SCINTILLATION SECONDARY ELECTRON DETECTOR FOR ESEM AND SEM

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Introduction

Specimens in environmental scanning electron microscopes (ESEMs) can be observed not only in vacuum conditions, but also in pressure up to thousands of Pascal of different gases in the specimen chamber. It makes direct observation of wet specimens, nonconductive specimens and phenomena on phase interfaces possible.

Detection of signal electrons in vacuum in the specimen chamber of the scanning electron microscope (SEM) is often based on the Everhart - Thornley scintillation detector. Detection of low energy secondary electrons by this detector requires adding voltage up to 10 kV to a thin conductive layer on the scintillator and creating an electric field in front of the scintillator. Secondary electrons emitted from the sample surface are accelerated in this electric field and receive sufficient energy to evoke scintillations in the scintillator. This method of the detection of secondary electrons cannot be used at a higher pressure of gases in the specimen chamber of the ESEM because of problems with electric discharges in the gas environment in the vicinity of the scintillator.

For the detection of secondary electrons at conditions of a higher pressure of gases in the specimen chamber ionization detectors [1] or scintillation detectors with the scintillator placed in the special vacuum pumped chamber [2], [3] are commonly used. At ionization detectors signal electrons are amplified in the process of impact ionization with atoms and molecules of gases, their operation requires presence of gases.

Detection Method

The scintillation secondary electrons detector for the ESEM pictured on Fig. 1 was presented in [4]. The conception of the vacuum system of the detector is based on usage of two pressure limiting apertures A1 and A2 and individual vacuum pumping of the chamber between apertures and of the chamber

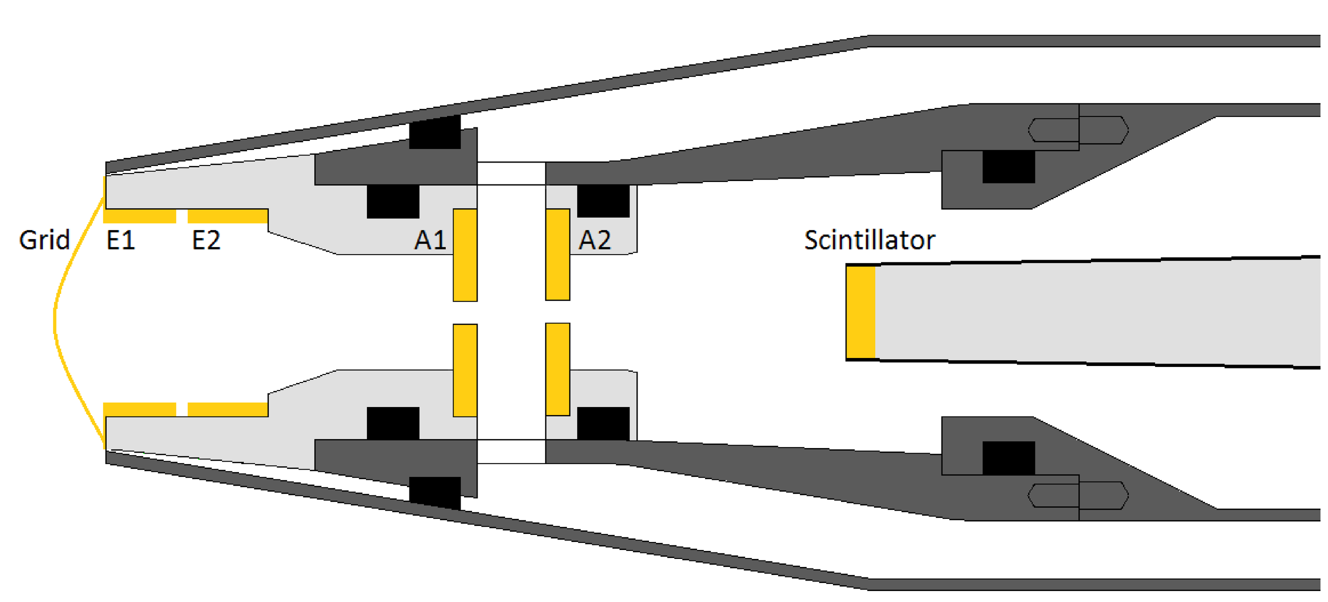

FIG. 1: Schematic drawing of scintillation secondary electron detector for ESEM and SEM.

with scintillator. Due to the system of differential pumping the pressure of 5 Pa at the most can be maintained in the scintillator chamber at the pressure of water vapor up to 1000 Pa in the specimen chamber. At the pressure up to 5 Pa in the scintillator chamber the voltage of 10 kV can be connected to the thin conductive layer on the scintillator avoiding the problem with electric discharge. Voltages connected to the grid of the detector, to electrodes E1 and E2 and to the electrostatic lens created from apertures A1 and A2 produce an electric field of the detector that allows passing of some secondary electrons emitted from the specimen to the scintillation chamber where they are accelerated towards the scintillator. The last version of this detector presented in [5] can detect secondary electrons at the pressure of water vapor from tens to 800 Pa. Usage of this detector at pressures under tens Pa is limited because of problems with the beginning of massive electric charging of holders of the grid, electrodes and apertures prepared from insulating plastic material.

The new detector for ESEM and SEM was designed with smaller insulating holders of all metallic components of the detector connected to different voltages and also the use of insulating materials in the vicinity of the scintillator was restricted. Moreover the formerly used YAG: Ce^{3+} scintillator was replaced in the new detector with the LuminiX (LXSR) scintillator.

Detection of secondary electrons by this detector was verified by observation of the voltage contrast, on emitter – base junction of a power NPN transistor, see Fig. 2.

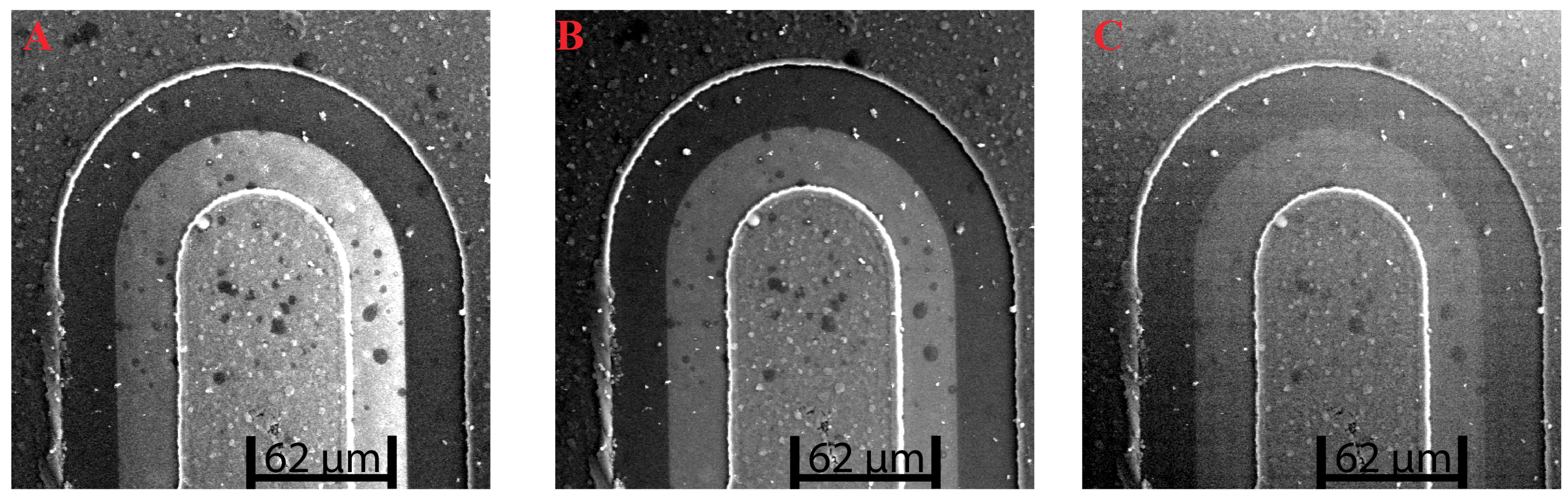

FIG. 2: Voltage contrast on PN junction of power NPN transistor. Reversed emitter - base voltage of 10 V. Pressure of water vapor: A - 0,01 Pa, B - 200 Pa, C - 500 Pa.

Possibility of the usage of the detector in the pressure range from 0.01 Pa to 900 Pa of water vapor is apparent from Fig. 3. Sample, fungus on carrot, was cooled by the Peltier stage to the temperature of 5 °C, pressure decreased during the observation.

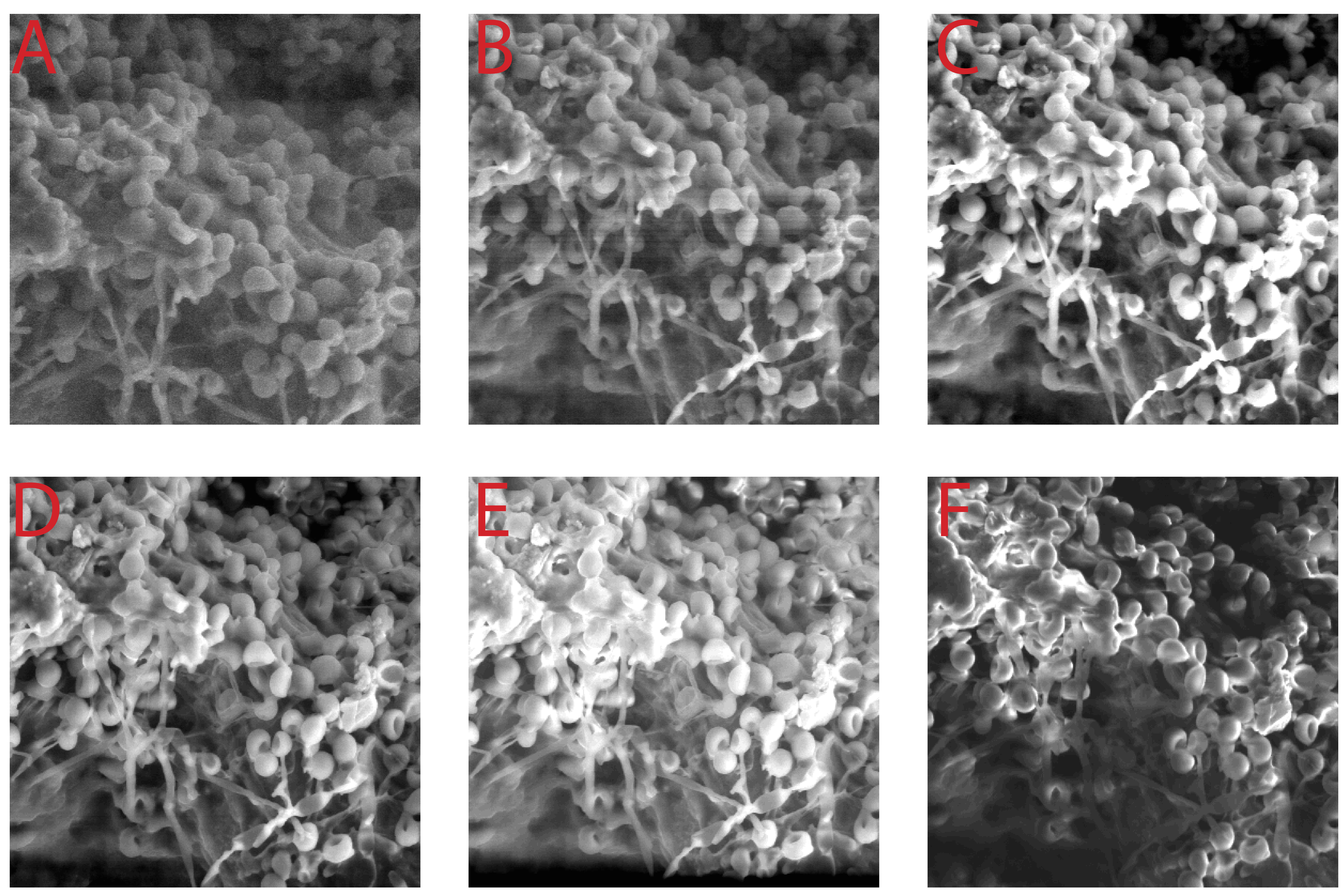

FIG. 3: Fungus on carrot. Sample temperature: 5 °C. Constant primary beam current 200 pA measured at 0.01 Pa in specimen chamber. HV = 20 kV. Field of view: 150 µm.
Pressure of water vapor: A - 900 Pa, B - 700 Pa, C - 500 Pa, D - 400 Pa, E - 200 Pa, F - 0.01 Pa.

Conclusion

The new scintillation detector for ESEM and SEM is exceptional due to its ability to detect secondary electrons from the pressure of 0.01 Pa in the specimen chamber (SEM conditions) to the pressure of 1000 Pa of water vapor (ESEM conditions). This ability offers new possibilities to observe specimens at different conditions by one detector of secondary electrons. Further expected improvements will be connected to changes of the vacuum pumping system of the detector based on computation results.

References

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