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NASA TECH BRIEF

Marshall Space Flight Center

Microcircuit Testing and Fabrication, Using Scanning Electron Microscopes

Scanning electron microscopes (SEM's) have been introduced into the nondestructive testing of microcircuits. They are used to determine both user-induced damages and manufacturing defects that are subtle enough to be missed by conventional light microscopy. Because of the greater depth of field and increased working distances of the SEM's, microcircuit failures are examined more closely than with light optics. However, the SEM's do not replace the light optics; rather, they complement the data obtained from optical microscopy. For example, microcircuits undergo preliminary screening with light optics to observe discolorations and irregular geometries. These in turn are more closely examined with SEM's.

With the SEM's the topology of the semiconductor devices is examined by using the standard secondary electron, or emissive, mode. This mode is used to observe various types of surface defects on the microcircuit. Examples are metallization flaws which typically include voids in the metal around contact windows, severed interconnects, and lifted metal. These defects are usually detected by examining the questionable areas at various tilt and rotational angles.

A more accurate technique called voltage contrast is used to confirm failures such as hairline cracks. With this technique a circuit is examined under static or dynamic conditions at TV scanning rates. A potential gradient on the surface of a material, alters the secondary emission by the polarity of localized areas. Hence, the normal topological contrast has a potential or voltage contrast superimposed upon it. This technique, in effect, provides an electrical continuity test of the device without physically probing the die.

Another area that is examined involves bonding problems usually associated with bonds that lift from the pad (or post) or with broken wires. Again, specimen orientation is very important in obtaining the right perspective to detect the fault.

A solid-state X-ray spectrometer is attached to the SEM to detect contamination in the form of particles or surface film. The spectrometer detects fluorine and heavier elements. Although this spectrometer is less sensitive than visible-light spectrometers, it is more accurate on the nonplanar surfaces encountered in microcircuits.

Further application of the SEM's is in microcircuit fabrication. The use of a SEM in lithography is comparable to the use of a light source in photolithography. An electron resist such as lucite is used instead of the photoresist. The electron beam is of great advantage where high resolution and/or high patterning density are required. With state-of-the-art techniques an order-of-magnitude gain in line separation (<1,000 Å) can be achieved easily. This reduces an area by a factor of 100 which increases the packing density and high-frequency capability of future semiconductor devices.

There are two general approaches to the electron-beam control: the analog technique, such as a flying-spot scanner (FSS), and the digital technique, using a general-purpose computer. Essentially, the FSS technique is cheaper and easier to implement. The patterning density and resolution capabilities of this scheme are severely limited by the cathode-ray tube (CRT) and by the associated optics of the FSS. However, the FSS is well suited to producing simple patterns such as the microbridges. The width of the bridge produced experimentally is approximately 1,000 Å.

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In contrast, the digital-computer approach to electron-beam control is by far the most advanced. The computer can coordinate all of the operations required for microcircuit patterning, such as pattern exposure, pattern registration, and the step-and-repeat operations. However, for simple patterns or prototype work the FSS technique is simpler.

Note:

Requests for further information may be made in writing to:

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Marshall Space Flight Center
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NASA has decided not to apply for a patent.

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