ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 8(36), DOI: 10.17485/ijst/2015/v8i36/90559, December 2015* ISSN (Online) : 0974-5645

The Orientation Effects during the Grazing Interaction of Fast Electrons with Structured Surfaces

K. A. Vokhmyanina[1], A. S. Kubankin[2], V. S. Levina[1], I. S. Nikulin[1], A. A. Pleskanev[1] and G. P. Pokhil[3]

[1]Laboratory of Radiation Physics, Belgorod State University, Belgorod, Russia;
vokhmyanina@bsu.edu.ru, levina@bsu.edu.ru, nikulin@bsu.edu.ru, pleskanev@bsu.edu.ru,
[2]National Research Tomsk Polytechnic University, Tomsk, Russia;
kubalkin@tpu.ru,
[3]Skobeltsyn Research Institute of Nuclear Physics, Moscow State University, Moscow, Russia;
pokhil@gmail.com

Abstract

Background/Objectives: The paper presents the experimental results of a study of the processes of grazing interaction of fast charged particles with structured surfaces. **Methods/Statistical analysis:** The experiments performed to study the radiation arising when the electrons pass along a structural surface are carried within a small angle region. According to the results presented in Figure 4 the maximum of electrons lifting can be observed at angles close to 1°-2°. So it will be necessary to use different grounding schemes to improve the yield efficiency. This can be achieved when both sides are grounded. **Findings:** The contribution of the structure of the target surface to the scattering of the incidence primary electrons was observed for different geometries for the interaction process of a 10keV electron beam with a diffraction grating. The experimental results demonstrate the possibility of increasing the total time of the interaction between the electron beam and the target, which opens the possibility to increase the effectiveness of radiation sources, based on diffraction mechanisms. **Applications/Improvements:** The effect of contactless transmission of electrons through dielectric channels causes great attention because of the potential use of simple and independent systems for electron beams formation.

Keywords: Direction of Ions, Fast Electrons, KeV Electron Beam, Structured Surfaces

1. Introduction

The effect of contactless transmission of electrons through dielectric channels causes great attention because of the potential use of simple and independent systems for electron beams formation. The idea of contactless transmission of charged particles through dielectric channels emerged in the 80s, and has been studied for pulsed intense beams of relativistic electrons[1-3], but an intensive study of the problem began only in 2002, after discovering the possibility to manage the direction of ions Ne7 + with an energy of 3keV using Nan capillaries, formed in a foil PET[4].

Therefore nowadays much attention is paid to the detailed study of the phenomena associated with the interaction between electron beams ofa wide energy range and different dielectric surfaces[5-10]. Most of the experiments were made for capillaries of different geometrical parameters and made of different dielectric materials. All the results indicate the formation of a self-consistent charge distribution on the inner walls of the channels providing partially contactless transmission of charged particles for grazing angles of incidence.

Different experiments with insulator plates were performedin order to study the character of the charge distribution[11-13]. The deflection angle of the beam from the surface of the Plexiglas plate depends, first of all, on the grounding scheme of the sides of the insulator.

** Author for correspondence*

A weak dependence on the initial incidence angle of electrons on the surface is also observed[12-14]. The use of different grounding schemes demonstrated the following regularities: the maximal angle slightly decreases when only the back side is grounded and decreases by more than two times when only the front side of the plate is grounded. A similar effect was observed for alumina in absence of grounding on any side, while for the solid Plexiglas sample this effect was observed upon grounding the front side of the plate. The charge on the surface of the dielectric is organized so that it attracts part of the electron beam declining it below the level of the alumina plate surface by 2°. Such a process is observed for Plexiglas plates when the back side of the sample is grounded.

The effect of "pressing" the beam towards the insulator surface when both sides are grounded occurs because of a complete absence of charging up processes from the front side (by normal incident of the primary beam) and from the back side (secondary electrons from the vicinity of the sample). This condition is achieved owing to metal masks installed at the entrance and exit of the target, which acts as shield and prevents charge accumulation. So the only processes that take place is the grazing interaction of the beam with the dielectric, which enables to attract the beam of electrons to the surface.

The study of such processes using metal coated gratings on dielectric substrate is of great interests because of its potential benefit of increasing the total time of the interaction between the electron beam and the target, which opens the possibility to increase the effectiveness of radiation sources, based on diffraction mechanisms. In this paper we present the results of a series of experiments on the interaction of the electron beam with a structured glass surface coated by aluminum.

2. Experiment

The experiment was performed at the laboratory of radiation physics of the Belgorod State University. An electron gun was used as electron source for the development of the experimental setup. The setup consists of electron magnetic optics, a target chamber with a goniometer and an electron beam detection system.

The scheme of the setup is presented in Figure 1. The 10 keV electron beam(2)with a 200 μA initial current was generated by the electron gun (1). The beam shape was formed by a 1 mm round aperture stainless steel collimator (3); the angular divergence and position of the beam inside the vacuum channel were controlled by solenoid magnetic lens (4) and a corrector (5) respectively. These devices allow to control the transverse and angular characteristics of the electron beam on the target (6) installed on the goniometer. The goniometer allows to adjust the target position along the transverse direction relative to the initial electron beam axis in the horizontal plane with a 0.2 mm accuracy and to rotate the target around the same axis with an accuracy better than 0.1°. The goniometer was built with nonmagnetic materials to avoid the influence of any magnetic forceobtained after its interaction with the target was visually detected from a luminescent screen (8) by the cam (7). The screen luminescent surface was grounded to avoid any charge accumulation. The vacuum inside the electron gun and the target chambers was better than 10^{-6}torr.

A 600 G/mm diffraction grating was used as target in our experiments. The grating relief measured by a probe microscope Integra Aura is presented in Figure 2. We used the 30x30 mm^2 size samples of aluminium coated diffraction grating formed in 15 mm thickness glass substrate. The entrance and exit sides of the grating were shielded by metal masks to prevent charge accumulation due to the electrons interaction with the glass side of the target. All the masks were placed 1 mm apart the samples without contact with the front and back sides of the samples in order to avoid grounding and damaging the thin coating layer. The upper edges of the front masks were approximately 1 mm above the surfaces to prevent charging up the front sides of the samples by the incident beam. The edge of the back mask had the same level as the surface of a sample.

The electron beam had the following parameters: an energy of 10 keV with a scatter of no more than 0.1%, a beam divergence of less than 0.25°, a beam diameter of approximately 2 mm. The source current was 0.2 mA andthe current in the target chamber was 120 nA. A part of the electrons of the beam passing the front grounded mask moves close to the structured surface interacting with it and the trace of the beam was seen on the glass screen covered with a thin layer of scintillation powder. The sample was tilted with a small angle step and snapshots were taken at each angle.

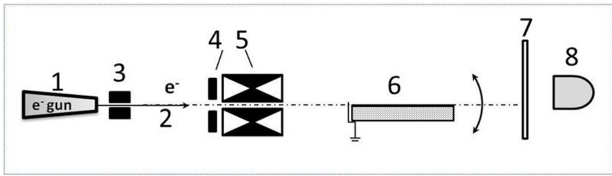

Figure 1. Experimental setup. 1 – electron gun, 2 – beam of electrons, 3 – collimator Ø 2 mm, 4 – solenoid magnetic lens, 5 – magnetic corrector, 6 – target in the goniometer, 7 – screen, 8 – cam

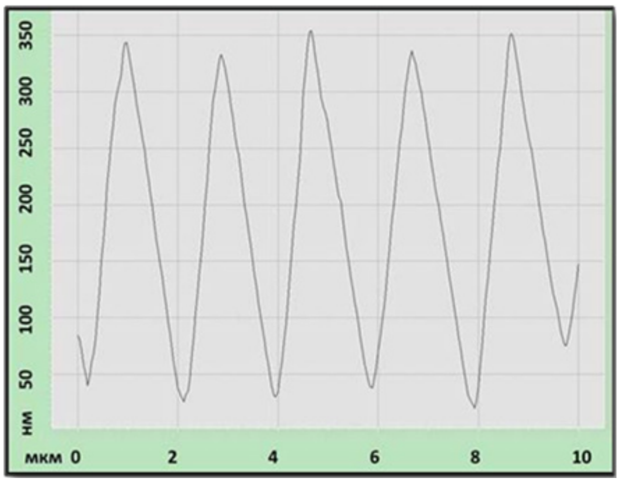

Figure 2. Profile of aluminum diffraction grating.

The study was performed to investigate the structure influence of metallic surface in two different grounding schemes (Figure 3). All experiments were made with two identical samples (aluminum grating 30x30 mm on glass substrate of 15 mm width) in the same grounding scheme in order to compare the results.

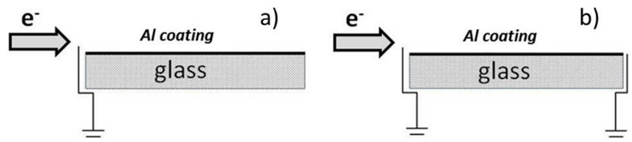

Figure 3. Schemes of grounding of the plates (a) front side grounded. b) both sides grounded.

3. Results and Discussion

The first experiments were performed for the grounding scheme presented in Figure 3 a), when the front sides of both samples were grounded. Figure 4 shows the plot of the displacement of the beam trace on the screen under tilting of two identical plates for different directions of the beam with respect to the surface structure. Curves 1, 2, and 3 on each plot correspond to different sets of experiments. Each set was taken after a 20 min pause and distinguishes from the previous set by the point of incidence of the

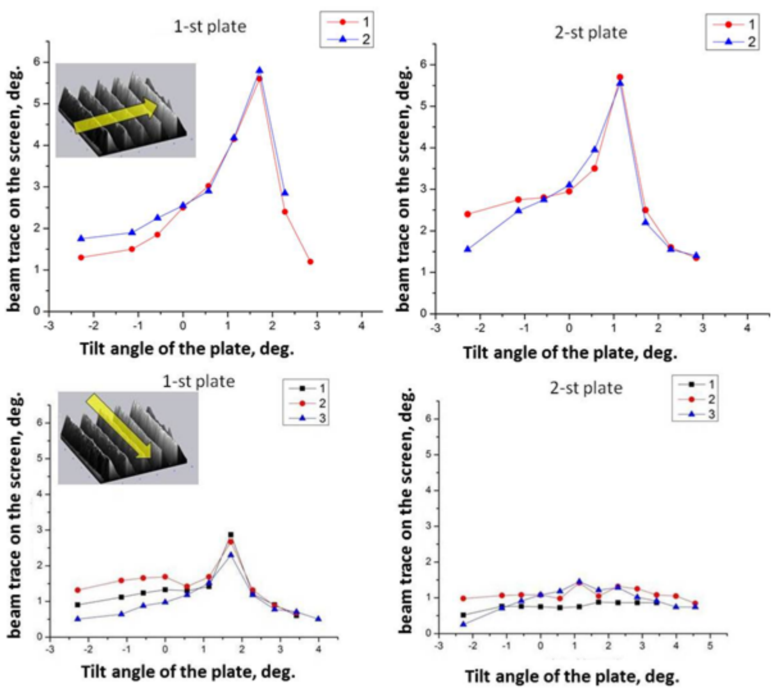

Figure 4. Displacement of the beam trace on the screen under tilting of two identical plates (left and right columns) for different directions of the beam with respect to surface structure (rows). Curves 1,2 and 3 on each plot correspond to different sets of experiments.

beam; this can explain the small divergence between the curves in Figure 5. Each point was taken with a 120 s exposure.

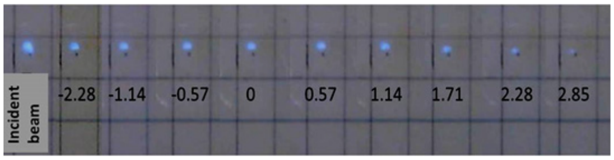

Figure 5. Displacement of the beam trace on the screen under tilting of the plate for the cross direction of the beam with respect to surface structure.

The same behavior of the beam was observed for the longitudinal direction of the incident electrons with respect to the surface structure for both samples. The experiments performed to study the radiation arising when the electrons pass along a structural surface are carried within a small angle region. According to the results presented in Figure 4 the maximum of electrons lifting can be observed at angles close to 1°-2°. So it will be necessary to use different grounding schemes to improve the yield efficiency. This can be achieved when both sides are grounded.

4. Conclusions

Thus the experimental results show the possibility to “press” the beam of fast electrons to the surface of the combined metal-dielectric sample in order to study more efficiently the radiation arising during electron movement above the periodically structured surface.

5. Acknowledgments

The work was supported by a program of the ministry of education and science of The Russian Federation for higher education establishments, project №14.578.21.0063 (RFMEFI57814X0063).

6. References

1. Zavadovskaya E, Annenkov Yu, Starodubtsev V, Vakhromeev V, Malofienko G. Electron-beam charging of an insulator. Russian Physics Journal. 1975; 17(1):144.
2. Kivenko E, Sergeev A, Yagushkin N. The study of the guiding process for 10 keV electrons by planar Plexiglass surfaces. Russian Physics Journal. 1991; 33(11):901.
3. Agafonov A, Bogachenkov V, Krastelev E. The study of the guiding process for 10 keV electrons by planar Plexiglass surfaces. Proceedings of 15th International Conference on High-Power Particle Beams; 2004.p. 143.
4. Stolterfoht N, Bremer J-H, Hoffmann V, Hellhammer R, Fink D, Petrov A, Sulik B. Transmission of 3 keV Ne7+ Ions through Nanocapillaries Etched in Polymer Foils: Evidence for Capillary Guiding. Phys. Rev. Lett. 2002; 88(13):133–201.
5. Das S, Dassanayake B, Winkworth M, Baran J, Stolterfoht N, Tanis J. Inelastic guiding of electrons in polymer nanocapillaries. Phys. Rev. A. 2007; 76(4).
6. Dassanayake B, Das S, Bereczky R, Tokési K, Tanis J. Dependence of electron transmission on charge deposited in tapered glass macrocapillaries at a tilt angle of 5.0°. Phys. Rev. A. 2010; 81.
7. Wang W, Chen J, Yu D, Yang B, Wu Y, Zhang M, Ruan F, Cai X. Transmission of electrons through a tapered glass capillary. Phys. Scr. 2011.
8. Wickramarachchi S, Dassanayake B, Keerthisinghe D, Ayyad A, Tanis J. Trace element quantification in high-resolution Rutherford backscattering spectrometry. Nucl. Instrum. Methods Phys. Res. B. 2011; 269(11): 1248–87.
9. Wickramarachchi S, Ikeda T, Keerthisinghe D, Dassanayake B, Tanis J. Angular dependence of electron transmission through a microsized tapered glass capillary. Nucl. Instrum. Methods Phys. Res. B. 2013; 317(PART-A):101–104.
10. Vokhmyanina K, Zhukova P, Irribarra E, Kubankin A, Le T, Nazhmudinov R, Nasonov N, Pokhil G J. Investigation of contactless electron transmission through dielectric channels. Surf. Invest. 2013; 7(2):271–75.
11. VokhmyaninaK, Zhukova P, Kubankin A, Le T, Nazhmudinov R, Pleskanev A, Oleinik A, Nasonov N, Pokhil G. Studying the interaction of 10-keV electrons with a dielectric surface. Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques. 2014; 8(2): 356–59.
12. Vokhmyanina K, Zhukova P, Kubankin A, Le T, Nazhmudinov R, Oleinik A and Pokhil G. Investigation of the guiding effect of 10-keV electrons using planar dielectric surfaces. Journal of Physics: Conference Series.2014; 517.
13. Vokhmyanina K, Zhukova P, Kubankin A, Kishin I, Klyuev A, Nazhmudinov R, Oleinik A,Pokhil. Investigation of the guiding effect of 10-keV electrons using planar dielectric surfaces. Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques. 2015; 9(2):286–89.
14. Noori A, Ziaie F. Investigation upon Recycling of High Energy Electron Beam Irradiated Alanine Dosimeter. Indian Journal of Science and Technology. 2011 Dec; 4(12):1657–60.