Secondary Electron Detector

Fig. 17 Everhart-Thornley Detector (Fig. 7-9, p. 215, Bozzola and Russell)

- Secondary electrons (SE) are attracted to Faraday cage because of its positive charge.
- Detector surface inside faraday cage (+12kV) accelerates electrons.
- Scintillator layer gives off photons when struck by electrons
- Light travels down the light tube (LG) and hits photocathode and converted back to electrons
Electrons from the photocathode pass through a series of dynodes in the photomultiplier which progressively increase their number. (total increase can be as high as $10^6$). This amplification or gain, is controlled by the contrast control on the SEM. An increase in contrast is seen as a selective increase in the highlights of the image, rather then the shadows.

The brightness of the image is controlled by the preamplifier or brightness control. In this case, both highlights and shadow areas of the image are amplified by the same amount.

- **Signal to Noise Ratio**
  - is a measure of the quality of the image
  - decreases as the gain control is increased
  - noise originates from backscattered electrons and electrical static in circuitry
Signal Processing and Gamma

Fig. 19 Image Gamma (Fig. 7-12, p. 217, Bozzola & Russell)
- measure of the contrast range of an image
- the gamma control on the SEM enables contrast in the highlight or shadow regions of the image to be extended without affecting the mid-range gray levels of the image.
- On the S-500, the 0 setting means gamma is off, and 1, 2, and 3 progressively decrease peaks and troughs of the waveform to enhance shadow and highlight contrast range.

The waveform in the diagram to the left shows extremes of bright and dark peaks in the image which will not be captured on the negative. The ideal image is usually produced by restricting the waveform so that the peaks and troughs lie within the two black lines that are taped onto the left computer screen in the S-500.

The waveform is modified by the brightness and contrast controls, and if necessary, the gamma control.

**Brightness** = height of the waveform

**Contrast** = peak-to-trough distance

Both brightness and contrast are affected by tilt, accelerating voltage, condenser lens current and aperture diameter.

Fig. 20 Waveform on Left crt of S-500 SEM
Factors Affecting Secondary Electron Image

**Fig. 21 Specimen Topography (Fig. 7-16, p. 219, Bozzola & Russell)**

Specimen Topography
In the diagram above, as the beam scans from left to right, areas marked B will be bright because they are scanned by the beam and in the line of sight of the detector. Areas marked I are intermediate in brightness because they are out of the line of sight of the detector. Regions D will be dark because they are not scanned with the beam at all.

Tilting the specimen will alter the specimen topography relative to the beam and detector and may enhance or reduce image quality.

**Beam angle relative to surface topography**

The edges of objects are often brighter than their centers due to interaction of the beam with the specimen surface. More secondary electrons escape from the edges because the zone of interaction is closer to the surface as the diagram below illustrates:

**Fig 22 Zone of Interaction (Fig. 7-17, p. 220, Bozzola & Russell)**
Surface projections and the edges of depressions in the specimen surface also generate more secondary electrons than flat surfaces, thus giving them a brighter appearance than flat surfaces. This effect is also due to the zone of interaction between beam and specimen.

**Fig. 23** Edge Effect (Fig. 7-18, p. 220, Bozzola & Russell)

**Accelerating Voltage**

- As accelerating voltage increases, the beam penetrates deeper into specimen, i.e. the zone of interaction gets deeper.
- As beam penetrates deeper into the specimen, less secondary electrons can escape.
- Secondary electrons can only escape from a limited depth ($E$) below the surface.

**Fig. 24** Effect of Accelerating Voltage on Secondary Electron Emission

For most biological specimens, 5 - 15 kV gives best combination of resolution and S/N ratio.

For dense biological specimens (i.e. diatoms, teeth, bones) 20 - 30 kV may give better results because the zone of penetration is reduced and the yield of secondary electrons is theoretically increased.

**Atomic Number**

- As atomic number increases, the yield of secondary and backscattered electrons increases and the image increases in brightness.
**Image Charging**

- Due to an inability of the specimen to ground absorbed electrons.
- Results in extreme brightness of some regions, i.e. hairs, adhering dust, etc.
- Can be minimized by reducing the number of primary beam electrons striking the specimen, by:
  a) reducing accelerating voltage
  b) increasing condenser lens current
  c) reducing aperture diameter
  d) increasing gamma
  e) recoating specimen (increases charge dissipation)