DETECTION OF BACKSCATTERED ELECTRONS IN LOW VOLTAGE SCANNING ELECTRON MICROSCOPE

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ABSTRACT

This paper deals with detection of backscattered electrons (BSE) in scanning electron microscope when the accelerating voltage is 5 kV and less. New detection system for low-energy backscattered electrons detection is shown. The system consists of fast and efficiency YAP scintillator, special light guide, retarding grid and photo multiplier. The high voltage about 5 kV is brought on the scintillator, which is covered with conductive layer. The retarding grid with voltage about –100 V is used to separate low-energy backscattered electrons from secondary electrons (SE).

1 INTRODUCTION

The scintillation detector on the basis of YAP (yttrium aluminium perovskite) and YAG (yttrium aluminium garnet) single crystal scintillators seems optimal for backscattered electrons detection [1]. While YAG single crystal scintillators are installed in the detection systems of all world producers of scanning electron microscopes (SEM), YAP single crystal scintillator has not been used for the detection of signal electrons commercially until nowadays. Relatively short wavelength of maximum light emission at 370 nm was a very serious limitation for commercial using of YAP because the light transmission of 370 nm wavelength is very low in light guide made from organic glass [2]. A special light guide material, which transmits light of 370 nm wavelength must be used (Figure 1). The quartz glass is a suitable material, but its brushing and polishing is expensive. Organic glass containing special organic dopants for light transmission increasing in a short wavelength region of the spectra is available now [3]. The light guide rod 150mm in length and 20 mm in diameter made from that material transmits up to 95% of YAP emitted light. On the other side, the light transmission wavelength of 370 nm is suitable for all types of usually produced photocathodes.

The very high self absorption of the YAP emitted light is the further problem. This problem was solved owing to the additional treatment of the YAP single crystal discs in oxygen and hydrogen atmosphere at very high temperature, impurities and colour centres in the crystal lattice have been suppressed. Self absorption of generated light was decreased by one half, o approximately 10%. The YAP surface is contaminated after the polishing process.

Micro particles of the polishing material are embedded into the micro cracks in the depth of some micron units. These impurities can be removed by a washing process only, in a special mixture of acids at a suitable temperature. The smoothness of the YAP surface is decreased by this treatment, but the relative efficiency of the electron – photon transfer is increased.

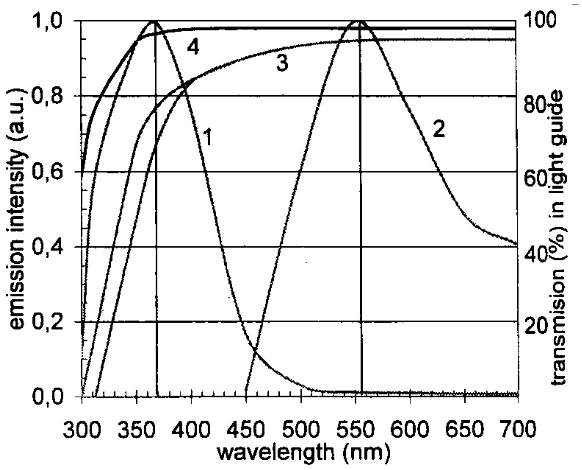

Fig. 1: *Emission spectra of single crystal scintillators and transmission spectra of light guides. 1. YAP emission, 2. YAG emission, 3. organic glass standard transmission, 4. organic glass modified transmission [3].*

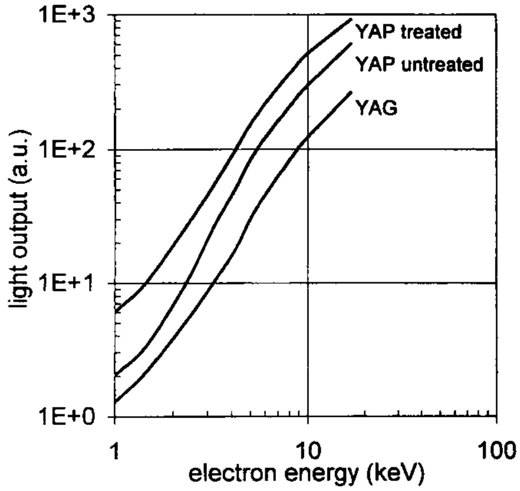

Fig. 2: *Relative efficiency of single crystals versus energy of incident electrons [3].*

The main part of the detector is YAP single crystal scintillator, which is covered with conductive layer and high voltage around 5 kV could be brought on the scintillator. The problem with filtration of accelerated SE from low energy BSE is solved owing to the retarding grid with negative voltage around 100 V. Secondary electrons are deflected from the scintillator through this electrostatic field. The elemental construction scheme of the detector is demonstrated in Figure 3.

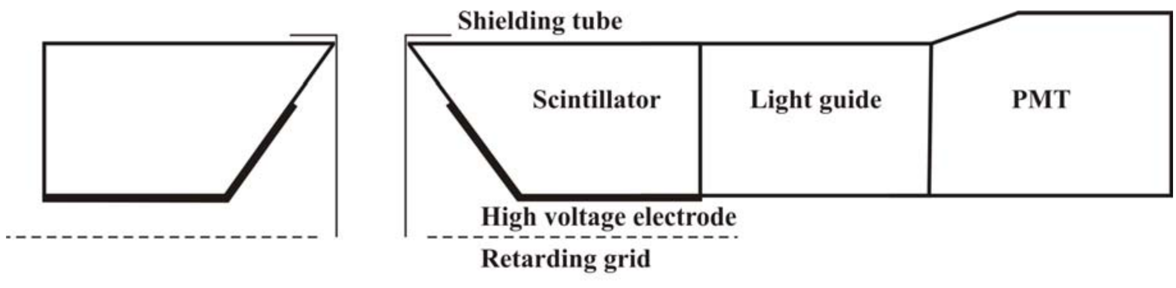

Fig. 3: *Elemental construction scheme of BSE detector in low voltage SEM.*

2 SIMULATION OF BSE AND SE TRAJECTORIES IN THE ELECTROSTATIC FIELD OF THE DETECTOR

Electrostatic field of the detector is created with the positive high voltage up to 7 kV on the electrode of the scintillator and with the negative voltage about 100 V on the retarding grid. This field affects signal electrons according to their energies. SE and low energy BSE trajectories were simulated in SIMION 3D software.

The high voltage on the electrode of the scintillator accelerates secondary electrons and low energy backscattered electron to the scintillator. Figure 4, 5 represents signal electrons trajectories, on the high voltage electrode is potential of 3 kV, on the retarding grid is potential of –100 V and the working distance is 5mm.

If we bring on the retarding grid negative potential of –80 V, a part of secondary electrons will be diverted from the scintillator. Low energy BSE are not influenced of this potential and reach the scintillator. This situation is pictured on Figure 6, 7.

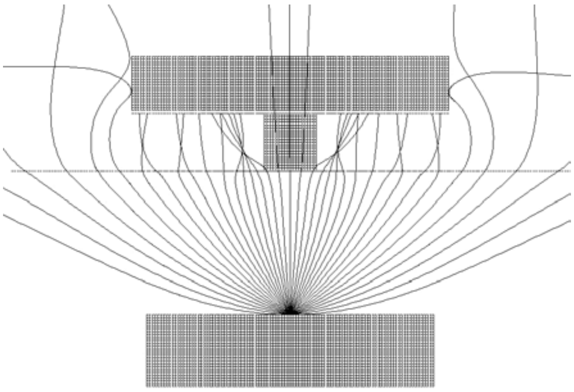

Fig. 4: *Trajectories of secondary electrons with energy of 50 eV, potential on high voltage electrode is 3 kV, working distance is 5 mm.*

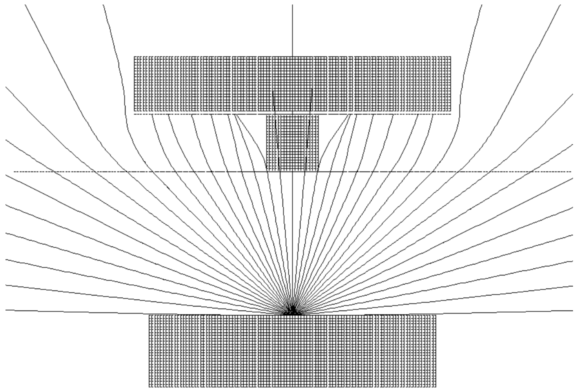

Fig. 5: *Trajectories of backscattered electrons with energy of 1 keV, potential on high voltage electrode is 3 kV, working distance is 5 mm.*

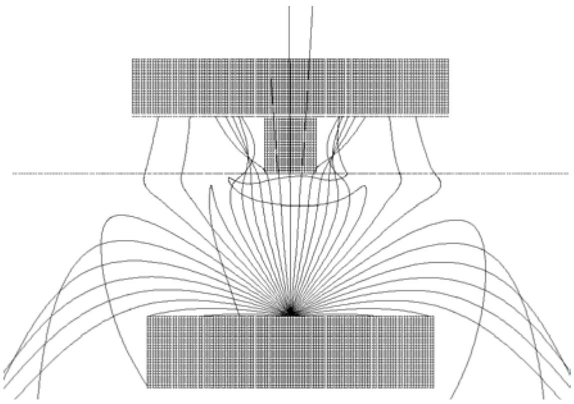

Fig. 6: *Trajectories of SE with energy of 50 eV, potential on high voltage electrode is 3 kV, potential on retarding grid is –80 V, working distance is 5 mm.*

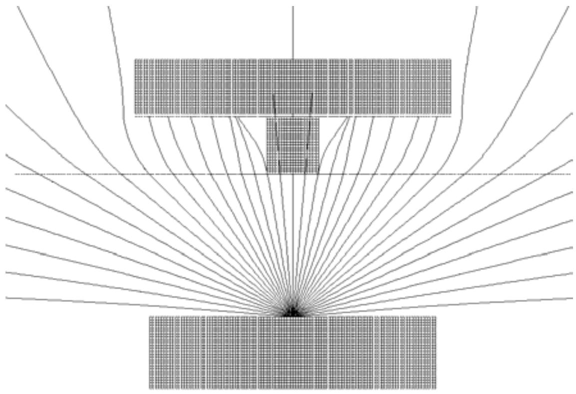

Fig. 7: *Trajectories of BSE with energy of 1 keV, potential on high voltage electrode is 3 kV, potential on retarding grid is –80 V, working distance is 5 mm.*

Potential of –100 V on the retarding grid deviates almost all secondary electron from the scintillator. Only the secondary electrons, which passed through approximately half millimetres wide hole between the retarding grid and the shielding tube, can reach the scintillator (Figure 8, 9).

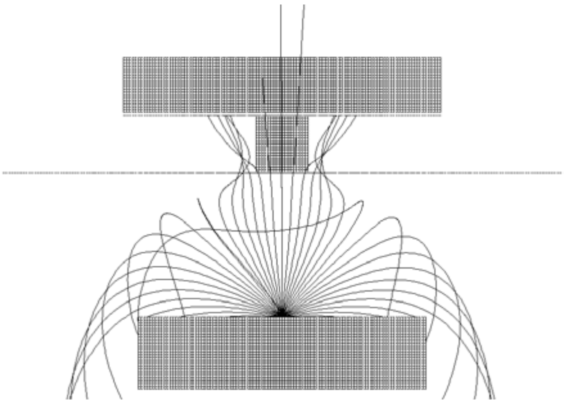

Fig. 8: *Trajectories of SE with energy of 50 eV, potential on high voltage electrode is 3 kV, potential on retarding grid is –100 V.*

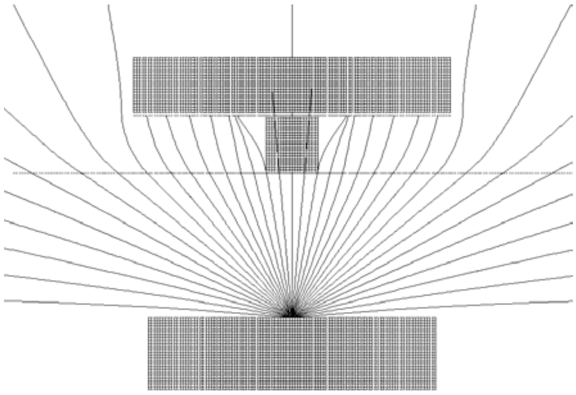

Fig. 9: *Trajectories of BSE with energy of 1 keV, potential on high voltage electrode is 3 kV, potential on retarding grid is –100 V.*

3 CONCLUSION

The YAP single crystal scintillator can be after additional treatment and with suitable light guide a very efficient detection system for scanning electron microscopes. Detection efficiency will be better than in YAG scintillation detector that is very popular in this time.

The main problem of detection of low energy backscattered electrons is separation of signal of low energy BSE from signal of secondary electrons. This problem was solved using the retarding grid with negative potential. This fact is confirmed by calculation of SE and low energy BSE trajectories with the SIMION 3D software.

ACKNOWLEDGEMENTS

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