SCINTILLATION SECONDARY ELECTRON DETECTOR FOR VARIABLE PRESSURE SCANNING ELECTRON MICROSCOPE

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ABSTRACT

This article deals with a newly modified scintillation secondary electron detector for variable pressure scanning electron microscope. Optimized voltages on the detector electrode system are presented for pressure range of 100 – 800 Pa.

1. INTRODUCTION

Variable pressure scanning electron microscope (VP-SEM) which works at pressure up to thousands of Pascals in the specimen chamber allows studying of wet specimens including biological ones, insulating materials without charging artifacts as well as effects on phase interfaces.

Detection of signal electrons at higher pressure of gases in the microscope specimen chamber is usually realized by ionization (ID) and scintillation detector (SD). ID utilizes impact ionization in gas environment of the specimen chamber for amplification of the signal of secondary (SEs) and backscattered electrons (BSEs). Voltage of few hundreds volts is attached to the electrode system of ID and created electric field gives enough energy to SEs for the impact of ionization process. Energy of BSEs is sufficient to evoke ionization process by itself.

Detection of signal electrons by SD is conditioned by sufficient energy of these electrons to evoke scintillations in the scintillation material. While BSEs have sufficient energy to evoke scintillation in the scintillator material, SEs with energy only up to 50 eV must be accelerated by adding voltages up to 10 kV to the scintillator. Because of high pressure in the specimen chamber of VP-SEM connection of 10 kV to the scintillator placed in the specimen chamber is impossible owing to the problems with electric discharges in gas.

2. SCINTILLATION DETECTOR FOR VP-ESEM

In our experimental SD for VP-SEM (Fig.1) the scintillator is placed in a special chamber, pumped by turbomolecular pump. The scintillator chamber is separated from the specimen chamber by two apertures A1 and A2. Room between apertures, marked as differential chamber, is evacuated by a rotary pump and it serves for gradual decreasing of pressure between the specimen chamber and scintillator chamber. Whole vacuum system of the detector allows achieving pressure under 3 Pa in the scintillator chamber at pressure up to 1 kPa in the specimen chamber.

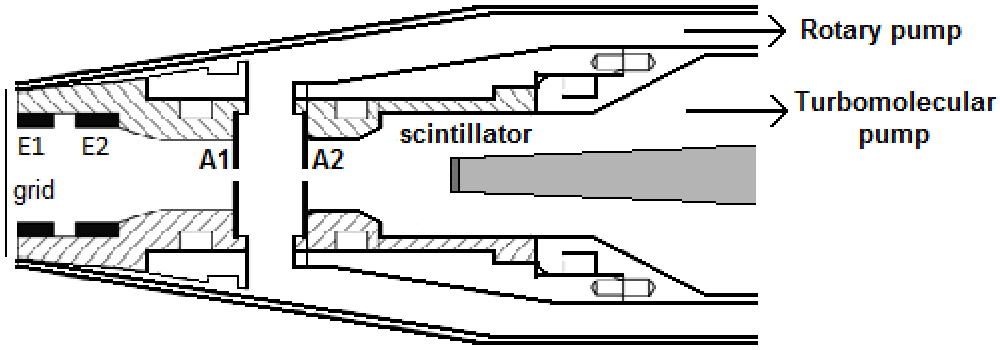

Figure 1: SD for VP-SEM

Voltage of 100 V up to 200 V on the grid of the detector serves for routing of SEs into the detector. Voltage on electrodes E1 and E2 are optimized to route SEs to the centre of apertures A1 and A2 which create an electrostatic lens. Trajectories of secondary electrons in the electrode system of the detector were simulated by a computer program Simion ver. 8. Simulations were used for optimization of the electrode system of the detector.

3. EXPERIMENT

The aim of the experiment was to optimize a new electrode system of the detector with the grid to obtain maximal signal SEs for pressure range of 100 – 800 Pa.

For the measurement of the signal level it was prepared a standard specimen from carbon cylinder with a diameter of 6 mm and height of 15 mm with a borehole in the middle of the cylinder. The borehole has diameter of 0,5 mm and depth 10 mm. The borehole was used for measurement and adjustment of the primary beam current at pressure of 0,1 Pa. The foil of platinum was attached near to the borehole by a carbon paste and it was used for the measurement of the signal level.

Signal levels from the specimen were evaluated from images of the standard specimen. The signal level from the borehole was used for setting of a zero signal level. The signal level from platinum was meassured as a mean value of the gray scale in selected area of the image of platinum. The evaluation was carried out by using a graphic editor Adobe Photoshop CS4. In all measurements the constant voltage of 680 V was set on the photomultiplier and primary beam current was 100 pA.

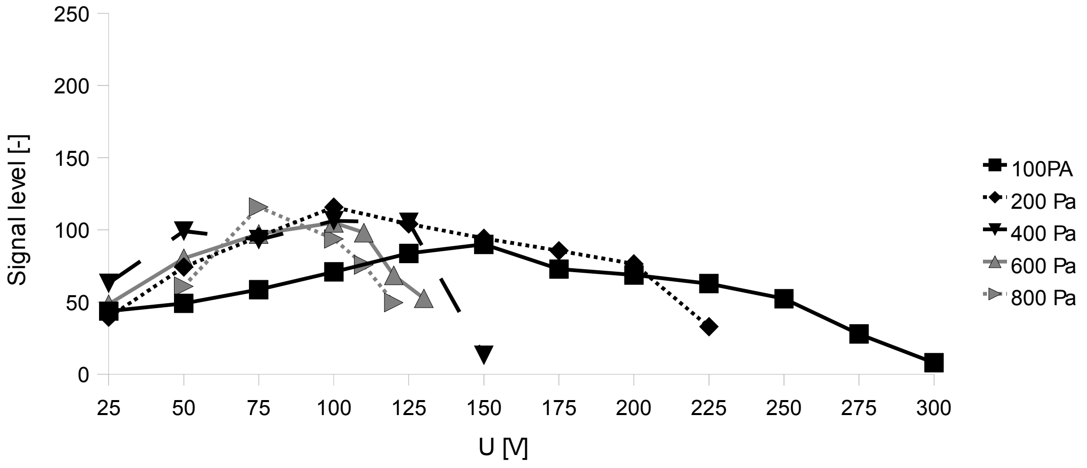

Figure 2: Dependencies of signal level from platinum foil on voltage on grid for pressures 100 Pa, 200 Pa, 400 Pa, 600 Pa and 800 Pa in the specimen chamber

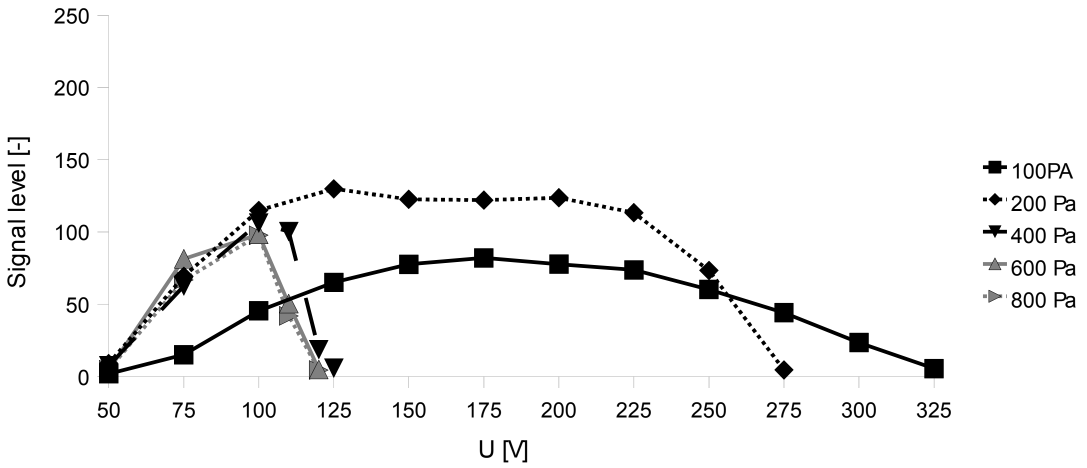

Figure 3: Dependencies of signal level from platinum foil on voltage on electrode E1 for pressures 100 Pa, 200 Pa, 400 Pa, 600 Pa and 800 Pa in the specimen chamber

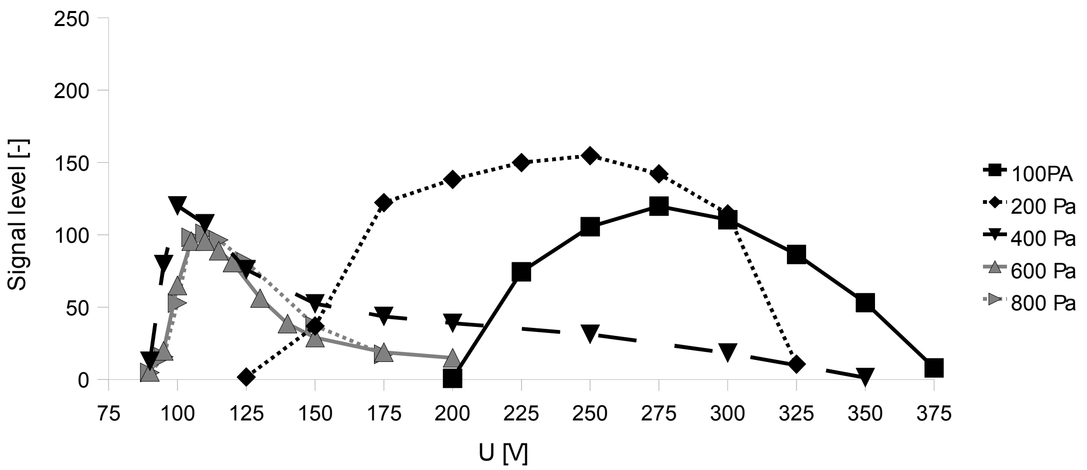

Figure 4: Dependencies of signal level from platinum foil on voltage on electrode E2 for pressures 100 Pa, 200 Pa, 400 Pa, 600 Pa and 800 Pa in the specimen chamber

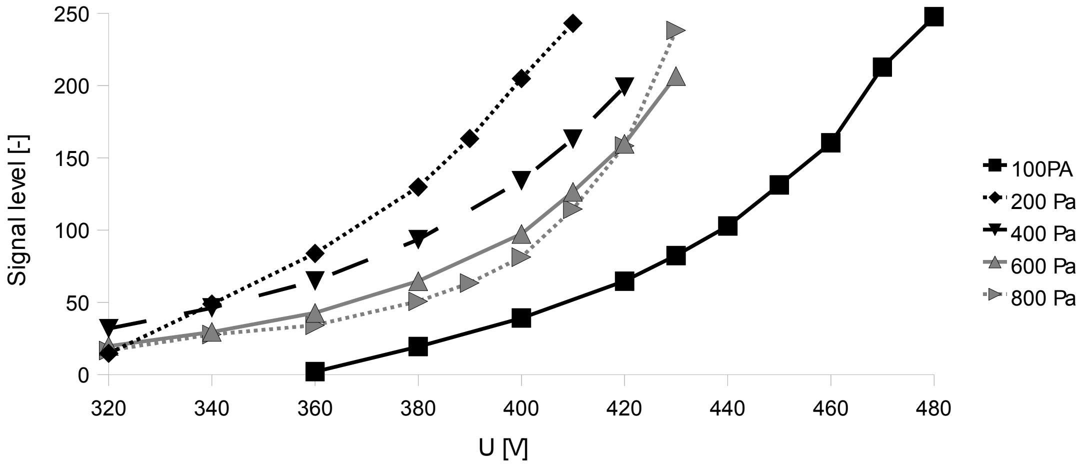

Figure 5: Dependencies of signal level from platinum foil on voltage on aperture A1 for pressures 100 Pa, 200 Pa, 400 Pa, 600 Pa and 800 Pa in the specimen chamber

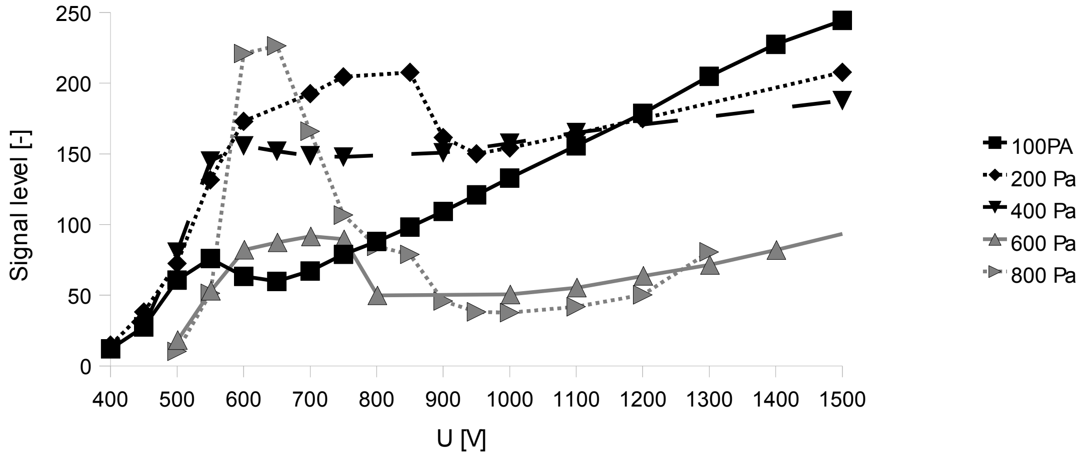

Figure 6: Dependencies of signal level from platinum foil on voltage on aperture A2 for pressures 100 Pa, 200 Pa, 400 Pa, 600 Pa and 800 Pa in the specimen chamber

Pressure [Pa]	U_{GRID} [V]	U_{E1} [V]	U_{E2} [V]	U_{A1} [V]	U_{A2} [V]
100	150	200	300	(Max 470)	750
200	100	150	250	400	750
400	100	100	110	400 (max 460)	750
600	100	100	110	400 (max 420)	750
800	100	100	110	400	750

Table 1: Optimized voltages on electrode system of the detector for pressure range of 100 – 800 Pa in the specimen chamber

4. RESULTS

Experiments proved that it is possible to optimize voltages on electrode system of the detector for pressure range of 100 – 800 Pa in the specimen chamber. Optimized voltages for this pressure are presented in table 1.

The increase of the voltage on A1 causes growth of the signal level. But at higher pressures it can also cause detector instability or electric discharges in gas that can damage the detector.

Experiments also proved that optimal voltages on grid and electrode E1 for pressure range of 400 – 800 Pa are the same and these electrodes can be connected.

The next work on the scintillation detector for VP-SEM will be oriented on a combination of the grid and of the electrode E1 and on a replacement of the scintillator $YAG:Ce^{3+}$ by the scintillator CRY18 which is more efficient even at lower energies of electrons, therefore at lower voltages on the scintillator.

ACKNOWLEDGEMENT

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