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Apparatus for Secondary Ion Emission Investigation from the Steel Surface Bombarded by A_r^+ Ions with the Energy 1 KeV*

Aparatura do badania emisji jonów wtórnych z powierzchni stali bombardowanej jonami A_r^+ o energii 1 keV

Установка для исследования вторичных ионов из стальной поверхности, бомбардированной ионами A_r^+ с энергией 1 Кэв

1. INTRODUCTION

Positive ion beam of determined energy inciding in a vacuum on a solid state surface causes, for the most part, the sputtering of the surface, but also the emission of positive secondary ions. [1] [2] (in a very small degree), as well as negative secondary ions, electrons, electromagnetic radiation and even some clusters of atoms. Part of the bombarding ions penetrates into the solide, and another part can be reflected. If the solid surface is not quite clean, one can observe ions of the gases absorbed on the solid surface. Therefore, a good vacuum is an important condition in the research on secondary ion emission.

The characteristic value of the secondary ion emission is its coefficient, which is determined as the ratio of the number of ions knocked out from the solid surface, N_w, to the number of the primary ions impinging the surface, in a unite of time – N_0:

$$K_i = \frac{N_w}{N_0} \tag{1}$$

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The values of the secondary ion emission for different elements, and primary A_r^+ ions of energy 40 KeV is given in the work [2]. There, the results of the investigations on the secondary ion emission from steel surface bombarded with A_r^+ ions with energy 2 KeV is presented.

Recently, it is great interest in the propriety of steel, because of its make more hardness after implantation with nitrogen and authers ions [3]. Then, the purpose of ours work is to investigate the steel sample at the point of view of the secondary ion emission.

2. APPARATUS AND MEASUREMENTS

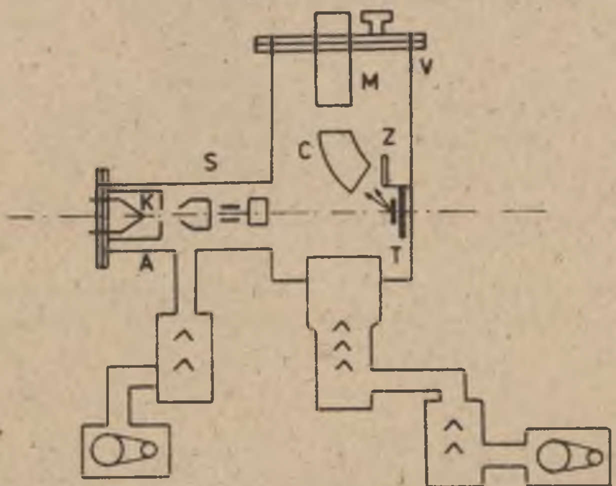

Fig. 1. Diagram of the apparatus: V – vacuum chamber, T – table, C – cylindrical electrostatic analyser, M – ion-electron multiplier, S – primary ion source

It consist of a vacuum chamber V in which there is a table T, to which a sample bombarded with ions is fastened, cylindrical electrostatic analyser C, ion-electron multiplier M, as well as a primary ion source introduced at the side of the chamber S. The apparatus used in our measurements was adjusted from the high vacuum system of the type UHV–P–2000, in which high vacuum is assured by: two rotary pumps, three oil diffusion pumps and one sorption pump.

The scheme of the primary ion source with the focusing system is shown in Fig. 2.

The cathode K of the ion source is made of tungsten wire 0.5 mm in diameter and is heated by direct current of 18 A. The anode A made of acid resistant steel has the form of the cylinder 5 cm in diameter and 6 cm in length. A gas, e.g. argon, is introduced into the discharge chamber through the capilary G. The arc discharge is initiated between the cathode and the anode at the pressure of the order 10^{-4} Tr. The value of the discharge current may be up to 1.5 A.

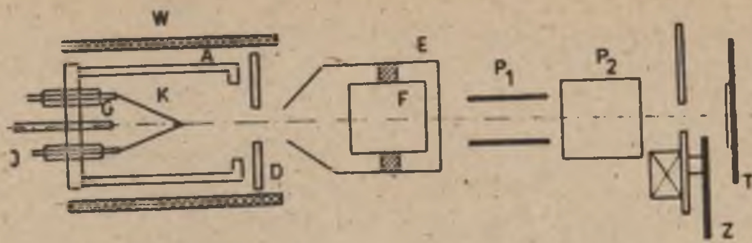

Fig. 2. Primary ion source with the focusing system:

K	–	tungsten cathode	A	–	anode
G	–	capillary	W	–	magnetic coil
D	–	additional electrode	E	–	extracting electrode
F	–	focusing lens	Z	–	movable shutter
P_1	–	two horizontal plates	P_2	–	two wertical plates
T	–	table			

In order to augment the degree of the ionization process in the ion source a magnetic field produced by the coil W is applied. The magnetic lines are parallel to the axis of the ion source and due to this, the electrons move along spiral lines, which makes the path of the electrons longer and thus the probability of ionization is increased. The effect of the ionization process is increased additionally by inserting an electrode D [4] between the anode and the extracting electrode. This system causes oscillation of electrons because they, after passing through the opening in the anode, return to the ion source chamber.

The ions are accelerated from the ion source by means of the electric field created between the ion source and the electrode E which is on the ground potential (extracting electrode). Inside this electrode there is another cylinder F on the positive potential of the value of $\frac{2}{3}$ that of the ion source potential, which plays the role of a focusing lens for the divergent ion beam going from the source. Then the ion beam passes through the system of deflection plates, which consists of two pairs of plates P_1 and P_2. Before the table on which there is the sample bombarded, an additional movable shutter Z, steered from the outside, is mounted. The purpose of this shutter is to determine exactly the time of the ion beam bombardment of the sample because the ions incide on the sample only when the shutter is aside, and to determine the exact value of the primary ion current intensity, just before the experiment.

To find the optimal conditions of the primary ion source work, several characteristics have been made: they are shown in the Figures 3 – 6.

Fig. 3 presents the dependence of the ion current of the A_r^+ ions, for various accelerating voltages, on the arc discharge current. One can see an increase of the ion current along with the increase of the arc discharge current, what is caused by the augmentation of the number of electrons emitted from the cathode, and consequent on that the greater ionization of gas atoms.

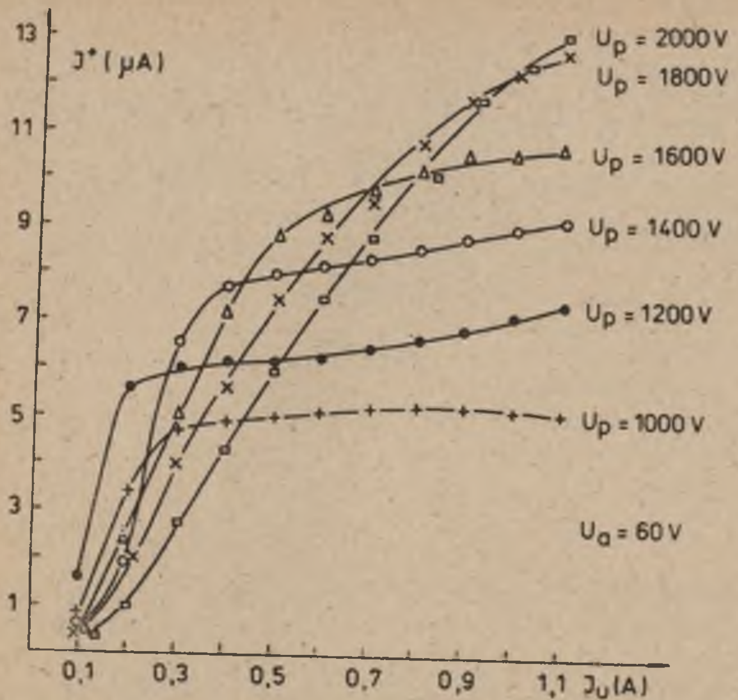

Fig. 3. Dependence of the ion current of the A_r^+ ions, for various accelerating voltages, on the arc discharge current

Fig. 4 shows the dependence of the ion current of the A_r^+ on the anode voltage for different values of accelerating voltage at the constant arc discharge current of 0.6 A. From the diagram one can see that the arc discharge begins at about 30 volts, and after 50 volts the ion current attains saturation.

Fig. 5 presents the dependence of the argon ion current on the focusing voltage for various values of accelerating voltage. The focusing voltage is applied to the lens which is inside the extracting electrode. One can see that the voltage necessary for the focusing of the ion beam increases with the accelerating voltage and is about 80% of that voltage.

Fig. 6 illustrates the dependence of the argon ion current on the coil current which produces a magnetic field, longitudinal to the geometrical axis of the ion source. The curves presented here were obtained for various accelerating voltages.

In secondary ion emission experiments, a steel target was used; the argon ion beam of the energy of 1000 eV and intensity of 6 μA, was used as primary ions. For a very small quantity of secondary ions emitted from the target, the ion-electron multiplier, counter, amplifier, and discriminator were used.

Fig. 7 shows the dependence of the number of the pulses counted from the secondary ions on voltages applied to the multiplier.

Secondary ions emitted from the target fall into the cylindrical electrostatic analyser which works as the energy analyser of those ions. By changing the voltage between the condenser electrodes one can obtain an energy spectrum of secondary ions.

In Fig. 8 the energy spectrum is shown, that is the dependence of the number of the pulses on the secondary ion energy (energetic spectrum). One can see that the maximum amount of the secondary ions has the energy in the range of 15 – 30 eV.

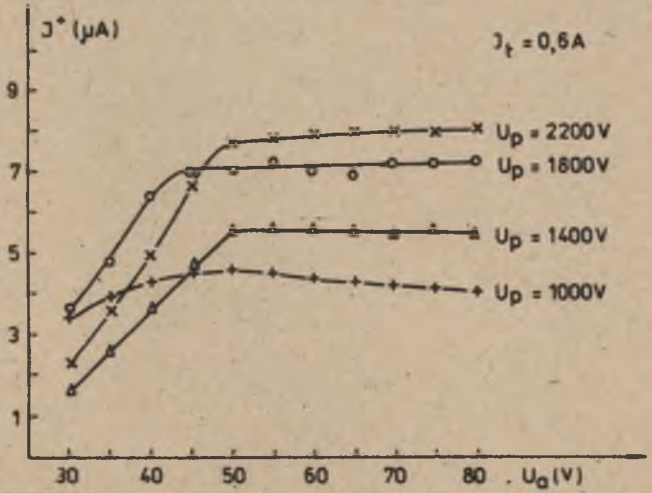

Fig. 4. Dependence of the ion current of the A_r^+ on the anode voltage for different values of accelerating voltage at the constant arc discharge current of 0.6 A

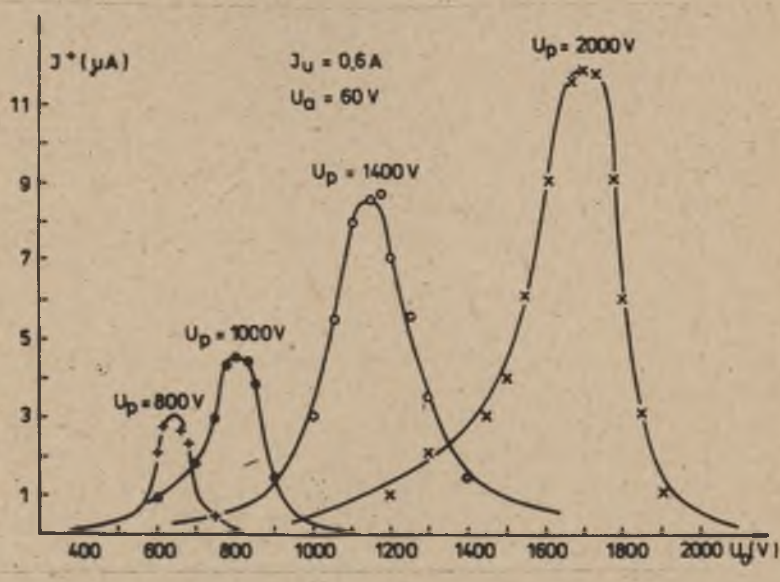

Fig. 5. Dependence of the argon ion current on the focusing voltage for various values of accelerating voltage (U_p)

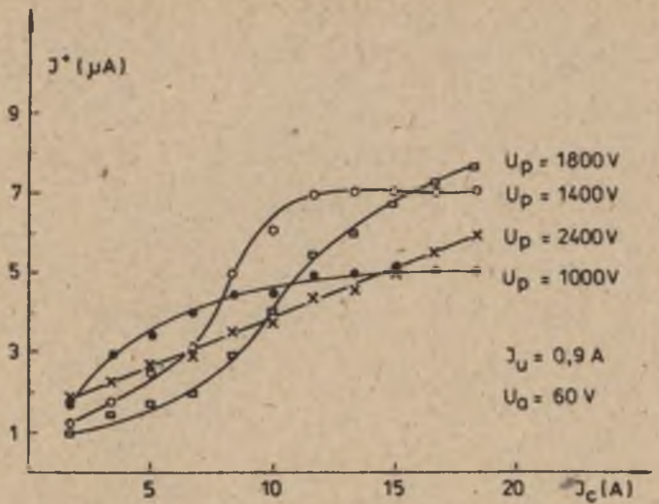

Fig. 6. Dependence of the argon ion current on the coil current for various accelerating voltages

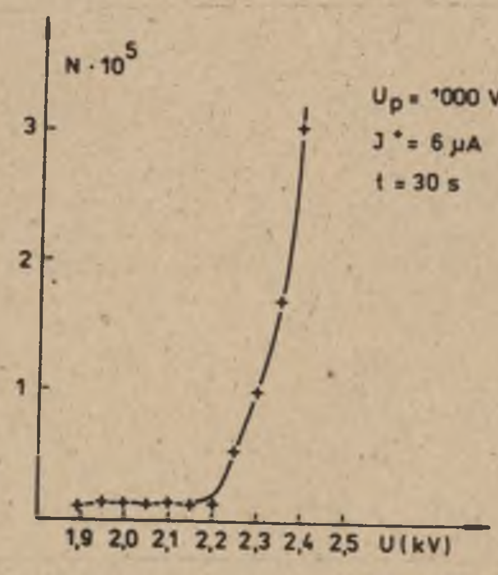

Fig. 7. Dependence of the number of the pulses counted from the secondary ions on voltages applied to the multiplier

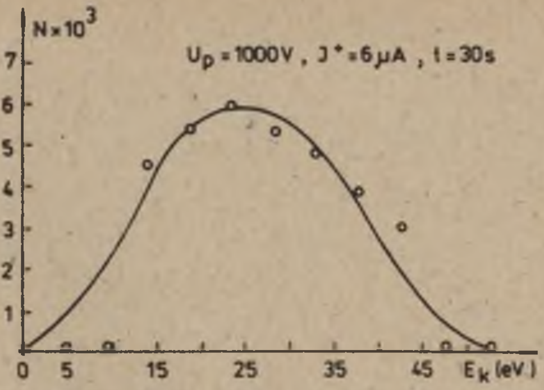

Fig. 8. Energy spectrum of the secondary ions emitted from the steel surface

3. CONCLUSION

The apparatus described in the article allows to investigate the secondary ion emission phenomena, at the angle of its energy by means of its energy spectrum. The ions emitted from the steel surface bombarded by A_r^+ ions with energy 1000 eV have differs energy, but the most amount of its have the energy comprised in the range of 15 – 30 eV.

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STRESZCZENIE

W pracy opisano aparaturę służącą do badania emisji jonów wtórnych. Jako przykład wybrano stal bombardowaną jonami A_r^+ o energii 1 keV i natężeniu 6 μA. Aparatura składała się z układu próżniowego pozwalającego osiągnąć próżnię 10^{-7} Tr, komory próżniowej, w której znajdowała się próbka bombardowana jonami, źródła jonów pierwotnych oraz układu pomiarowego jonów wtórnych.

Podano kilka charakterystyk źródła jonów pierwotnych, jak również przedstawiono wykresy dotyczące emisji jonów wtórnych.

РЕЗЮМЕ

В работе представлена установка для исследования вторичных ионов из стальной поверхности, бомбардированной ионами A_r^+ с энергией 1 КэВ и током 6 мкА. Установка состоялась из вакуумной системы, позволяющей получать давление 10^{-7} Тр, вакуумной камеры, в которой находился образец бомбардированный ионами, источника ионов первичных и системы измерений вторичных ионов.

Представлено некоторые характеристики источника первичных ионов и графики связанные с эмиссией вторичных ионов.

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