

Wireless Preamplifier for the Specimen Current Mode Detector in a SEM

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Abstract

Using a scanning electron microscope (SEM) in the back-scattered electron (BSE) mode the composition of multi-element specimens may be determined based on the strong dependence of emission coefficient η on the average atomic number of elements Z . The output video signal of the usual BSE detectors is produced from their sensors, and the larger proportion of high-energy electrons with modified spectrum is added. Since $\eta = i_s/i_p$ (i_s and i_p currents of specimen and probe), better accuracy must be achieved by direct measurements those currents on the specimen surface. Here, an experimental model of a current detector for a presented specimen is described. The cage is mounted on the carousel of the moving specimen stage. The input of the preamplifier is connected to the specimen holder in the form of a disk, the diameter of which is 12 mm. When the probe along its surface scanned, the input potential begins to pulsate with a negative polarity. The output of this preamplifier is connected to a small light-emitting diode, which creates intensity-modulated radiation in the chamber. Thus created the light video signal will be picked up by the photomultiplier of the E-T detector. The modes of true SE and BSE are set by applying tens bias volts of various polarities to the specimens or the cage itself.

Keywords

Scanning Electron Microscopy, Backscattered Electron Imaging, Wireless Specimen Current Preamplifier, Universal (SE/BSE) Dyukov Detector

1. Introduction

Reed in [1] outlined for non-specialists the possible applications of SEM in different analytical modes for reliable identification of the studied specimens. In this monograph determination of the compound composition using the Z -contrast of

BSE images was considered. The list of the common minerals with the corresponding values of average atomic numbers Z is given. In work [2], an empirical formula is proposed that approximates the dependence $\eta = f(Z)$. This formula use adjustable parameters, some of which reflect the SEM operating mode. A comparison of measurement results of the same specimens using EDX analysis and based on the Z -contrast imaging has confirmed that composition can be correctly determined with a fairly high reliability. In spite of the time-consuming manipulations when performing such analyzes and the need to use an increased arsenal of tools, the obtained results are impressive. At the same time, there is a tendency to try to simplify the approach to obtaining images in SEM with the correct Z -contrast without such complex equipment.

Specimen current imaging is considered in [3], where almost all information about the secondary emission as a phenomenon was presented. The charge balance existing when incident electron probe with current i_p impinge upon a conducting specimen surface can be expressed by the equation $i_p = i_{SE} + i_{BSE} + i_s$, where i_{SE} and i_{BSE} are the emitted secondary slow and fast electron currents respectively. Under usual SEM operating conditions i_s being small may be used to create directly a video signal forming the specimen current images which have reverse contrast to the their copies obtained in SE or BSE modes. With help of a probe current meter it's possible to estimate η of the observed specimen, image of which has atomic number contrast. The probe must be directed firstly on orifice which usually is on specimen stage and write the indicated i_p . After this, the small Au piece posed nearby may be choice as target. If the probe will be directed on it measured i_s became less two time. It means that in the given case selected the single-element pure metal with high $Z = 79$ Au with obtained value $\eta = 0.500$ is suitable to verify $\eta = f(Z)$ curve.

2. Features of the Typical Conventional BSE Detectors

In the review [4], the features of commercially available and designed in laboratories SEM detectors that realize specimen current SC and BSE modes of those years are considered. It is reasonable to remain, that in the conventional BSE detectors emitted from specimen fast electrons irradiates the surface of sensors in general having form of flat disks with holes in the center placed under objective lens. These disks can be made of Si with a shallow p-n junction or of a phosphor optically coupled to a photomultiplier, which convert irradiation incident onto their surface into induced current or light glow, respectively. The conversion efficiency is determined by underlying physical mechanisms. For indicated sensors the output signal increases with the incident electron energy, as it is presented on graph (see **Figure 1**).

In this review, the detectors with sensors are also considered based on the disk-shaped microchannel plates (MCP) having an aperture on the axis to pass an electron probe. In some cases in SEM in quality of SE and BSE detectors, instead of MCPs are used their highly efficient analogs called channel electron multipliers (CEM), or channeltrons. They have the form of a funnel-shaped curved tube. The

detectors on the basis of MCP or CEM for SEM in typical cases attain the conversion efficiency exceeds 10^3 , which allows obtain high-quality images at an extremely low probe current. More over these detectors have an extended frequency band which permit to operate with fast scanning and smoothed energy dependence without thresholds (see graph in **Figure 2**).

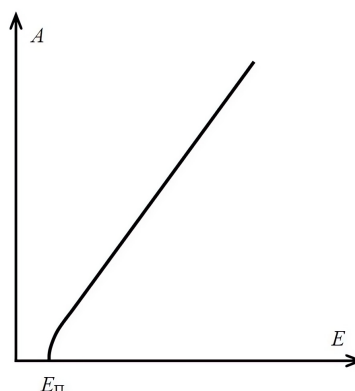


Figure 1. The generalized graph shows relative electron signal gain A as function of the incident electron energy E for typical Si and phosphorescent material similar to single-crystal yttrium aluminum garnet sensors. The last is commonly used in Autrata BSE detectors. E_{π} is the lower limit or threshold, which corresponds to a value of 2 - 3 keV.

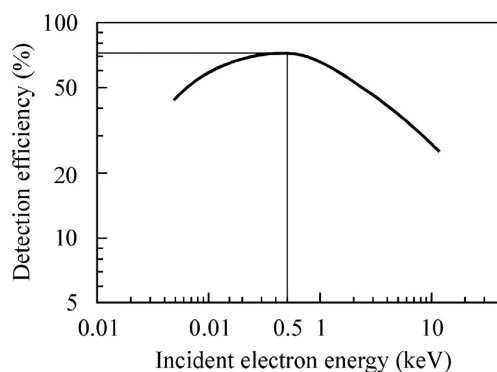


Figure 2. Typical dependence of the detection efficiency of the MCP and CEM on the energy of incident electrons.

In article [5], a transimpedance amplifier designed for scanning tunneling microscope was presented. The authors indicate that it may also find applications for specimen current imaging and electron-beam induced current measurements in scanning electron microscopy, and as a photodiode amplifier with a large dynamic range. To apply this amplifier to a wireless detector, it needs to add a cascade the output of which is connected to an LED. As it seems using in SEM reasonable probe current 10 - 50 pA it is possible made a band pass > 0.5 MHz.

3. Wireless Preamplifier Realized SC/BSE Modes and Its Testing

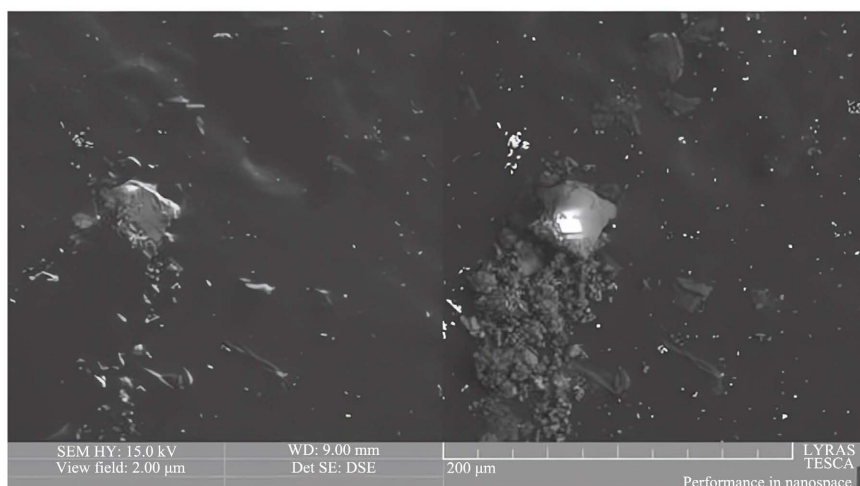
The considered experimental modification of wireless SC/BSE detector is autonomous

device that do not distort the distribution of electric or magnetic fields in the space where it is placed. Its purpose is to provide amplification of weak picoampere pulsating currents induced by charged particles incident on the specimen with subsequent conversion to synchronously pulsating light radiation within a band pass less than 1 megahertz. This prototype of an SC detector, which can be used both in the SE and the BSE modes, was successfully tested in the SEM model LYRA 3 (Tescan) with a conventional E-T detector, in which high voltage of 10 kV and the bias voltage on the grid were shut off with help of relevant software. On the top of the detector housing, which has the form of a hollow cylinder with a conical protrusion, there is an opening with a spring clip for installing the specimen holder. Under it there is a printed circuit board with integrated circuits of operational amplifiers. The output of the last amplifier is connected to a green light-emitting diode placed on the side wall. The holder with the installed specimen is connected to the negative polarity input of the ADA 4530 operational amplifier, which also is shunted by the resistor of 20 MOhm. In order to start using the SC detector, the amplifier must be connected to the power sources (batteries) located in the lower part of the housing. It is also necessary to ensure that the light-emitting diode glows with an intensity corresponding to the level of “zero signal” at the input. External views of the detector from the top (green LED is visible) and from the side of the mode switch selector show in **Figure 3(a)** and **Figure 3(b)**.

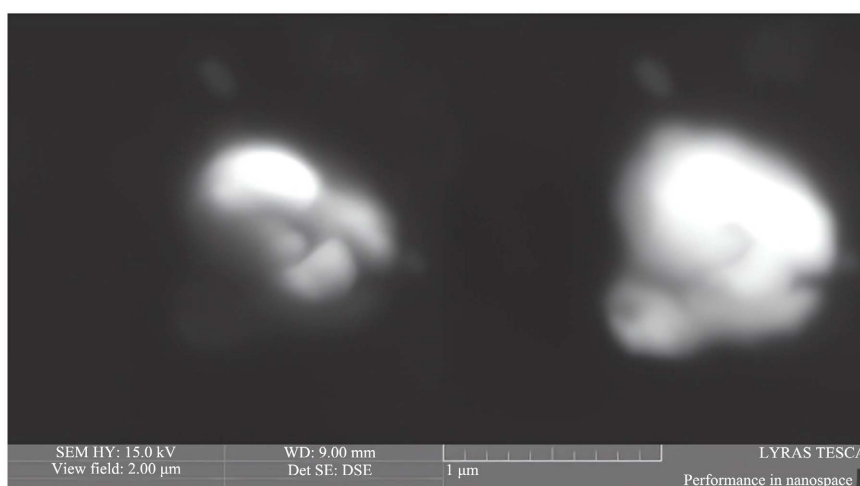


Figure 3. (a) and (b) External views of the detector from the top (green LED is visible) and from the side of the mode switch selector. In its initial position, shown in the photo, the input of the amplifier is grounded to the cage. It often happens that operators, as well as ordinary people, accidentally accumulate a charge that “goes” to foreign objects with a spark discharge. When the sample holder in the mushroom shape (a standard disc has a diameter of 12 mm) is inserted into the site hole, the input stage may be damaged. On the left side is the power on switch.

Micrographs of the same area of the carbon film surface with deposited particles of industrial dust, taken with 2 various BSE detectors at different magnifications in the same conditions with the formation of one common frame is presented on **Figure 4(a)** and **Figure 4(b)**.



(a)



(b)

Figure 4. (a) and (b) Micrographs of the same area of the carbon film surface with deposited particles of industrial dust, taken with 2 various BSE detectors at different magnifications in the same conditions with the formation of one common frame. The view field sizes of the upper (a) and lower (b) are 250 and 2 μm , respectively. The images on the left (with the indication SE) were obtained with the “new” detector.

SEM operating parameters used when above micrographs were obtaining. Voltage 10 kV for the scintillator of E-T detector was shut off with help of relevant software, and its grid was under “zero”. To implement the BSE mode, a bias +24 V was applied to the sample holder. Between him and the objective lens pole piece end the decelerating field for the slow electrons were created. The right images were obtained with a retractable detector type “scintillator-light guide-photomultiplier”. Accelerating voltage is 15 kV, “analytical” working distance-9 mm. As one can see the shape and visible size of a typical micron-sized single particle (located in the panoramic cadre center) differ. Its structure is reproduced in more details on the left picture. In a low-magnification image, the contrast of the particles has changed significantly.

4. Conclusion

These outlined results convincingly demonstrate the real ability of the proposed detector to form the correct Z -contrast. When creating a preamp using modern low-voltage components, its cage size will not exceed a matchbox. For non-modern SEM the addition of such non-expensive preamp to the specimen camera with an ET detector installed increases its analytical abilities.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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