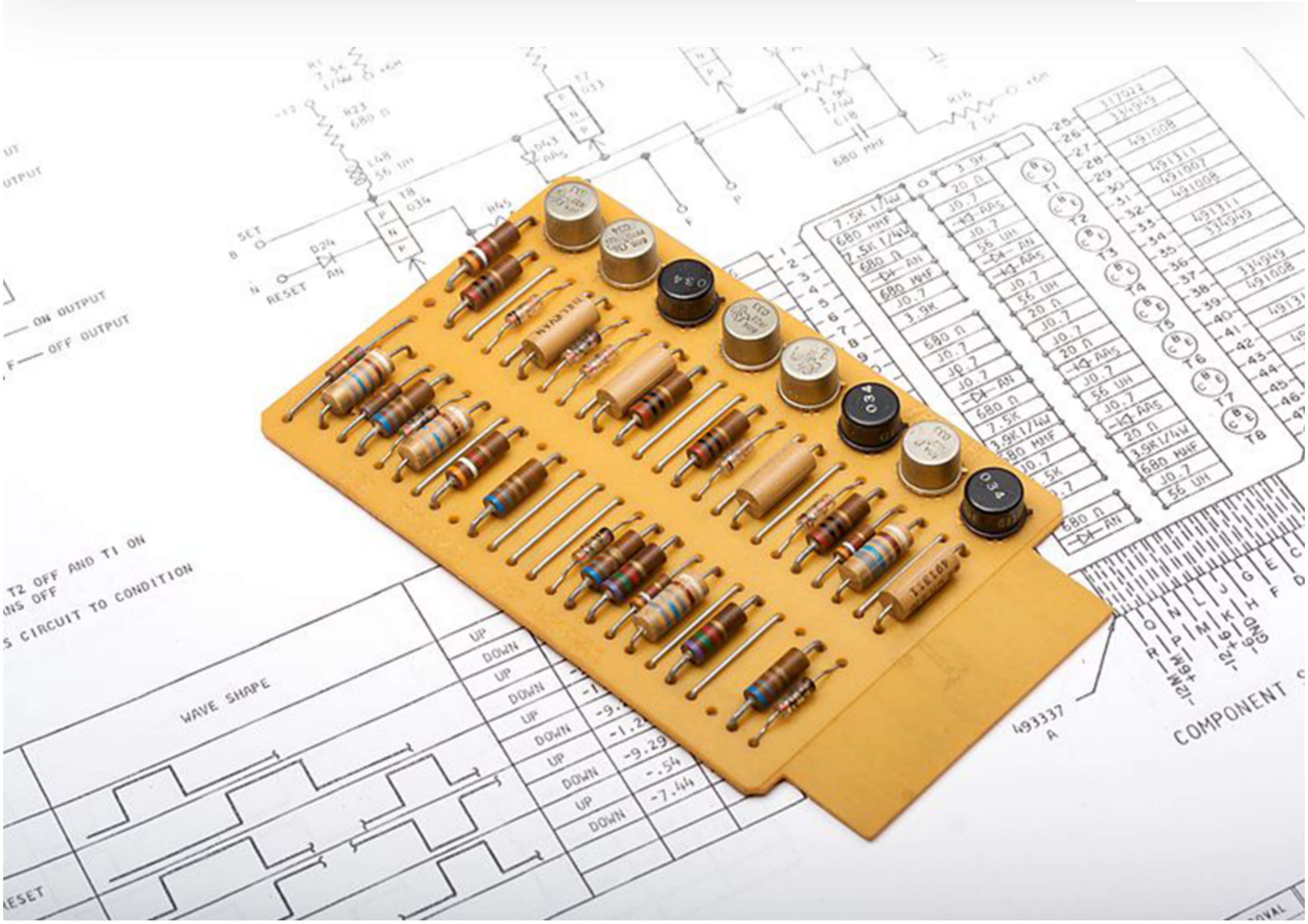
Semiconductor Front-End Process Episode 2: Protecting Key Components Through Oxidation

December 21, 2022

In the previous chapter, we looked at how computers, transistors and semiconductors became a vital part of our society, and that the goal soon became how to efficiently develop these technologies. When producing semiconductors, there are eight main processes involved ranging from wafer manufacturing to packaging. This series will explain each of these processes in detail. In this chapter, we look into the process of oxidation and the crucial role it plays in protecting semiconductor components.

Producing and Connecting the Semiconductor Components

Before explaining the process of producing semiconductors, it's easier to think about the makeup of ordinary electronic devices. It's clear from looking at disassembled electronic equipment that a number of parts such as transistors, batteries, storage batteries, and coils are soldered on a PCB[1] board. When manufacturing this *soldered on its surface. These boards are found in most electronic devices.*



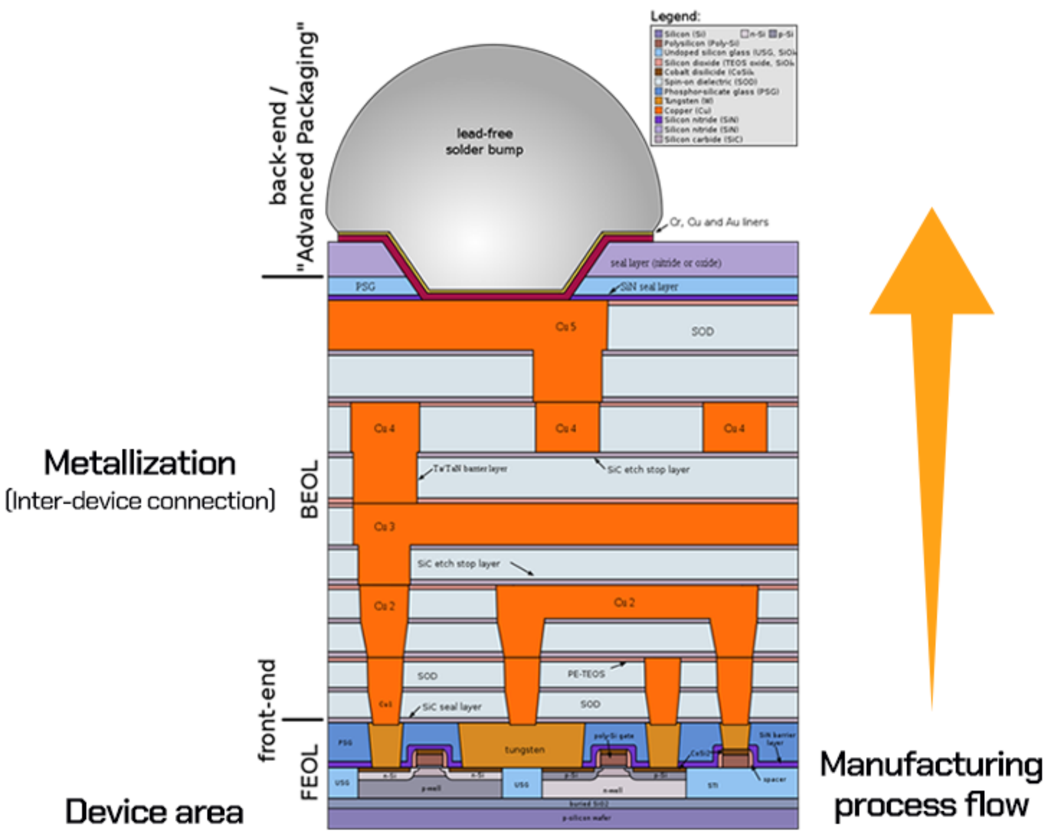
▲ Figure 1. Just as computer CPUs were made in the past, various devices are soldered onto the PCB. (Image Source)

This order of procedure is also applied to the MOSFET (Metal Oxide Semiconductor Field Effect Transistor) that is placed on top of a silicon wafer. The first step in wafer manufacturing is to make various types of discrete devices. Although “made,” it’s more accurate to say that they are engraved on the wafer’s surface. This process is called FEOL (Front End Of Line). Afterwards, a process tantamount to soldering follows, but such small devices cannot be directly soldered on. So, techniques that are similar to FEOL are used to create fine wires that interconnect billions of

SK hynix NEWSROOM

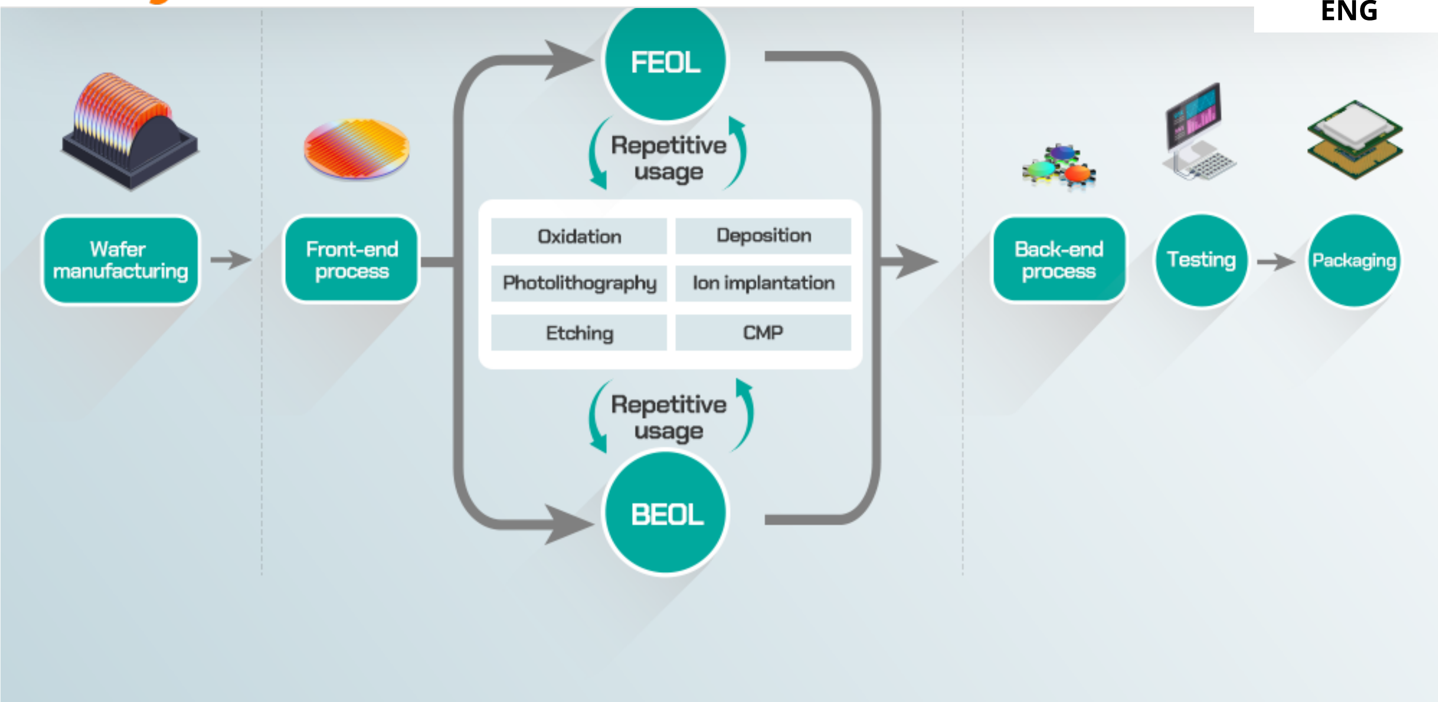
ENG

front-end process.



▲ Figure 2. The actual flow of the manufacturing process. A MOSFET is formed in the FEOL area, and on top of this area are metal wires which connect the components of FEOL instead of soldering them together. (Image Source)

Various processes including oxidation, photolithography, and etching are methods used in FEOL and BEOL. The frequency of using certain equipment varies according to the purpose of each respective step in the process, but the main purpose remains the same: creating many fine patterns.



▲ Figure 3. A simplified version of the semiconductor manufacturing process and the companies involved.

The eight main semiconductor processes are wafer manufacturing, oxidation, photolithography, etching, deposition, metallization, testing, and packaging, but such a categorization of the processes is not absolute. As evident from Figure 3, wafer manufacturing does not strictly occur within a semiconductor factory. Moreover, in the case of metallization, testing, and packaging, they are not single processes such as photolithography, etching, and deposition, but rather are broad categories of processing that are executed for a certain purpose.

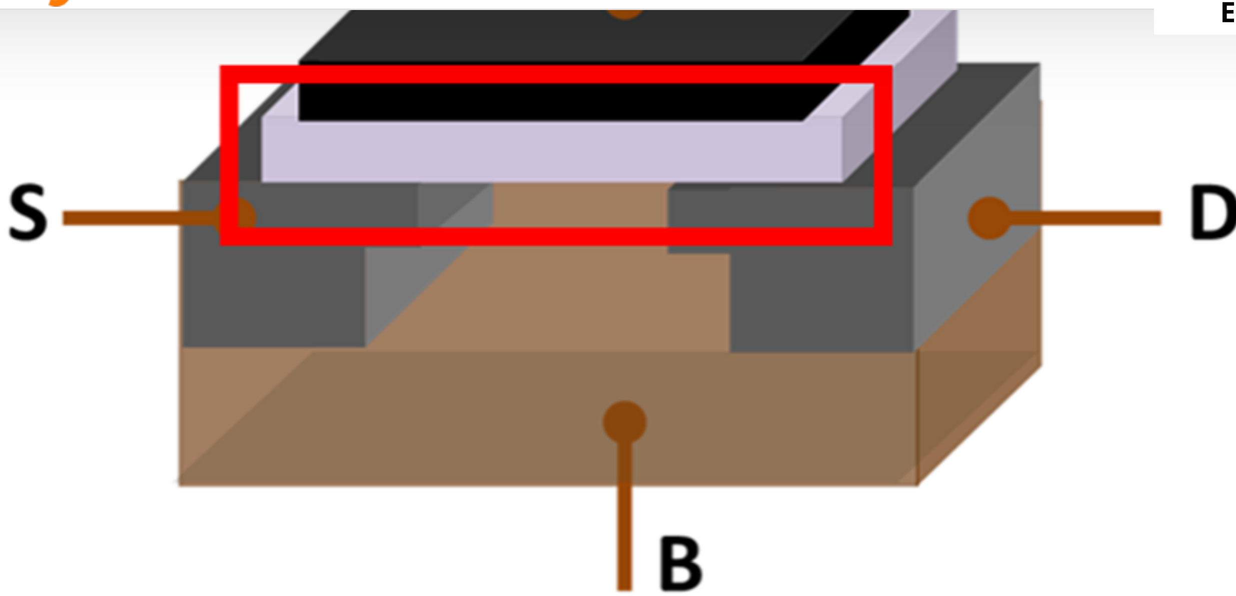
Oxidation: Protecting Silicon Wafers Through Glass Coating

As shown in Figure 2, the semiconductor manufacturing process starts at the bottom and flows upward. To evenly create various shapes inside the semiconductor, come into contact with unwanted areas. In addition, there are parts in the semiconductor that may short-circuit if they are in direct contact with each other. Thus, there needs to be a way to create some type of a barrier between them, and this process is called oxidation.

The oxidation process involves covering a protective film on a silicon wafer. When silicon (Si) reacts with oxygen, it becomes silicon dioxide (SiO_2), otherwise known as glass. Glass is not only strong but also has low reactivity, so it is used to store various beverages as well as chemicals including hydrochloric acid and sulfuric acid. As a protective material that possesses these characteristics, oxide film blocks the entry of other substances and proves to be useful in the ion implantation process[2].

Additionally, oxide films are also used to intentionally block current flow. The core part of the MOSFET structure is the gate. Unlike previous transistors such as BJT[3], the gate of the MOSFET does not directly touch the path of the current (the area between S and D in Figure 4) but only exerts an indirect influence. An oxide film, which is also called a gate oxide, is often used as the material to block the gate and the current's path. In the case of the latest advanced semiconductors, the reduction in semiconductor sizes leads to various alternative materials such as HKMG[4] being used as gate insulating films.

[2]Ion Implantation: The process of implanting group 3 or group 5 ions to convert pure silicon wafers into semiconductors in the semiconductor manufacturing process.
[3]BJT (Bipolar Junction Transistors): A transistor made using a PN junction, which refers to the boundary between two regions of a P-type semiconductor and an N-type semiconductor inside a semiconductor.
[4]HKMG (High-K Metal Gate): A newly developed MOSFET gate that effectively reduces leakage current. A transistor that replaces the polysilicon gate with metal and substitutes silicon oxide insulating film for High-k.



▲ Figure 4. A gate insulating film (shown in the red box) blocking the gate labeled G and the current path between S and D. Silicon dioxide (SiO_2) was previously widely used as such a film but now other materials are taking its place. (Image Source)

The 3 Types of Oxidation Processes

The oxidation process can be divided into three types: wet, dry, and radical.

Type of Oxidation

Type	Inlet gas	Temperature	Pressure	Oxidation speed (for the same temperature)
Wet	H_2O	Over 600°C		Fast

Radical	$H_2 + O_2$	Over 600°C	Less than 1 torr	Slow

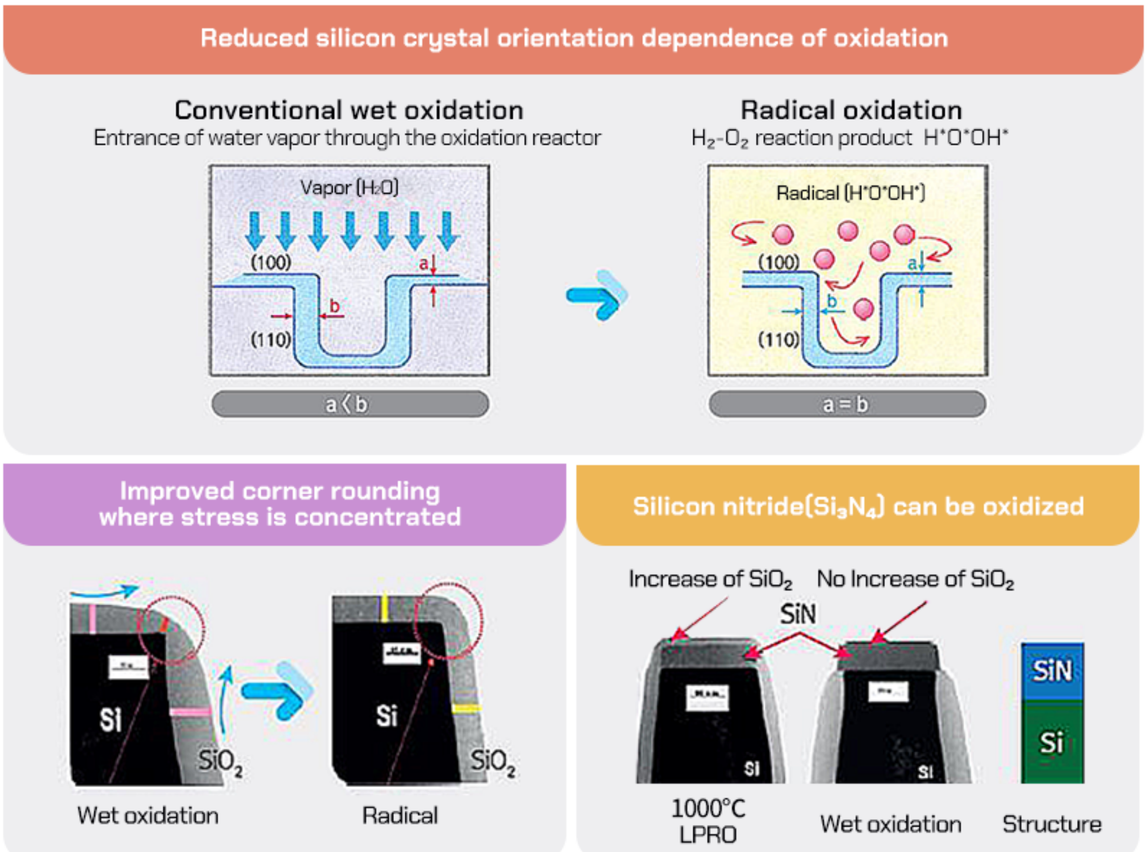
▲ Figure 5. Types of Oxidations (Source: *The Understanding of the Semiconductor Manufacturing Technology*, p. 143)

Wet oxidation is a method in which a silicon wafer reacts with high-temperature vapor (water). In other words, it's similar to rusting the surface of silicon using high-temperature water. A silicon oxide film can grow very fast through a wet process, but characteristics such as overall uniformity and density of the oxide film are deteriorated. As it's not easy to adjust the characteristics of the film, it becomes difficult to use it in key instances where the product's performance is significantly affected. In this process, hydrogen (H_2) is produced as a by-product.

In the case of dry oxidation, high-temperature oxygen gas is directly sent to the silicon wafer. Oxygen molecules are heavier than water molecules[5], so they penetrate the silicon wafer relatively slower. Unlike in wet oxidation, hydrogen (H_2) is not generated as a by-product and, instead, a dense and uniform oxide film is produced. Due to these characteristics, the oxide film in the semiconductor gate—which has a significant effect on the performance of the final product—is made by dry oxidation.

[5]*When the atomic mass of hydrogen (H) is 1, the atomic mass of oxygen (O) is 16. Therefore, the molecular weight of oxygen (O2) is 32 and the molecular weight of water (H2O) is 18, so the oxygen molecule is heavier.*

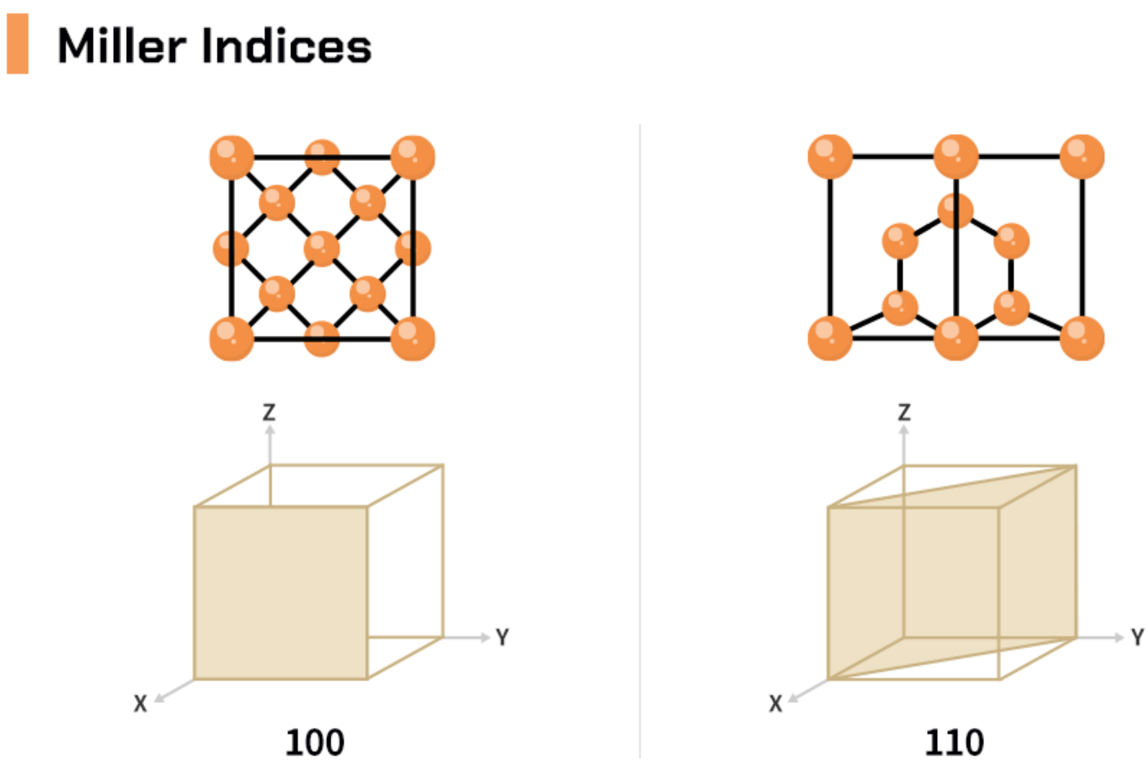
Radical oxidation proceeds in a somewhat different process from the two oxidations discussed above. During wet and dry oxidation, natural gases are raised to a high which react with silicon wafers. Radicals can produce oxide films of much higher quality compared to the dry oxidation process as radicals are highly reactive.



▲ Figure 6. Characteristics of Radical Oxidation (Source: *The Understanding of the Semiconductor Manufacturing Technology*, p. 149)

In addition, the thickness of the oxide film can be uniform even in a three-dimensional structure by using radical oxidation. Silicon wafers used by semiconductor companies are single-crystal, and silicon atoms on the entire surface of the wafer have the same crystal orientation.

the wafer (100) is slow and the oxidation rate is fast in the side (110) direction. The reason for these differences lies in the fact that the silicon atoms arranged in the (100) direction are denser. If the atoms are closely arranged, it is difficult for dry or wet oxidizing gas to penetrate the crystal and react. However, radical oxidation is significantly less impacted by this issue.



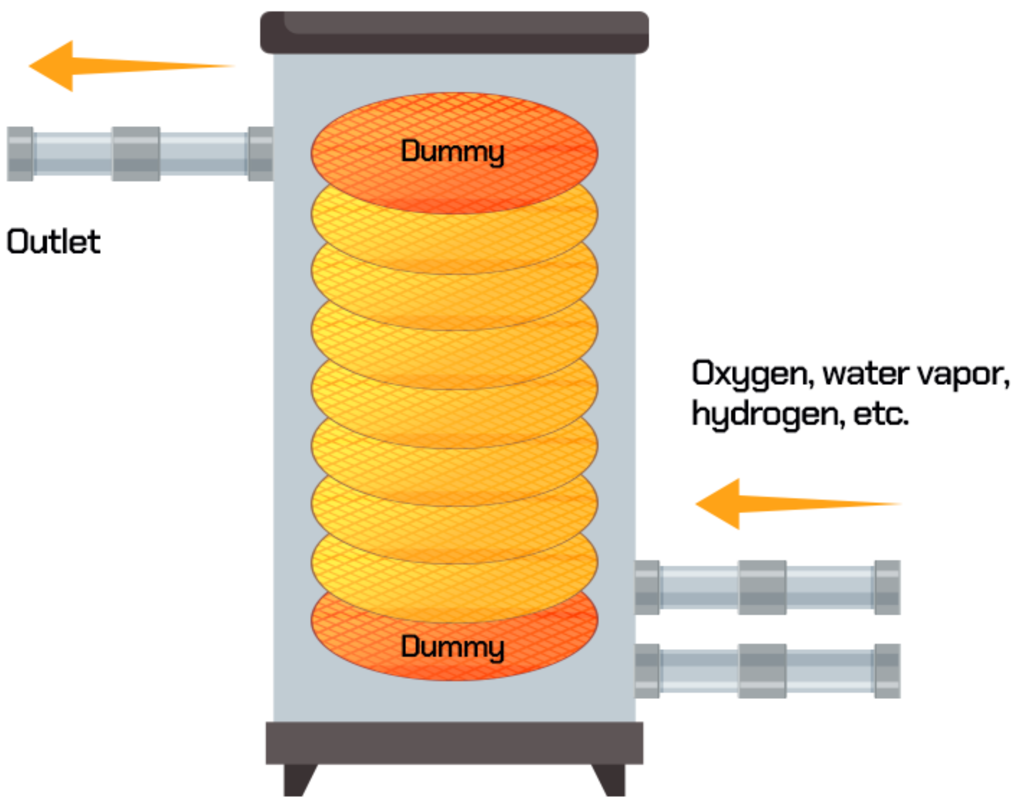
▲ Figure 7. The appearance of silicon atoms according to the Miller indices.

In addition, radical oxidation creates a uniform oxide film even on the corners where it was previously difficult to do so. Radical oxidation induces silicon nitride (Si_3N_4)[6] to cause an oxidation reaction as it has a relatively low reactive rate.

As the miniaturization of semiconductors seems to be getting closer to its technological limits, semiconductor companies are increasingly introducing three-dimensional structures into semiconductors. For this reason, the technology of making a uniform high-quality film is becoming more critical in semiconductors. This also applies to the oxidation process.

Oxidation Equipment: Gas Reacts With the Wafers

Although oxidation equipment is complex, the simplified image below shows the key components.



▲ Figure 8. Structure of wafer oxidation equipment wafer. Additionally, some dummy wafers are inserted alongside the loaded The dummy wafers are used to fill in the difference in reaction speed between the wafers at both ends of the device, which inevitably occurs due to the structure of the device. As dozens of wafers are simultaneously injected into the oxidation equipment, oxidation is considered to be a relatively quick process.

<Other articles from this series>

Semiconductor Front-End Process Episode 1: The Birth of Computers, Transistors, and Semiconductors

Semiconductor Front-end Process Episode 3: Forming Patterns on Wafers Through Photolithography

Semiconductor Front-End Process Episode 4: Etching Fine and Identical Wafer Patterns

Semiconductor Front-End Process Episode 5: Supporting Wafer Miniaturization Through Deposition

Semiconductor Front-End Process Episode 6: Metallization Provides the Connections That Bring Semiconductors to Life

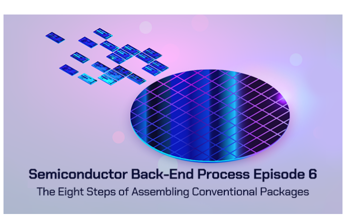
Semiconductor Back-End Process Episode 1: Understanding Semiconductor Testing

Semiconductor Back-End Process, Episode 2: The Roles, Process, and Evolution of Semiconductor Packaging

Semiconductor Back-End Process Episode 3: Understanding the Different Types of Semiconductor Packages

TAG #semiconductor #front-end process #Oxidation

RELATED POSTS



Semiconductor Back-End Process Episode 6: The Eight Steps of Assembling

Open Communication, Creative Research, and Agile Problem-Solving: The Keys

The Story Behind SK hynix's AAA-Rated Global Compliance Program

[Tech Pathfinder] Small Size, Big Impact: Unveiling the Latest Advances in

SK hynix NEWSROOM

ENG

Contact us SK hynix.com Sitemap Careers Terms of Use TOP