USING THE SCANNING ELECTRON MICROSCOPE ON THE PRODUCTION LINE TO ASSURE QUALITY SEMICONDUCTORS

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Metallization defects introduced during batch processing of semiconductor devices have been a major problem in several GSFC flight projects in recent years. Partial discontinuities in metallization at the step in the oxide at contact windows (Figure 1) have resulted in latent failures in systems already fabricated and tested. This condition cannot be detected with an optical microscope (Figure 2). The line at the oxide step is typical of that normally seen for a good device, but here the metallization is almost completely discontinuous. By contrast, Figure 1, which is a scanning electron microscope (SEM) picture, shows that the line is not a shadowing effect and clearly describes the actual condition of the metallization.

Defects like this are not confined to a single vendor, a single point in time, or a particular device type, but rather to small geometry contact windows in both discrete transistors and integrated circuits. Users have been penalized not only by suffering latent in-system failures, but also by the eight- to nine-month procurement and delivery cycle (for devices built to high reliability specifications), with no assurance that a replacement order—or its successor—will be free of this defect.

Although the SEM is capable of detecting this metallization anomaly, its use heretofore has been confined to the laboratory. A method of determining metallization integrity has been developed that culminates in a procurement specification, which uses the SEM on the production line as a quality control tool. Batch process control of the metallization operation is monitored early in the manufacturing cycle. When bad metallization is detected, lost time is reduced to about five weeks from the 30 weeks necessary for complete manufacturing and screening tests. A paramount requirement of the method was that the disturbance to vendors' normal process flows be minimal.

There are a number of key points to the specification:

Metallization Inspection–The SEM is the instrumentation used to examine metallization on samples. Critical viewing parameters are specified, including magnification at 6000X and proper positioning of the sample relative to the incident electron beam.

Sampling–A typical single metallization run of 20 to 30 slices may yield potentially 300,000 transistor dice. Normal sampling techniques would require a sample size of over a thousand dice to be examined, but this is impractical for the SEM. Instead, since this is a batch process detection method, 15 to 25 dice are selected from specific sites in the metallization chamber. The exact number and sites are determined by order size, die size, geometrical configuration of the slice holder in the metallization chamber, number and type of metallizing source elements, and static or dynamic position of the slice holder relative to the source(s).

Metallization Quality Evaluation–Written and pictorial standards constitute the acceptance/rejection criteria. Judgment of metallization quality is based on many examples of good (Figure 3), bad (Figure 1), and marginal (Figure 4) metallization.

It has been demonstrated that the method is practical, its details have been worked out, and it is acceptable to vendors. It is also operational, since semiconductors have been bought to the specification. Finally, its use is being extended, as shown by current efforts to incorporate it into the Department of Defense General Specification for Micro-electronics, Mil-M-38510. Thus, the user can be assured that the type of anomaly discussed here will not be present in devices built to this specification.

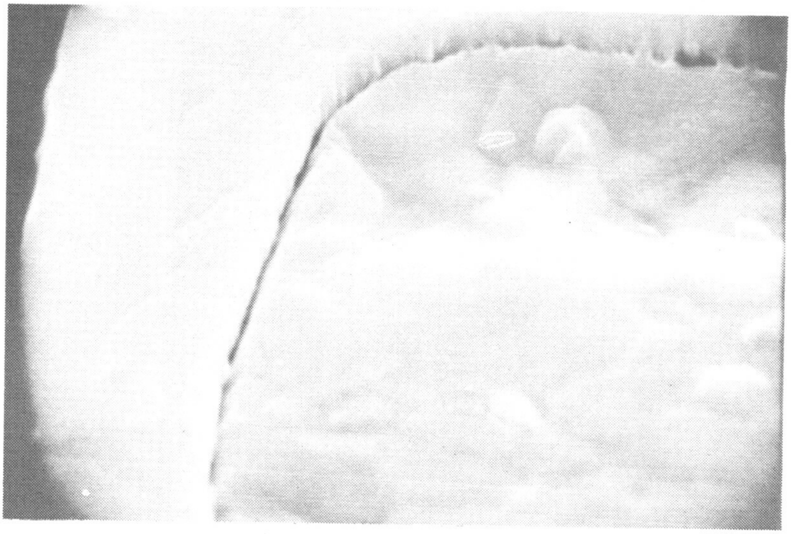

Figure 1–SEM picture of edge of contact window. Magnification is 5000X.

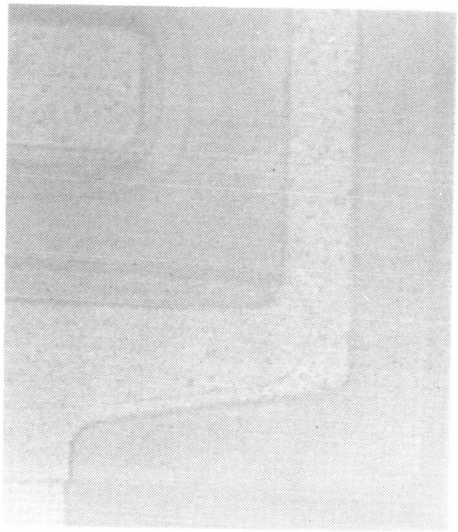

Figure 2–Optical microscope picture of transistor contact window. Metallization at S_1O_2 step appears good but is discontinuous. Magnification is 400X.

Figure 3–SEM picture of good metallization. Aluminum at oxide step is smooth and continuous. Magnification is 5500X.

Figure 4–SEM picture of marginal metallization. A borderline case because of the number of discontinuities in aluminum at oxide step. Magnification is 5500X.