Scintillator secondary electron detector for Variable Pressure and Environmental SEM

W. Slówko, M. Krysztof

Faculty of Microsystem Electronics and Photonics , Wroclaw University of Technology, ul. Janiszewskiego 11/17, 50-372 Wroclaw, Poland

witold.slowko@pwr.wroc.pl
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Classic Scanning Electron Microscopy (SEM) is a vacuum technique while many kinds of specimens have to be investigated in gaseous atmosphere. This is possible in Variable Pressure or Environmental SEM (VP/E SEM) in which the sample chamber operates at elevated pressure with the electron optical column maintained at high vacuum. The two regions are separated by the intermediate pressure chamber with two pinhole throttling apertures preventing intensive gas flow. A problem inherent in the VP/E SEM technique, is the detection of the secondary electron (SE) signal. As a rule, this is done in the sample chamber, and consists in collecting secondary electrons multiplied by ionising collisions with gas molecules [1] or alternatively detecting photons produced by atoms excited in the collisions [2]. However, signals received by both detectors depend strongly on the type and pressure of gas filling the sample chamber.

The authors arranged a scintillator detector inside the intermediate chamber (Fig. 1a) where the pressure level is low enough to apply voltages of a few kV [3]. Three electrodes of the detector system, i.e. a throttling aperture (1), an anode (2) covered with scintillator (2a) and a screening tube (3) create a miniature electrostatic unipotential electron lens, placed inside a light pipe (4, 4a, 4b) leading to a photo-multiplier. Aberration coefficients of the lens are very small (Fig. 1b). The anode bias causes strong electric field penetrating through the throttling aperture to extract secondary electrons generated from the sample. When the pressure in the sample chamber is high enough the anode field supplemented with that generated by the throttling aperture bias, causes an ionising avalanche multiplying the electron signal emitted from the sample. Secondary electrons focused on the throttling aperture, flow into the intermediate chamber where are captured by the anode electric field to gain a high kinetic energy converted into light signal on the scintillator layer. Light is transported to the photomultiplier to be converted back into electric signal and amplified.

Usually, a pressure in the intermediate chamber is low (about 0.1 mbar or less), so in this region the gas amplification is negligibly small and the detector works similarly to the classic E-T scintillator detector. There is also a possibility to work at higher pressures in the intermediate chamber, approaching 1 mbar. In this case, the electron signal can be multiplied in ionising processes and relaxations of excited particles may be a source of the light signal.

General principles and properties of the detector are like the standard Everhart-Thornley detector. Basically, it does not need gas ionisation, which makes the detector system fast and universal with regard to the vacuum range (Fig. 2), i.e. from high vacuum to pressures exceeding 10 mbar. The detector head height limiting the working distance WD may be less than 10 mm, while the distance to the sample traversed by the primary electron beam at elevated gas pressure (WDG) may be shorter than 1 mm. This allows a low accelerating voltage without scattering the electron beam, which improves the contrast of light element samples, especially biological ones.

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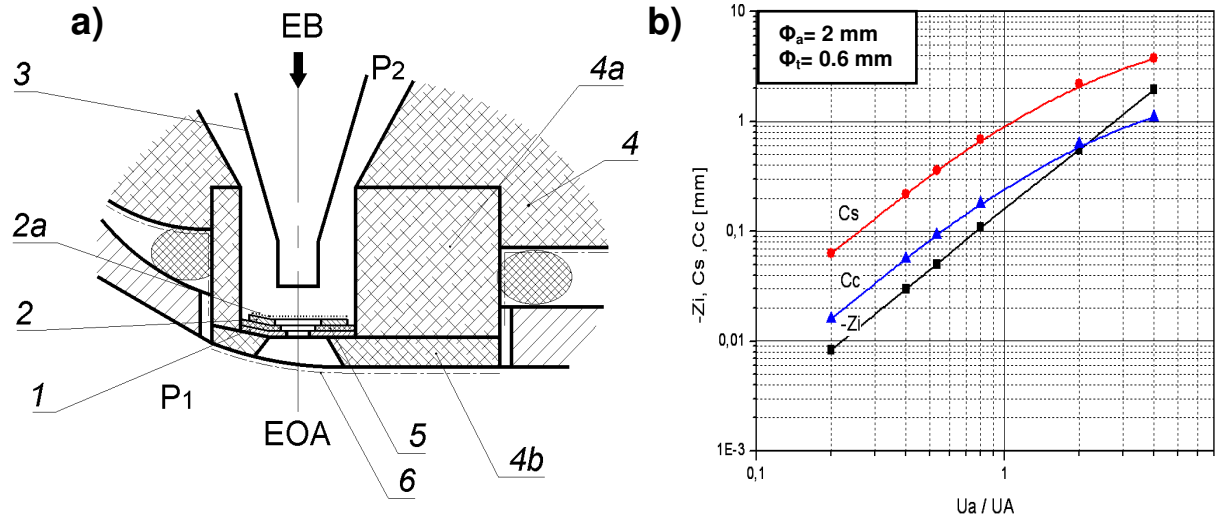

Figure 1. Detector system: a) scheme (1 – throttling aperture; 2 – anode; 2a – scintillator; 3 – screening tube; 4, 4a, 4b – light pipe elements; 5 – insulating separator; 6 – screening layer; EB – electron beam; P_1, P_2 – pressures in the sample and intermediate chamber), b) coefficients of spherical C_s and chromatic C_c aberrations and the objective lens focus position Z_i, vs. the anode voltage U_a to the accelerating voltage U_A ratio.

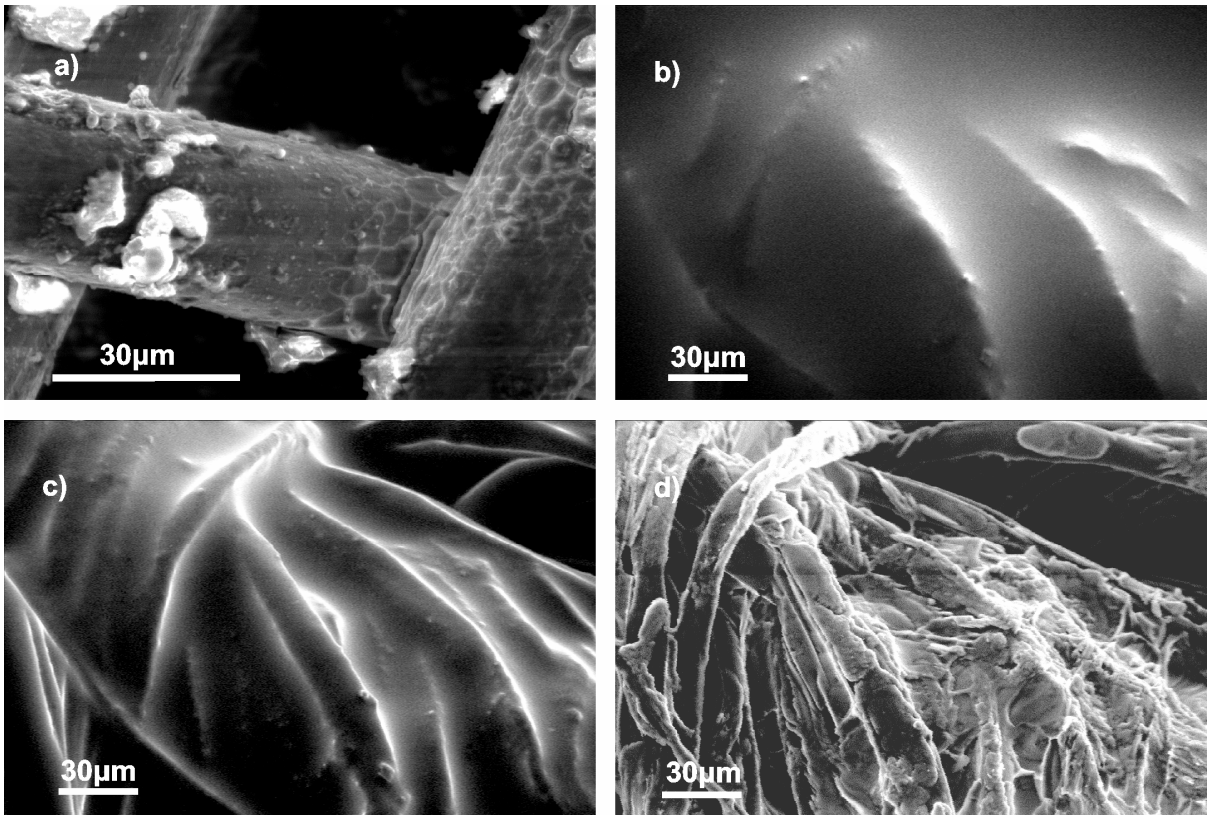

Figure 2. Images obtained with use of the detector (U_A = 20kV, water vapour, WDG = 1.2 mm): a) bronze bars of a grid (P_1 = 0.6 mbar, 20°C); b, c, d) three phases of water evaporation from a NaCl solution covering a cloth (P_1 = 4.6 mbar, ~0°C).

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