Computer optimized design of BSE scintillation detector for SEM

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The design of an efficient backscattered electron (BSE) scintillation detector for a scanning electron microscope (SEM) depends to a great extent on the size and the arrangement of pole pieces and the specimen holder of the SEM. Therefore, for different microscopes, different scintillator - light-guide detection systems must be constructed. However, the efficiency of these edge guided signal (EGS) scintillation detectors is very strongly shape dependent (1). Even apparently insignificant changes in the light-guide geometry can degrade the efficiency of the EGS detection system to one tenth of its optimal value. Furthermore, owing to the low symmetry of EGS detection systems, the efficiency is very hard to estimate or calculate analytically. The best way of avoiding inefficient EGS detection systems is Monte Carlo (MC) simulation optimisation method for the photon transport through the scintillator and light-guide.

The computer optimized design (COD) method intended for nearly any scintillation detection system for SEM is presented. It has been expanded from the previous MC model (2) intended for rotationally symmetric Everhart-Thornley (ET) detectors (program SCIUNI v. 1.0). Version 2.0 of the SCIUNI has been extended using a new algorithm for the interaction of a photon with scintillator and light-guide surfaces. Thus simulated detector systems may comprise almost all actual surfaces (1). In addition, the presented 3.0 version of SCIUNI program involves new loops for the light-guide shape optimisation. The source code of the program has been written in Fortran 77 and compiled on different computer platforms. At present, versions for the MS-DOS, UNIX, and RTE-A (Hewlett Packard) operating systems are available. The results presented in this paper have been obtained by computing on Iris Indigo (Silicon Graphics) work station under IRIX operating system.

The designing of a new BSE scintillation detector for the S 4000 Hitachi SEM was chosen to demonstrate the capability of the introduced COD method. The starting (non-optimized) detector design was given by the fixed shape and material of the scintillator, and by the fixed material, length and the output diameter of the light-guide (Fig. 1(a) and 2(a), respectively). A YAG:Ce single crystal disc scintillator (N15 x 2.5 mm) with a conical hole (N1.5/0.7 mm) and with an indium tin oxide (ITO) coating on the impact surface was available for the EGS detector. The light-guide material was polymethyl methacrylate. The 150 mm long detection system was given by the distance of electron optical axes from the photomultiplier tube (PMT). The output of the light-guide of 20 mm in diameter was given by the limited space in the specimen chamber and by the size of the PMT window. The initial light-guide geometry was given by the size and by the shape of pole pieces and of the specimen holder (Hitachi S 4000), respectively. During optimization, only the steps which bring a considerable increase in efficiency were recorded. Geometries and light-guiding efficiencies corresponding to these steps (from the worse (a) to the best (e)) are shown in Figures 1 or 2 and in Table 1, respectively. The simulated mean efficiency of the photon transport through the basic (a) configuration was about 0.04, as obvious from Table 1. It is better than that for the classical ET detector with a disc scintillator (1, 2), and no significant improvement was expected during the detector optimization. But it has been found, that even a small shift of the bottom widening plane to the same coordinate as that for the top plane (Figures 1(b) and 2(b)), increases the efficiency to 126 %. However, a much greater improvement (to 256 %) has been achieved with geometry (c), after shifting the widening planes

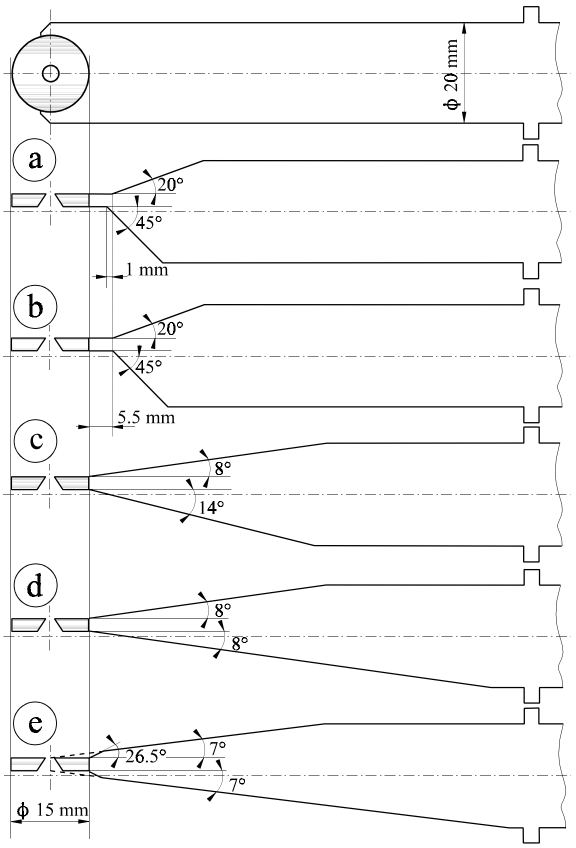

Figure 1. Schematic drawing of the geometry of key configurations during optimization of BSE scintillation detector S 4000 (Hitachi).

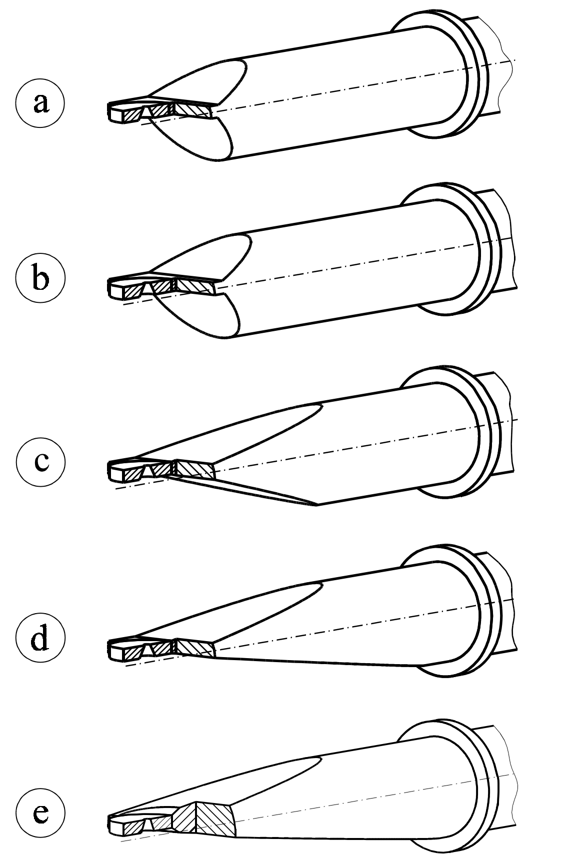

Figure 2. 3-D images of the S 4000 BSE scintillation detection systems. Efficiency is improving from the basic (a) geometry to the final (e) geometry.

as close as the scintillator disc, and after decreasing the angles of the top and the bottom planes to 8° and 14°, respectively. A further improvement (to 356 %, geometry (d)) has been achieved after configuring the bottom plane so that its slope becomes identical with that of the top plane. The final refinement (geometry (e)) has been acomplished by integrating a conical light-guiding ring (close to the scintillator) into the widening planes of the light-guide. The slopes of the planes were only slightly reduced with regard to geometry (d). The final light-guiding efficiency is about 400 % compared with the starting one.

Table 1. Light-guiding efficiency of the S 4000 BSE scintillation detector in the dependence on different light-guide geometries.

LG Geometry[1]	Light-Guiding Efficiency		
	mean[2]	total improve-ment[3]	rel. improve-ment[4]
(a)	0.043	1.00x	-----
(b)	0.054	1.26x	1.26x
(c)	0.110	2.56x	2.04x
(d)	0.153	3.56x	1.39x
(e)	0.176	4.09x	1.15x

[1]See Fig. 1 and 2. [2]Over the electron impact surface.
[3]Related to the starting geometry.
[4]Related to the previous geometry.

REFERENCES

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