A high resolution low noise secondary electron spectrometer for IC failure analysis

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This paper presents a high resolution secondary electron (SE) spectrometer for IC failure analysis inside the scanning electron microscopes (SEM). The SE spectrum has been widely used for many applications such as voltage contrast [1], monitoring specimen charging [2], and semiconductor dopant mapping [3]. Recent work on semiconductor dopant mapping [3] requires the monitoring of meV shifts in the SE spectrum. A recent second-order focusing toroidal spectrometer is predicted to have a high energy resolution [4] and has been used for quantitative material identification by monitoring the backscattered electron (BSE) spectrum. [5] The research work reported here naturally follows on from this previous work, utilizing the second-order focusing toroidal spectrometer as an attachment inside the SEM to monitor the SE spectrum.

Fig. 1 depicts the experimental setup of the spectrometer as an attachment inside the conventional SEM. The inner sector is grounded and the outer sector is biased with a negative potential -V that is ramped to capture the SE spectrum. The specimen is surrounded with two spherical caps that allow the specimen to be biased to a certain negative or positive potential. The spectrometer is designed to capture an angular spread of $\pm 8^o$ with respect to the central entrance angle of 45^o in the polar direction. The input angular spread in the azimuthal direction is 100^o. Fig. 1 also shows 16 simulated secondary electron trajectory paths traced from the specimen through the spectrometer on to a scintillator placed behind the output aperture. The field solution and trajectories were simulated by LORENTZ-2EM [6]. Fig. 2b shows the shot-noise of a selected part of the experimental SE spectrum of an Iron (Fe) specimen acquired by the above setup (shown in Fig. 2a). The experiment was carried out inside a Tungsten JEOL JSM-5600 SEM. It clearly shows that the shot-noise is relatively small, allowing for SE spectral shift measurements of 12 mV or below to be monitored, a factor of around 4 times better than the off-axis multi-channel analyzer proposed by Kienle and Plies. [7] Further results and details of the applications for IC failure analysis will be presented at the conference.

References

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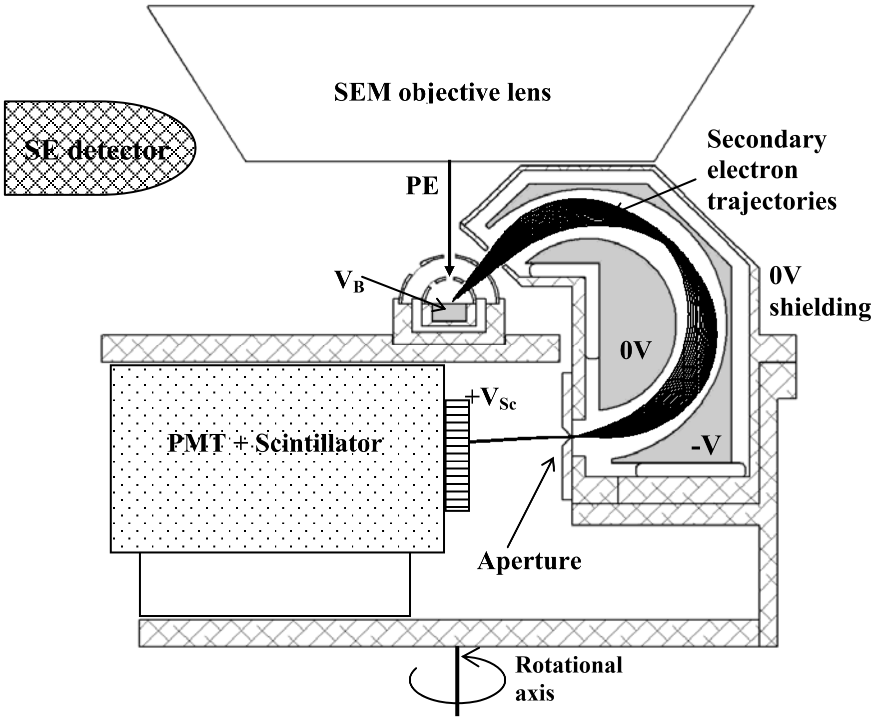

Fig. 1. Experimental layout of the high-resolution toroidal secondary electron spectrometer inside the SEM. 16 electron trajectory paths with an input angular spread of ± 8° around the central angle of 45° are simulated

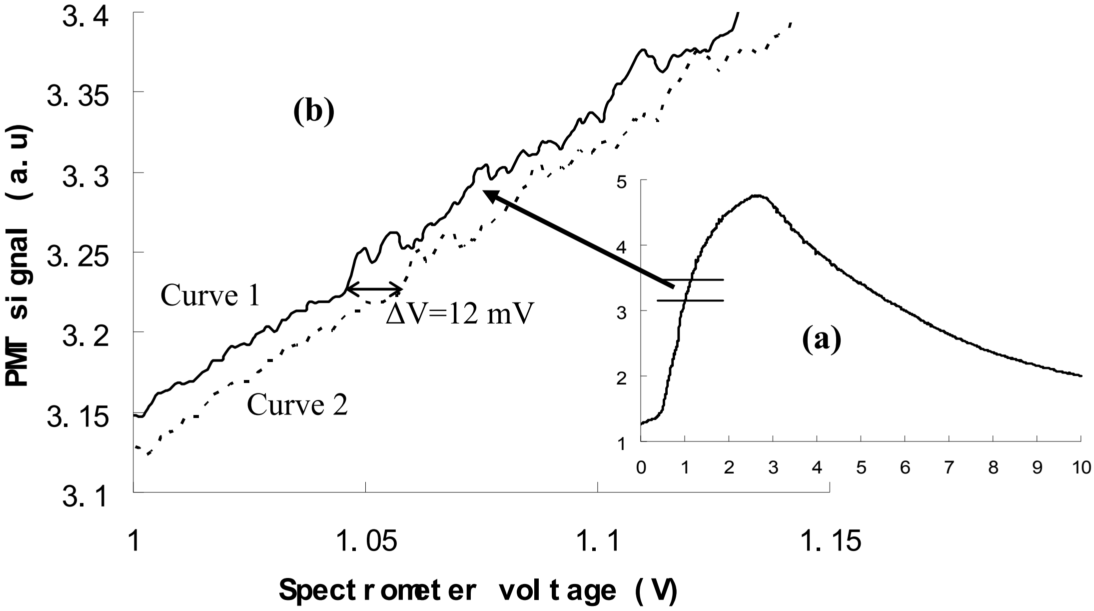

Fig. 2. Experimental SE spectrum of an Iron (Fe) specimen: (a) Full acquired SE spectrum; (b) Shot-noise of a selected part of the SE spectrum in which the curve 2 is shifted 12 mV with respect to the curve 1.