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APPLICATION NOTE

Semiconductors

Imaging and elemental analysis for quality checks

Electronics are now an indispensable part of modern life. Advances in technology, coupled with improved performance tolerances, are helping to drive global demand and fuel innovation in this fast-growing field. When it comes to the electronic components market, three segments immediately catch the eye: passive components (resistors and capacitors), semiconductor components (integrated circuits), and printed circuit boards. Semiconductors have had a monumental impact on our society. You will find them at the heart of microprocessor chips, and anything that is computerized or uses radio waves depends on them.

Today, most semiconductor chips and transistors are made from silicon wafers. The production of electronics devices can be divided into four steps: 1) wafer production, 2) front-end, 3) back-end and 4) PCB materials.

The production of wafers can be broken down into the following processes: slicing, lapping, etching and polishing. As these are all sensitive processes, scanning electron microscopy (SEM) is used for quality assurance at a number of different stages. It is mainly used to inspect the wafer cuts, but is also an important tool if there has been a suspected particle contamination.

Front-end production

In **Figure 1**, a general schematic explains the front-end production process. Manufacturing devices begin with a bare silicon wafer, which must be thoroughly cleaned.

The first oxidation step creates an oxide layer, on top of which other materials (typically conductive) are deposited. This is the process that produces the so-called SOI (Silicon Over Insulator) wafers.

In the next step, a first level of circuitry is produced by lithography. During this step, the wafer is covered with a light-sensitive polymer, called a photoresist that is exposed to light. The use of masks permits only certain regions of the wafer's surface to be exposed.

In the development step, the unexposed photoresist, is removed. After that, another material layer can be deposited directly onto the substrate, or any material that is not covered by the photoresist can be removed first by etching.

It is possible that an ion implantation step may be performed, where ions are bombarded and diffuse in the material to change its chemical or physical properties. A material layer can then be deposited, followed by a polishing step. If necessary, the entire cycle can be repeated.

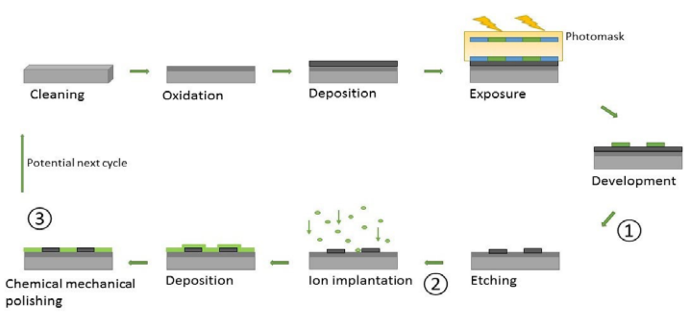

Figure 1. Front-end production process description

Front-end production involves several steps. Quality control is essential, and SEM analysis plays an important role in three key steps. SEM inspection is mainly used for the measurement of critical dimension (steps 1 and 2). After processes such as lithography are performed, the smallest patterned features, called the critical dimension, are analyzed and its dimensions measured to verify the quality of the process. SEM imaging is also widely employed for the detection of possible defects (steps 1–3), which include damage, deformation or the presence of dirt particles.

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Thermo Scientific™ Phenom™ Desktop SEMs can also play a role in the inspection of interconnections. In this case, cross sections of the fabricated devices, made by ion milling, reveal the interconnections between different layers of the chip. In this step, it is of utmost importance to check for cracks and measure the grain size. In this instance, the resolution requirement can be easily achieved with a desktop system. Moreover, as Phenom Desktop SEMs are equipped with a high brightness source combined with a backscattered electron detector for perfect material contrast, the contrast of the images is crisp and carries valuable information. In addition, all Phenom Desktop SEMs can be equipped with an EDS detector for the analysis of the elemental composition of samples. When integrating a Phenom Desktop SEM into the inspection process, extra attention needs to be paid to the sample preparation, as samples may need to be cut or polished due to the small chamber size. With their size and speed, Phenom Desktop SEMs are ideal for placement inside factories, as they can enable quality checks to be done right next to the production line.

Back-end production

The back-end production process includes wafer testing, dicing and packaging. Here, SEM inspection's main roles are in quality control and failure analysis. In quality control, SEMs are employed for the inspection of die cuts and possible chipping, as well as bond pads and wiring. In back-end production, the quality of the connections plays a critical role, as cracks or misplaced connections can cause defects or device malfunctions. In failure analysis, the devices are checked after being packaged. Phenom Desktop SEMs are a perfect fit for the back-end production process. The Thermo Scientific™ Phenom™ XL Desktop SEM is particularly appropriate, as it has the best characteristics in terms of maximum sample size with regard to the footprint of the microscope.

PCB manufacturing

Printed circuit boards (PCBs) are the rigid supports that host electronic devices and the connections between them. While components are typically soldered onto the PCBs, the conductive tracks and pads are built-in.

Figure 2. Layers of a printed circuit board (PCB)

In **Figure 2**, the general structure of a PCB is shown. The rigid base, or substrate, typically consists of fiber-reinforced plastic (FRP).

This solid core gives the PCB its rigidity and thickness. There are also flexible PCBs built on flexible high-temperature plastic. On top of the substrate, there is a thin copper foil, which is laminated to the board with heat and adhesive. On common, double-sided PCBs, copper is applied to both sides of the substrate. In low-cost electronic gadgets, the PCB may have copper on one side only. The number of layers can differ from as few as one layer to as many as 16 layers or more. The layer on top of the copper foil is called the soldermask layer. It is this layer that gives the PCB its green color. The soldermask layer is overlaid onto the copper layer to insulate the copper traces from accidental contact with other metal, solder, or conductive parts. It is built to facilitate the soldering process and prevent solder jumpers. The white silkscreen layer is applied on top of the soldermask layer. The silkscreen adds letters, numbers, and symbols to the PCB that allow for easier assembly and help users to better understand the board.

SEMs are employed in this field for quality checks, mainly to verify the correct overlap between layers. Typically, before the SEM inspection, PCBs are cut and analyzed as cross sections for any cracks or potential broken solder joints.

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