Micron STEM

Cookie Wafer Fabrication Presentation

Reviewed 2025

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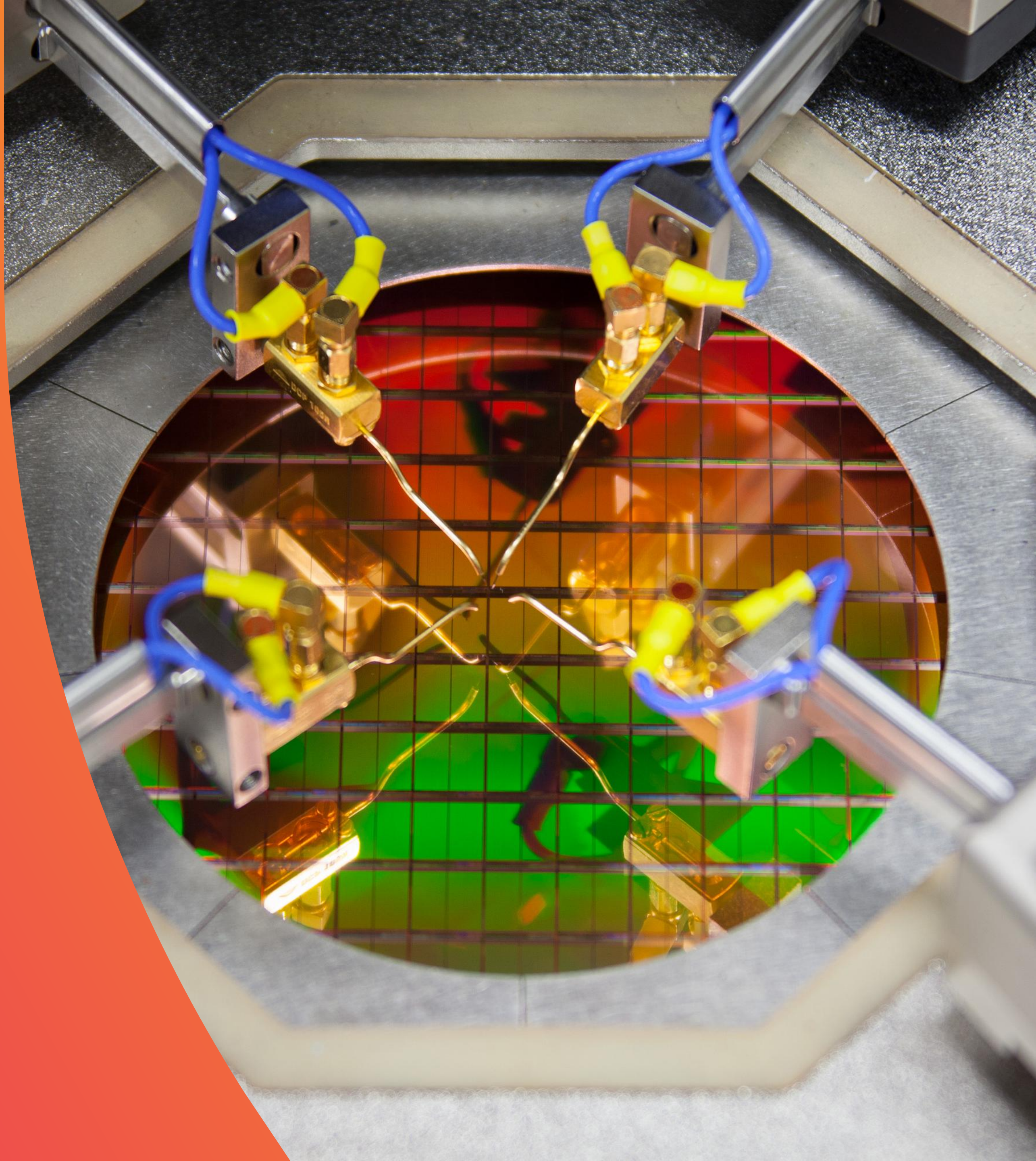
What is a Semiconductor?



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Hi, my name is Eliza Stack and I am an engineer at Micron. I will be your guide through this fun cookie wafer fabrication module!

Semiconductors

Semiconductors are a group of materials with very interesting properties. In their pure state they are not very good electrical conductors (like copper), and they are not very good insulators either (like rubber).

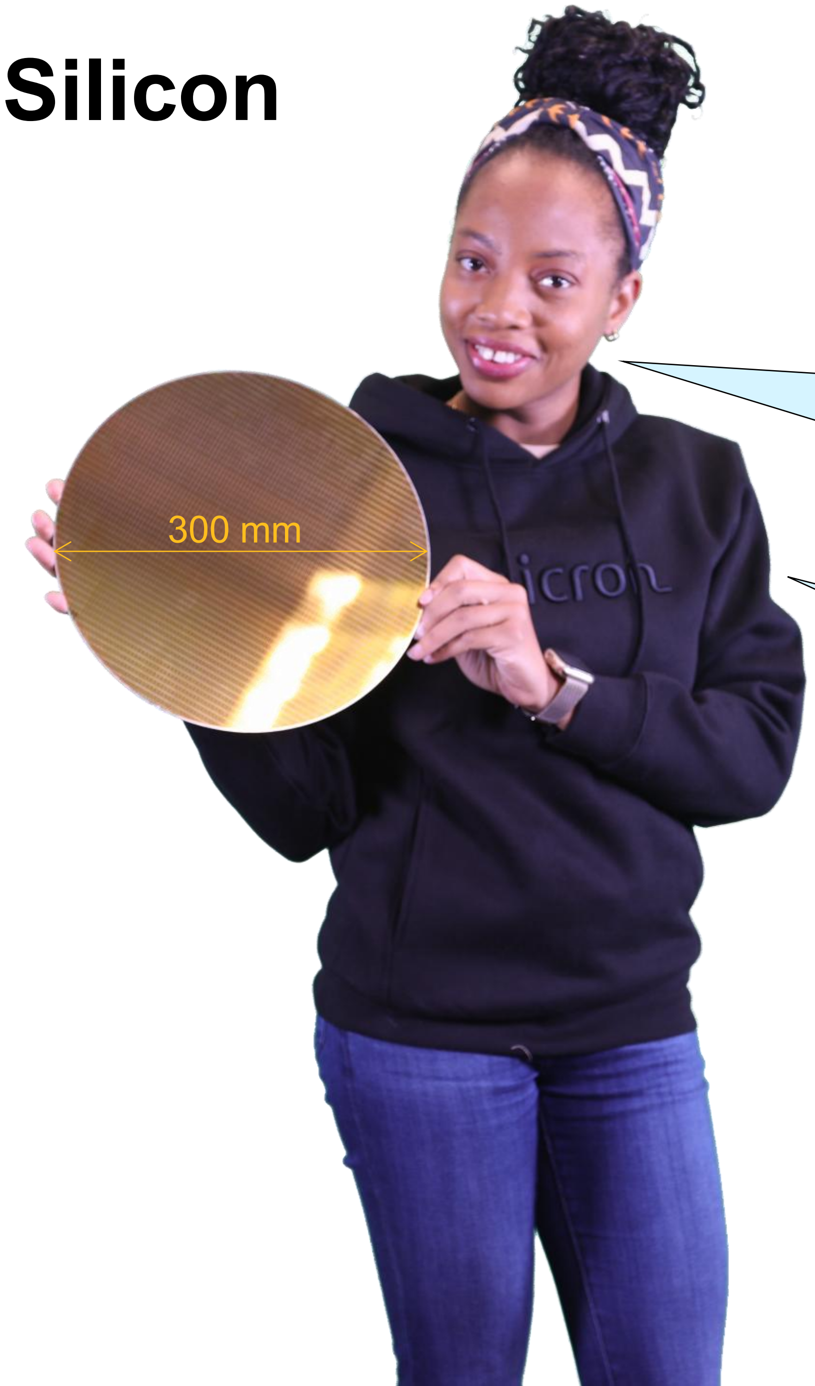
Scientists and engineers have discovered how to modify the properties of semiconductors to make them more conductive under certain conditions or make them behave as an insulator under different conditions.

The ability to control the electrical conductivity of semiconductor materials allows us to fabricate very, very small electrical circuits on these semiconductor materials. This has revolutionized the computer industry!

Later I will explain the exact process we use to modify the electrical properties of semiconductors. (Psst! It’s called “doping”, and we will use sprinkles to represent that!)

To learn more about conductors and insulators, you can check the K-12 STEM Electricity module at www.micron.com/educatorhub

Silicon



Silicon is a semiconductor material. Let's explore why silicon is the semiconductor material of choice to build many types of semiconductor chips.

At Micron we build our semiconductor memory chips on 300 mm diameter wafers made of silicon just like this one!

Note: in this session I am holding wafers and reticles in my hands to show the scale of these items, but we never touch these items during fabrication to prevent contaminating them!

To learn more about the silicon element, you can check the K-12 STEM Atoms Level 2 and Atoms Level 3 modules at www.micron.com/educatorhub

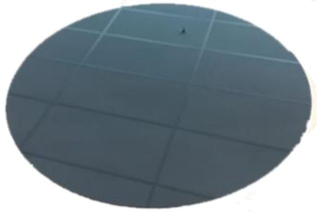
Sand to Chip

Silicon is a semiconductor and the 2nd most abundant element by mass in the Earth's crust (2nd to Oxygen) making it relatively inexpensive and widely available hence an ideal choice to build many types of semiconductor chips.

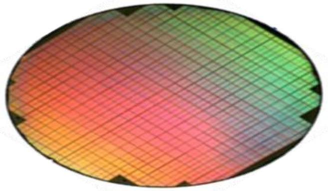
Semiconductor Manufacturing Process

Sand

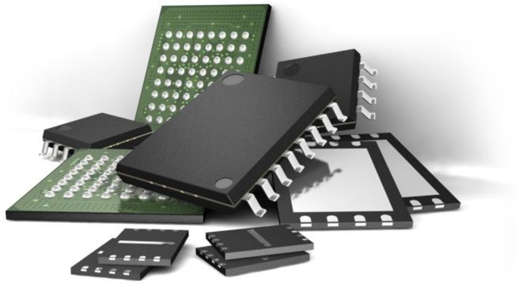
Silicon



Silicon wafer



Wafer fully processed



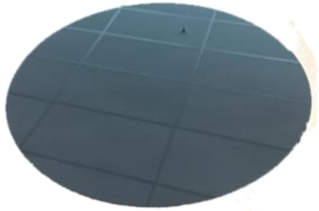
Chip
(also know as Integrated Circuit or IC)

Fabrication

Fabrication is the multi-step process of building circuits on a semiconductor wafer substrate. Wafers are exposed to hundreds of different processes inside different specialized tools or equipment. Fabrication takes place in a **cleanroom** where all aspects of production (temperature, chemistries, moisture, contamination, etc.) are tightly controlled. The cleanroom is also called a "Fab". Micron's fabs never stop! They run 24 hours a day, 7 days a week, all 365 days of the year!

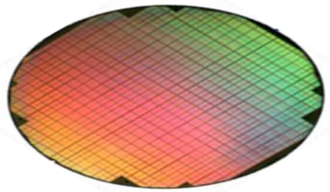
Were you wondering how long it takes to complete fabrication? Depends on the product but it takes more than a month!

Silicon wafers are purchased from suppliers



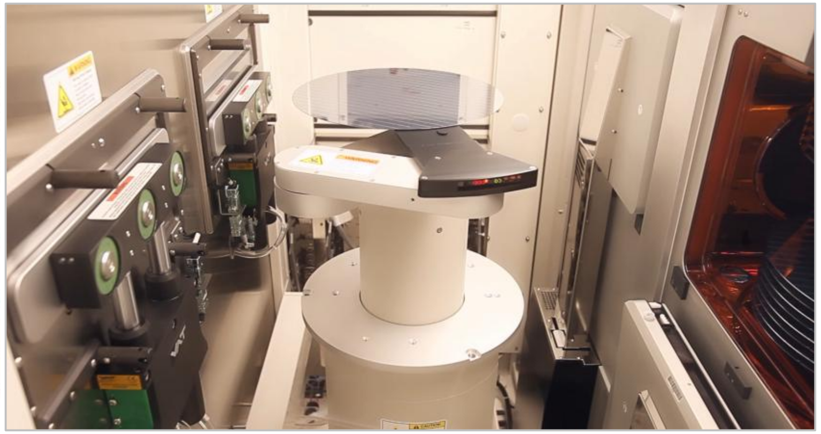
Silicon wafer

Fabrication (also known as Manufacturing)



Completed wafer ready for testing

Picture inside a cleanroom fab

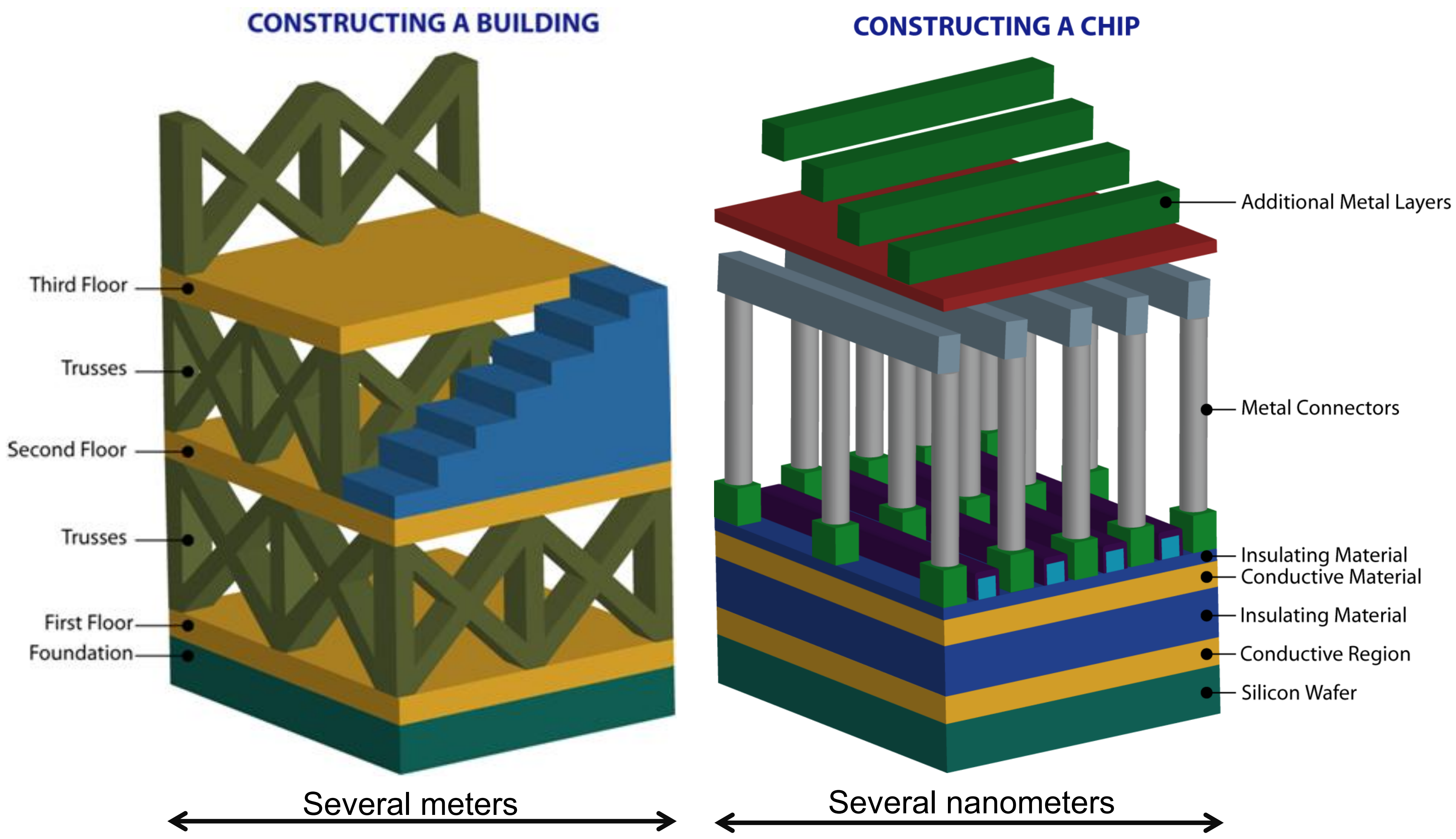


Picture inside a tool: robot that handles wafers

Picture of an equipment or tool

Construction Analogy

- The wafer fabrication process is similar to the construction of a building, except on a MUCH smaller scale.
- We start out with designs and plans and then build the foundation followed by many interconnecting layers (or floors).

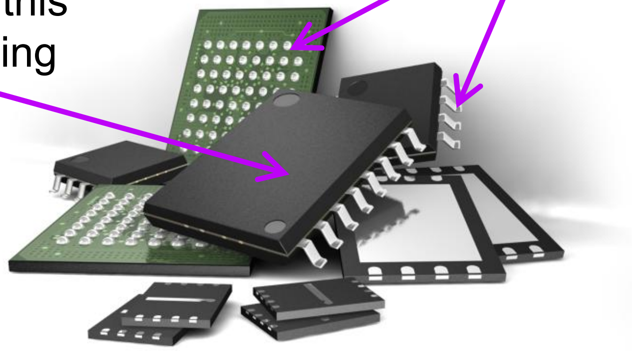


From Wafer to Chip

After the wafer completes its fabrication process, each of these little rectangles is called a die. We build hundreds of die on one silicon wafer. Once we test them and cut them, each good die is then going to be packaged into a chip with connectors.

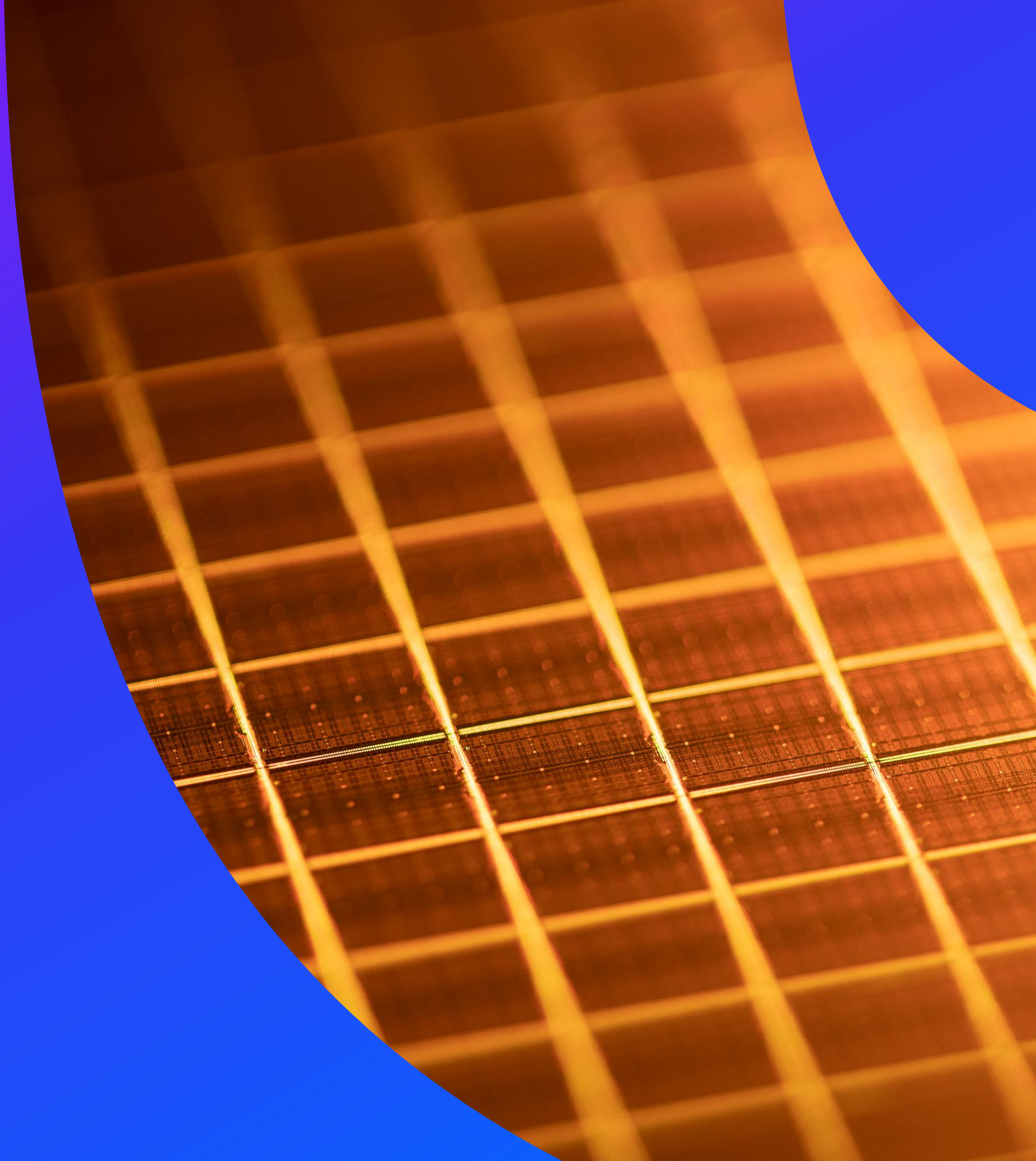
These pins and bumps are the chip connectors

The tiny die is embedded inside this protective packaging



Chips

Cookie Wafer Fabrication



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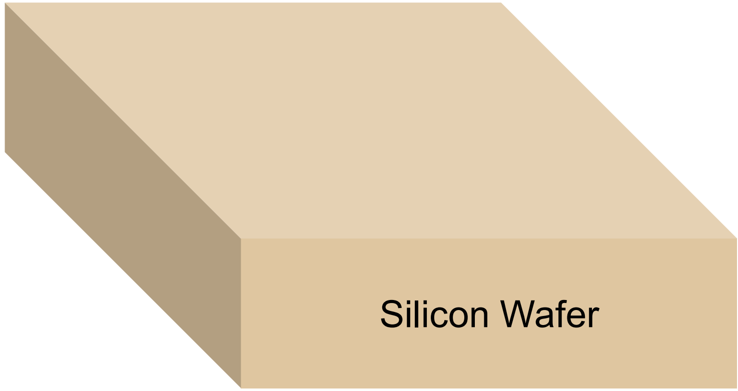
Wafer Inspection and clean

The fabrication process starts with bare silicon wafers. When the silicon wafers are received, they are inspected and then they are put in boxes of up to 25 wafers. The boxes protect the wafers during transport from tool to tool. The first step the wafers go through is a clean to ensure there is no contamination on them before the fabrication starts.

Then we are ready to start building electrical circuits on the clean silicon wafer substrate.

Now starts the fun! We are going to learn about wafer fabrication using cookies!

Wafer Start



Perspective view

Side view

Cookie view

Diffusion

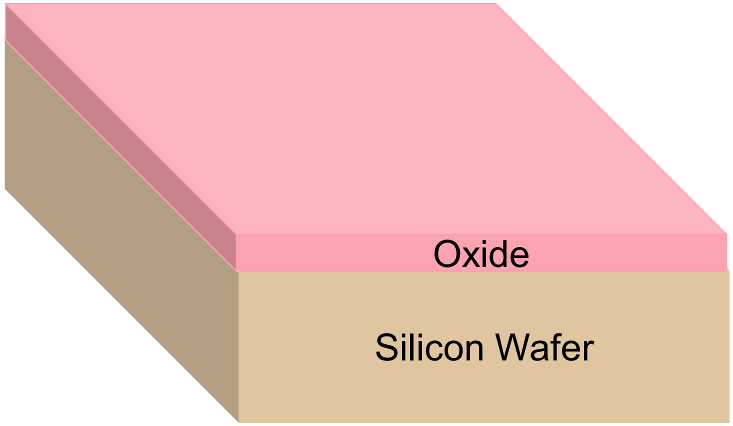
After cleaning the wafer, the next fabrication step is a process to deposit or grow a thin material on the wafer surface called silicon dioxide, or SiO_2 - usually called “oxide” in the semiconductor industry. This oxide is **non-conductive** and acts like armor to protect the silicon wafer.

There are different types of equipment or tools in the fab used to deposit or grow a layer of material on the wafer. One of these tools is called a Diffusion furnace.

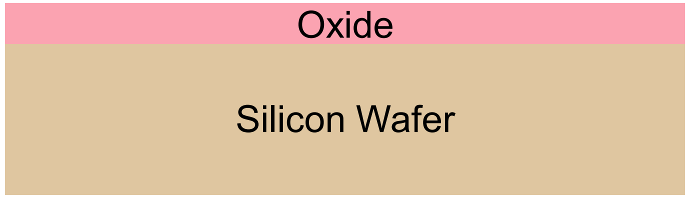
The wafers are placed into a Diffusion furnace that can be as hot as 1000 degrees Celsius and one or more gases are introduced into the furnace. The chemical reaction causes a new material to be deposited or grown on the wafer.

This first layer of frosting represents the oxide layer. Go ahead and spread the frosting as uniformly as you can!

Note: water boiling temperature is 100 degrees Celsius. So, this furnace is VERY HOT!



Perspective view



Side view

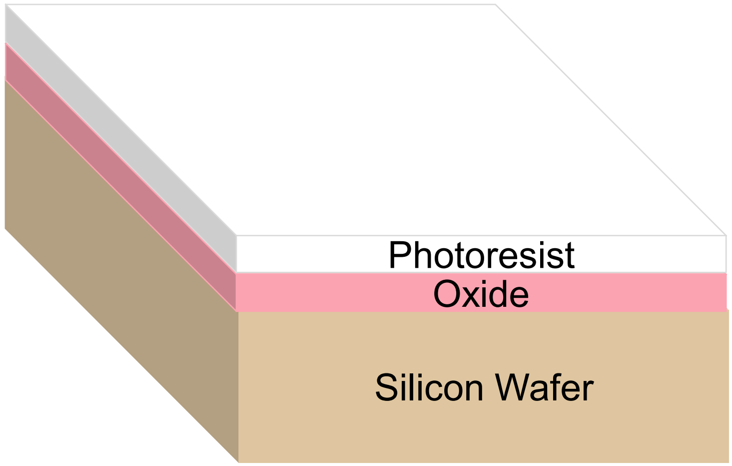
Cookie view

Photolithography

A variety of patterns are placed on the wafers – much like a house starts with the layout or blueprint. Many different patterns are used to complete the fabrication of chip circuitry. Patterns are exposed on wafers in the Photolithography area – in 3 steps:

STEP 1 – Coat & Bake

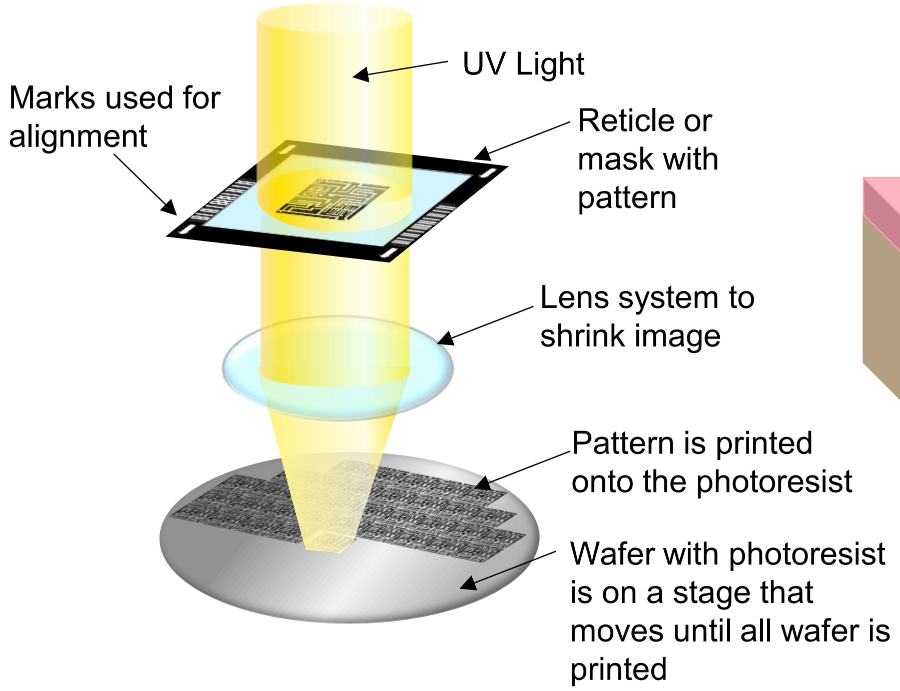
Deposit a material on wafer surface that is sensitive to UV light. This material is called photoresist. Being sensitive to UV light means that it can change properties when exposed to (ultraviolet) light.



Perspective view

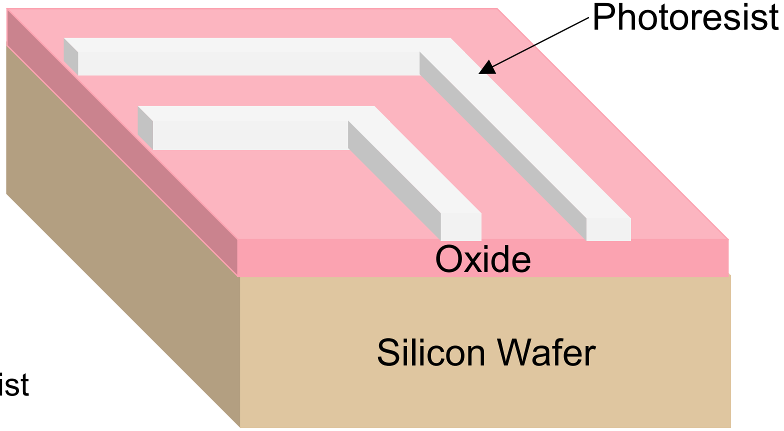
STEP 2 – Align & Expose

Align a "Mask" with a circuit pattern on the wafer and then shine UV light through clear regions of the mask to transfer the circuit pattern into the photoresist



STEP 3 – Develop

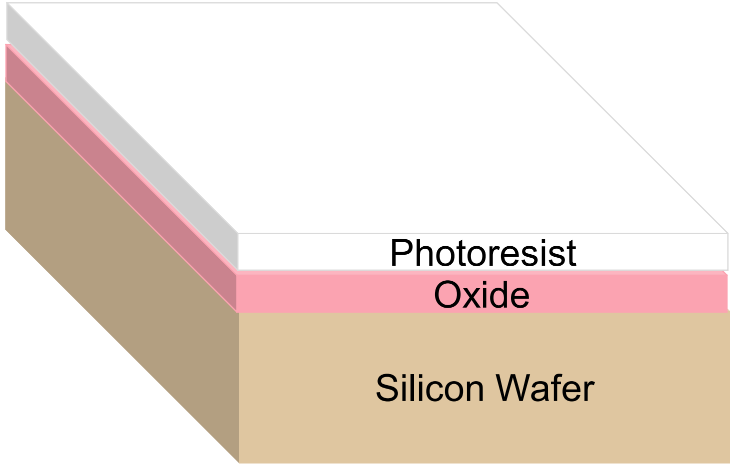
Using a chemical solution, the photoresist areas that were hit by the UV light are removed



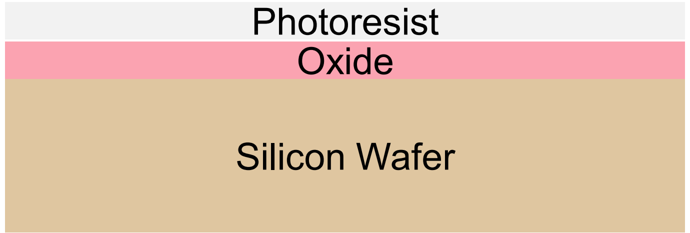
Perspective view

Photolithography – Step 1: Coat & Bake

- Apply layer of UV-sensitive photoresist on top of oxide layer. During the Coat process the photoresist is in viscous liquid form.
- Photoresist acts like the film in a camera and allows transfer of a pattern onto the wafer
- The process includes a Bake because the photoresist is heated (baked) to harden it



Perspective view

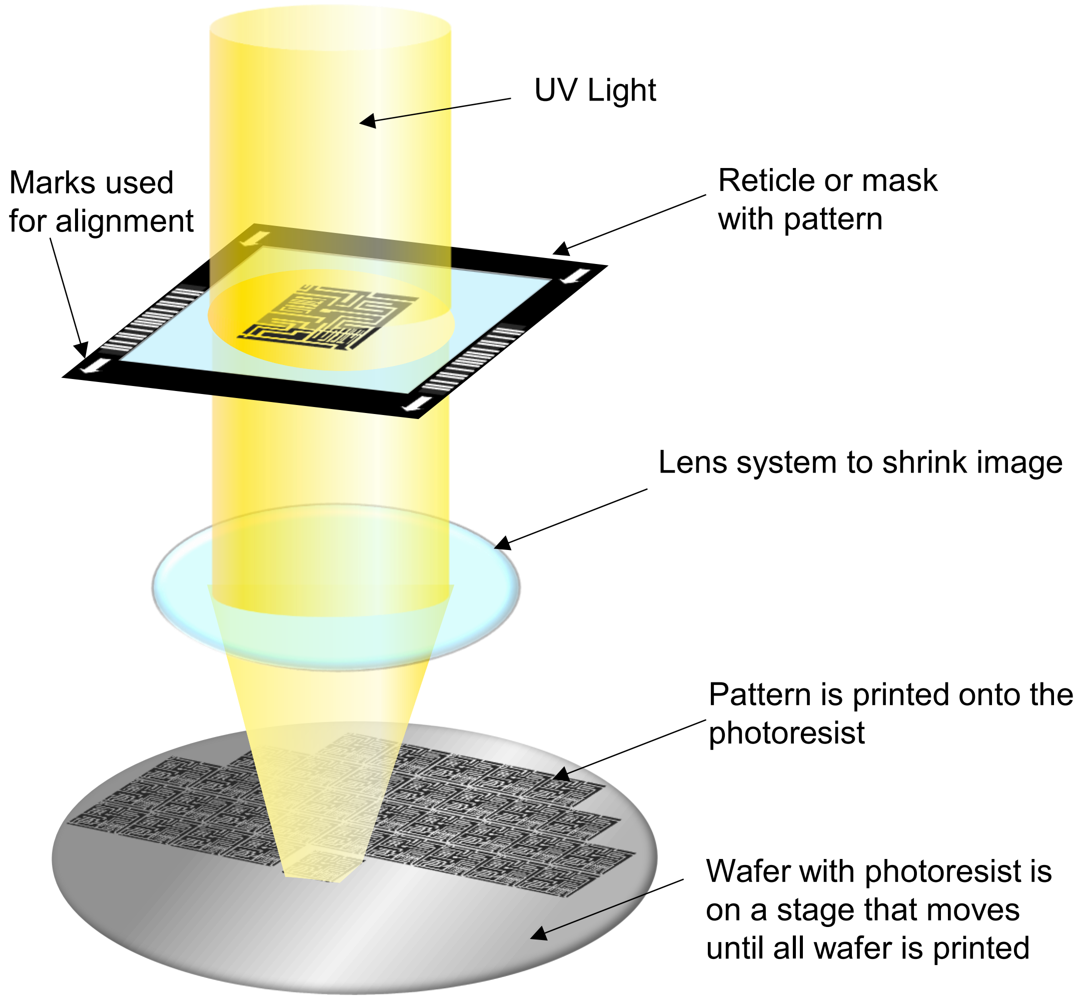


Side view

Cookie view

Photolithography – Step: 2 Align and Expose

- Align a reticle or mask containing the pattern to transfer onto the photoresist. The reticle has some dark areas and some transparent areas. Light can go through the transparent areas.
- UV light passes through the reticle and then passes through a lens system. The lens system shrinks down the reticle's pattern. Next the light continues and transfers the shrunken pattern onto the photoresist.
- The photoresist regions hit by UV light are chemically altered. These altered regions are easy to remove in the next Develop step.

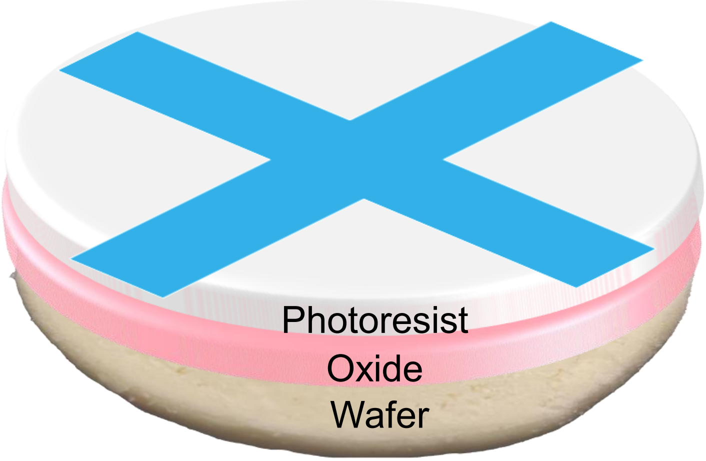


Photolithography – Step 2: Align and Expose

Here is a reticle or mask used at Micron with a pattern we want to transfer onto photoresist. Micron manufactures these reticles in our own Mask Shop in Boise, Idaho!

Cookie Wafer Step:

- The ‘X’ pattern represents the dark pattern in the reticle or mask.
- We want to transfer this pattern onto the photoresist (top frosting layer)
- To represent a mask, place the ‘X’ pattern on top of the frosting as shown below

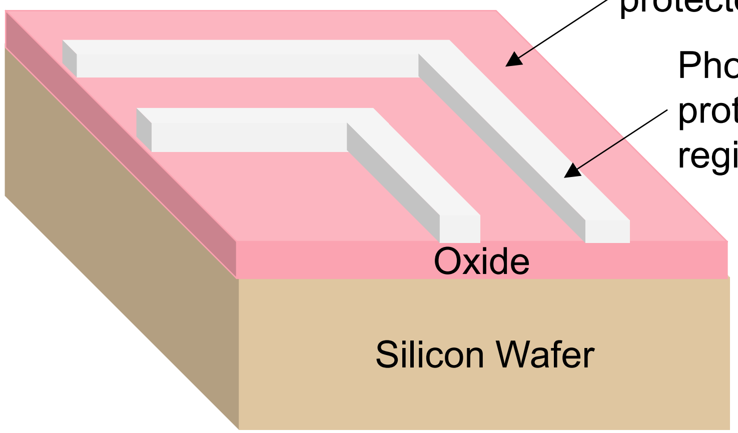


Cookie view

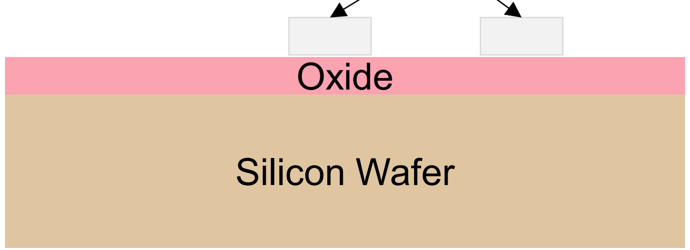
Photolithography – Step 3: Develop

- "Develop" is when a chemical solution is placed on the wafer and the regions of the photoresist exposed to light are removed by the chemical solution. Note: this chemical solution only affects the photoresist and not the films under the photoresist.
- After the Develop step, we now have some oxide film still protected by the photoresist and some oxide not protected by photoresist

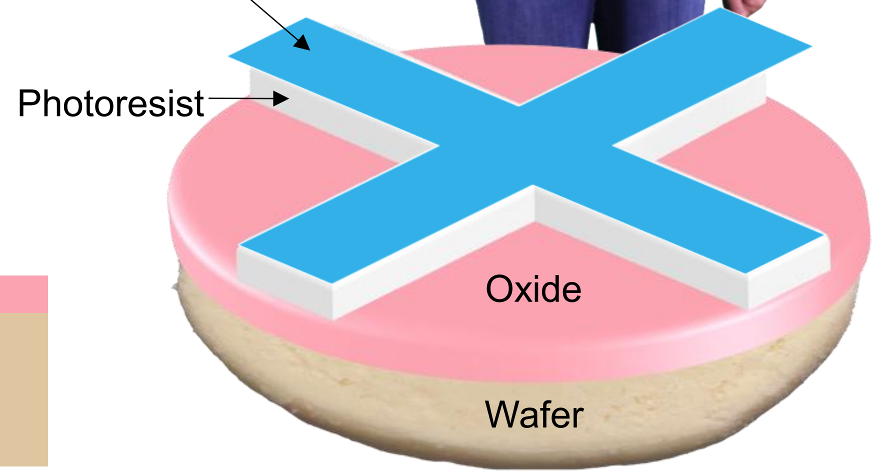
This is a tricky step ☺ Be careful when using a knife to remove the top photoresist frosting! And make sure no lower oxide frosting gets removed! After you are done, peel away the "X".



Perspective view



Side view



Cookie view

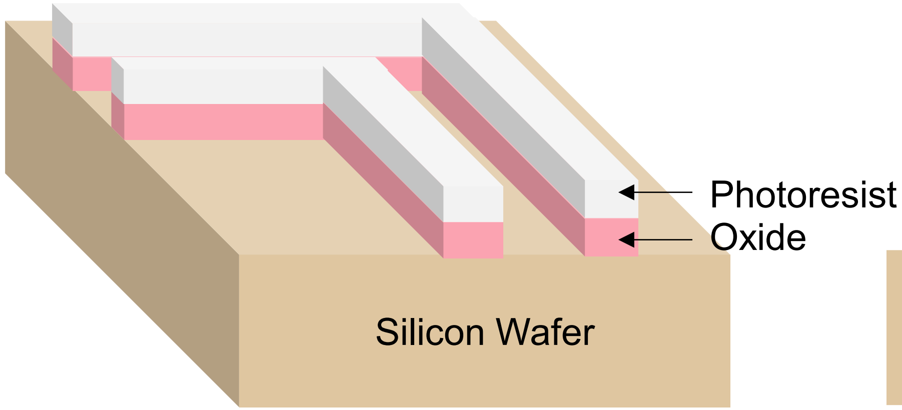
Etch

The next fabrication step is a process to remove the oxide film (bottom frosting) from regions not protected with photoresist.

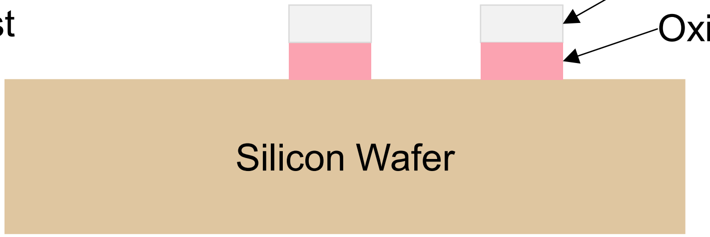
There are different types of equipment or tools in the fab used to **remove** materials from a wafer:

- Dry Etch tools use gases/plasma to etch away unwanted material.
- Wet Etch tools use liquid chemicals to remove unwanted material.

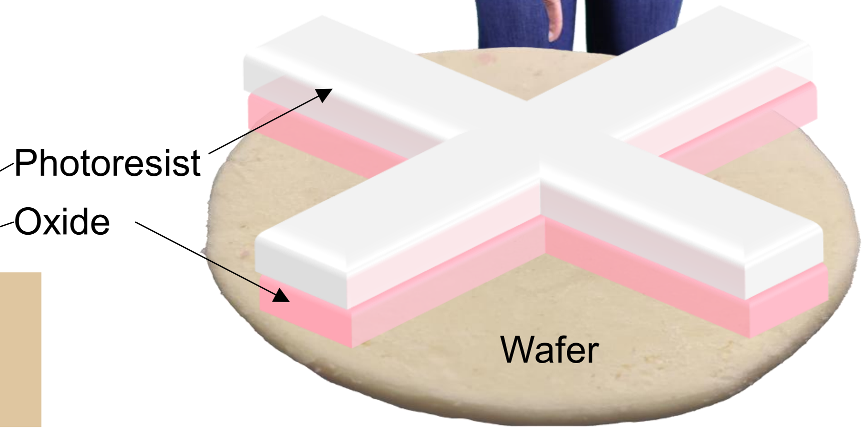
To represent the etch process, remove the lower oxide frosting not protected by photoresist.



Perspective view



Side view

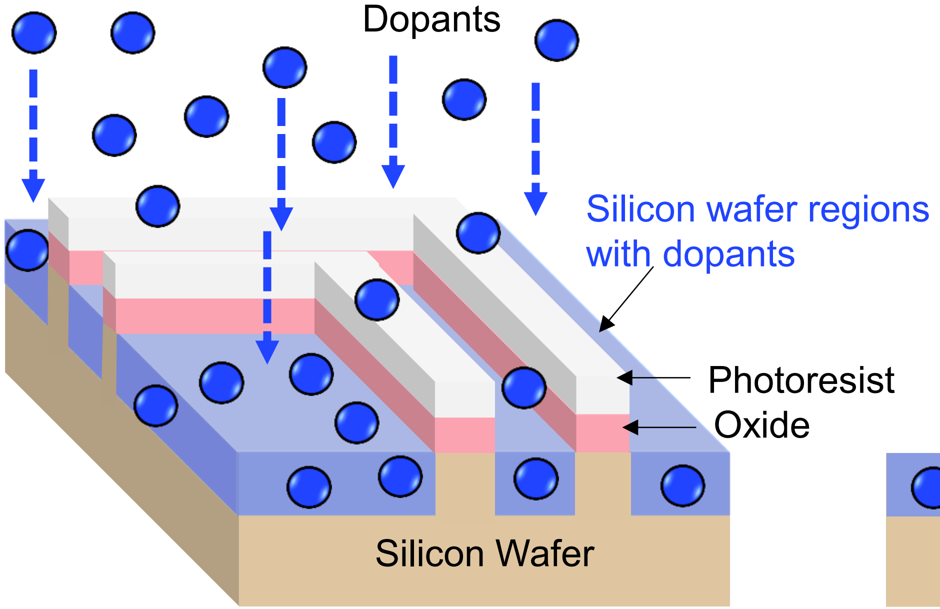


Cookie view

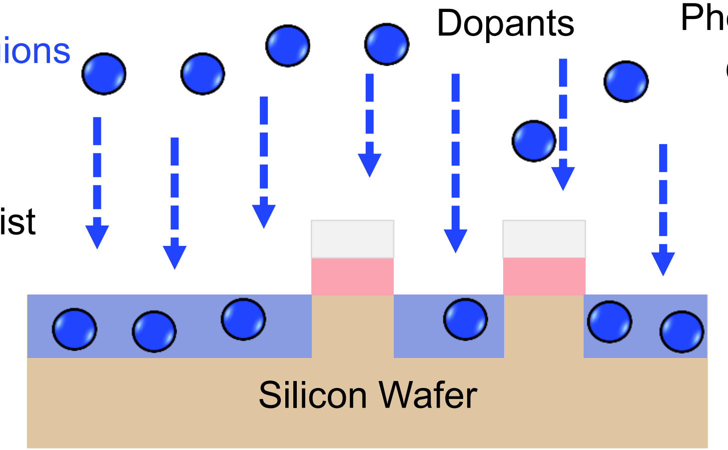
Implant (a.k.a. Doping)

The next fabrication step called Implant or Doping is performed to change electrical characteristics of the silicon semiconductor material in unprotected regions of the wafer.

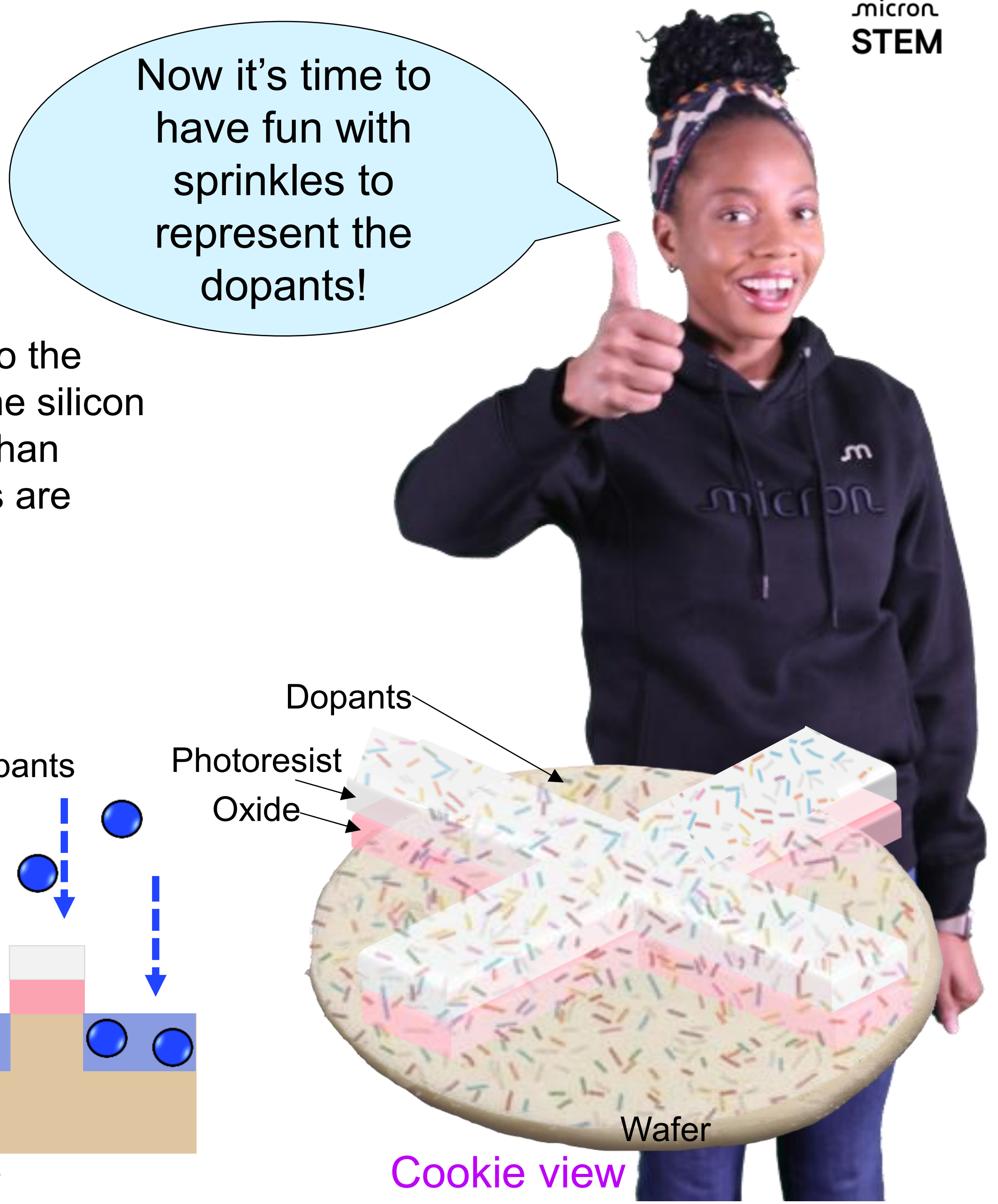
During an Implant step, specific ions* are accelerated and implanted into the areas of the silicon wafer not protected by photoresist. The regions of the silicon that now have these ions implanted have different electrical properties than protected regions of the wafer. The most common ions used as dopants are Phosphorous, Arsenic and Boron.



Perspective view



Side view



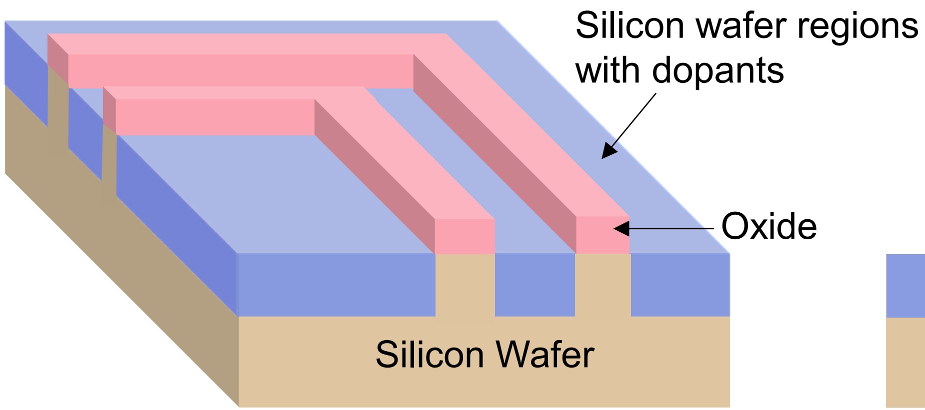
Cookie view

Ions: atoms that are missing electrons or have extra electrons

Strip photoresist

The next fabrication process will remove the photoresist which is no longer needed on wafer as it has already served its purpose. We call this process stripping the photoresist, or "Strip". This can be done with a Dry Etch process using gases/plasma to remove the photoresist, or a Wet Etch process using a chemical bath. After strip, all photoresist is removed.

Carefully remove the photoresist frosting with the knife.
And big applause!
You finished the Cookie Wafer Fabrication activity!



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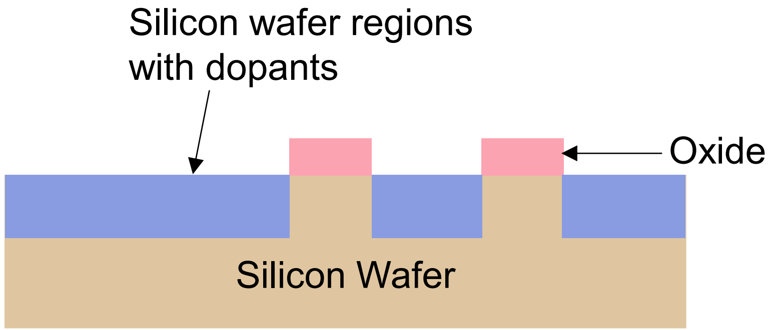
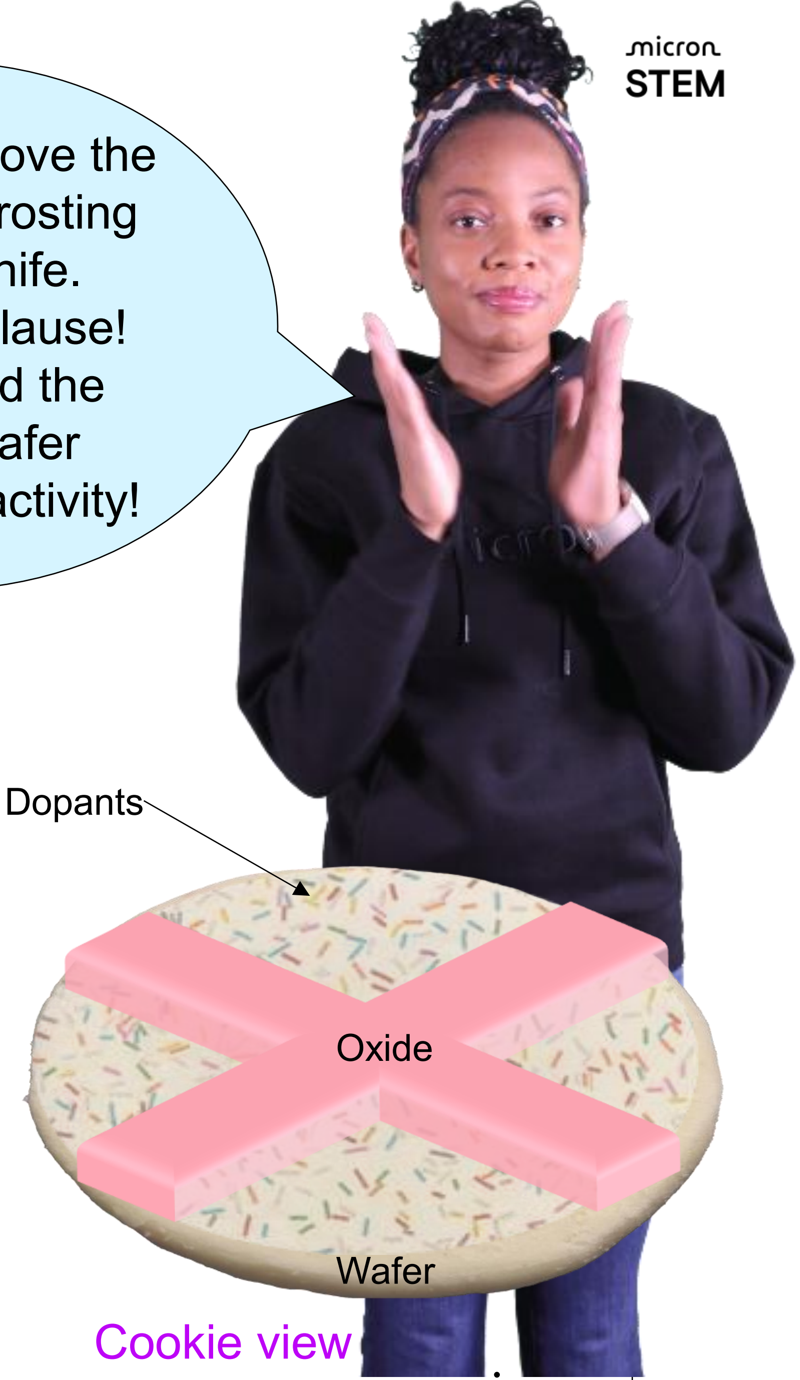


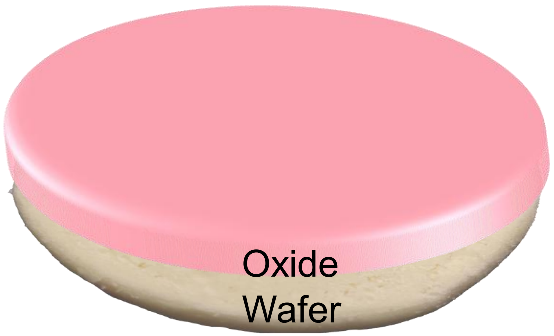
Side view



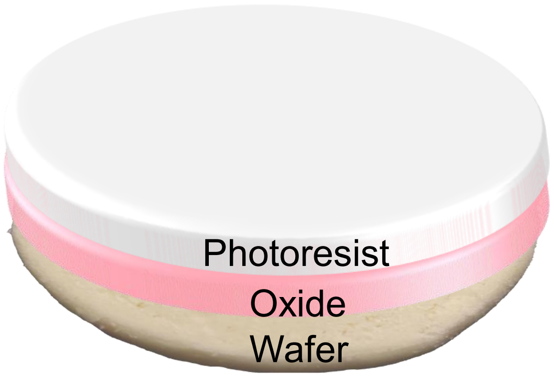
Cookie view

Cookie wafer fabrication process activity summary

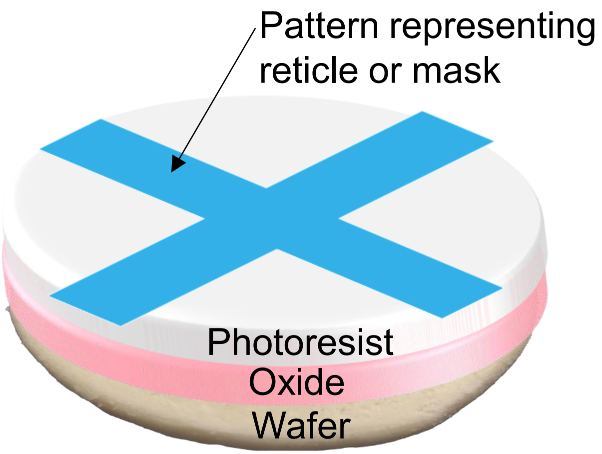
Start with a Silicon wafer



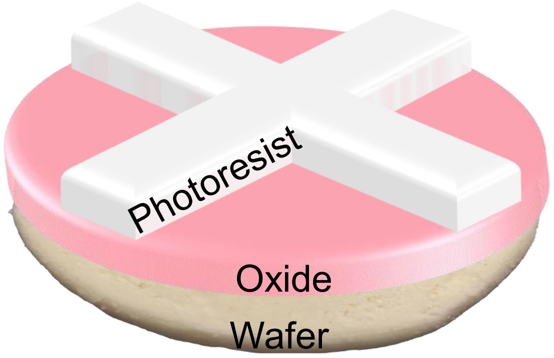
1) Oxide layer



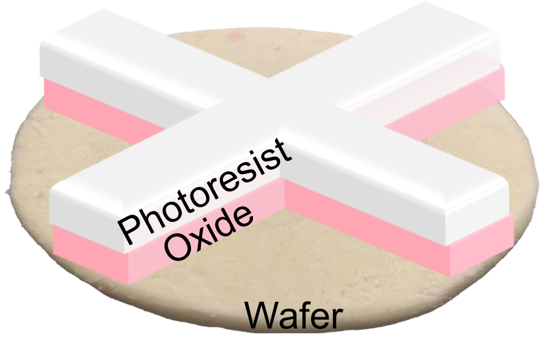
2) Photoresist Coat & Bake



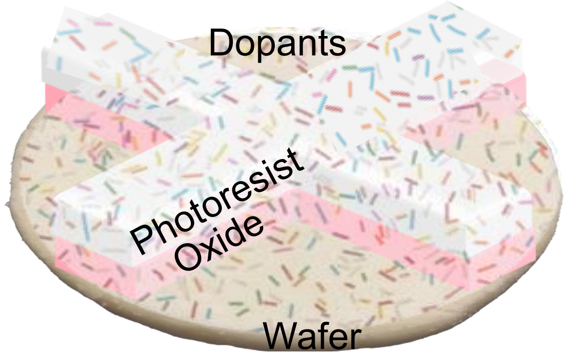
3) Photolithography Align & Expose



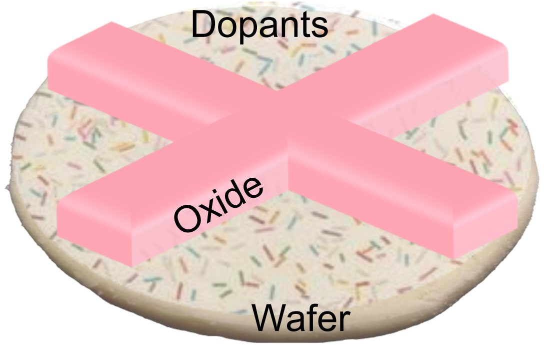
4) Photolithography Develop



5) Etch



6) Implant



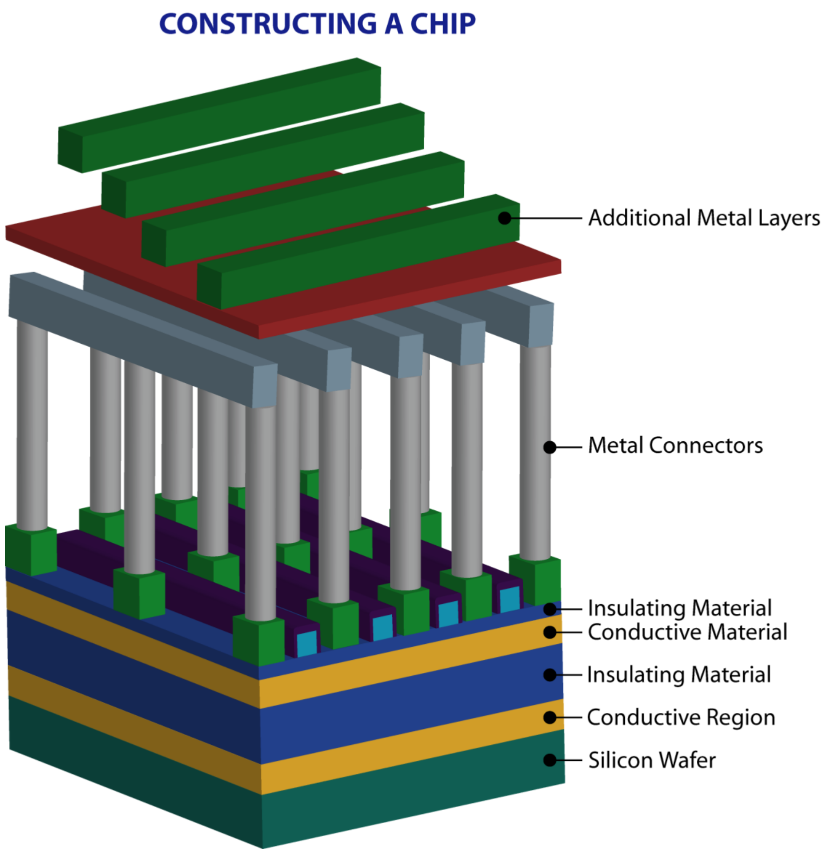
7) Strip photoresist

Wafer fabrication process

During the memory semiconductor manufacturing process, a wafer will go through a specific sequence of process steps until the total design is complete.

For example, a wafer may go through dozens of Photolithography steps, where each time a different pattern is printed on photoresist; it may go through 10 or more Implant steps where each time a different region of the wafer is implanted with different dopants; and it may go through dozens or hundreds of deposition steps where different materials are deposited on the wafer.

It can take several hundreds of process steps and more than a month until the wafer fabrication is complete!



I had a lot of fun showing you what the wafer fabrication process is like!
I hope you had fun too and feel inspired to keep exploring the fascinating world of semiconductors!

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