Imaging with surface sensitive backscattered electrons

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Modern integrated circuit failure analysis often makes use of the physical and chemical properties of surfaces and interfaces of semiconductors and thin films. Surface analysis is normally carried out in dedicated instruments, like auger electron spectroscopy (AES), reflection high-energy electron diffraction (RHEED), x-ray photoelectron spectroscopy (XPS), and transmission electron microscope (TEM)[1-3]. This paper presents a surface sensitive wide angle backscattered electron (BSE) imaging technique in a scanning electron microscope (SEM). Monte-carlo simulations[4] were used to calculate the BSE spectra and depth distributions of BSE scattering events at different emission angles, as shown in Fig 1. Simulation results predict that when the primary electron beam lands normal to the specimen, BSEs with large emission angles (with respect to the surface normal) experience 80 percent of their scattering events within 1 nm below the surface. Experimental SEM images indicate that when BSEs with emission angles between 89 to 90 degrees are used for imaging, much greater contrast of surface details is obtained, as shown in Fig 2. Less surface information is obtained as θ decreases. Surface sensitive images may be used to locate surface contamination, as the BSE yield changes with the average atomic number of the sample. This technique also has potential for BSE tomographical analysis and film thickness measurements.

1. R. F. Egerton, *Electron Energy-Loss Spectroscopy in the Electron Microscope, 2nd Edition* (Plenum Press, New York, 1996)
2. B. Strawbridge, R. K. Singh, C. Beach, S. Mahajan, and N. Newman, J. Vac. Sci. Technol. A **24 (5),** 1776 (2006)
3. C. J. Powell, J. Vac. Sci. Technol. A **21(5)**, S43 (2003)
4. D. C. Joy, *Monte Carlo Modeling for Electron Microscopy and Microanalysis* (Oxford University Press, New York, 1995)

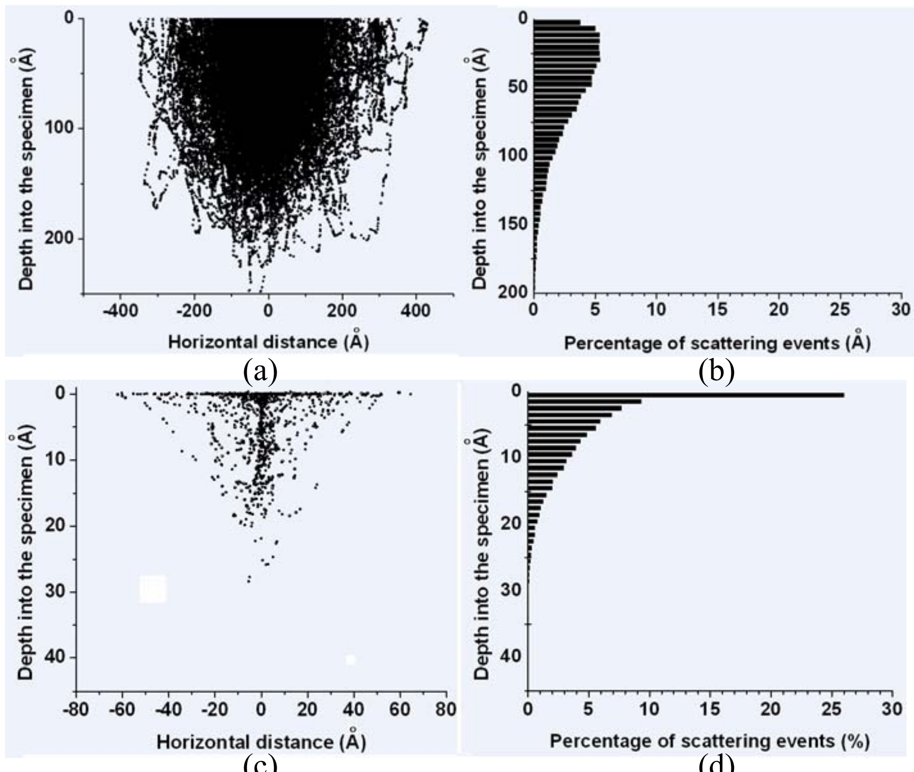

Fig 1: Simulated BSE scattering events distribution: (a) positions of BSE scattering events with emitting angles between 0°to 90° (b) the depth distribution of BSE scattering events (emitting between 0°to 90°) (c) positions of BSE scattering events with emitting angles between 89°to 90° (d) the depth distribution of BSE scattering events (emitting between 89°to 90°)

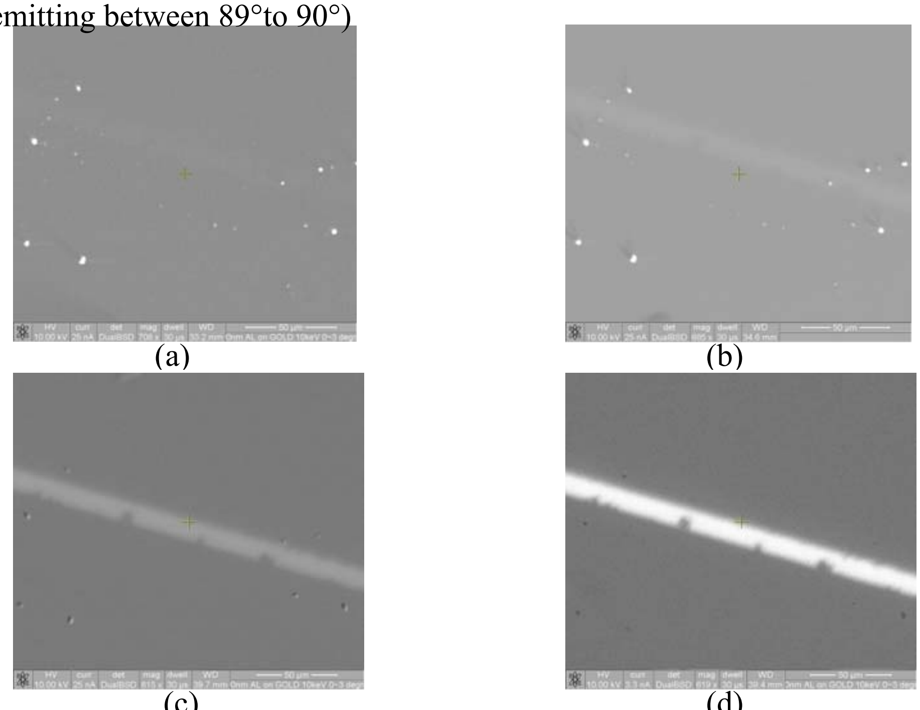

Fig 2: BSE images of a buried gold line below a 100 nm thick aluminum film at different emission angles: (a) 89°~90°(b)82°~83° (c) 45°~46° (d) 9°~10°