

## Short Communication

## Experimental Setup for Studying the Processes Occurring During Interaction of Fast Electrons with Matter

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Experimental setup designed for studying the processes occurring under fast electrons interaction with a matter is presented. The setup is based on an electron gun, which produces the electron beam with current in range from 10 nA to 5  $\mu$ A and electrons energies from 8 up to 60 keV. The rest parts of the setup are the electron gun chamber, electromagnetic system for the electron beam formation, target vacuum chamber, target goniometer, equipment for the beam diagnostics and spectrometry.

**Key words:** Detector, Dielectric surface, Electromagnetic lens, Electron beam, Goniometer, Spectra.

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## 1. INTRODUCTION

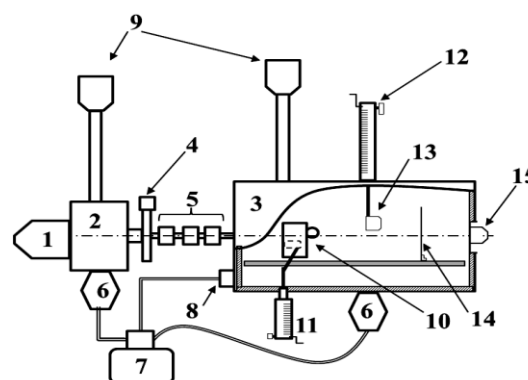
Surface scattering of electrons, secondary electron emission, electromagnetic radiation, thin-film physics, modification of materials and many other actual problems can be solved with the use of compact laboratory installations based on source of accelerated electron beams with energy of electrons up to 100 keV. In the last decade, work is actively carried out to study the processes occurring during the grazing interaction of accelerated electrons with dielectric surfaces in a framework of so-called guiding-effect study [1-4]. The guiding-effect is the ability to control the spatial characteristics of a beam of charged particles by means of dielectric channels of various configurations. This effect is quite unstable for nonrelativistic electron beams, since electrons with energies of several keV are very sensitive to any external electromagnetic fields and have high surface mobility in contrast with ions. Thus, it became necessary to create special laboratory setup in order to study the regularities that arise when accelerated electrons fall on the surface of a dielectric at grazing angles.

On the base of the Laboratory of Radiation Physics of the Belgorod National Research University, a setup was designed on which it is possible to perform a wide range of experimental studies of the processes arising from the interaction of fast electrons with matter. The setup is based on an electron gun, which produces the electron beam with current in range from 10 nA to 5  $\mu$ A and electrons energies from 8 up to 60 keV. The rest parts of the setup are the electron gun chamber, beam transport system, target vacuum chamber, target goniometer, electromagnetic system for beam formation, the equipment for the beam diagnostics and spectrometry.

## 2. EXPERIMENTAL SETUP

The general scheme of the installation is shown in Figure 1. The setup consists of two independently pumped parts: electron source and target vacuum volumes. Electron source includes electron gun (1), mound-

ed on vacuum chamber (2). Target section includes vacuum chamber (3) with target goniometer (10), linear manipulator (12) for translation of Faraday cup (13), glass screen (14) covered by conductive scintillator powder and CCD-camera (15) for observation a position of the beam trace on the glass screen. The turbomolecular pumps (6) and dry scroll fore vacuum pump (7) are used. The initial formation of the electron beam is carried out by a diaphragm of 0.5 mm diameter mounted at the exit of vacuum chamber (2). The next formation is carried out by electromagnetic system (5) fixed on the pipeline between the chambers (2) and (3). The electromagnetic system consists of solenoid lens for focusing of the electron beam and X-Y corrector for beam adjustment in vertical and horizontal directions. Just after the vacuum chamber (2) there is vacuum gate-valve that allows to keep an electron gun in vacuum during changing experimental conditions in the target section at atmosphere.



**Fig. 1** – Scheme of experimental setup: 1 – electron gun, 2 – vacuum chamber of the electron gun, 3 – target vacuum chamber, 4 – vacuum gate-valve, 5 – focusing solenoid lens and electromagnetic corrector of beam position, 6 – turbomolecular pumps, 7 – fore vacuum pump, 8 – valve, 9 – vacuum gauge, 10 – goniometer, 11 and 12 – linear manipulators, 13 – Faraday cup, 14 – glass screen with scintillator, 15 – CCD camera

The fore vacuum pump (7) is common for the whole setup. The pumping system provides vacuum level better than  $10^{-7}$  Torr in electron gun section and better than  $10^{-6}$  Torr in the target section. The electron beam has normal current density distribution with FWHM of 1 mm at the target location point.

In Figure 2 the target chamber is demonstrated. It is developed specifically for experiments on the study of the guiding-effect. It has plane platform on the bottom and 16 flanges located on different positions of the chamber body. On the rear cover of the chamber there is a window for the CCD-camera. All specified parts are designed to mount almost any possible devices that can be used for the study.

The main device necessary for conducting experiments is goniometer with three degrees of freedom. Model of the goniometer and its position in the target chamber are shown in Figure 3 and 2 correspondently. It has to be noticed that all elements of the goniometer are made of non-magnetic materials (duraluminum, fluoroplastic). In addition, the target is controlled in manual mode using vacuum linear manipulators.

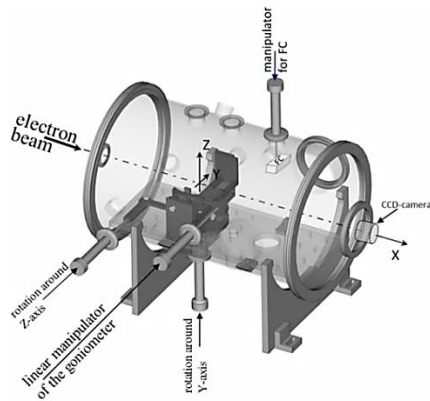


Fig. 2 – 3D-model of target vacuum chamber with goniometer

Linear manipulator 1 (Fig. 3) allows moving the target platform 4 along axis Y in range 0...100 mm with accuracy 0.1 mm. Length of the target platform of 10 cm is enough to place several samples on it. Linear manipulators 2 and 3 provide rotation of the front side of a sample around Z-axis and Y-axis correspondently. X, Y and Z-axes intersect at one point. Manipulators 2 and 3 are equipped with metric scales, which allow to rotate the sample with accuracy of 0.1°. Knowing the geometric

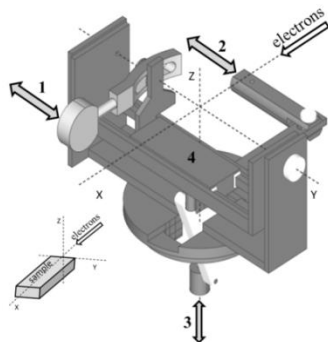


Fig. 3 – Target goniometer. At the left-down corner there is manipulator 2 provides the rotation within  $\pm 10^\circ$  and manipulator 3 allows tilting sample within  $\pm 20^\circ$

parameters of the system, it is possible to estimate the goniometer axes location relative to the sample correspondence between the metric scale of the manipulators and the angle of rotation of the sample.

The correspondence between the metric and angular scales was verified experimentally. Results of the calibration are shown in Figure 4.

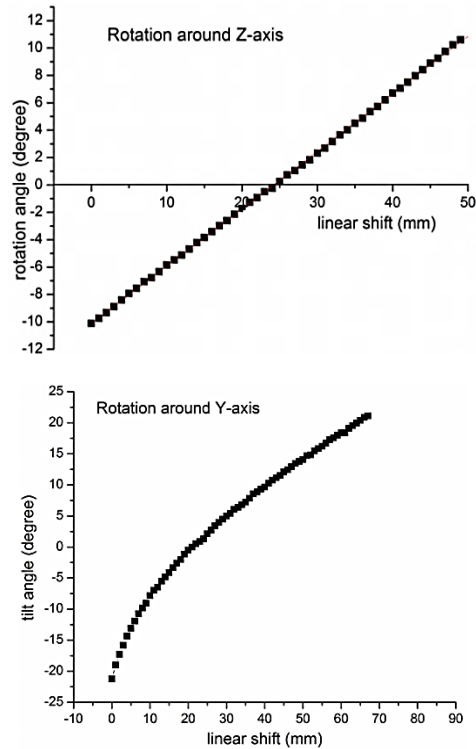


Fig. 4 – Calibration of the goniometer. top – manipulator 2, bottom – manipulator 3

It can be seen from the Figure 4 that in the range of small angles (close to 5 degrees) the dependences are close to linear. However, measurement errors increase when working with the manipulator 3, where the dependence is nonlinear. Thus, only the compiler 2 can be used to perform experiments that require high accuracy for rotating the sample. The goniometer enabled adjustment of the target orientation with an accuracy of 0.1°.

Another important part of the target section is the equipment for the beam diagnostics and spectrometry. The set of elements depends on experimental task. For example if the purpose is to determine the position of the beam in the chamber, to measure the beam current value or its profile it is enough to have glass screen with scintillate powder, CCD-camera and Faraday cup. This set is shown in Figure 2. Faraday cup is fixed to a vertical linear manipulator. It has a shape of a box with a slit which size is of 1 mm by 6 mm and a depth of 8 mm. This design allows measuring the current value and the vertical or horizontal (depending on the location of the manipulator) beam profile. It is possible to fix a frame with a thin conducting wire instead of FC for a more accurate definition of the beam profile and its position relative to the position of initial beam profile. Described equipment was used in several experiments to study the guiding of 10 keV electrons by means of dielectric tubes, plates and plane channels [5-7].

The more difficult task is to measure the energy of electrons after interaction with insulator surface. The most obvious step is to use deflecting electrostatic plates. Unfortunately this method has substantial error for beams with small currents and large angular divergence that is realized for the beam interacting with the target. In case of small currents and for more precise measurements it was tried to use curved electrostatic spectrometer [6]. But in case of large divergence of electron beam after transmitting through, for example, tapered channels, it was decided to get information about electrons energy measuring X-ray spectra, generating in metal target placed at the vicinity of rear side of a sample. It is possible to obtain information about electrons energy from measured X-ray spectrum. The spectra are measured by X-ray detector Amptek XR100SDD FAST with 12.5  $\mu\text{m}$  thick beryllium window and effective area 21  $\text{mm}^2$ , mounted on one of the flanges of the target chamber. This method is described in detail in [7].

### 3. CONCLUSIONS

Experimental setup is designed for studying the processes occurring under fast electrons interaction with a matter. The use of nonmagnetic material allows to achieve good quality of the electron beam. The setup is consists of two independent section. Electron gun section based on the electron gun, which produces the electron

beam with current in range from 10 nA to 5  $\mu\text{A}$  and electrons energies from 8 up to 60 keV, and the electron gun chamber. The rest parts of the setup, target vacuum chamber, target goniometer, the equipment for the beam diagnostics and spectrometry, are included into target section. These sections connect with each other by vacuum pipeline with electromagnetic system for beam formation on it. Separation of the sections makes it possible to change the setting of the experiment without damaging the electron gun. It is important that the elements of the setup close to the beam line (the pipeline with electromagnetic beam correction system, goniometer) are made of non-magnetic materials. The presence of a large number of flanges on the camera body allows the introduction of new beam diagnostic elements and developing the setup for solving a wide range of tasks: generation of electromagnetic waves, development of electron beam systems on the base of guiding effect and modification of the materials by the electron beam.

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