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POSSIBILITY OF USING DIELECTRIC CHANNELS AS DEFLECTING SYSTEMS FOR CONTROLLING ACCELERATED ELECTRON BEAMS

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The results of an investigation of the passage of 10-keV electron beam through dielectric channels fabricated from ceramic (zirconium dioxide) and pyroelectric crystals (lithium niobate) are presented. The angle of deflection of the electron beam by the channels was measured as a function of the angle of interaction of the beam with the internal walls of the channels. The obtained results indicate the possible prospects of using dielectric surfaces as effective deflectors of accelerated charged particles.

Key words: ceramic, dielectric surface, control effect, electron beam, dielectric channels.

When a charged particle beam is incident on the surface of a dielectric at glancing angles a self-consistent charge distribution, capable of deflecting the bulk of the beam at considerable angles without any additional electromagnetic devices and power sources, can form on the surface under certain conditions [1, 2, 8]. This distribution depends on a host of factors: the impact parameter and energy of the particles in the beam as well as the dielectric material (dielectric surface) and surface roughness. All these factors affect the formation process of the surface charge distribution owing to the ionization of the surface atoms, capture of the beam particles by the surface, as well as the rate of charge flow off the surface.

The bulk of the work on studying the control effect, i.e. the possibility of deflection of charged particle beams with the aid of a dielectric surface oriented at an angle from the axis of the incident beam (here and below the *Z* axis), was performed for the surface of materials such as polyethylene terephthalate [1 – 3], quartz and borosilicate glass [4 – 7], and polymethylmethacrylate [8]. The results of the indicated works demonstrate the existence of the control effect for charged particle beams in a quite large range of angles (to 20°C) for dielectric channels as well as isolated surfaces.

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An important feature of this effect is that it opens up a new possibility of developing new devices for controlling charged particle beams. Such devices are small and do not require power sources.

In the present work we present the results of an investigation of the possibility of using as control systems dielectric channels fabricated from ceramics based on zirconium dioxide and pyroelectric crystals $LiNbO_3$. The experimental results indicate a possibility of controlling accelerated electron beams with the aid of systems fabricated from such materials.

EXPERIMENT

A electron beam generating a beam of 10 – 60 keV electrons with current 10 – 400 nA is used as the electron source. At the location of the dielectric channels (targets) the width at half-height of the intensity distribution of the beam profile is 1.5 mm and the angular divergence < 0.25°. The scheme used to measure the shift of the track of the beam passing through a channel upon deflection of the longitudinal axis of the channel from the beam axis *Z* is presented in Fig. 1; the pressure in the vacuum chamber during the experiments was less than 10^{-5} Torr.

The electron beam passes through the channel formed by two dielectric plates and strikes a glass screen, one side of which (on the target side) is coated with a half-transmitting

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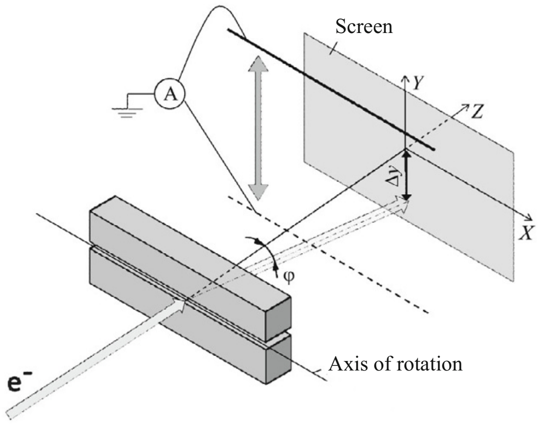

Fig. 1. Scheme for measuring the shift of the track of a beam passing through a channel with the longitudinal axis of the channel deflected from the beam axis *Z*: φ) angle of deflection of the longitudinal axis of the channel from the *Z* axis of the incident beam, the rotation axis of the channel passes through the entry end of the channel; Δ*y*) displacement along the *Y* axis of the electron beam after passage through the channel.

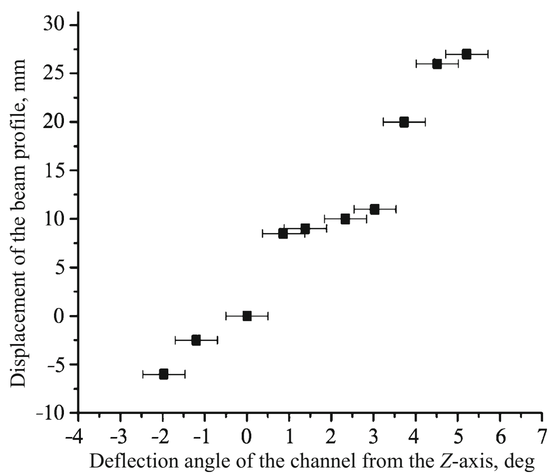

Fig. 2. Displacement of the electron beam profile passing through the channel versus the deflection angle of the channel from the *Z*-axis. The channel is fabricated from zirconium dioxide.

conducting layer of silver, on which, in turn, a layer of a scintillator is deposited. The vertical profile of the beam is measured by scanning the beam with a 170 μm thick copper

TABLE 1. Characteristics of the Experimental Channels

Material	Geometric characteristics of plates, mm			Distance between the plates (channel height), mm
	Width	Length	Thickness	
ZrO_2	29.5	7.6	7.0	0.5
$LiNbO_3$	13.0	15.0	0.5	0.5

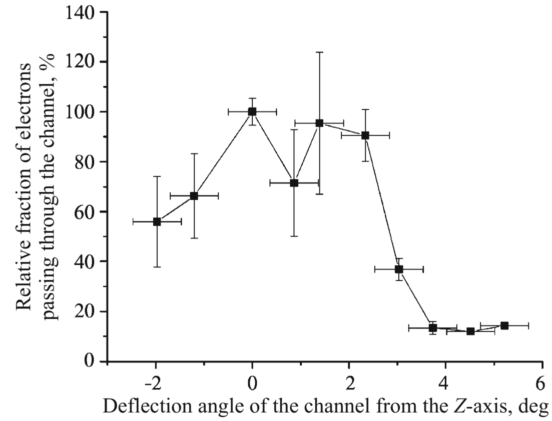

Fig. 3. Relative fraction of electrons passing through the channel versus the deflection angle of the channel from the *Z*-axis. The channel is fabricated from zirconium dioxide. The quantities are normalized to the maximum intensity of the electron beam, when the longitudinal axis of the channel is parallel to the beam axis *Z*.

filament secured in a linear manipulator. A picoammeter is used to measure the current from the filament.

The measurements were performed for two dielectric channels, whose characteristics are presented in Table 1.

The dielectric channels, established in a goniometer on a metal substrate, deflected the beam by an angle φ from the *Z* axis, as shown in Fig. 1. The deflection of the electrons passing through the channel was monitored visually with the aid of a scintillation screen. The vertical profile of the beam was scanned in a vertical direction (along the *Y* axis) with step 0.5 mm (the distance from the rotation axis of the channel to the axis on displacement of the filament was 205 mm).

EXPERIMENTAL RESULTS

The measurements of the position of the 10 keV electron beam with different angles of deflection of the channel, fabricated from zirconium dioxide, from the *Z* axis of a primary electron beam are presented in Fig. 2. The measurements were performed by scanning the transverse profile of the beam in the vertical direction. It is evident from the figure that the beam follows the turn in the channel to within several degrees.

The change in the relative magnitude of the intensity of the electron beam passing through the channel with respect to the intensity of the primary beam for different orientation angles of the channel relative to the *Z*-axis of the primary beam is shown in Fig. 3 (the data are normalized to the maximum intensity of the electron beam, corresponding to the position of the channel parallel to the axis of the incident beam *Z*).

Similar results were observed for a channel fabricated from pyroelectric material — lithium niobate $LiNbO_3$. The data on the displacement of the profile of the 10 keV electron beam accompanying the deflection of the axis of the channel

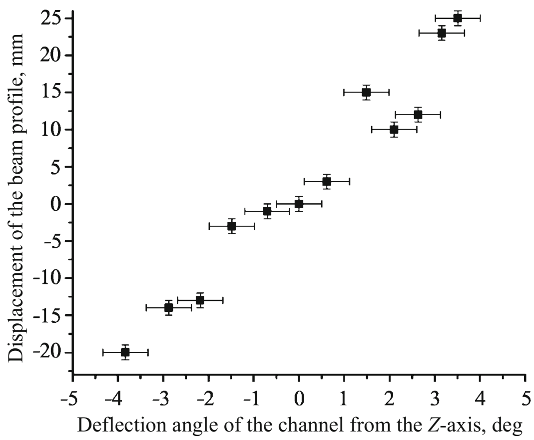

Fig. 4. Displacements of the electron beam profile versus the deflection angle of the channel access from the *Z* axis. The channel is fabricated from lithium niobate $LiNbO_3$.

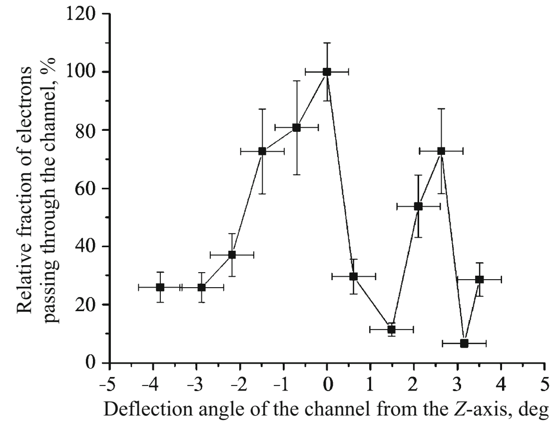

Fig. 5. Relative fraction of electrons passing through the channel versus the deflection angle of the channel axis from the *Z* axis of the beam; the channel is fabricated from lithium niobate $LiNbO_3$. The quantities are normalized to the maximum intensity of the electron beam, when the longitudinal axis of the channel is parallel to the beam axis *Z*.

from the *Z* axis of the beam are presented in Figs. 4 and 5, and the fraction of electrons passing through the channel, normalized to the maximum value of the current for the position of the channel axis parallel to the *Z* axis of the beam, is shown.

It should be noted that the presented results are the first such results obtained. Similar experiments were performed previously for samples with a screened entry in order to avoid blocking of the channels as a result of charging of the inner walls of the channels, but in the present work the experiments were performed without screening and no blocking of the channels was observed.

CONCLUSIONS

The studies performed in this work indicate the possibility of developing devices on the basis of lithium niobate and zirconium dioxide that deflect charged particle beams. The indicated deflection of an electron beam is due to the formation of a charge distribution on the dielectric surface of the channel that allows passage of the beam through the channel without significant loss of intensity, even for relatively large angles of inclination of the longitudinal axis of the channel from the axis of the incident beam. The results of the investigations indicate the possibility of deflection of beams of fast electrons by individual surfaces, i.e. the use of separate plates as deflectors of charged particle beams.

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