ELECTRON TRAJECTORIES SIMULATION IN SECONDARY ELECTRONS SCINTILLATION DETECTOR FOR ESEM

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ABSTRACT

This work deals with the electron trajectories simulation in electrostatic field of the secondary electrons scintillation detector for ESEM. The influences of the applied voltage on detector electrodes and of the detector geometry are taken into account.

1 INTRODUCTION

The environmental scanning electron microscope (ESEM) works with a gaseous environment in the specimen chamber. Air or water vapors in the pressure range from 100 to 2000 Pa are often used as gaseous environment. Main advantages of the environmental scanning electron microscopy are possibilities of the observation of wet specimens and no electrical charging of insulting specimens.

However, the detection of signal electrons in the environmental conditions is complicated. The usage of a classic scintillation detector is not possible for the secondary electrons (SE) detection. The successful SE detection by scintillation detector requires the voltage of several kV on the scintillator. This voltage causes discharges in the gaseous environment of the specimen chamber. Therefore another type of detector – an ionization detector is used for the SE detection. The ionization detector collects both secondary electrons and backscattered electrons.

The secondary electrons scintillation detector is completely new solution for ESEM. In this detector, pressure is gradually lowered in the direction from the specimen chamber to the scintillator.

2 SECONDARY ELECTRONS SCINTILLATION DETECTOR FOR ESEM

This new detector detects only secondary electrons providing mostly topographic contrast. The gaseous environment of the specimen chamber is pumped by rotary pump in the room between apertures and by turbomolecular pump in the room between the last aperture and the scintillator. The pressure of about 1 ÷ 5 Pa is reached in the area at the scintillator, which avoids discharges there. The apertures are also used as electrodes to produce the electrostatic field for the SE trajectories control. Trajectories were simulated to optimize the geometry and voltages on the electrodes via a software SIMION 3D 7.0.

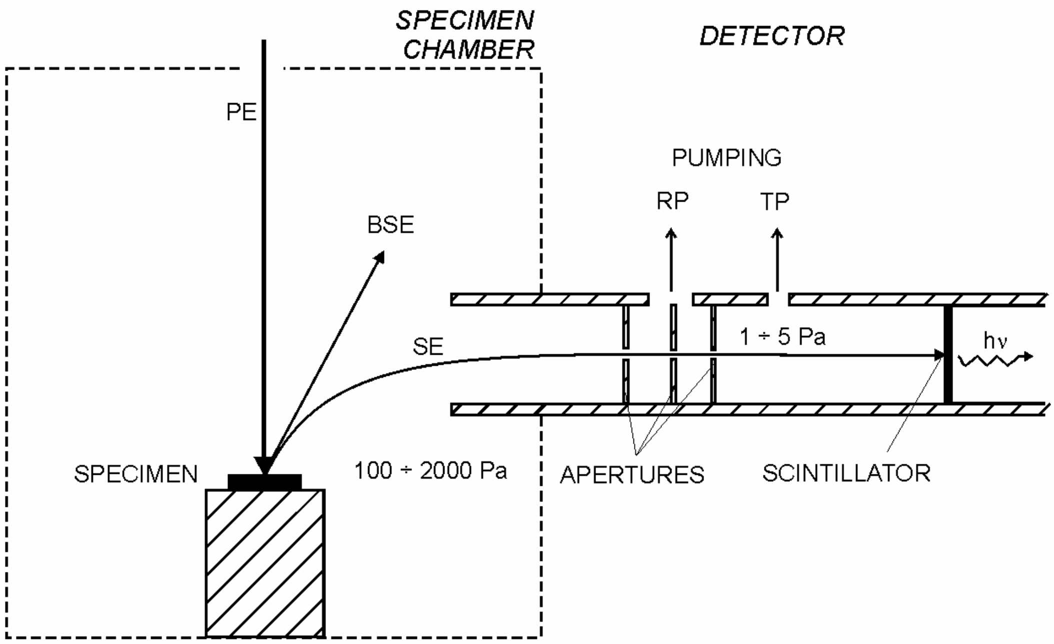

Fig. 1: *Principle of the secondary electrons scintillation detector for ESEM. PE – primary electrons, SE – secondary electrons, BSE – backscattered electrons, RP – rotary pump, TP – turbomolecular pump*

3 SIMULATION OF SECONDARY ELECTRON TRAJECTORIES

At first, secondary electron trajectories were simulated for the existing version of the detector, as presented on Fig. 2. Then the electron trajectories simulation for changed geometries and different voltages on electrodes were accomplished (Fig. 3, 4).

Detector system efficiency was monitored. This efficiency is defined as a ratio of quantity of electrons reaching the scintillator and quantity of electrons entering the electrode system. As a result of simulations, higher detector efficiency was found.

3.1 PREVIOUS VERSION OF ELECTRODE SYSTEM

	Voltage [V]	Outer diameter [mm]	Inner diameter [mm]	Length (thickness) [mm]
Casing	0	13	11	-
Control grid	up to 400	9	8	7
Aperture 1	up to 400	8	0.7	0.3
Aperture 2	up to 400	8	0.3	0.3
Aperture 3	up to 800	8	0.5	0.3
Scintillator	6 000	10	-	-

Tab. 1: *Parameters of the previous version of the electrode system*

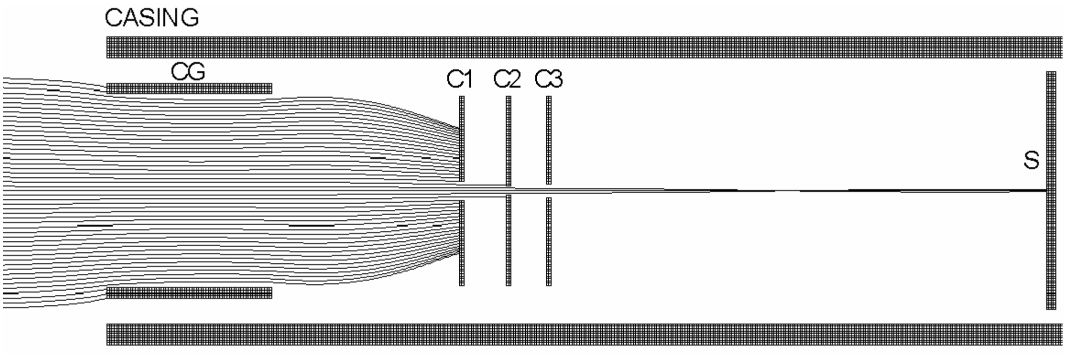

Fig. 2: *Electron trajectories simulation for the previous version of the electrode system. CG - control grid, C1÷C3 – apertures, S – scintillator. Energy of accelerated SE 130eV (CG 130V), C1 400V, C2 400V, C3 700V*

Electron energy [eV]	Control grid [V]	Aperture 1 [V]	Aperture 2 [V]	Aperture 3 [V]	Scintillator [V]	Efficiency [%]
130	130	50	200	700	6 000	7
200	200	50	200	700	6 000	7
200	200	350	0	0	6 000	7

Tab. 2: *Detector system efficiency of the previous version for different voltages*

Electron energy [eV]	Control grid [V]	Aperture 1 [V]	Aperture 2 [V]	Aperture 3 [V]	Scintillator [V]	Efficiency [%]
130	130	350	0	0	6 000	30
130	130	350	0	400	6 000	30
200	200	350	0	0	6 000	21

Tab. 3: *Detector system efficiency of the previous version for different voltages: optimized emplacement of apertures*

3.2 NEW VERSION OF ELECTRODE SYSTEM

	Outer diameter [mm]	Inner diameter [mm]	Length (thickness) [mm]
Casing	13	11	-
Control grid 1	9	8	1
Control grid 2	9	8	5
Aperture 1	8	1.0	0.3
Aperture 2	8	0.6	0.3
Aperture 3	8 or -	0.6 or -	0.3 or -
Scintillator	10	-	-

Tab. 4: *Parameters of new version of the electrode system*

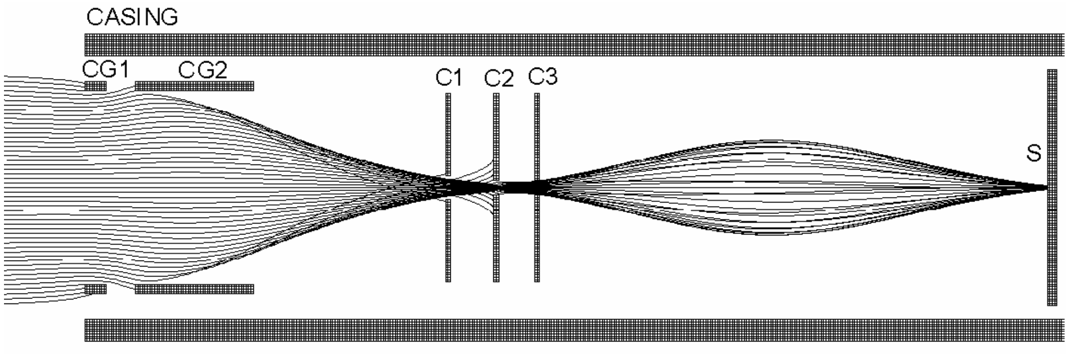

Fig. 3: *Electron trajectories simulation for new version of the electrode system, 3 apertures. CG1, CG2 - control grids, C1÷C3 – apertures, S – scintillator. Energy of accelerated SE 30 eV (CG 30V), CG2 -14V*

Electron energy [eV]	Control grid 1 [V]	Control grid 2 [V]	Aperture 1 [V]	Aperture 2 [V]	Aperture 3 [V]	Scintillator [V]	Efficiency [%]
50	50	-29	350	0	400	6 000	50
50	50	-30	350	0	400	6 000	54
50	50	-30	350	0	700	6 000	59
50	50	-31	350	0	400	6 000	59
50	50	-32	350	0	400	6 000	54
50	50	-35	350	0	400	6 000	50
31	31	-14	350	0	400	6 000	67
40	40	-22	350	0	400	6 000	63
80	80	-54	350	0	400	6 000	53
150	150	-110	350	0	400	6 000	49
200	200	-150	350	0	400	6 000	49

Tab. 5: *Detector system efficiency of new version for different voltages, 3 apertures*

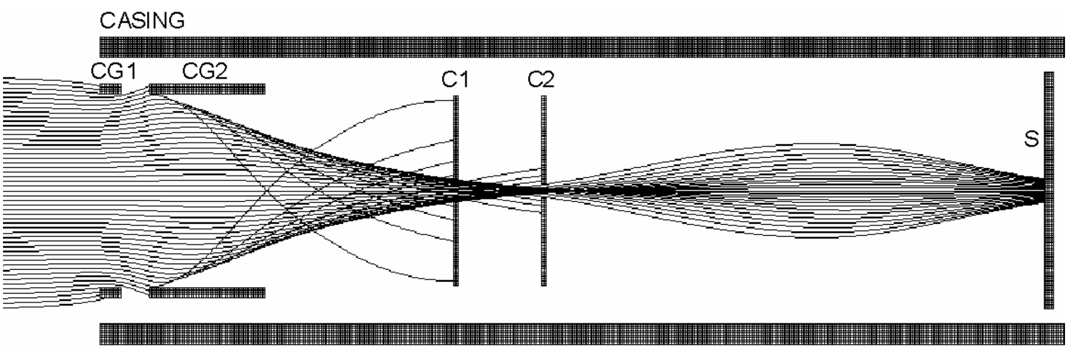

Fig. 4: *Electron trajectories simulation for new version of the electrode system, 2 apertures. CG1, CG2 - control grids, C1, C2 – apertures, S – scintillator. Energy of accelerated SE 150 eV (CG1 150V), CG2 -110 V*

Electron energy [eV]	Control grid 1 [V]	Control grid 2 [V]	Aperture 1 [V]	Aperture 1 Ø [mm]	Aperture 2 [V]	Aperture 2 Ø [mm]	Scintillator [V]	Efficiency [%]
150	150	-80	350	1	400	0,6	6 000	53
150	150	-92	350	0,6	400	0,6	6 000	44
150	150	-100	350	0,4	400	0,6	6 000	35
200	200	-132	350	0,4	400	0,6	6 000	35

Tab. 6: *Detector system efficiency of new version for different aperture diameters, 2 apertures*

4 RESULTS OF SIMULATIONS

Following features were found at the electron trajectories simulation for different geometries and voltages on the electrode system:

- higher voltage on the aperture C1 causes higher beam bending to a beam axis,
- an increase of the voltage on the aperture C2 (over 0V) does not increase the electrode system efficiency,
- it is suitable to set the voltage on the aperture C1 at about 400 V,
- the grounded casing has a significant influence on the electron trajectories,
- the beam bending to the beam axis is well controllable by adding the control electrode with a low negative voltage.

5 CONLUSSION

On the basis of accomplished simulations, the electrode system of the secondary electrons scintillation detector was optimized. The scintillation detector with new arrangement of electrodes reaches higher detection efficiency that provides better imaging of specimens in ESEM.

ACKNOWLEDGEMENTS

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