Optimization of Signal Detection in Scintillation Secondary Electron Detector for ESEM and SEM

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INTRODUCTION

Scintillation secondary electron detector for environmental scanning electron microscope (ESEM) that uses two pressure limiting apertures to decrease pressure in scintillator chamber to values which allow to connect voltage of 10 kV to the scintillator while water vapor pressure in the specimen chamber of the microscope reaches up to 1000 Pa was introduced in [1]. Furthermore the possibility of detection of secondary electrons with this detector, even at pressure of 0.01 Pa (vacuum conditions) in the specimen chamber was demonstrated in [2].

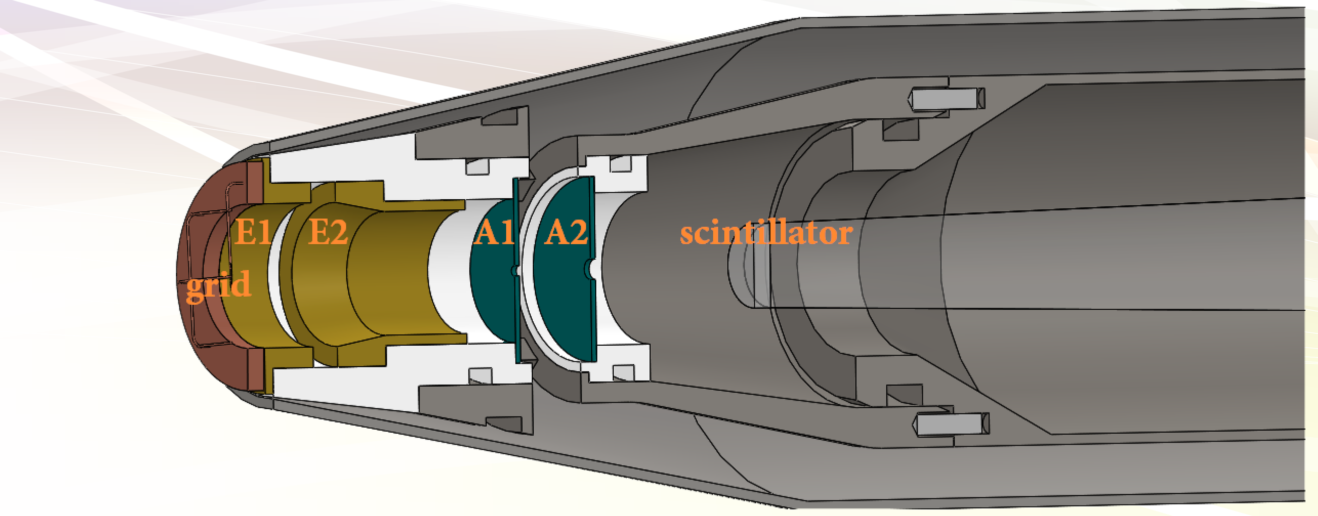

Fig. 1: Sectional view of scintillation secondary electron detector for ESEM and SEM.

In this detector, pictured on Fig. 1, the space between apertures A1 and A2 is vacuum pumped by a rotary pump and the scintillator chamber by a turbomolecular pump. Voltages connected to the grid, to the electrodes E1 and E2 and to the electrostatic lens created by apertures A1 and A2 produce electrostatic field that attracts secondary electrons emitted from the specimen to the detector and allow them to pass to the scintillator chamber where they are accelerated to the scintillator.

The aim of this work is to find optimal configuration of apertures A1 and A2 of the detector electrode system for signal detection from vacuum conditions to pressure of several hundreds of Pa. Theoretically signal level should grow with increasing diameter of openings in apertures A1 and A2, but at the same time, pressure in the scintillator chamber grows too. Therefore it is necessary to find an optimal size of openings in the apertures so that the signal level will be high enough for detection and pressure in the scintillator chamber will stay small enough to allow connection of 10 kV to the scintillator without problems with discharges.

EXPERIMENTS AND RESULTS

Based on previous experience, the following diameters of openings in the apertures A1 and A2 were used: A1 - 0.4, 0.5, 0.6 and 0.7 mm and A2 - 1.0 and 1.1 mm. Measured dependences of the pressure in the scintillator chamber on water vapor pressure in the specimen chamber for different combinations of apertures A1 and A2 are shown on Fig. 2. The same dependences measured for pressure in the chamber between apertures A1 and A2 (differential chamber of the detector) are pictured on Fig. 3.

All signal level measurements were realized in these standard working conditions: accelerating voltage of primary electrons 20 kV, primary beam current 100 pA, voltage on the scintillator of detector 10 kV, working distance between the specimen and last pressure limiting aperture of the microscope 4 mm, specimen - Pt foil on carbon holder, environment of water vapors in the specimen chamber. Three different settings of voltages on the grid, on electrodes E1, E2 and on apertures A1 and A2 of the detector were used - see Tab.1.

Dependences of signal level on the pressure in specimen chamber, measured under standard conditions, are plotted on Fig. 4 for voltages from the Tab. 1 - setting 1 and on Fig. 5 for setting 2.

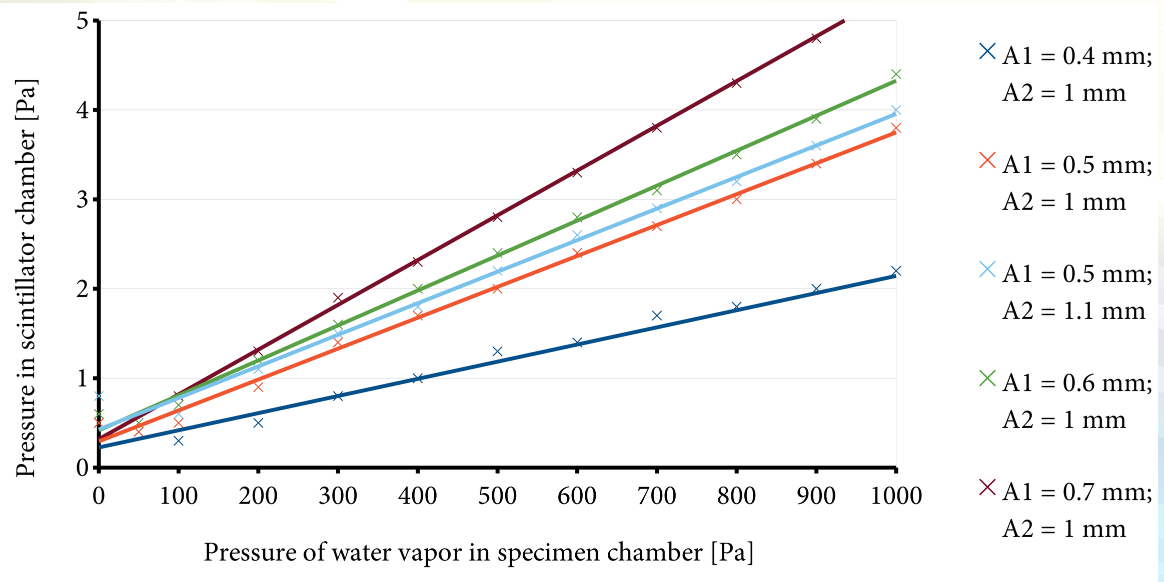

Fig. 2: Dependence of pressure in scintillator chamber on water vapor pressure in specimen chamber.

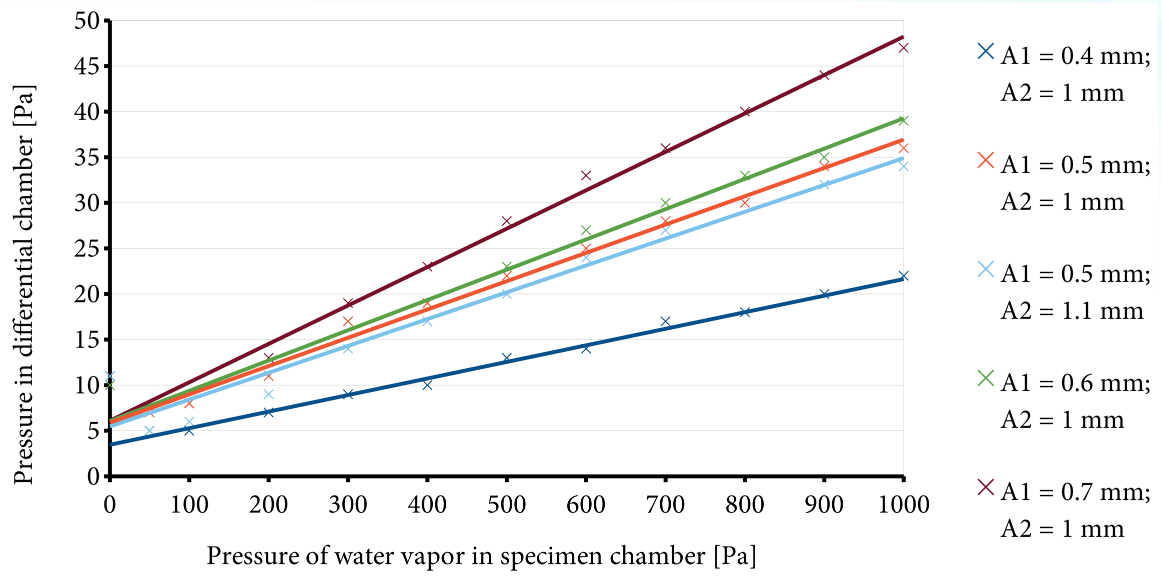

Fig. 3: Dependence of pressure in differential chamber on water vapor pressure in specimen chamber.

Tab. 1: Voltages on electrodes and apertures of detector.

	Setting 1	Setting 2	Setting 3
$U_{E1+GRID}$	300 V	300 V	100 V
U_{E2}	400 V	330 V	130 V
U_{A1}	550 V	440 V	250 V
U_{A2}	1 kV (1.5 kV in vacuum)	1 kV (1.5 kV in vacuum)	1 kV

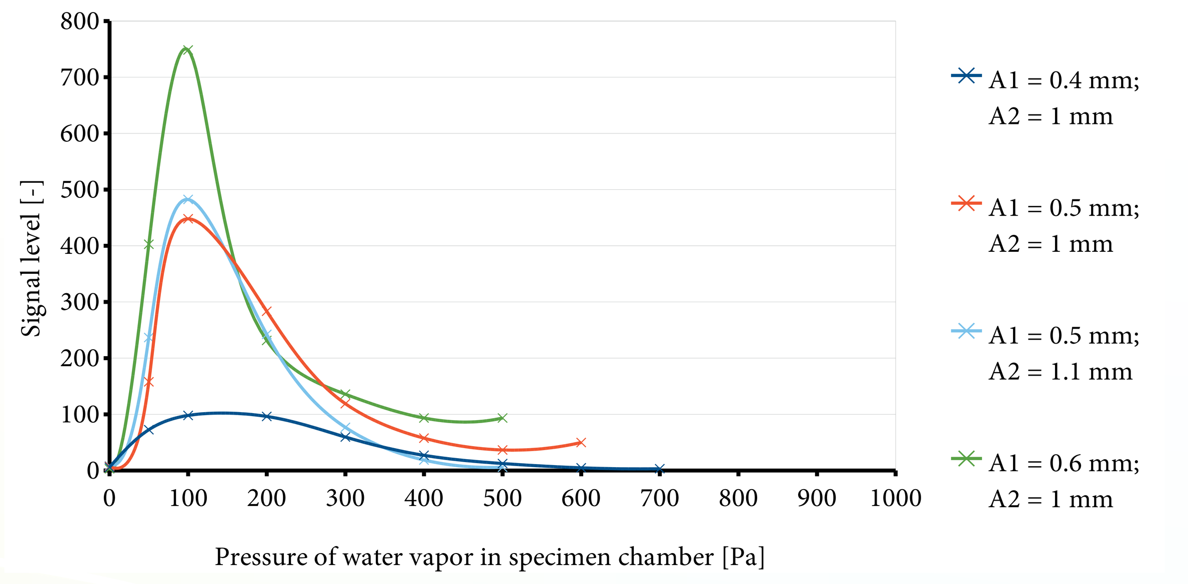

Fig. 4: Dependence of signal level on pressure of water vapor in specimen chamber for different diameters of apertures. Voltages on electrodes and apertures of detector according to setting 1.

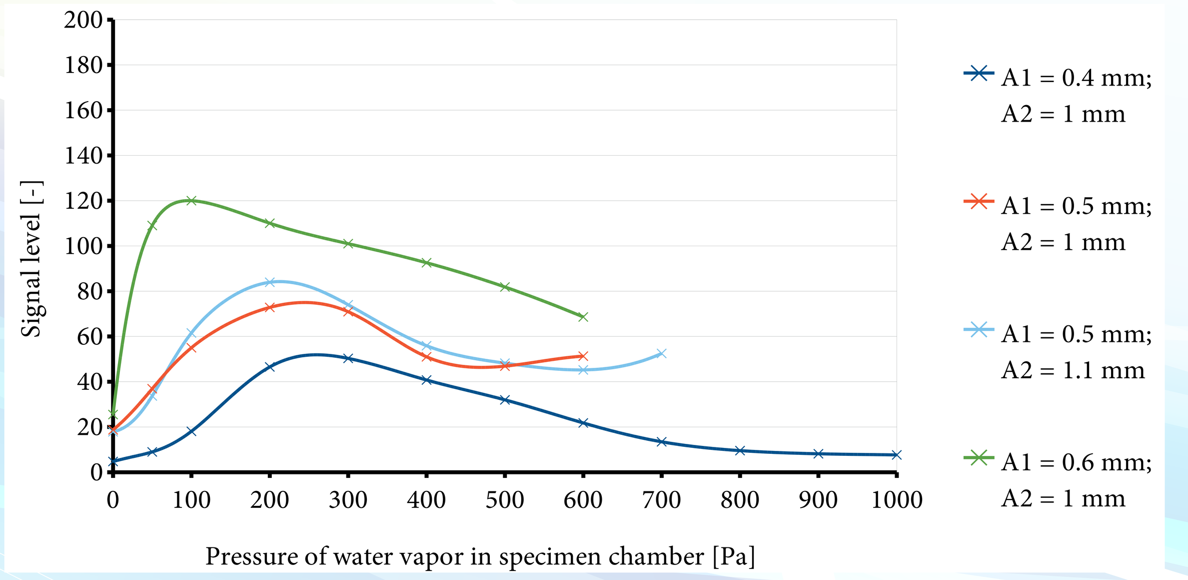

Fig. 5: Dependence of signal level on pressure of water vapor in specimen chamber for different diameters of apertures. Voltages on electrodes and apertures of detector according to setting 2.

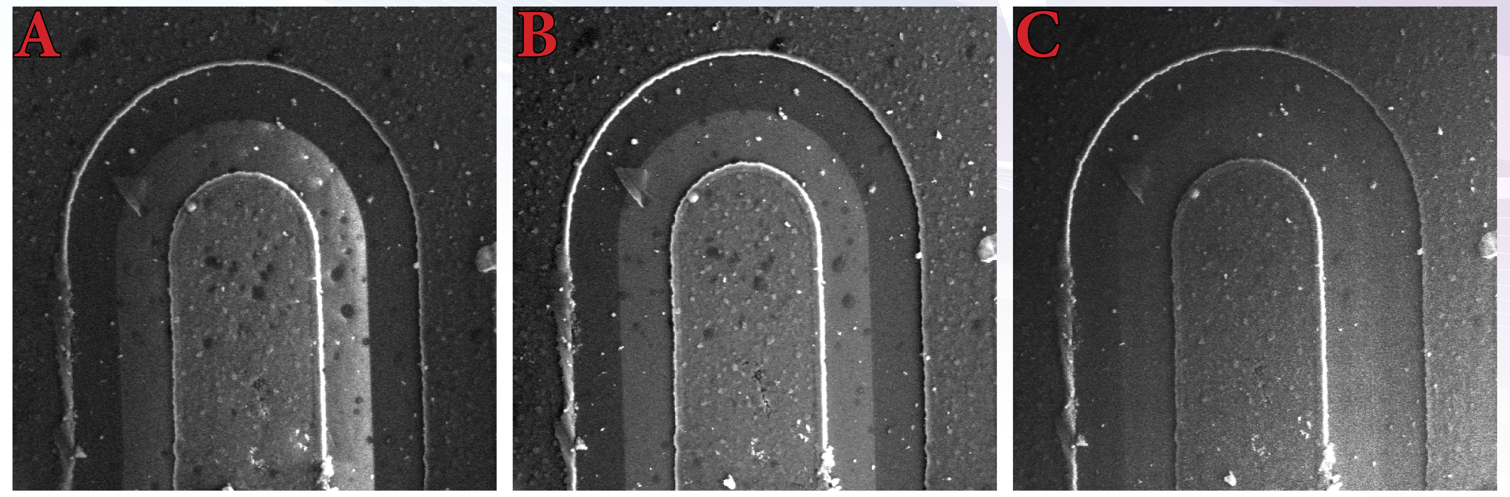

Fig. 6: Voltage contrast on emitter-base junction of NPN transistor. Field of view: 85 μm.
Pressure of water vapor in specimen chamber: A - 0.01 Pa, B - 200 Pa, C - 600 Pa.

DISCUSSION

It is seen from dependences pictured on Fig. 4 and Fig. 5 that larger diameter of the opening in the aperture A1 brings higher detected signal level but also expected increase of pressure in the differential chamber of the detector (Fig. 3). The increasing pressure in the differential chamber limits usage of the detector with voltages according to setting 1 (Tab. 1.) to lower values of the pressure in the specimen chamber, for higher values of pressure voltages according to setting 2 must be utilized.

Realized measurements also proved that very good results can be obtained by usage of the aperture A1 with diameter of opening of 0.5 mm and the aperture A2 of 1.1 mm. With these apertures the pressure in differential chamber of the detector is low enough to allow maintaining of voltages according to setting 2 (Tab. 1) up to water vapor pressure of 700 Pa in specimen chamber. The signal level is high with low noise that leads to good quality images. For pressures above 700 Pa it is necessary to change voltages on electrodes and apertures of the detector according to setting 3.

Voltage contrast on PN junction of power transistor, which is not visible in the image of backscattered electrons, was observed to demonstrate the detection of secondary electrons by this detector at pressures from 0.01 Pa to 600 Pa. Images of emitter base junction of the transistor with connected reversed voltage of 10 V are seen on Fig. 6.

CONCLUSION

Realized experiments with the scintillation detector of secondary electrons equipped with system of differential vacuum pumping proved that it is possible to operate this detector with pressure ranging from vacuum (conditions of SEM) up to pressure of 1 000 Pa of water vapor in the specimen chamber (conditions of ESEM). Optimal conditions for operation of the detector in this pressure range were found.

REFERENCES

[1] J Jirák *et al*, Journal of Microscopy **239** (2010), p. 233.
[2] J Jirák *et al*, Microscopy and Microanalysis (2012), p. 1266.
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