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HIGH-PERVEANCE CHARGED PARTICLES SOURCE FOR IMPLEMENTATION OF E-BEAM TECHNOLOGY

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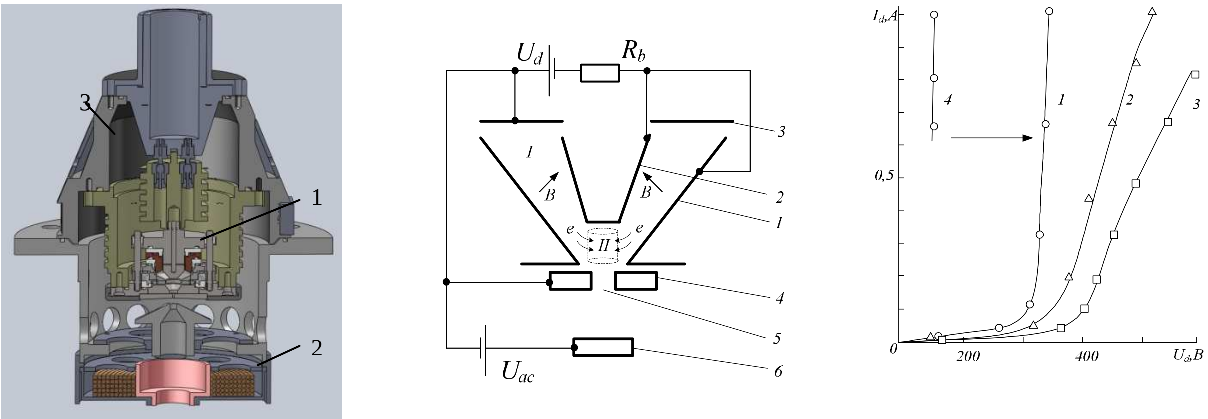
Presented a number of electron-beam technologies, it is possible to implement by high-perveanced plasma source of charged particles. A discharge structure of high-perveance source that can form electron and ion beams, with parameters satisfying presented technologies.

Introduction. By now the electron-beam technologies found quite widely used in various industries. This has stimulated the development of electron sources, implementing a wide range of technological parameters that differ in power, current density, operating modes, gas-dynamic conditions. The variety of requirements to technological electron beam cannot be realized in the sources of the one type. The most widely used are three main types of electron beam sources – electron source with thermocathode, sources based on high-voltage glow discharge, and plasma electron sources [1].This paper presents the construction of high-perveance plasma source of charged particles based on a discharge in crossed E × H fields, to implement a wide range of electron beam technologies.

Fig. 1 shows the construction (*a*) and electrode structure (*b*) of plasma electron source that implements principles of the emission current due to creating conditions for the switching without axial plasma inhomogeneity restricted in extraction efficiency over the known electron sources based on the hollow cathode [1].

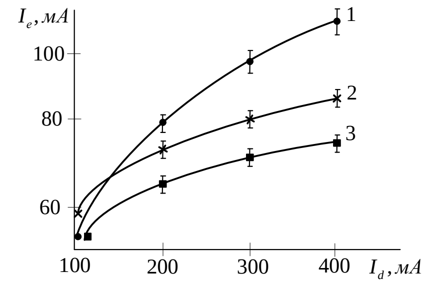
The discharge is excited in the space between the cathodes 1 and 2 (*a*) (region I, in Fig. 1, *b*). The plasma-forming gas is fed into the space between cathodes and the pressure differential, provided by geometry of the emission channel. The emerging in the discharge between the cathode plasma diffuses into the region of the emission channel. It is promoted by additional electrodes 3 and 4 (with anode or intermediate potential [2]), which serve as the emitter electrode (see. Fig.). Extracting electrons carried out of the emission channel in the emitter electrode with anode (or close to it) potential. The presence of a magnetic field almost all the volume of the discharge structure facilitates to efficient gas ionization. In this electrode structure excludes the initiation stage of the discharge, which is reflected in the form of current-voltage characteristics (see. Fig. 1, *c*).



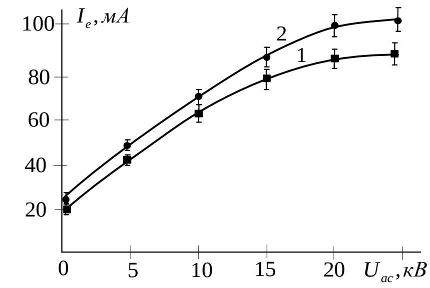
a *b* *c*

a – 1 – plasma source; 2 – magnetic lense; 3 – case
b – 1 – outlet cathode; 2 – inlet cathode; 3 – anode; 4 – emitter electrode;
5 – эмиссионный канал; 6 – ускоряющий электрод;
U_d – discharge voltage ; U_{ac} – accelerating voltage; R_b – ballast resistance ; *B* – magnetic induction
c – gas puffing , mPa·m^3/sec: 1 – *2,8*; 2, 4 – *1,7*; 3 – *1,25*
Fig. 1 – Plasma electron source:
a – construction; b – electrode structure; c – current-voltage characteristics

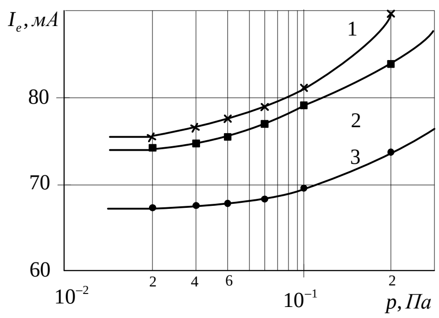
Fig. 2 shows the typical characteristics of the source. The main advantage of this source is the weak dependence of the emission current from the pressure up to 0.3 Pa (fig. 2, c). This feature is implemented as due to the special electrode configuration of the discharge chamber, and due to the additional self-stabilization of the electron beam parameters by inclusion resistance emitter electrode chain with respect to anode [2].Figure 2, d, are presented current density distribution and power density of the electronic starting over the cross section. Analysis of distributions indicates that the maximum power densities $q_{\max} \approx 10^9$ W/m^2 and the effective diameter of the electron beam (defined at 0.1 $q_{\max}$) corresponds to typical values of the power density of the electron beams used for electron beam welding [3]. This fact and appearance of and the gas characteristics show the possibility of using this source for welding, including materials with high gas separation during heat treatment [3].



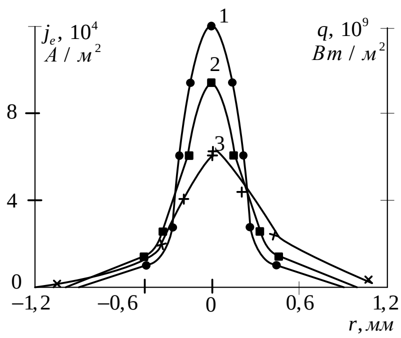
a



b



c



d

e

f

a – emission characteristic: accelerating voltage 18 kV;
gas puffing 1,5 mPA·m^3/sec; pressure, Pa: 1, 2 – 0,04; 3 – 0,1; $R_{см2}$, kOhm: 1 – 0; 2, 3 – 1;
б – current-voltage characteristic: gas puffing 1,5 mPa·m^3/sec; discharge current 0,2 A;
gas pressure, Pa: 1 – 0,04; 2 – 0,1; в – gas characteristic: accelerating voltage 16 kV; gas puffing 1,5 mPa·m^3/sec;
$R_{см2}$, kOhm: 1 – 0; 2 – 0,5; 3 – 1;
d – current density distribution and power density distribution over the beam cross-section:
accelerating voltage 18 kV; gas puffing 1,5 mPa·m^3/sec; current discharge 0,2 A;
emission current *0,08A*; $R_{см2}$, kOhm: 1 – *1*; 2 – *0,5;* 3 – *0*
Fig.2 – The main characteristics of plasma electron source (a, b, c, d) and beam appearance
in process of welding different materials (e, f)

Applications

Listed above characteristics suggest the possibility application presented the plasma source for the implementation of the "classical" welding technology. At the same time the traditional application of electron beam welding (EBW) usually involves getting deep keyhole penetration to great depths (up to hundreds of millimeters). However, there are many variants of products that are not necessarily getting keyhole welds, requiring a very high quality. It is a product with high quality and reliability of welded joints, as well as the details of the high-purity and high level metals. Here are some examples of possible use of presented electron source.

1. An electron beam melting of highly active metals

One of the traditional electron beam technology is remelting of highly active metals, which are necessary to conduct in a vacuum. When this beam load factor reaches 90% [1]. When metals and alloys are remelting dirt and metal fumes removed out of them get into the EB gun, in the case of an incandescent cathodes they quickly fail. Practice has shown that for metallurgical processes associated with intense evaporation is advisable to hold guns with plasma source of electrons.

Because highly technological waste metals (zirconium, titanium, niobium, etc.) by remelting can obtain homogeneous casting structure, which are suitable for reuse, such as the target cathodes. As a material for the EB remelting zirconium turnings (Tm = 1855 ° C) and titanium (Tm = 1668 ° C) are used. Practiced manufacturing methods for creating new and regeneration of used cathodes by EB remelting - targets for magnetron and vacuum arc sputtering systems from pure Ti, Zr, Hf, Ti and Zr alloys with Cr, Al, B, Mo, etc., from scrap and turnings.

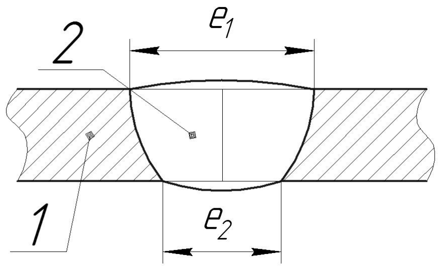
2. Management of spent nuclear fuel (SNF)

Analysis of available data on the shelving structures for wet and containers for dry near-station storage of spent nuclear fuel says that for these purposes lengthy tube from stainless steel of thickness 4.5-5.0 mm with high boron content. Tubes are manufactured by means of electron-beam or laser welding. Using shelves with packed arrangement pitch pipe allows to place and stored safely in pools a considerable amount of spent nuclear fuel.

3. Create a high-superconducting resonators

Work is underway to create a high-superconducting niobium RF 1.3 GHz cavities by electron-beam welding (Fig. 3, *a*). Microwave resonators from very pure niobium for charged particle accelerators can be made only with the use of electron-beam welding. EBW process ensures the preservation of the original metal high-purity in weld joint, as well as the required geometry of welded joints: full penetration weld with e1 and e2 width of not less than 4 mm (Figure 3, *b*.).

a



b

Fig. 3. 1,3 GHz single-cell niobium cavity microwave (*a*) and studied the geometry of the weld (*b*);
1 – the main metal; 2 – weld joint

Manufacturing technology of microwave resonators are used for most large-scale construction and planned currently charged particle accelerators, including half-cell cavity stamping, welding them together, as well as other design elements. The most responsible step is the welding of the two half-cells at the equator. Upon receiving the welded joints of the microwave resonators high demands are made to the geometry of weld joints and metal chemical purity of the compounds, which shall not be less than the starting niobium. The latter is the key to saving the superconducting properties of niobium high purity is achieved by etching welded edges before welding in the acid mixture, with compliance of purity during storage and transportation of parts before welding.

Obtaining the required geometry of the weld when welding components Nb microwave resonators is not an easy task and requires a detailed study of the relationship between the EBW regime parameters and welds characteristics. However, there are publications showing about obtaining of defects in welding equator half-cells, including the production of cavities in series with exhaust welding conditions [4].

Presented plasma source has characteristics that allow to realize a wide range Electron Beam technology, makes it a quite universal technological equipment.

REFERENCES

1. Окс, Е.М. Источники электронов с плазменным катодом: физика, техника, применения / Е.М. Окс – Томск : Изд-во НТЛ, 2005. – 216 с.
2. Источники электронов с плазменным эмиттером / Ю.Е. Крейндель [и др.] ; под общ. ред. Ю.Е. Крейнделя. – Новосибирск : Наука, 1983. – 120 с.
3. Плазменный эмиттер электронов с сеточной стабилизацией. Ч. I / А.В. Жаринов [и др.] // ЖТФ. – 1986. – Т. 56, Вып. 1. – С. 66 – 70.
4. Разработка и применение источников интенсивных электронных пучков: сб. науч. тр. / науч. ред. Г.А. Месяц. – Новосибирск : Наука, 1976. – 191 с.