THE USE OF PULSED POWER ION/ELECTRON BEAMS FOR STUDYING OF UNITS OF ELECTRONUCLEAR REACTOR

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Abstract. The questions of using power pulsed ion beams for studying some units of model's electronuclear installation are considered in this report. It allows to analyze the question of heating loads on the targets, entering and output windows for beams of charge particles. The methods of increasing a life-time of these windows on the basis thin foils with help of surface modification of materials by high current pulsed ion beams are considered.

INTRODUCTION

A new method of production of electric power based on the ideas proposed by C. Rubbia [1] has been practical interest. In this case the questions of stable work units of the pilot installation for test of electronuclear method for production of electropower is very important. The general scheme of this installation includes a proton accelerator, target unit and a device for transformation of beam energy to electropower [2]. Among a lots of the units the window for entering the beam to the target is haughty.

Investigations on using the pulsed high power electron/ion beam technologies for surface modification of materials [3,4] allow to find application for study of two questions of electronuclear rector:

1. heating loads for different materials for this reactor;
2. increasing life-time of window for proton beam.

The main questions of using the pulsed high current electron/ion beams for several units of the electronuclear installation are considered in the this report.

THE MAIN PRINCIPLE OF PULSED POWER ELECTRON/ION BEAM TECHNOLOGIES

STUDY OF HEATING LOADS ON THE MATERIALS OF ELECTRONUCLEAR INSTALLATION

Pulsed electron or ion beam is a pulsed energy source. This energy separates in the solid state at the during interaction of beam with irradiated sample. For example, for beam current I = 200 A, pulse length t = 250 ns, kinetic energy E= U = 500 KeV (kV), energy for one pulse is W = I U t= 200 5 10(5) 250 10(-9) = 25J. For beam current 1000 A this energy is 50 J. This is high energy for pulse on the small depth penetration determined kinetic energy. This energy enough for different processes in solid state.

In the dependence of beam kind (electron or ion) we can see special peculiarities, which consist in the next.

Electron pulsed beam (Fig.1a):

- small size of electrons;
- small ionization losses;
- the depth of penetration for kinetic energy 100 - 1000 keV for many materials consists of 10 - 500 mm;
- adiabatic heating processes of interaction by pulsed electron beam with solid state;
- electron beam mixing.

Ion pulsed beam (Fig.1b):

- large size of ions in comparison with electrons;
- large ionization losses;
- small depth of penetration with comparison with this parameter for electron beam, for example for kinetic energy 100 - 1000keV depth of penetration is about 0.05 - 1.0 mm;
- adiabatic heating processes of interaction by pulsed ion beam with solid state;
- synthesis of components of samples;
- ion beam mixing;
- ion spray of irradiated samples;
- long distance effects.

The properties of these beams allow to use these technologies for test experiments with materials for electronuclear reactor.

The pulse length of electron beam t for rapid thermal processes, especially for complex materials, when necessary have stable stoichoimethric relationship must satisfy next condition:

$$t << t(p) = 2h^2\rho c / \lambda, \qquad (1)$$

where: t(p) - heating constant of sample;
h - depth of penetration;
ρ, c, λ - density, heat capacity and heat conductivity of irradiated materials.

In this case we have step distribution of temperature in their radiated sample. The last means, that energy release of electron beam can be on the depth penetration, which determined kinetic energy of electrons. The temperature T in an irradiated sample on electron rate depth can be calculated from formula :

$$T = 2Wt / h \rho S, \qquad (2)$$

where W- electron beam power density;
S- irradiated square.

For pulsed ion beams we have another situation and for calculation of heating of sample we must use next formula:

$$T = 2Wt^{0.5} / (3.14 \lambda \rho c)^{0.5} \qquad (3).$$

More detail description of main principles of beams pulsed technologies can find in the [3,4].

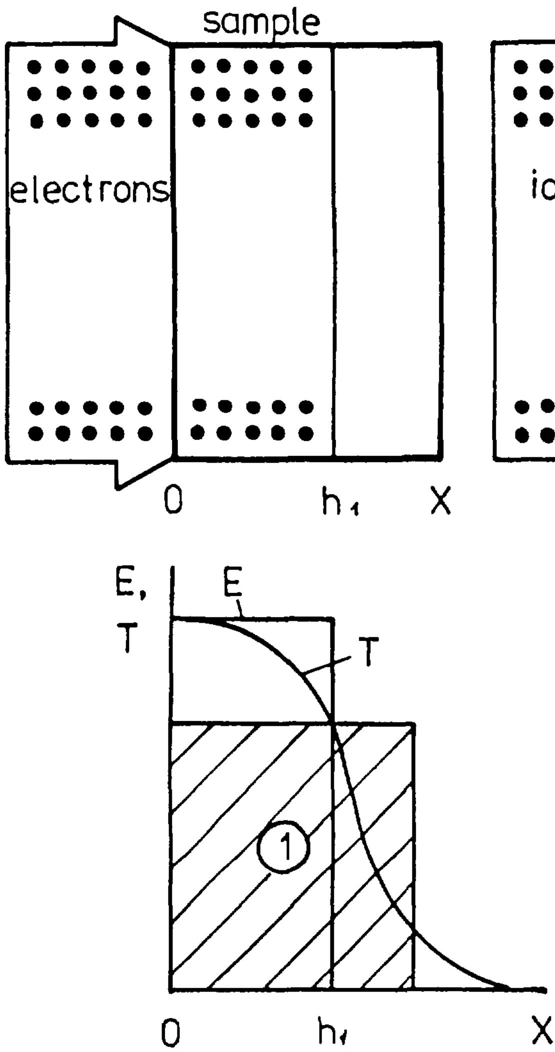

Fig. 1a. Pulsed electron beam.

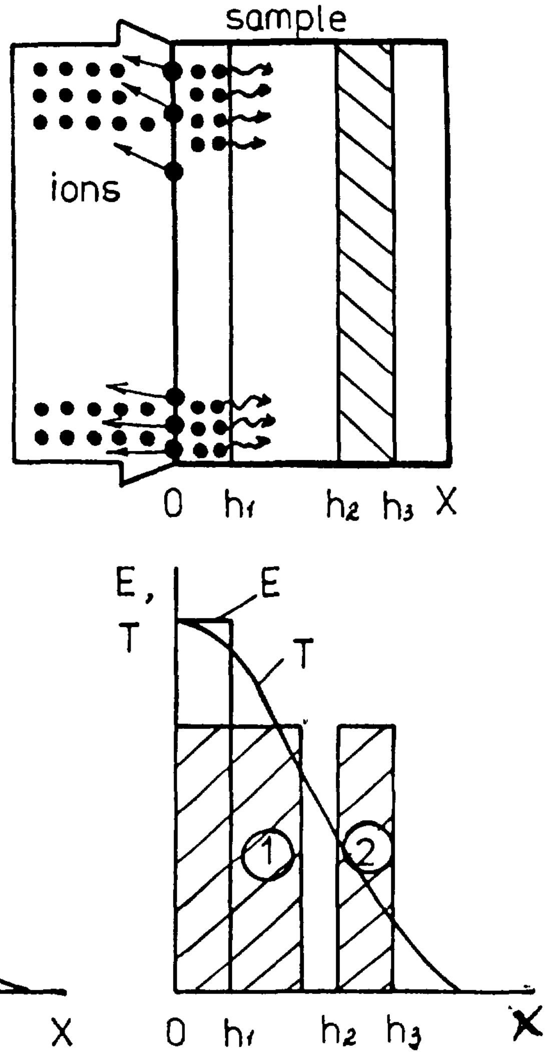

Fig.2. Pulsed ion beam

MODIFICATION AND DEPOSITION OF FILMS AND COATINGS ON THE FOILS WINDOWS

The surface modification of materials consists in the ion/electron mixing, surface melting and other surface effects which can make better properties of these materials for its using for different units, which can work in the intensive loads and conditions. Also for increasing life-time of window's foils for intense proton beams can be used foils with special films and coatings. For receiving effect of increasing life-time of foils necessary have films or coatings with more stable heating and corrosion properties.

The main problems of this method is very good adhesion films with substrate. An electron or ion mixing in the ion diode with explosive ion emission [5] allows to decide this problem.

EQUIPMENT

The source consists of the high voltage pulsed generator, vacuum high voltage diode with vacuum system, diagnostic system and vacuum chamber for irradiation of samples and for substrates - foils for windows of target units.

The pulsed high voltage generator has got next main parameters:

- voltage 100- 700 kV;
- pulse duration 300 - 1000 nsec;
- stored energy 100 - 500 J;

- repetition 1-5 Hz.
High voltage vacuum diode consists of stainless steel vacuum chamber , high voltage insulator made from capralon, an anode with anode plasma initiator, a extractor electrode and diagnostics devices. Beam current measurements are carried out with an integrating Rogowski transformer and Faraday cup, and a high resistance divider is used for measurements of pulsed voltage.

The main emission characteristics of source for electron and ion regimes are given in Fig. 2,3.

The mode of operation can be changed from ion beam to electron beam.
This is done by changing the polarity of the voltage on the output side of the pulsed high voltage generator.

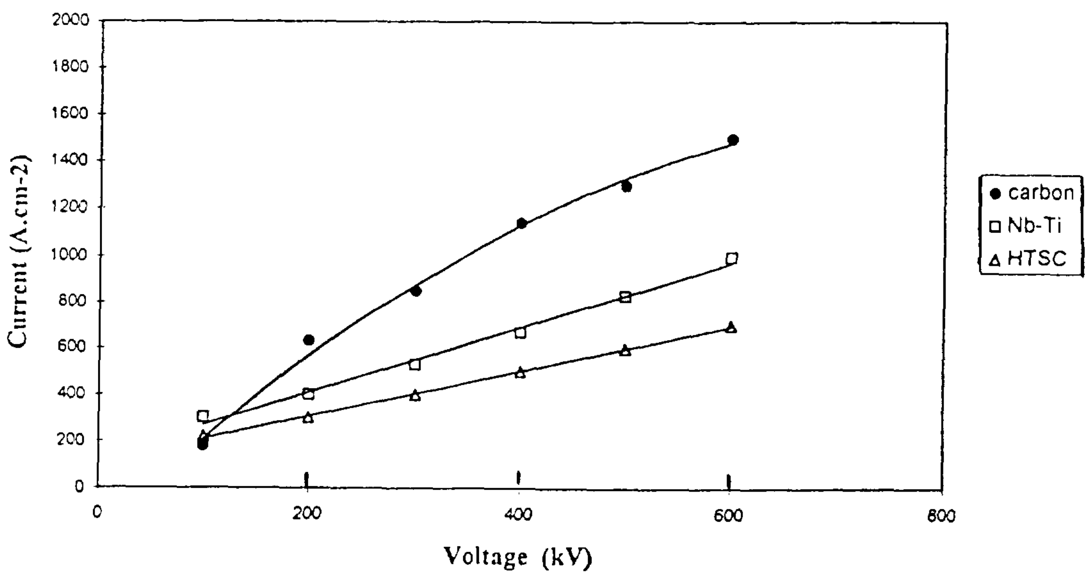

Fig.2. Emission characteristics of source in an electron regime.

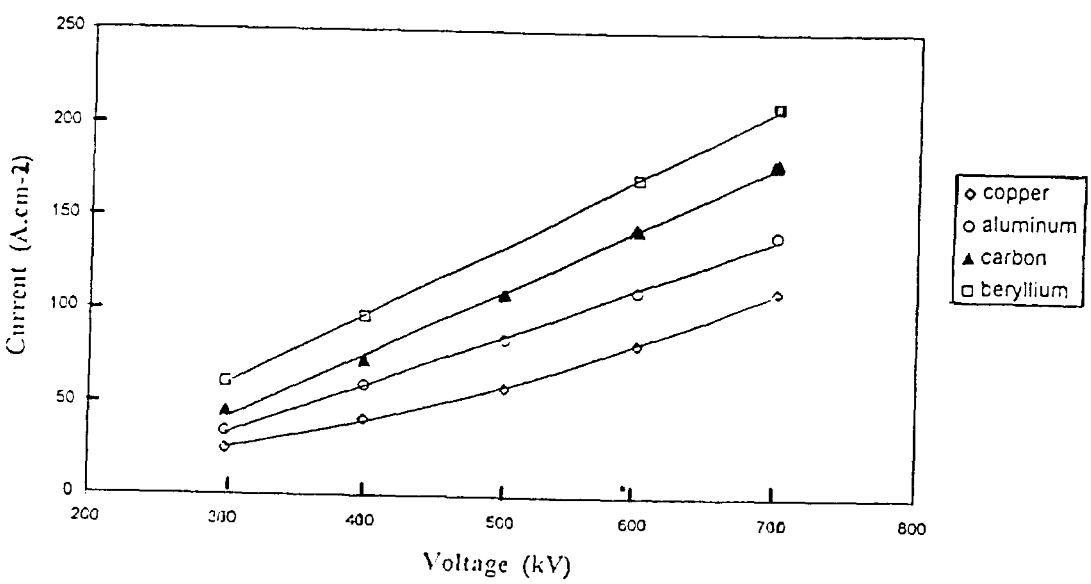

Fig.3. Emission characteristics of source in ion regime.

This ion source uses for deposition of films or coatings with ion/electron mixing.

FOIL'S WINDOWS FOR BEAM

The special technology for preparation of output foils for charge particle beams was elaborated on the basis of carbon films on the Al and Be foils. It concerns with problem of increasing a life-time. For proton beam of this reactor better use carbon coating thickness about 30-50 mkm on the Be foil of thickness 0.5 - 3 mm. The technology consists of first deposition of carbon or diamond-like films or coatings with ion mixing on the Be or Al foil from both sides and after electron mixing for more long depth of mixing of C and substrate. The typical foil's window is given in Fig. 4.

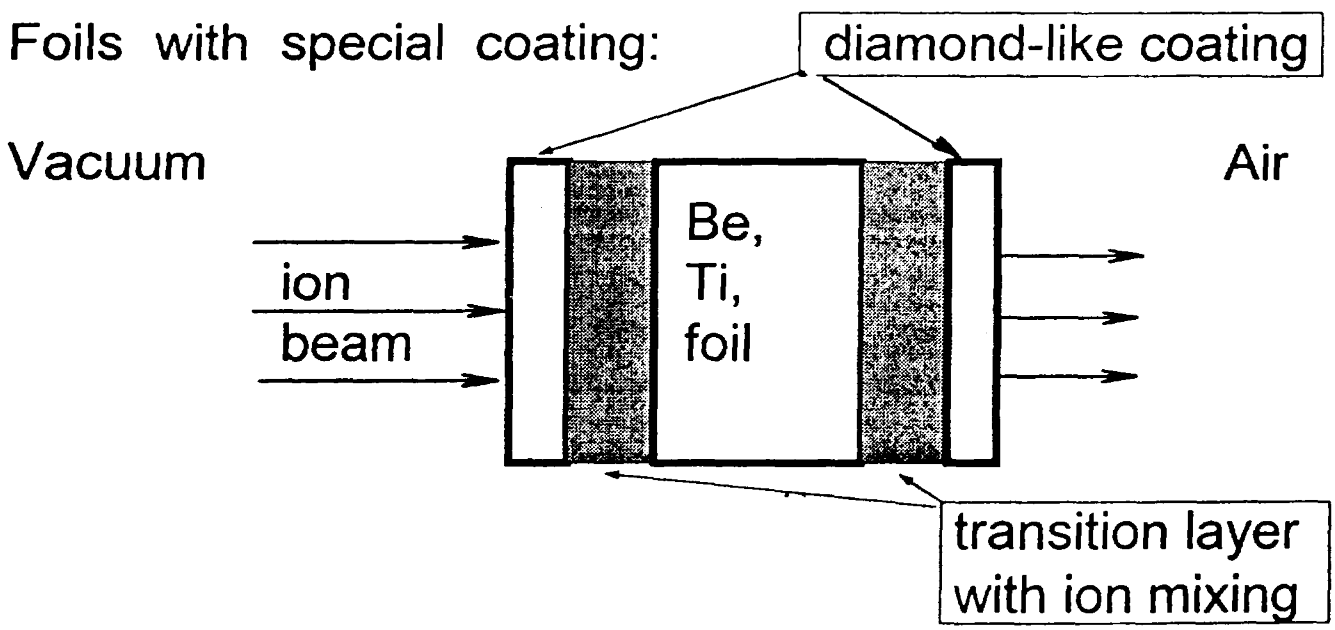

Fig.4. Typical foil's window with additional coatings.

Test experiments with high power pulsed electron beams show increasing life-time to 10 times with comparison with clean Be and Ti foils.

The measurements of oxidation resistance acids show stable characteristics at the during 8 hours.

CONCLUSION

1. New method for test of materials of electronuclear reactor is suggested.
2. New method of increasing life-time of foil's window is suggested and is tested.
3. Surface modification of materials by pulsed high current ion/electron beams can be used for preparation of materials for electronuclear reactor and similar systems.

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