Application of Nanoprobing and Electrical Failure Analysis

Product used: Scanning Electron Microscope (SEM)

The nanoprobing system (Figure 1), equipped with microscopic probes that directly contact the circuitry of semiconductor devices within the specimen chamber of a scanning electron microscope (SEM), is utilized for evaluating semiconductor devices, identifying failure locations, and determining the causes of these failures. By probing the electrodes of a transistor in a semiconductor device, the IV characteristics of the transistor can be evaluated. Additionally, an EBIC (Electron Beam Induced Current) image can be acquired to visualize the positions of depletion regions at the pn junctions of a semiconductor device. Furthermore, an EBAC (Electron Beam Absorption Current) image, which shows the current flowing through the wiring, can be obtained while probing the wiring in the semiconductor device, enabling the visualization of shorts and opens in the wiring. In these analyses, it is crucial to set the appropriate accelerating voltage. For instance, probing at low accelerating voltages is necessary to prevent changes in IV characteristics caused by electron beam incidence on transistors. Recently, advances in the resolution and signal detection of SEMs at low accelerating voltages have made it feasible to perform probing even at accelerating voltages of 1 kV or lower.

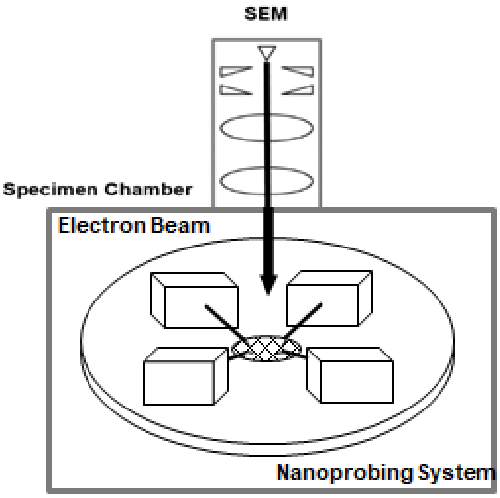

Figure 1 Schematic diagram of a nanoprobing system

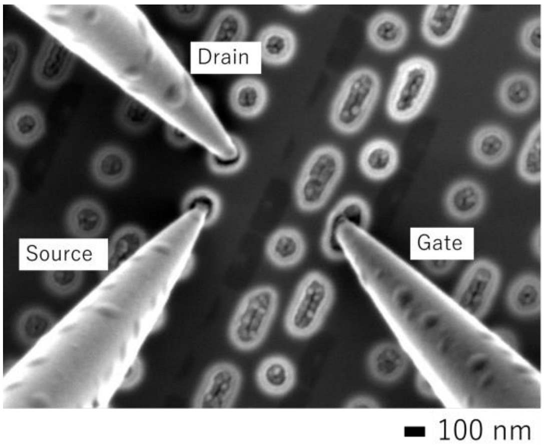

Figure 2 Nanoprobing of semiconductor elements (SRAM 22 nm node)

- Sample: 22 nm node SRAM, probed at the contact layer
- SEM: JEOL Schottky emission scanning electron microscope JSM-IT800<i>
  Accelerating voltage: 1 kV
  Detection signal: Secondary electrons
- Nanoprobing system
  Imina Technologies Nanoprobing Solution with integrated Point Electronic EFA module

Transistor IV characteristics by nanoprobing

After probing a single transistor in a semiconductor device, as shown in Figure 2, the IV characteristics of the transistor are evaluated. Figure 3 shows an example of the IV characteristics of a transistor obtained by nanoprobing an SRAM transistor.

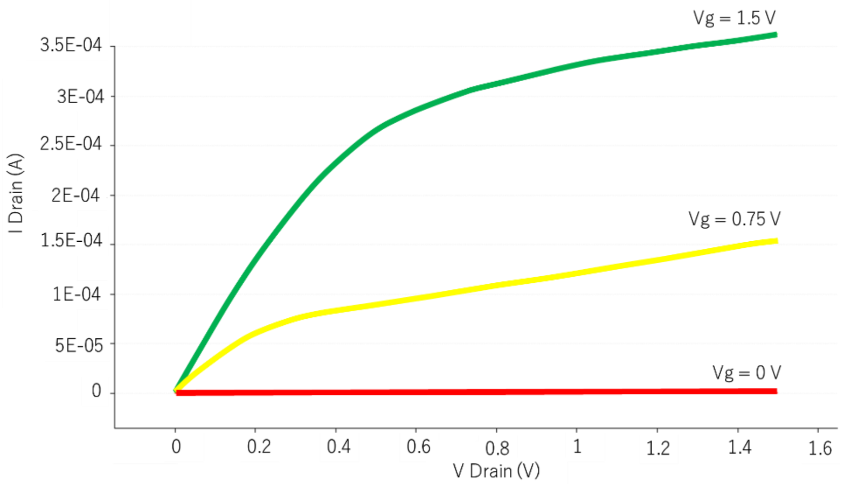

Figure 3 IV output characteristics to SRAM transistors

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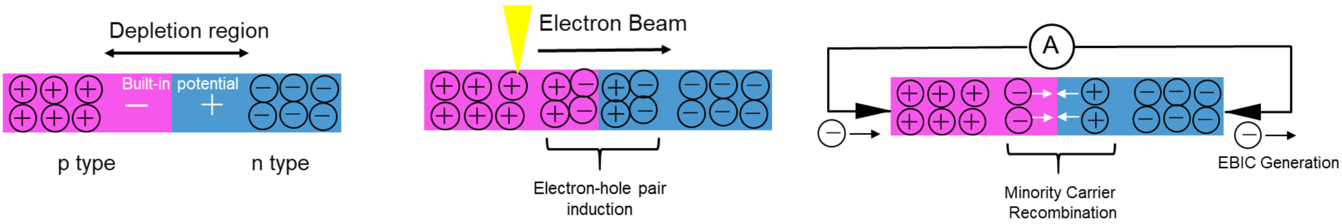
Electron Beam Induced Current (EBIC)

When a depletion region of a pn junction in a semiconductor device is irradiated with incident electrons, electron-hole pairs are induced in the process of inelastic scattering of electrons (Figure 4). The electrons and holes are then separated by the built-in potential in the depletion region. The current generated in this process is called EBIC. EBIC can be measured by connecting the electrode to a transistor terminal to which this current flows. Figure 5 shows a composite image of an EBIC signal superimposed on a secondary electron image of the surface of a delayered semiconductor chip. The EBIC signal is shown in red. By superimposing an EBIC image on a SEM image, the position and expansion of the pn junction can be confirmed.



(a) (b) (c)

Figure 4 Schematic diagram of EBIC generation

(a) Depletion region and built-in potential of pn junction
(b) Electron-hole pairs induced by electron beam irradiation
(c) EBIC generation and detection by probing

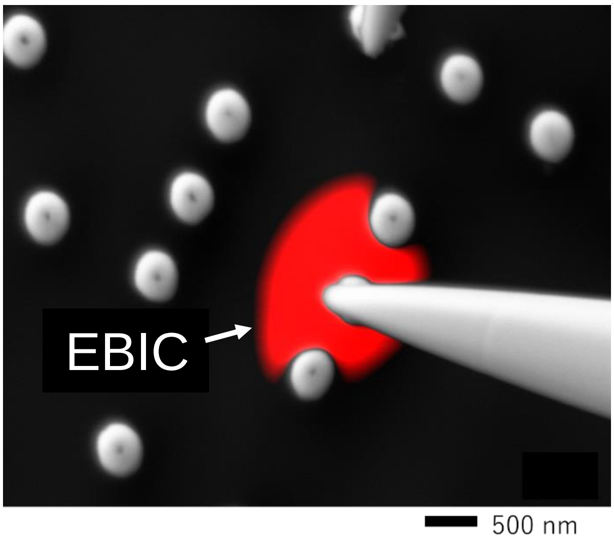


Figure 5 EBIC obtained from the surface direction of the semiconductor device

The EBIC generated at the PN junction between the P+ and N- well in the transistor below the contacted point is visualized.

●Sample: Silicon Sensor Chip

●SEM: JEOL Schottky emission scanning electron microscope JSM-IT800<i>,
Accelerating voltage: 10 kV, Irradiation current: 3 nA,
Detection signal: Secondary electrons and EBIC

●Nanoprobing system:
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Electron Beam Absorption Current (EBAC)

When a sample is irradiated with an electron beam, some electrons are absorbed by the sample in a process of repeated elastic or inelastic scattering. When the sample is conductive, the absorbed electrons flow through the sample. This current is called EBAC. EBAC helps to visualize shorts or opens in a wire that the probe is in contact with by highlighting the flow of absorbed current through this wire. Figure 6 shows how to detect a high-resistance defect between two probed wire locations based on the contrast of the EBAC image. One probe is electrically grounded and the other is connected to an ammeter. Most EBAC generated in the wire between the high resistance spot and the probe on the ammeter side, wire B, is detected by the ammeter. However, most EBAC generated in the wire between the high resistance spot and the probe connected to ground, wire A, flows to the grounded side, and this EBAC detected by the ammeter is small. The change in the absorption current detected by the ammeter can be used to identify the high resistance spot. Figure 7 shows an example of detecting an open spot in the wire from a composite image of secondary electron and EBAC images.

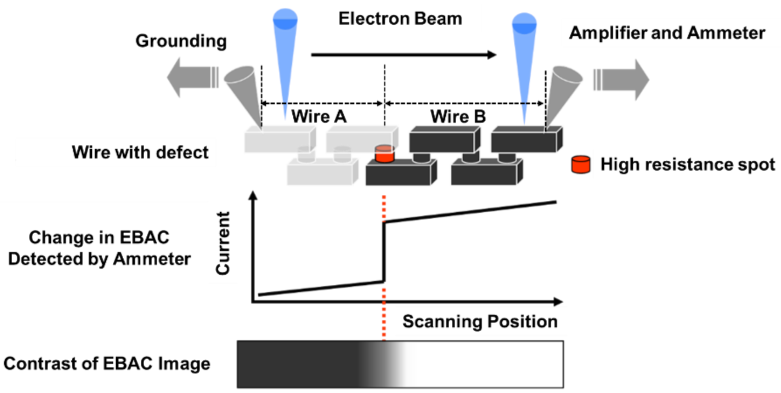

Figure 6 Method of detecting high resistance points in wiring by EBAC image

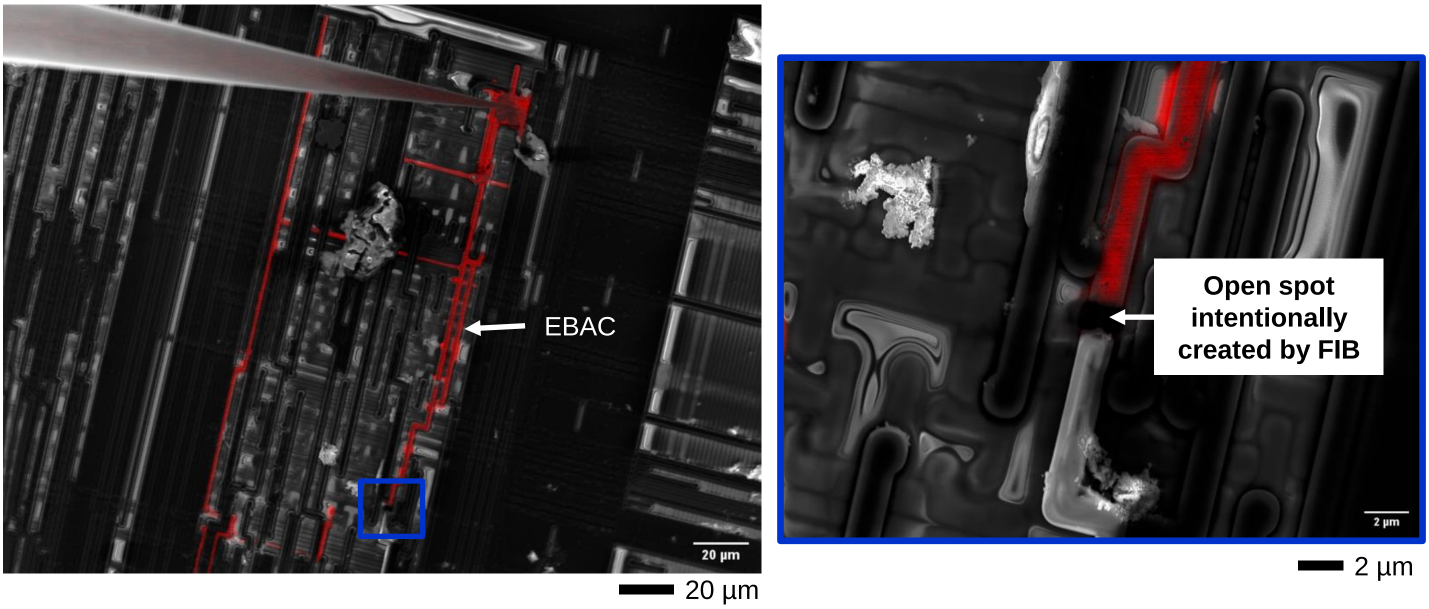

Figure 7 Example of detecting an open spot (high resistance spot) in a wire by EBAC

A hole is made in the passivation layer and tungsten is embedded into the hole. The tungsten is probed and connected to an amplifier and an ammeter. The other probe is contacted off-screen to a ground pad in a sample. The wire connected to the probe on this image is visualized.

- ●Sample: Semiconductor chip without delayering (with passivation layer)
- ●SEM: JEOL Schottky emission scanning electron microscope JSM-IT800<i>
  Accelerating voltage: 10kV, Irradiation current: 3nA
  Detection signal: Secondary electrons and EBAC
- ●Nanoprobing system
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