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The study of the guiding process for 10 keV electrons by planar Plexiglass surfaces

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Abstract. Experimental study of electron beam reflection from a single planar surface of Plexiglas was made. The distinct guiding effect for the part of the beam was observed for 10 keV electrons within angles of incidence from 0 to +3 degrees. The experiments using Poly plates showed a number of features of the process such as the dependence of the reflection on the plate surface quality and material of the surfaces, the divisions of the beam into two parts with different behaviour depend on tilt angle and the beam current value, the effect of an elevation angle of the beam in compare with initial beam trace at negative and zero tilt angles of the plate.

1. Introduction

In recent years the possibility to guide electrons by insulating nanocapillaries attracts considerable attention because of its potential practical use in different areas of technology and science. Ion and electron transmission through the channels with large aspect ratio has been studied after the discovery of the guiding of 3 keV ions of Ne7+ transmitting through PET [1]. But the behavior of electrons passing through the capillaries is somewhat different from the behavior of ions indicating the inequality in the mechanism of the interaction of charged particles with insulating surface. Works in this area were carried out since 70 years of the last century, but the studies were focused mainly on high-current electron beams of high energy [2–4].

The set of experimental studies for the electrons with energy up to 1.4 keV was made previously [5–9]. Most of the experiments were made for the capillaries created in Mylar, SiO2, Al2O3 and for straight and tapered glass capillaries. All the results indicate the formation of the self-consistent charge distribution on the inner walls of that channels providing partially contactless transition of electrons even for non-zero angles of incidence.

Straight transmission of electrons with energies from 2 to 10 keV through glass polycapillaries, tubes, and tapered capillaries revealed that the energy of the electrons was almost unchanged. It follows from the measurement results that the electron transmission through capillaries is controlled by the potential at the inner channel surface induced by the charge injected during irradiation.

In the last our work [7] a similar experiments were carried out for a planar channel formed by two glass plates. The distinct guiding effect was observed for 10 keV electrons within angles of incidence from 0 to +3 degrees. To reveal the mechanism of the non-contact transmission of electrons through different insulating channels, an experimental study of beam reflection from a single planar surface was made. The experiments using plates showed a number of features of the process, such as the deviation of the reflection angle from the specular angle and the dependence of the reflection on the plate length, the division of the beam into two parts with different behaviour depend on tilt angle, and the dependence of the beam trace position on the beam current value.

Clear understanding of the mechanism will give the opportunity to select the most suitable materials and geometry of the capillaries to optimize the guiding process.

2. Experiment

In order to reveal the mechanism of electron-surface interaction the experiment with planar surface was made. The material of Plexiglas was used as a target. We used 10 keV energy for electrons. The diagram of experimental setup is shown in figure 1.

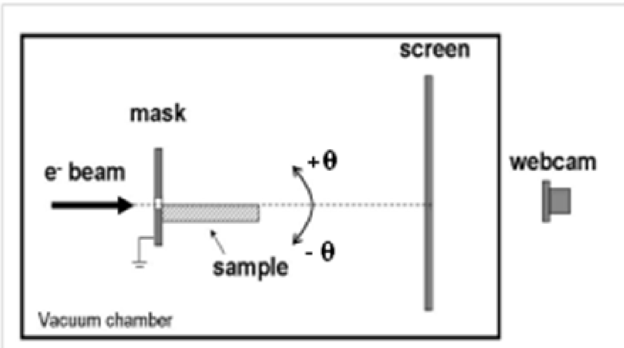

Figure 1. The diagram of experimental setup in vacuum chamber (θ – tilting angle).

The sample in the special holder can be tilt with respect to the beam axis while the entrance of the sample stands still. The holder can be shifted horizontally letting explore several samples and check the primary beam. In front of the sample there is a copper mask that allows regulate beam size (height and width of the beam cross section). The electrons passing though the slit of the mask move close to the insulating surface interacting with it and fall on the glass screen covered with thin layer of scintillation powder. The sample was sequentially tilted and a snapshot was taken at each angle.

Several types of Poly surfaces were used: rough (seed size of about 20um) and smooth plates with different lengths, ~6 mm of thickness. The diameter of the initial beam was 2 mm; the beam current was 170 nA. The monochromaticity of the beam is better than 0.1%.

The tilting of the plates was made in small angle interval typically from -2 degrees to +5 degrees. When the plate surface reaches the positive angles in most experiments with Plexiglas without mask the spot on the screen is split into two parts: central narrow static spot (which can be seen without mask) and the halo that can be in form of arc or “cloud” (figure 2 a, b). The halo can be guided by the plate (figure 2 b).

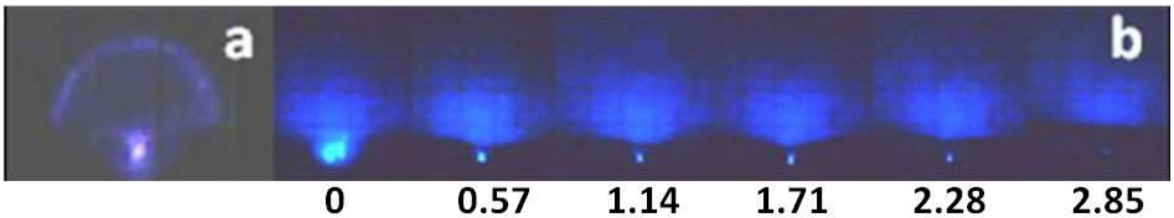

Figure 2. Types of the form of the halo: a- “arc”, b- “cloud”, that can be guided by the Plexiglass plate (On the photo the appropriate tilting angles (in degrees) of the plate are indicated).

The corresponding dependence is shown in figure 3 (The dependence was measured for the lower edge of the halo from the straight beam direction). The “cloud” follows the planar surface from 0 to 3 degrees without movement of the “central” part. The similar situation was observed with glass plates earlier [10].

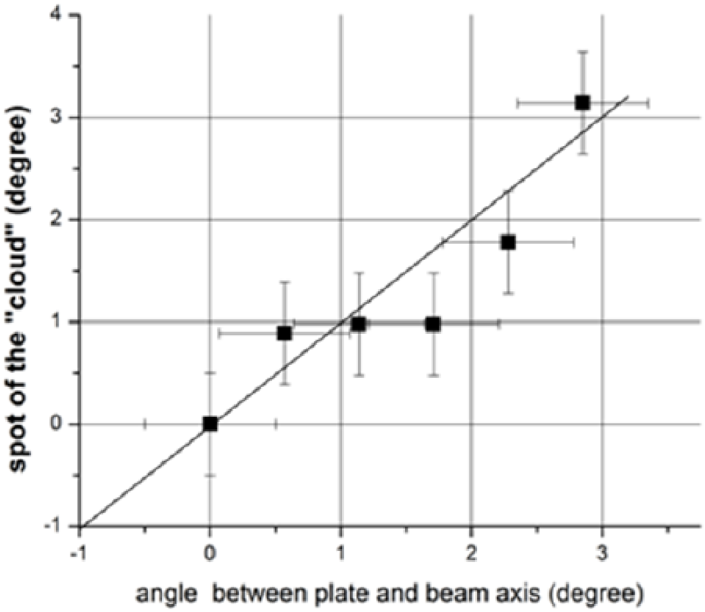

Figure 3. The guiding effect of the “cloud” by planar surface of Poly.

Studying guiding effect we discovered that some types of Poly surfaces were modified by the beam of 10 keV electrons (figure 4 a, b). That modification was different depend on current of the beam.

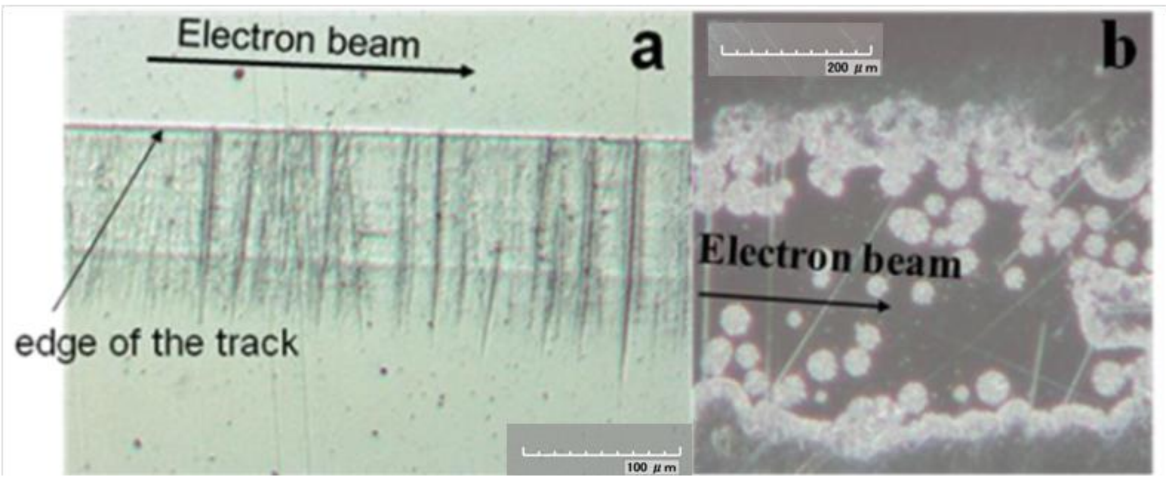

Figure 4. Modification of the Poly surface under the irradiation by 10 keV electrons
a- beam current is 10 nA, b - beam current is 100 nA.

For sufficiently small currents (about 10 nA) on the edges of the track there were needle-like structure perpendicular to the direction of motion of the electrons, and with high current (~ 100 nA) we observed "drops" of dendrite structures on the track that remind insulator surface discharge.

3. Results

Experimental study of electron beam reflection from a single planar surface of Plexiglas was made. As for the ions the deviation of the reflection angle from the specular angle and moving of electrons along the surface was obtained. The experiments using Poly plates showed a number of features of the process such as the dependence of the reflection on the plate surface quality and material of the surfaces, the divisions of the beam into two parts with different behaviour depend on tilt angle and the beam current value.

Several types of Poly surfaces were used: rough (seed size of about 20um) and smooth plates with different lengths. The tilting of the plates was made in small angle interval typically from -2 degree to +5 degree. When the plate surface reaches the positive angles in most experiments with Plexiglas without mask the spot on the screen is split into two parts: central narrow static spot and the halo that can be guided by the plate. The same situation was observed with glass plates earlier. That behaviour cannot be explained by the bulk charge due to too little energy of the incident electrons (less than 100 эВ). Moreover, the shape and behaviour of the spot on the screen indicating some structure in the charge distribution on the surface that can be dynamically changed by tilting the plate.

The halo can be in form of arc or cloud. We assume it depends of initial beam current and quality of surface. To explain this effect it is necessary to simulate the formation of surface charge based on ionization, secondary electron emission and draining overcharge on the surface.

After the interaction of an electron beam with an energy of 10 keV with a Plexiglas surface at grazing incidence (-0.5 ÷ 0.5 deg.) in some experiments there was a noticeable modification of the surface under the action of electrons. And for sufficiently small currents (about 10 nA) on the edges of the track there were needle-like structure perpendicular to the direction of motion of the electrons, and with high current (~ 100 nA) we observed "drops" of dendrite structures on the track that remained surface discharge in dielectrics. It should be noted that despite of the substantial current density of the incident beam, the surface modification was observed only in some cases.

Formation of tracks on the surface of the Plexiglas for a long time irradiation does not affect the position of the pattern at the screen (the position was measured within 30 minutes and significant changes in the intensity or position of the spot have not been identified).

4. References

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