INFLUENCE OF SPECIMEN SIZE ON IONIZATION DETECTOR SIGNAL DETECTION

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ABSTRACT

The article deals with the influence of the specimen size on the signal detection by the ionization detector in environmental scanning electron microscope. Results of the computer simulations and the experimental data are used for understanding a relation between the detected signal and the specimen size.

1 INTRODUCTION

An ionization detector is often used for signal detection in environmental scanning electron microscope. This detector utilizes an impact ionization in an electrostatic field in a space between a specimen and the detector for amplification of signal electrons. The electrostatic field is created between the grounded specimen and a detector electrode attached to a voltage of several hundred volts.

In previous work, the influence of the ionization detector electrode area size on the signal detection was in the interests [1]. The signal increased with the increasing electrode area size; however, contrast remained the same. Grounding of the outer detector electrode had a positive influence on the detected signal. During these experiments, an influence of the specimen size on a signal level was observed, thereby this work concerns with this problem.

2 EXPERIMENT

2.1 EXPERIMENT ARRANGEMENT

The ionization detector consisting of four concentric electrodes was used in the experiment. Signal level was detected by three inner electrodes on the potential of 400 V; the fourth outer electrode was grounded, as shown in fig. 1. As specimens, four carbon cylinders of diameters of 5, 10, 15 and 20 mm were used. Each carbon cylinder had a central hole of 0.5 mm in diameter and platinum foil next to the hole (fig. 1). These materials were chosen, since carbon has a low and platinum has a high emission coefficient of signal electrons.

2.2 SIGNAL DETECTION

The signal levels in dependency on pressure were acquired from the hole in the carbon cylinder, a carbon surface and the platinum foil as mean values of histogram grayscale at the relevant position of the specimen image (fig. 2). The signal level from the hole in carbon at the pressure of 30 Pa was considered as the zero signal level. At the pressure of 30 Pa, the probe current was set to a value of 15 pA for each carbon cylinder at the start of imaging and verified at the end of imaging. The working distance of 3 mm between the detector electrode system and the specimen was always the same for all measurements. Primary electrons (PEs) energy was 20 keV; water vapors were used as a gaseous environment.

2.3 CONTRAST

If the black level of the microscope electronics equals zero, the contrast is defined by the following formula [1]:

$$C_{I/II} = \frac{S_I - S_{II}}{S_{II}}$$

where S_I and S_{II} are the signal levels from location *I* and *II* at the specimen. In our case, location *I* is the platinum foil and location *II* is the carbon cylinder surface; both materials are flat without a topographic structure, thus the material contrast is acquired.

2.4 COMPUTER SIMULATIONS

A grounded specimen creates the opposite electrode of the ionization detector plate electrode system. For understanding the electrostatic field distribution of the ionization detector system, simulations in the program Simion 3D [2] are a part of this work.

The maximum number of secondary electrons (SEs) is emitted at energies from 3 eV to 5 eV and the maximum number of back-scattered electrons (BSEs) is considered with energy as about 75 % of the primary electrons energy. Thus, energies of 5 eV, 400 eV and 15 keV were used for the signal electrons trajectories simulations in the program Simion 3D. The electrostatic field distribution and the signal electrons trajectories are pictured in fig. 5 and fig. 6.

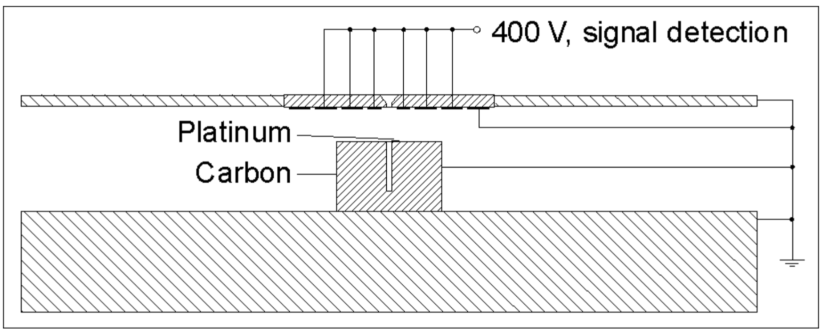

Fig. 1: *Electrodes of ionization detector system*

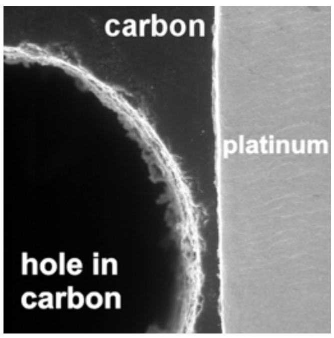

Fig. 2: *Specimen of carbon cylinder with hole and platinum foil*

3 RESULTS

The signal level dependencies on pressure from the platinum foil are shown in fig. 3 and the dependencies on pressure of the contrast between platinum and carbon are shown in fig. 4.

It is obvious that the signal level and the material contrast grow with the increasing specimen diameter. A reason of this phenomenon can be found in the results of the electrostatic field simulations (fig. 5) and the signal electrons trajectories simulations in vacuum (fig. 6.)

For the higher specimen diameter, the electrostatic field is more concentrated in the space between the detector electrodes and the specimen (fig. 5). SEs accelerated by the electrostatic field up to the energy of 400 eV reach 50-times higher ionization efficiency of water vapors molecules than BSEs or PEs. However, BSEs have longer trajectories in the space in which BSEs can ionize gas molecules (fig. 6). Thus, for the higher specimen diameter, the stronger electrostatic field along the BSEs trajectories provides the higher amplification by the impact ionization for the electrons that were created by collisions of BSEs and gas molecules.

As shown in fig. 6, SEs as well as BSEs trajectories are affected by the change of the specimen diameter insignificantly. Therefore, the SEs amplification and the direct BSEs collection should remain the same for all specimen diameters.

SEs provide mostly topographic contrast and BSEs provide material contrast. According to the facts mentioned above, the growth of the signal level and the material contrast with the increasing specimen diameter is caused by the increase of the contribution from collisions of BSEs and gas molecules.

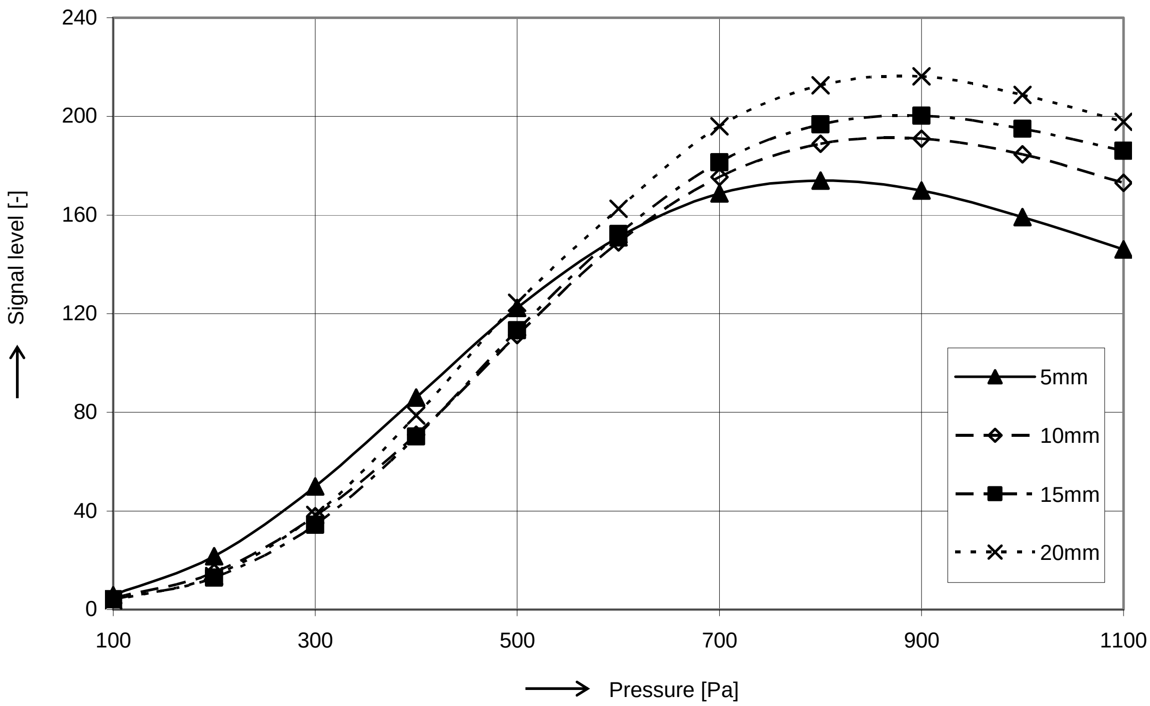

Fig. 3: *Signal levels from platinum foil in dependency on pressure for specimen diameters of 5, 10, 15 and 20 mm*

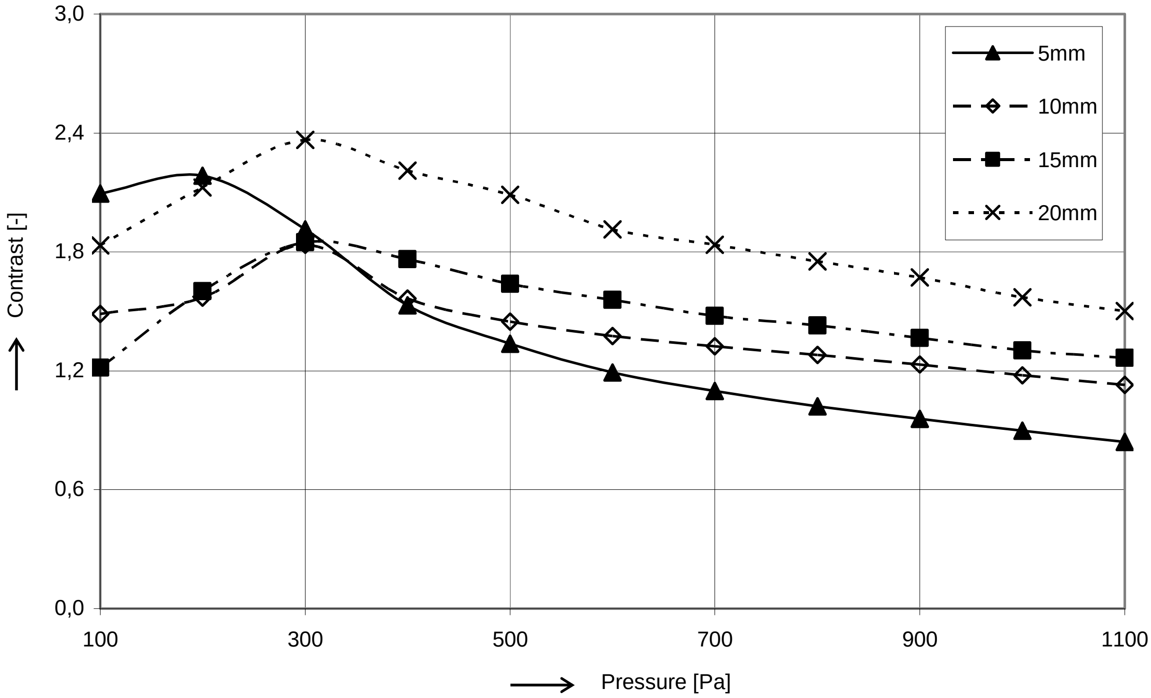

Fig. 4: *Contrast between platinum and carbon in dependency on pressure for specimen diameters of 5, 10, 15 and 20 mm*

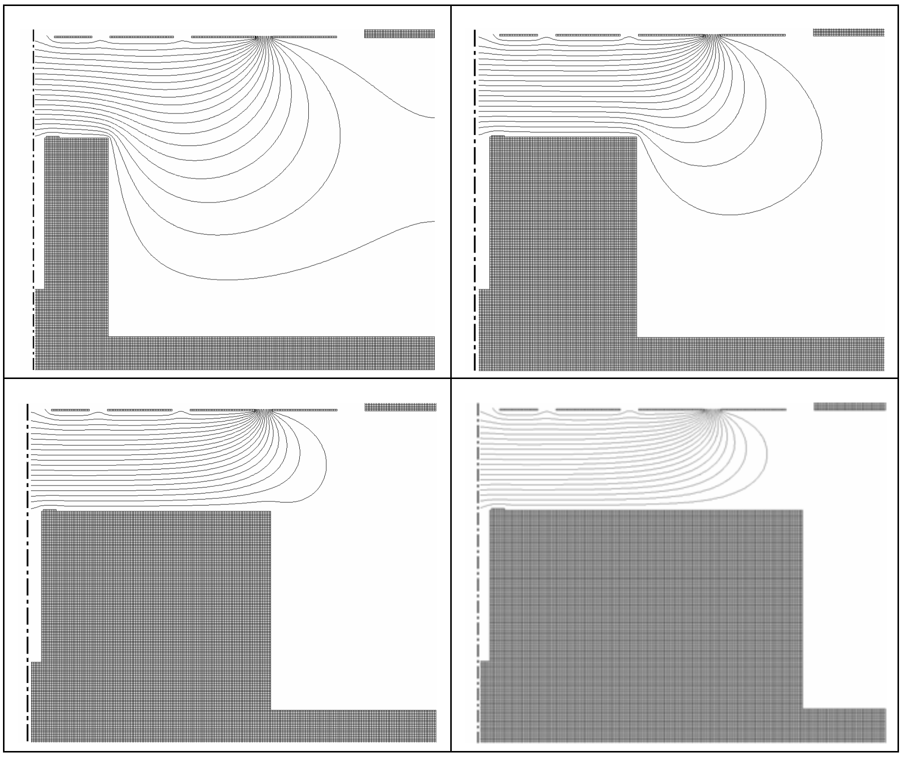

Fig. 5: *Simulated electrostatic field distribution for specimen diameters of 5, 10, 15 and 20 mm; distance between detector electrode system and specimen 3 mm, voltage of 400 V at inner detector electrodes, outer detector electrode grounded, 20 V per each equipotent line*

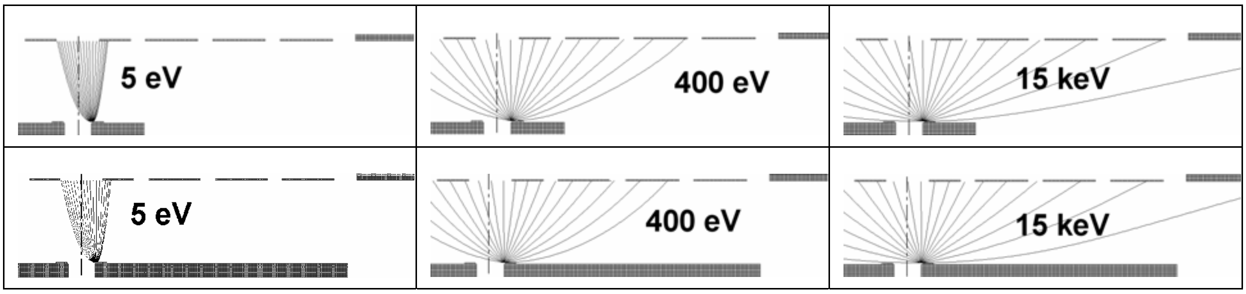

Fig. 6: *Signal electron trajectories simulations in vacuum for electron energies of 5, 400 and 15000 eV and specimen diameters of 5 and 20 mm; distance between detector electrode system and specimen 3 mm, voltage of 400 V at inner detector electrodes, outer detector electrode grounded*

4 CONCLUSION

With the increasing specimen diameter, the contribution of back-scattered electrons increases, which provides higher material contrast. The phenomenon is explained by the stronger electrostatic field between the detector and the specimen for the higher specimen diameters.

ACKNOWLEDGEMENTS

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