TARGET FOR PRODUCTION OF X-RAYS

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Abstract

The patented new type of X-rays target is considered in the report. The main concept of the target consists in the sandwich structure of deposited coating from materials with high Z on the substrate with low Z, high thermal conductivity and high thermal stability. The target presents multiply layers system. The thermal conditions for X-Rays target are discussed. The experimental results for Ta target on the Al and Cu substrates are presented. This type of target allows improving the cooling system.

INTRODUCTION

The development of X-rays target technology links with high progress in the applications of electron beams and requirements of modern technologies on the basis of X-rays. The main reason of big interest to x-rays target is large depth of penetration of x-rays to condensed matter in comparison with electrons. The standard X-rays target presents Ta or W foil with cooling plate. The optimal thickness of X-rays target can be calculate from empirical formula for electrons with kinetic energy 1-10 MeV [1]:

$$h_{opt} = \frac{0.89 \cdot (E - 0.7)^{0.46}}{\rho \cdot Z^{\frac{0.17}{E^{0.2}}}} [cm] \qquad [1]$$

where: E is kinetic energy of electron [MeV], ρ is density of material target [g/cm^3], Z is atomic number of material target.

According this formula we can see, that variation of optimal thickness for target from Ta has range 0.14 to 0.93 mm and target from W has range 0.12 to till 0.8 mm for this range kinetic energy of electrons.

The conversion factor of electrons to X-rays is small and 2.5 to 12% for Ta target for kinetic energy of electrons 1 to 10 MeV. For kinetic energy of electrons 0.1 –1.0 MeV, this factor is low and has range approximately 0.2 –2.5% for Ta target. The computer simulation of absorbed doses for this range of thickness of target shows, that electron beam can not to converse to X-rays on the 100%. The comparison of these data allows to make conclusions, that two factors lead to partial using of electron beam and after target we have electron beam with low kinetic energy and x-rays with broad energy spectra.

The other problem of target is thermal processes. For low factor of conversion of electron beams to X-rays determines big dissipation of energy.

For example for kinetic energy 1 MeV for Ta target , the factor of conversion is about 2.5%. The present of dissipated energy in the target for optimal thickness 0.2 mm according Monte- Carlo simulation is 70%.

For average power of beam 10 kW we have dissipated power in the target is about 7 kW. The cooling conditions of foil target are difficult and main problem is thermal contact with foil (target) and cooling plate.

The new concept for design of target for produce of X-rays was suggested in U.S.A. Patent [2]. The description of this concept and results of primary tests is considered in this paper.

CONCEPT OF X-RAYS TARGET

The main concept of new X-rays target consists in the coating from material with high atomic number on the substrate with good thermal conductivity and low atomic number. The variant of cooled target for high power accelerator is presented on Fig.1. The variant of target for pulsed accelerator is given on Fig.2.

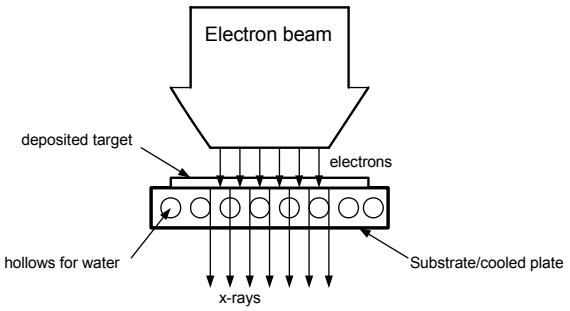

Figure 1: The target for high power beam.

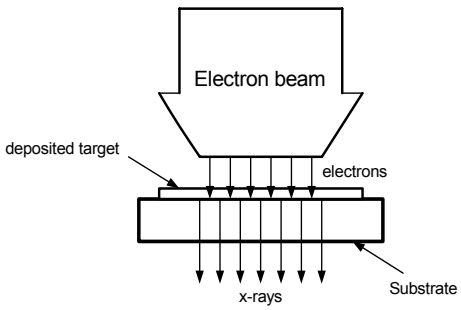

Figure 2: The target for pulsed beam

The thickness of coating depends on kinetic energy of electrons and according (1) is presented in Table 1.

Table 1:

Kinetic energy, MeV	Thickness of Ta target, mm	Thickness of W target, mm
1.0	0.14	0.12
2.0	0.31	0.27
3.0	0.43	0.37
4.0	0.53	0.46
5.0	0.614	0.53
6.0	0.69	0.61
7.0	0.759	0.65
8.0	0.82	0.71
9.0	0.88	0.76
10.0	0.93	0.80

The sandwich multi-structure of target is shown on the Fig 3. The computer simulation of propagation of electrons across the sandwich target gives information about full dissipation of electron beams and decreasing of kinetic energy and decreasing the kinetic energy.

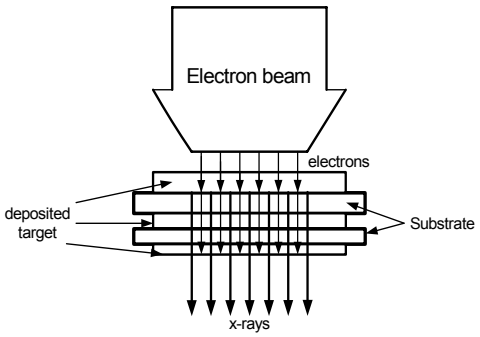

Figure 3: The multi-layers target.

The deposition of large thickness of coating presents complex task which links with adhesion of large thickness of coating with substrate. It is very important for target on the kinetic energy of electrons more 1 MeV. The design of X-rays target for electron with kinetic energy 100 – 500 keV is very simple, because the thickness of target is 5-10 microns from Ta or W. For deposition of small thickness of target can be used all standard methods of deposition of films: Magnetron spattering, lased ablation, electron beam evaporation, cluster deposition using vacuum ion diode. For first case, the preparation of surface for deposition consists in the forming roughness for improving of adhesion of coatings to substrates. The experimental results of deposition of large thickness of coating with roughness of Ta, W coating on the Cu, Al substrates shown, that this effect allows to improving the adhesion of coating to substrate and improving the thermal contact for good cooling. The deposition of large thickness of target also is possible by nano-particles spray method.

EXPERIMENTAL RESULTS

The few samples of X-rays Ta target with thickness 10, 25 and 600 microns were prepared for test experiments. The Ta thin foils with same thickness were used for comparison of data.

The test experiments were conducted on the 2 accelerators: Pulsed electron accelerator with kinetic energy of electrons 200 - 400 keV, and Rhodotron with 5 MeV beam line.

The measurements of temperature is presented on Fig. 5 from Rhodotron with 600 microns targets. The simple experiments with nature air cooling gave results, that gradient of temperature 100^{o}C for power of beam 5 kW for 120 seconds for Ta foil target, and same gradient temperature was received for 450 seconds. These experiments didn't use the water cooling. The simulation of water cooling of target shown decreasing of requirements for water cooling conditions.

The measurements of electron components with electrons and x-rays are gave very important information about decreasing of value of electron after target with Al substrate for thickness about 1-1.5 mm. The energy spectra of X-rays is wide and main average kinetic energy of x-rays has very good correlation with calculated from empirical formula from [3].The substrate allows to decrease the low energy X-rays. Tthe optimal thickness of Al substrate is 1.25 mm for electron with kinetic energy 400 keV.

CONCLUSION

As a results of conducted investigation we can make next conclusions:

1. The suggested concept of X-rays target allows to decrease the requirements on the cooling system.
2. This target is very easy in design.
3. This target with substrate allow improving the energy spectra of X-rays.

REFERENCES

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