnetic conductor and screens are made; samarium cobalt magnets. The value of magnetic field intensity at the magnet surface is 1544 kA/m.

To solve the tasks of magnetic statics in the software complex ELCUT it is necessary to create a geometrical model. In our case the model was given according to the magnetron configuration presented in Fig. 1. Due to the fact that ELCUT is able to solve only the final tasks our model is necessary to surround by a condition boundary which limits the magnetic field. In order to keep the calculation accuracy the condition boundary is located at the distance which is much bigger than the size of our geometrical model. The boundary conditions of our task are the following: the magnetic potential is $A_0 = 0$ at the condition external boundary of the calculation area. The magnetic field intensity over the magnet surface is $H_C = 1544$ kA/m; the direction of coercive force of edge magnets is 90°, and of central one is –90°; the properties of magnetization of magnetic conductor and screens were taken from the data base of ELCUT for A131/B steel (ASTM USA).

The calculation of magnetic field inductance was done at 6-mm distance over the magnetron body surface from its center to periphery (Fig. 2). The choice of this calculation height is related to the fact that while operating at this type of magnetron the targets 6 mm in thickness are more often used.

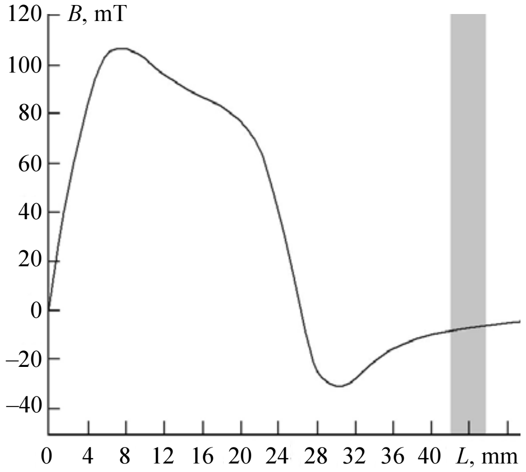

Fig. 2. The values of magnetic inductance

The area of construction element sputtering is indicated in grey color.

From Fig. 2 it is seen that in the area positioning out of the core boundaries (in the area of construction element sputtering of magnetron) the values of magnetic construction were about 10 mT. By tests it was found out that to eliminate the material sputtering in this area it is necessary to create magnetic field with the value lower than 5 mT.

It is also necessary to note that when suing this magnetron construction a sharp increase of magnetic inductance and its further significant drop take place by the central magnet. The presence of such peak is accompanies by the knife-like sputtering of target by the central magnet what leads to a fast wear of target and to a low factor of material usage. The presence of magnetic field inductance peak is related to the use of magnetron of samarium-cobalt magnets. Their peculiarity is a high value of magnetic field inductance at the magnet surface and its fast decrease of distance from magnet.

To eliminate these disadvantages we offered to change the magnetron configuration. At that, one of the determining conditions was that the value of magnetron inductance on the cathode-target sputtering zone should not be less than 50 mT [3].

In the result of optimization calculations a new construction of magnetron was offered presented in Fig. 3.

In the offered construction of magnetron we put magnets at the periphery. The mass of these magnets is twice higher than ones in the central part, also we changes the shape of the screens.

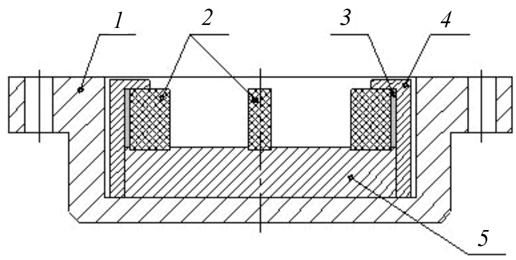

Fig. 3. The altered configuration of magnetron: *1* – magnetron body; *2* – constant magnet system; *3* – dielectric; *4* – G-shape screen; *5* – magnetic conductor

The calculation results for this configuration are shown in Fig. 4.

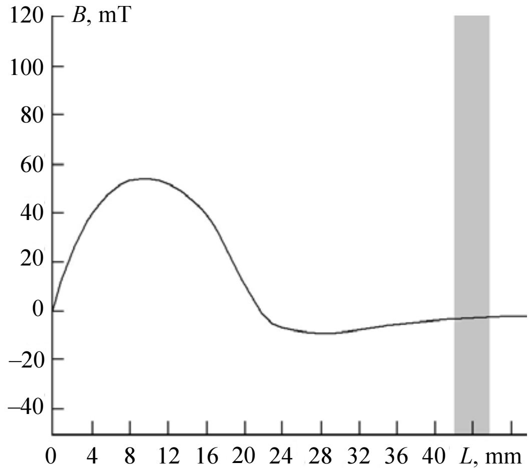

Fig. 4. The value of magnetic inductance of the altered magnetron configuration

From Fig. 4 it is seen that the alteration of magnetron configuration allowed us getting the magnetic field inductance value lower than 5 mT in the area of construction element sputtering.

To check the truth of the obtained results the experiments for the measurement of magnetic inductance value at the magnetron target surface were done Fig. 5.

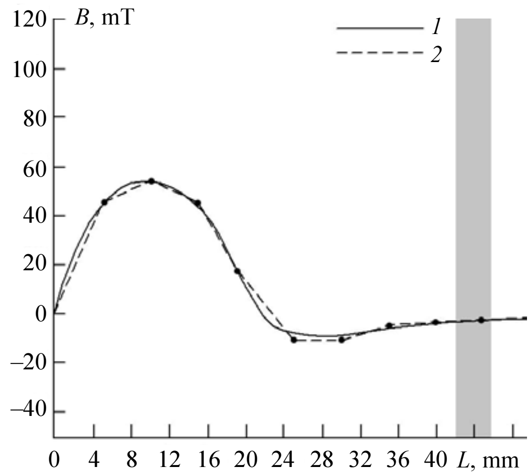

Fig. 5. The comparison of calculation and experimental values of magnetic inductance: *1* – calculation values; *2* – experimental values

The measurement of magnetic inductance was done by the universal milliteslameter TP2-2U.

The results of the experiment presented in Fig. 5 showed a good coincidence to the calculation value. This indicates the correctness of the software used by us and the given boundary conditions.

The comparison of the magnetic field inductance values of the existing configuration of magnetron and configuration offered by use is shown in Fig. 6.

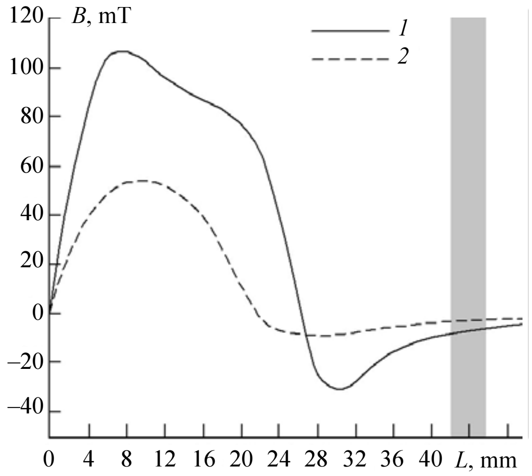

Fig. 6. The comparison of magnetic inductance values: *1* – existing magnetron configuration; *2* – offered magnetron configuration

Analyzing the obtained results we would like to point out the following advantages of the offered magnetron configuration over the existing one:

– the curve of the magnetic inductance in the target sputtering area get a flatter shape so the target sputtering zone became wider and more circular what in its turn led to the increase of material use factor;

– the value of magnetic inductance is lower than 6 mT in the area of magnetron construction element sputtering. The decrease of magnetic inductance took place in the result of magnetron configuration alteration what in its turn allowed us avoiding the plasma formation in the area of construction element sputtering as well as to evoke such disadvantage as contamination of film deposited to the substrate by the admixtures.

References

[1] Description of software complex ELCUT: [e-resource]. http://tor.ru/elcut/feat_r.html.

[2] S.D. Dubitskiy, EDA Express. No. 12, 24–29 (2005).

[3] Users of software complex ELCUT: [e-resource]. http://tor.ru/elcut/cust_r.html.

[4] V.V. Zhukov, V.P. Krivobokov, V.V. Patsevich, and S.N. Yanin, *Properties of Magnetron Discharge at DC. Part 1. Mechanism of Target Sputtering,* Proc. of Tomsk Polytechnic University, 2005, Vol. 308, No. 6, pp. 69–74.