

SEM STUDIES IN MICROELECTRONICS

by

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ABSTRACT

A review of the Scanning Electron Microscope (SEM) is presented with attention given to its applications in the field of Microelectronics.

INTRODUCTION

The SEM has proven to be one of the most versatile and widely used tools today in the Microelectronics industry. The fact that devices are continually getting smaller and the need for 3-dimensional images, of surface topography mandate the use of a SEM with its advantages of submicron resolution, depth of field, and accuracy.

The SEM consists of an electron gun, electromagnetic lenses and apertures, vacuum system, specimen stage, signal detection and display components. A diagram of the SEM is as follows:

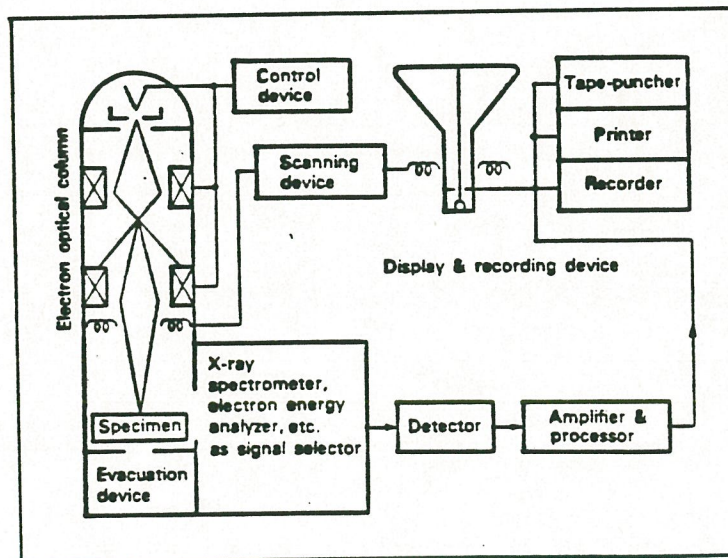


Figure 1. Schematic of SEM.

The SEM utilizes a focused beam of high energy electrons that systematically scans across the surface of the specimen. The solid specimen exhibits complex interactions with primary beam electrons. These interactions result in a variety of signals that may be detected. The varying energy of some of these electron signals enable them to conveniently be collected. The signal is used to modulate the intensity of a second electron beam which impinges on a CRT view screen. Through synchronization and amplification, a specimen image is created.

The primary electrons in the beam undergo scattering interactions with the specimen atoms. Some of the possible secondary emission are shown in Figure 2.

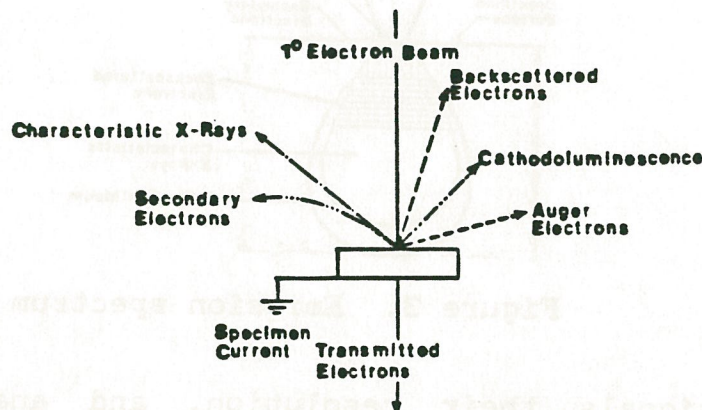


Figure 2. Signals

The interaction of the primary beam electrons and the specimen atoms causes a loss of energy to occur. Transmitted electrons are those electrons which travel through thin samples and undergo both elastic (some energy is lost) and inelastic (no energy transfer) collisions. Backscattered electrons bounce back with little energy loss. Secondary electrons are low energy photoemitted electrons in which the energy absorbed from the primary has been lost to elastic scattering events. Cathodoluminescence is the emission of photons of the IR, visible and UV wavelength. This signal will only occur for certain materials. Characteristic x-rays can be emitted which are a result of the relaxation of electrons into empty core levels which have caused photons to be formed. These photons have x-ray energies and are characteristic of the element. Auger electrons are emitted once an electron relaxes to a new empty level which was created by secondary emission. This relaxation releases a photon which is absorbed by a secondary electron that is then photoemitted. The other signal which can be monitored is the specimen current. This is the

difference between the beam current the the emissive current which is the sum of all current leaving the specimen by the emission of electrons.

A limitation is seen on the depth of penetration. Penetration of the beam electrons is dependent on the magnitude of their energies. The volume and depth of excitation multiplies with the increasing beam energy and decreases with atomic number. The resulting emissions also show a depth dependence because lower energy signals are emitted from a shallower region. Figure 3 shows this.

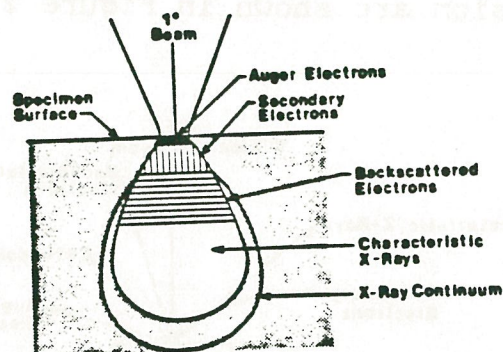


Figure 3. Emission spectrum

Typical signals, their resolution, and analysis use are given in Table 1.

SIGNAL	RESOLUTION	USE
Backscattered electrons	> 1 micron 1,000 nm	Atomic number contrast Topographical contrast
Secondary electrons	10 nm or better	Surface structure
Cathodoluminescence	< 80 nm	Impurity concentration
Characteristic x-rays	Measured in eV's, an integral of peak width of a given line	Elemental composition
Auger electrons	Measured in eV's, an integral of peak width of a given line	Surface composition
Transmitted electrons	5 nm or better	Internal ultrastructure
Specimen current	poorer than 2° electron image	Atomic number contrast
Continuum x-rays		Not a useful signal

Table 1. Signals, resolution, and uses.

EXPERIMENTAL

Throughout any integrated circuit processing, a SEM can be used to inspect the samples at various steps in fabrication. The results obtained at these times can provide valuable information. Integrated circuit processing begins with oxidation of the silicon surface. At this point, it is valuable to determine whether the oxidation has produced any defects on the surface. To determine this the wafer can be Wright etched. This etch makes the defects more prominent. Figure 4 shows the defects which can occur.

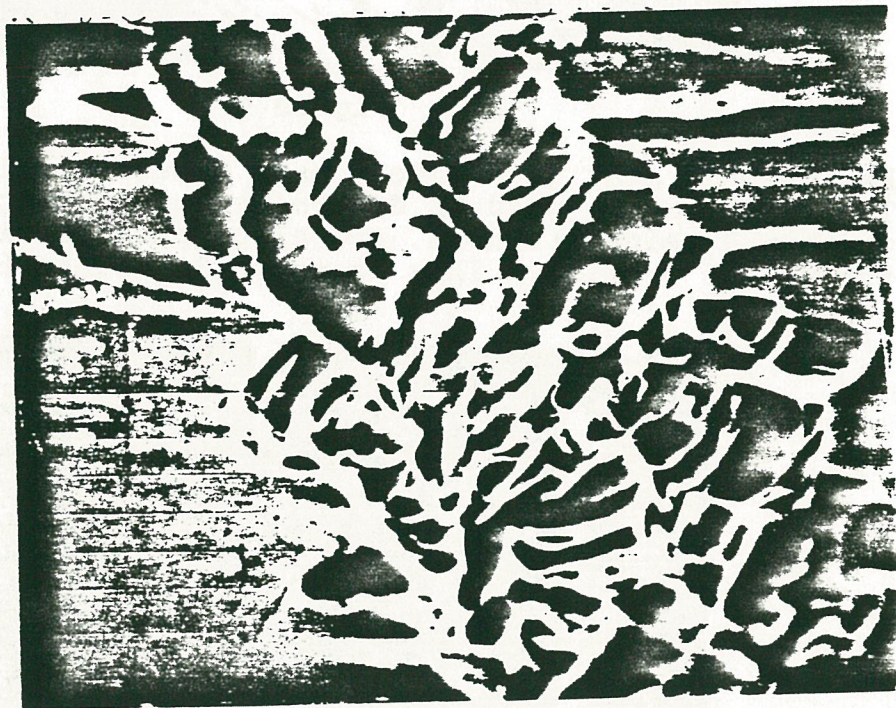


Figure 4

The next processing step is to perform a diffusion. This is the introduction of impurities into the wafer. The junction depth is determined by the time and temperature of the process. Junction depth can be measured by using a stain technique. A mixture is used which causes the p-type material to stain. This can then be viewed by cross-section using the SEM. This is shown in Figure 5.

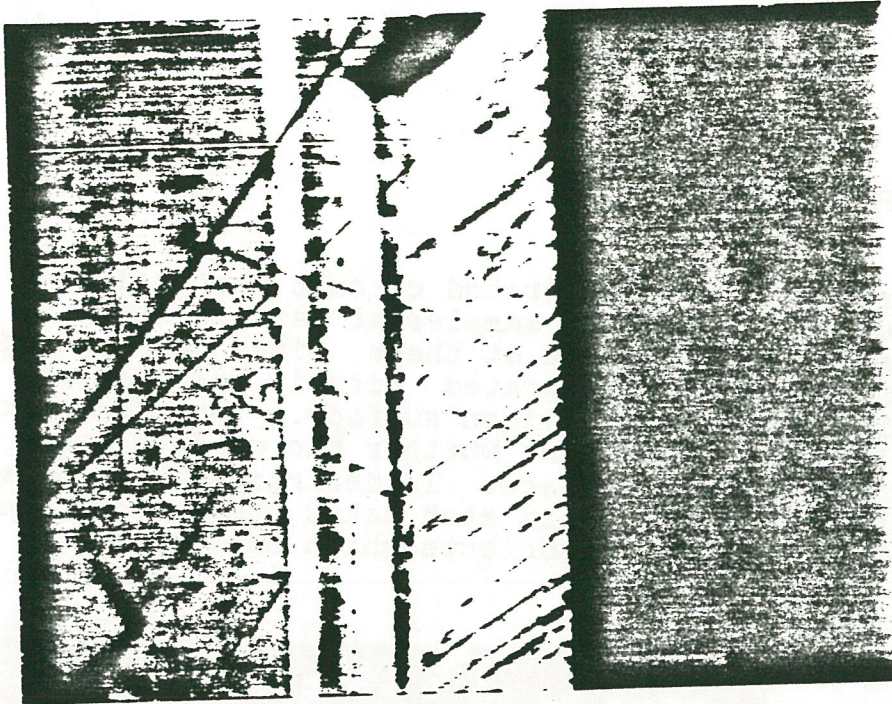


Figure 5

Photolithography is a widely used aspect of IC processing. The SEM can be used to determine the accuracy of the lines which are being produced, and also provide information on the resist profile. This is shown in Figure 6.

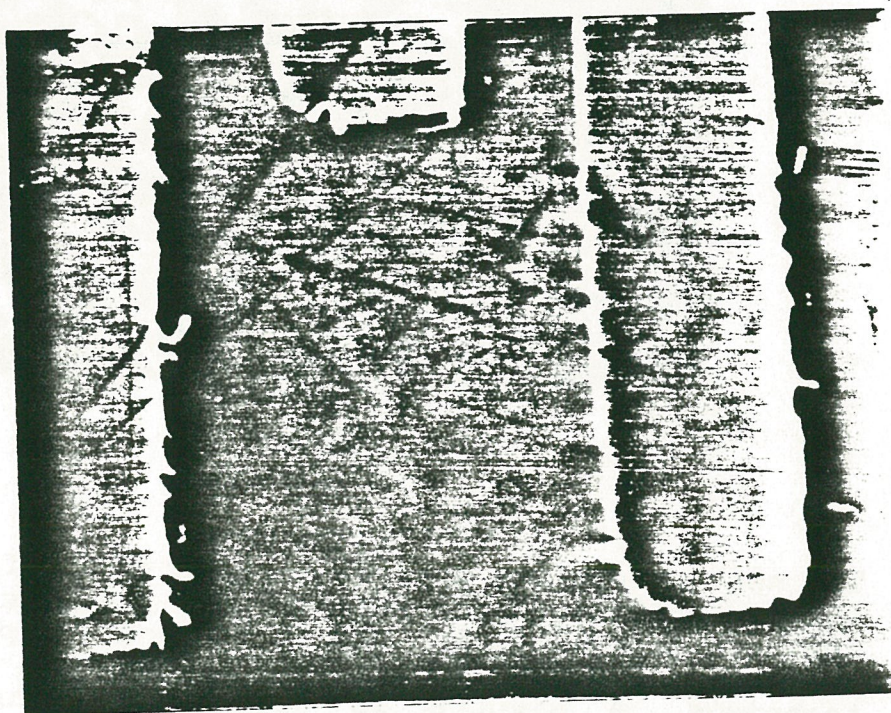


Figure 6

Metal deposition is the final step in processing. When the metal is to be deposited onto the surface, there is a great deal of topography which must be encountered. Topography can cause a decrease in the uniformity of the metal layer. To account for this, a trilayer process can be implemented. This is shown in Figure 7.

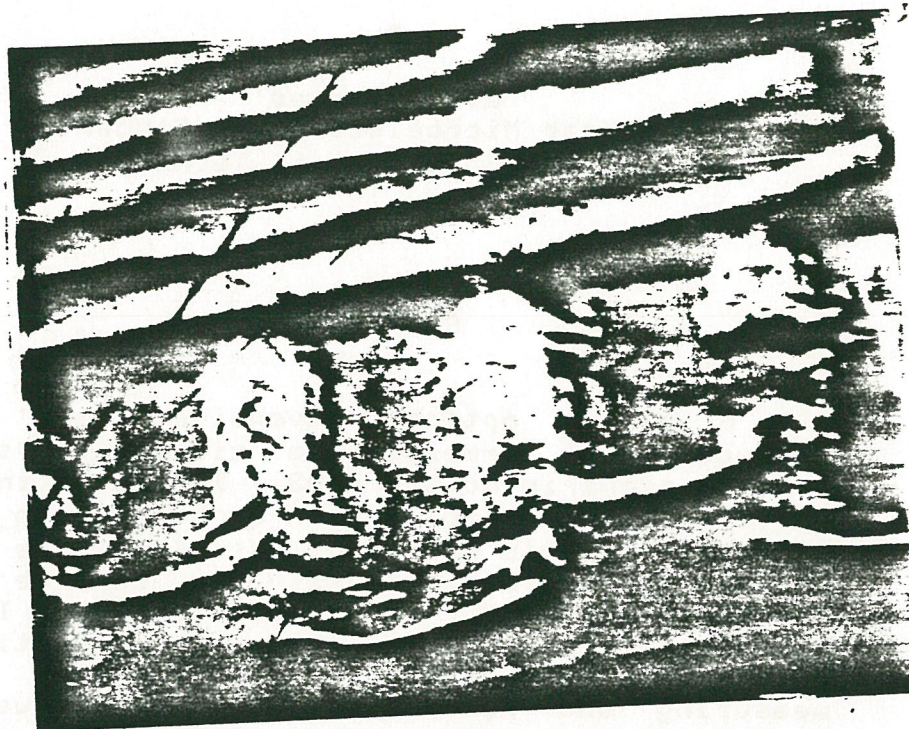


Figure 7

There is a variety of data which can be collected to provide valuable information on the SEM and on the process being tested itself.

CONCLUSIONS

It has been shown that the SEM is a widely used instrument. The uses vary dependent upon the task which is to be performed. An overview of the analysis which can be done with the various signals was given. Pictures of actual analysis on defect analysis, junction depth, and image profiles are shown.

REFERENCES

1. JEOL News, Electron Optics Instruments Application, Volume 10e, number 2, 1972, The Scanning Microscope as a System, S. Kimoto.