INFLUENCE OF SIZE OF IONIZATION ELECTRODE SYSTEM IN ENVIRONMENTAL CONDITIONS

Luděk SCHNEIDER, Doctoral Degree Programme (3)
Dept. of Electrical and Electronic Technology, FEEC, BUT
E-mail: schneide@feec.vutbr.cz

Supervised by: Dr. Josef Jirák

ABSTRACT

The Environmental Scanning Electron Microscope (ESEM) is a form of Scanning Electron Microscope (SEM), which supports a gaseous atmosphere and the presence of liquid water in the specimen chamber. This opens up new possibilities for the use of ESEM to the study of many biological and wet based systems, which previously could not be observed.

609 Pa is the minimum pressure, at which we can observe wet samples without any degradation by evaporation. Nowadays scanning electrons microscopes are called environmental if they operate with pressure from 300 to 2000 Pa.

1 INTRODUCTION

Ionization detector is a device, which uses the atmosphere in the specimen chamber for the detection and amplification of the signal electrons.

The theoretical principles of gas ionization were described in detail in [5]. The total amplified ion current, can be found by summing all cascade contributions. These contributions are given by primary electrons, secondary electrons and backscattered electrons, Fig. 1. Coefficient k is:

$$k = \frac{\exp(\alpha d) - 1}{\alpha \{1 - \gamma [\exp(\alpha d) - 1]\}} \tag{1}$$

where α is Towsend first ionization coefficient and γ is Towsend second ionization coefficient.

With knowledge of ionization properties of a given gas, we can calculate the amplification of electrons in the gas as a function of pressure, working distance and electron beam energy.

Detection volumes allocated with concentric annular electrodes of the ionization detector are shown on Fig. 2. The electrode with the smallest radius collects mainly secondary electrons, larger ones collect growing contribution of backscattered electrons.

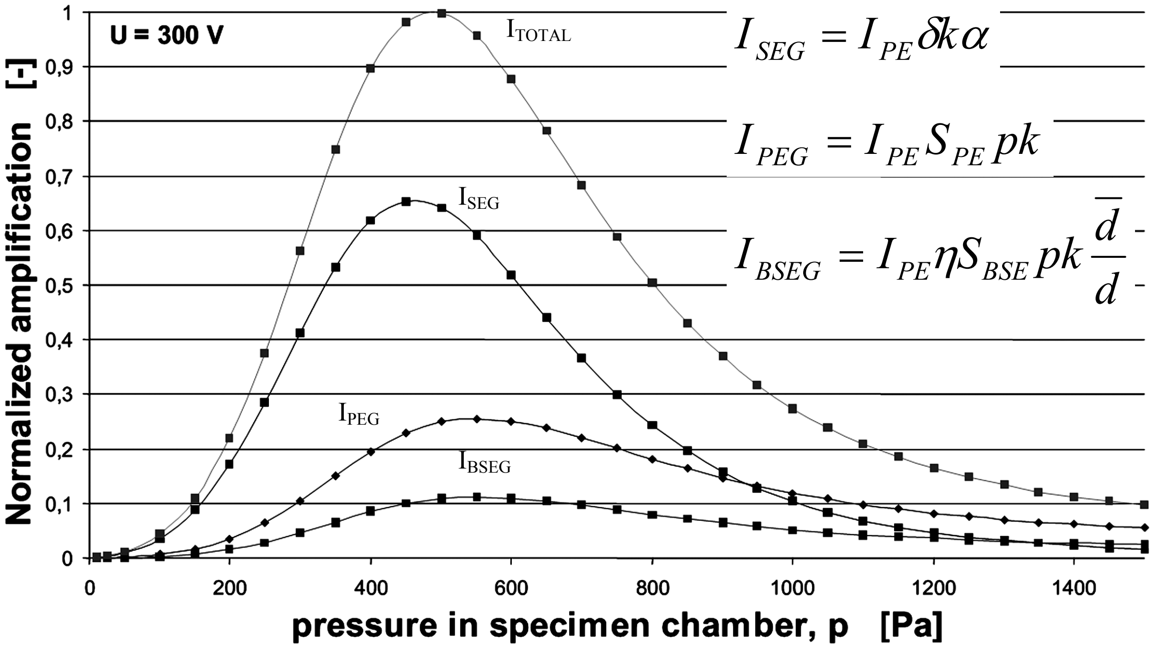

Fig. 1: *The calculated contributions of SEs, BSEs and PEs to the total signal amplification. Specimen Au, E_P = 20 keV. Where I_{PE} is primary beam current; p is pressure; d is working distance, $\bar{d}$ BSE path length; δ and η are SE and BSE coefficients.*

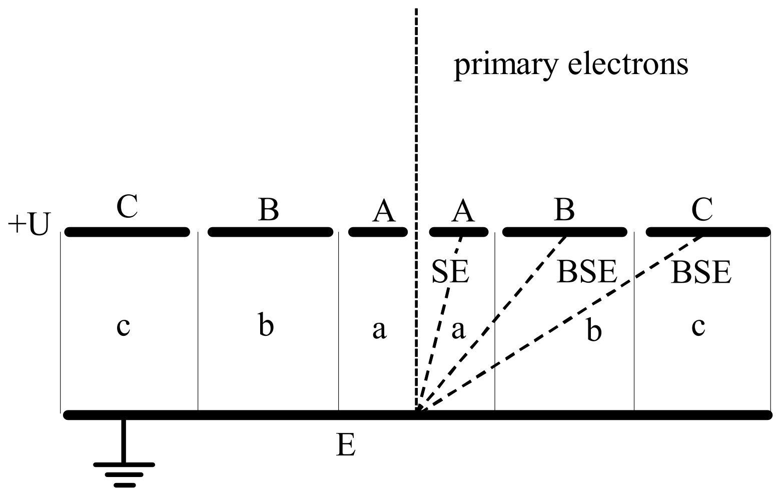

Fig. 2: *Separation of detection volumes by concentric annular electrodes with uniform electric field. In volume (a) SEs are mainly detected, in volumes (b) and (c) various types of BSEs are detected [1].*

2 EXPERIMENT

We prepared three different annular electrode systems of ionization detector to research how the size of the electrode affects detecting signal and its dependence on the pressure in the specimen chamber. The inner electrode radius was for all electrodes the same (1.1 mm). The outer radius changed and was 3.3, 7 and 14 mm, Fig. 2.

For these three electrodes we measured the dependence of the signal obtained from the surface of the gold and carbon on the working pressure of air in interval from 100 to 1000 Pa. The primary beam current was the same for all experiments, 140 pA, measured at the pressure 20 Pa in the specimen chamber. The dependence was intended for electrode voltages 300 V and for working distance between specimen and detector 1, 2, 3, 4 and 5 mm.

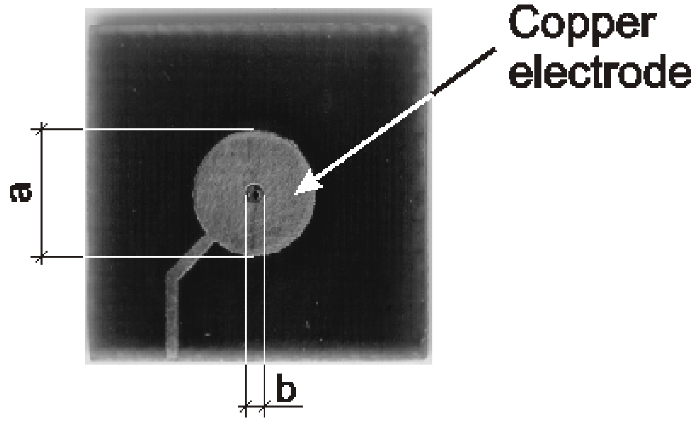

Fig. 3: *Experimental electrode prepared by PCB technology. Inner radius (b) 1.1 mm, external radius (a) 3.3, 7 and 14 mm.*

3 MEASURED VALUES

a) The measured dependences of the relative signal level from the surface of the gold on pressure for all three electrodes are pictured on Fig. 4.

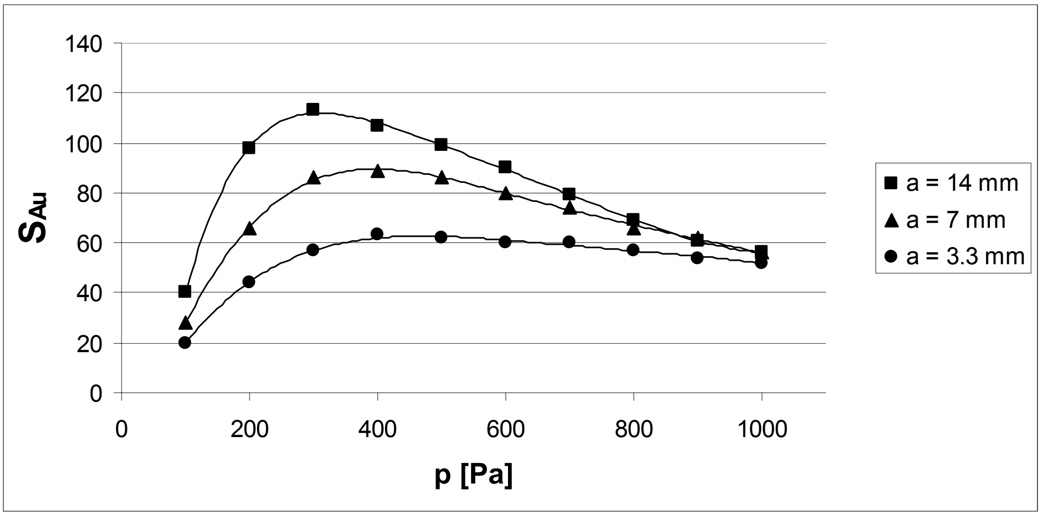

Fig. 4: *Dependences of the relative signal level from the surface of gold on working pressure for electrodes with outer diameter 14, 7, 3.3 mm. Working distance 4 mm, electrode voltage 300 V, primary beam current 140 pA.*

b) Similar dependences of material contrast are shown on Fig. 5. Material contrast, in our case, is taken as the difference of relative signal from the surface of gold and carbon.

c) Both dependencies are plotted for the working distance 4 mm. The signal level was the highest for this working distance for all three electrodes.

d) Micrographs of the Au, Cu, Al specimen obtained with the biggest electrode of the ionization detector at different pressures are pictured on Fig. 6.

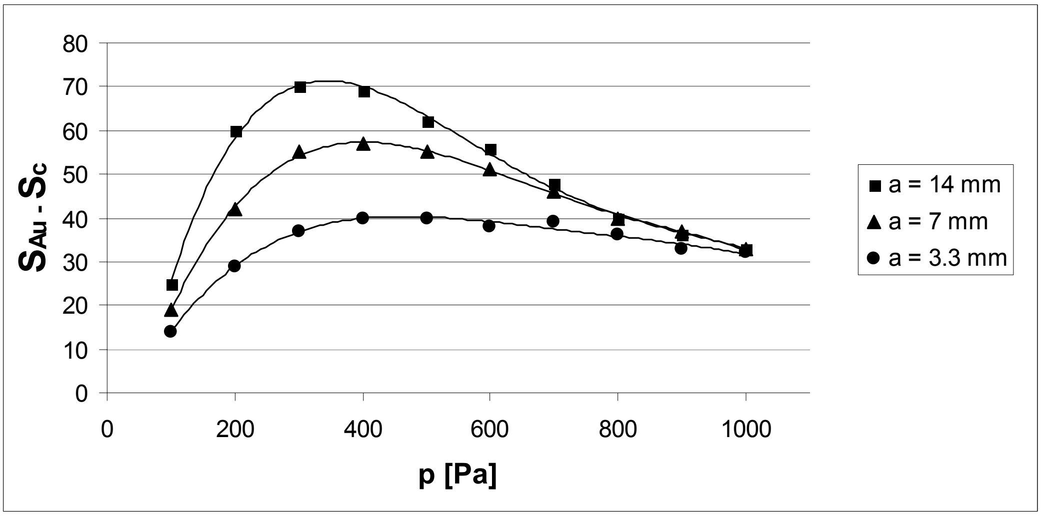

Fig. 5: *Dependences of material contrast on pressure for electrodes with outer diameter 14, 7, 3.3 mm. Working distance 4 mm and voltage 300 V. primary beam current 140 pA.*

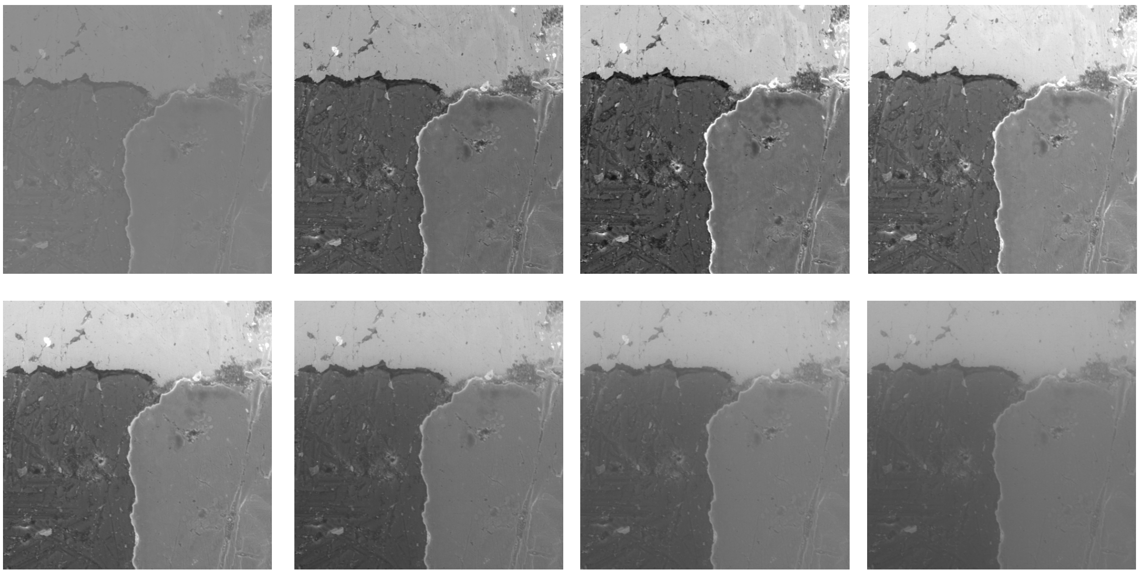

Fig. 6: *Micrographs of the Au, Cu, Al specimen obtained with the biggest electrode of the ionization detector at different pressures (50, 100, 200, 300, 400, 500, 600, 700 Pa).*

4 CONCLUSION

We proved at our experiments that the relative signal level from the surface of gold and the material contrast are the highest at the usage of the largest annular electrode. This electrode collects SEs and almost all BSEs, so they increase cascade contribution of BSEs in the process of impact ionization. The best conditions for observation the sample by this electrode are working distance 4 mm and air pressure 300 – 400 Pa in the specimen chamber.

It is evident that maximum of amplification of the signal and contrast with increasing radius of the electrode is moved to smaller values of pressure. Both it was caused by growing contribution of backscattered electrons with increasing dimension of the electrode on total detected signal.

ACKNOWLEDGEMENT

This research has been supported by FRVŠ under the contract FRVS 2173/2003.

REFERENCES

[1] DANILATOS, G. D.: Foundations of Environmental Scanning Electron Microscope. Sydney, Academic Press, 1988, 122 p.

[2] DANILATOS, G. D.: Theory of Gaseous Detector Device in the Environmental Scanning Microscope. Sydney, Academic Press, 1990, 103 p.

[3] MEREDITH, P., DONALD, A. M., THIEL, B.: Electron-Gas Interactions in the Environmental Scanning Electron Microscopes Gaseous Detector. Scanning 18, 1996, p. 467-473.

[4] HIPPEL von, A. R.: Molekulova fyzika hmoty. Praha, SNTL, 1963, 674 p.

[5] ENGEL von, A.: Ionised Gases. Oxford, Clarendon Press, 1995, 220 p.