SIGNAL DETECTION WITH NEEDLE AND HALVED SEGMENTAL IONIZATION DETECTOR

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ABSTRACT

This article deals with signal detection by a needle ionization detector and by a halved segmental ionization detector. The signal detection dependency on the shape and size of an ionization detector electrode and its position towards a specimen is studied. Electron trajectories in an electrostatic field in a vacuum simulated via program Simion 3D 7.0 are considered during the experiment.

1 INTRODUCTION

The gaseous ionization detector [1] is often utilized for signal detection at a higher pressure in the specimen chamber of the environmental scanning electron microscope. In the experiment, it was examined the influence of the detector electrodes shape, size and position towards the specimen on the signal detection. These parameters lead to different types of the contrasts in a specimen image, the material, topographic, shadow and diffusion contrasts. For the explanation of an electrons behavior in the ionization detectors, the electron trajectories in the detectors electrostatic fields were simulated via program Simion 3D 7.0 during the experiment.

2 EXPERIMENT

Two types of the ionization detector differing in the shape, size and position of the electrode were examined.

In the first case, the ionization detector consisting of two electrodes of sharpened needles positioned at the left and right side above the specimen was used. As shown in Fig. 1, the needle ionization detector with the tips diameter of 3 μm was made by modification of a segmental ionization detector, described below. The needle electrodes were orientated towards the specimen, as illustrated in Fig. 2. The signal was detected by the left or right needle electrode at a voltage of 450 V, as shown in Fig. 5a, Fig. 5b and Fig. 6a.

As the second type, the halved segmental ionization detector consisting of four concentric plate electrodes divided into left and right halves was used, as seen in Fig. 3. The signal was detected by the left and right smallest electrodes (A_L+ A_R) at a voltage of 450 V while all other electrodes were grounded, as shown in Fig. 4 and Fig. 6b.

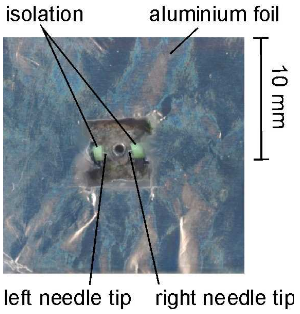


Fig. 1: *Needle ionization detector; aluminium foil grounded*

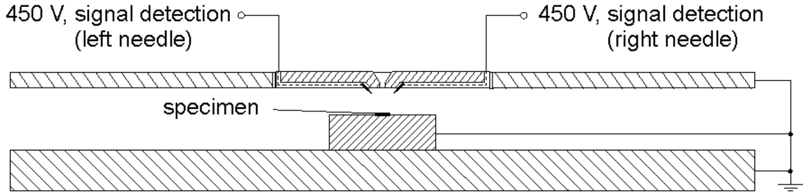


Fig. 2: *Signal detection with needle ionization detector by left or right needle electrode at voltage of 450 V; distance between electrodes and specimen 2 mm; specimen grounded*

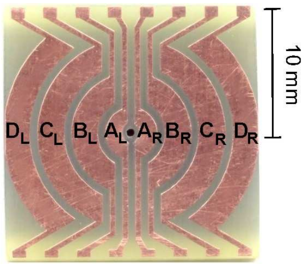


Fig. 3: *Halved segmental ionization detector*

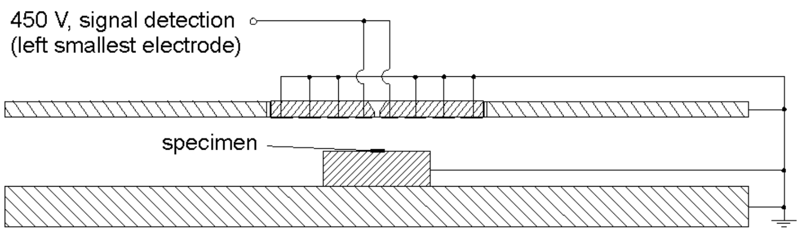


Fig. 4: *Signal detection with halved segmental ionization detector by electrodes A_L+A_R at voltage of 450 V; all other electrodes and specimen grounded; distance between electrodes and specimen 3 mm*

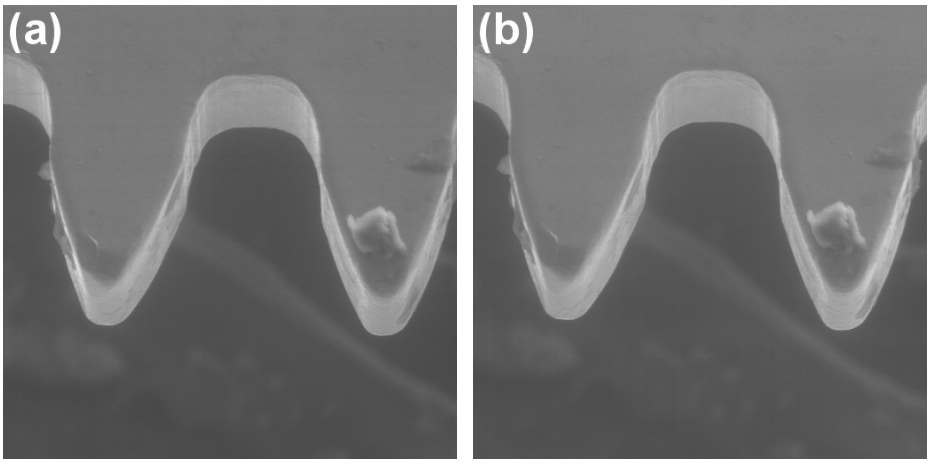


Fig. 5: *Signal detection by needle ionization detector by left (a) and right (b) needle electrode at voltage of 450 V; brass toothed wheel, water vapors environment 700 Pa, magnification 500x*

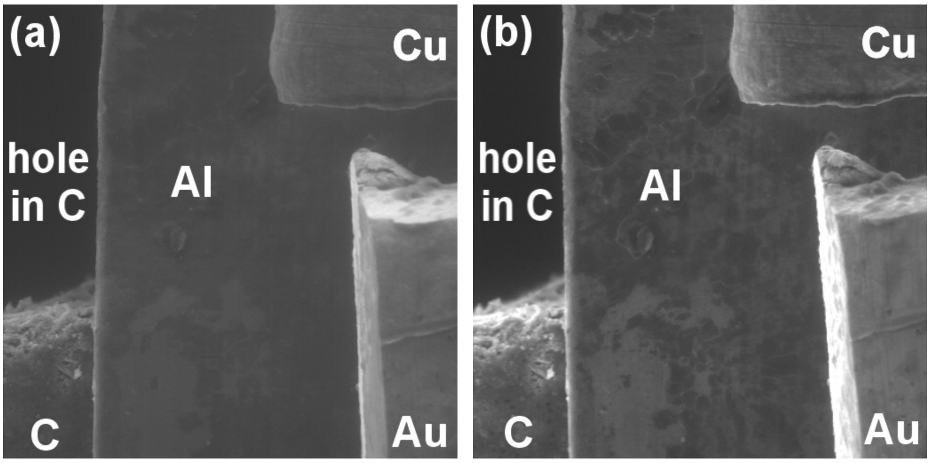
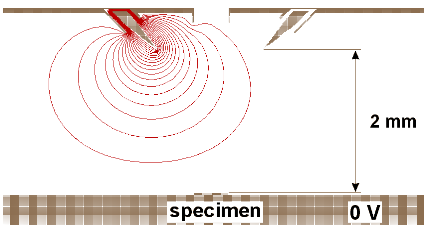


Fig. 6: *Material and topographic contrasts; specimen consisting of hole in carbon, carbon, aluminium foil, cuprum foil and gold foil; water vapors environment 700 Pa, mag. 700x; (a) needle ionization detector, detection by left needle electrode at voltage of 450 V; (b) halved segmental ionization detector, detection by electrodes A_L+A_R at voltage of 450 V; all other electrodes grounded; 10 times higher probe current in case of (a) then in case of (b)*

3 SIMULATION

Since the program Simion 3D 7.0 simulates the ions trajectories in the vacuum, it cannot give a true picture of the process of the signal electrons amplification by the impact ionization in gas environment in the space between the specimen and the detector electrodes. However, the program is able to explore the influence of the detector electrostatic fields on the signal electrons. Therefore, the simulations of the electron trajectories are illustrated for secondary electrons with energy of 5 eV emitted from the specimen, back-scattered electrons with energy of 15 keV emitted from the specimen and environmental secondary electrons with energy of 12.6 eV emitted within the space between the specimen and the detector, shown in Tab. 1 for needle ionization detector and Tab. 2 for halved segmental ionization detector. The reason of the electron energies values is following: the most probable energy of secondary electrons is about 5 eV, the most probable energy of back-scattered electrons when the primary electron energy is 20 keV is about 15 keV and the energy of 12.6 eV is the ionization threshold of water vapors molecules [2] that represents the lowest energy of newly created electrons in the process of the impact ionization. These environmental secondary electrons are placed in the simulations so as create in the middle between the detector and the specimen. The electrode system arrangement in the simulations corresponds to the signal detection experiment. Equipotent lines of the detectors are shown in Fig. 7.



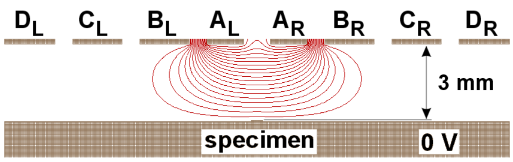
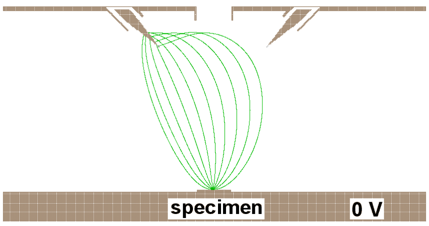
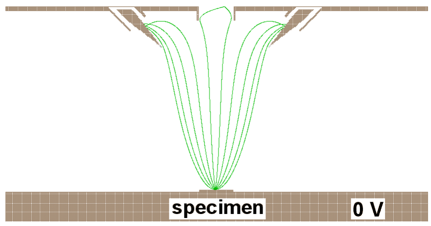
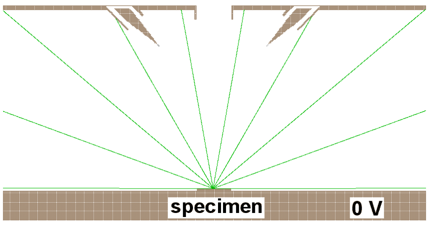
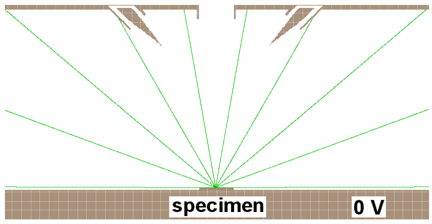
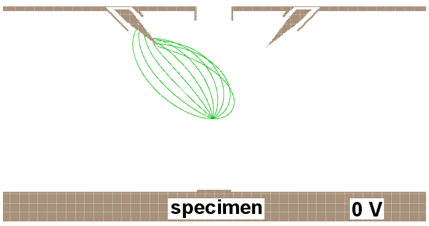
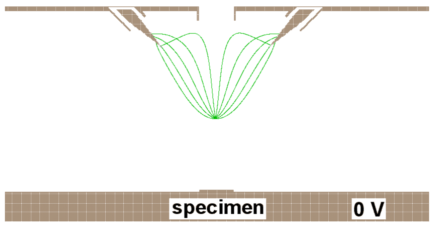
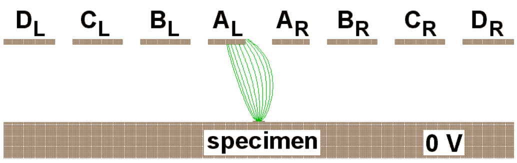
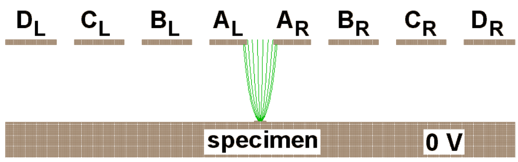
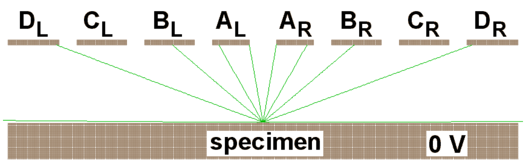
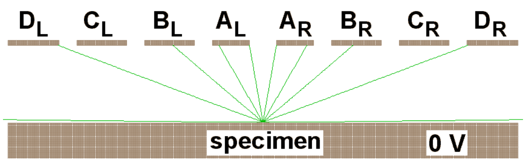
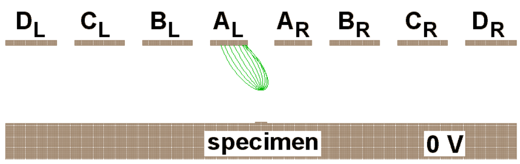
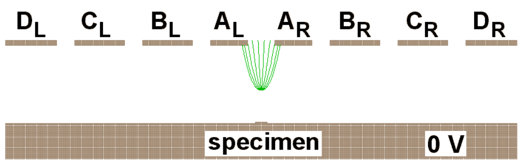


Fig. 7: *Equipotent lines for needle ionization detector (left) and halved segmental ionization detector (right); voltage of 450 V on left needle electrode; voltage of 450 V on electrodes A_L+A_R; other electrodes and specimen grounded; equipotent lines by 22.5 V*

Electron energy	Left needle electrode at 450 V, right needle electrode at 0 V	Left and right needle electrode at 450 V
5 eV		
15 keV		
12.6 eV		

Tab. 1: *Electron trajectories simulation for needle ionization detector in vacuum; voltage of 450 V on left needle electrode, voltage of 0 V or 450 V on right needle electrode; specimen grounded; projection angle of electrons 0 to 180 degrees for 10 electrons*

Electron energy	Electrode A_L at 450 V, other electrodes at 0 V	Electrode $A_L + A_R$ at 450 V, other electrodes at 0 V
5 eV		
15 keV		
12.6 eV		

Tab. 2: *Electron trajectories simulation for halved segmental ionization detector in vacuum; voltage of 450 V on electrode A_L, voltage of 0 V or 450 V on electrodes A_L+A_R; other electrodes and specimen grounded; projection angle of electrons 0 to 180 degrees for 10 electrons*

4 RESULTS AND CONCLUSION

Fig. 5a and Fig. 5b show no change of the angle of view at the specimen, a change of shadow and diffusion contrasts, respectively, at the signal detection by the left or right needle electrode of the needle ionization detector, although it was expected before this experiment. The explanation of this behavior is visible from the electron trajectories simulations in Tab.1 for energies of 5 eV and 12.6 eV. At the detection by one of the needle electrodes, all low-energy electrons are attracted to this electrode. According to the simulations, the change of shadow and diffusion contrasts should be observed when both of detector electrodes are attached to the same voltage and the signal is detected only by one of these electrodes. This connection is designed for a future experiment. As obvious and visible from the simulations, high-energy back-scattered electrons are influenced by the ionization detectors electrostatic fields insignificantly.

The comparison between the signal detection by the needle and the halved segmental ionization detector is shown in Fig. 6a and Fig. 6b. Obviously, both ionization detectors provide the same topographic and material contrasts, the same ratio of secondary and back-scattered electrons, respectively. However, a significantly smaller detection electrode area at detection by the needle ionization detector requires a significantly higher probe current, which results in lower topographic contrast.

ACKNOWLEDGEMENTS

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