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Week-12
Lecture-60

Lec 60: Metamaterial Fabrication Technique: Pattern Transfer

Introduction to Microwave and Optical Metamaterials

Lecture 60

Metamaterial Fabrication Technique: Pattern Transfer

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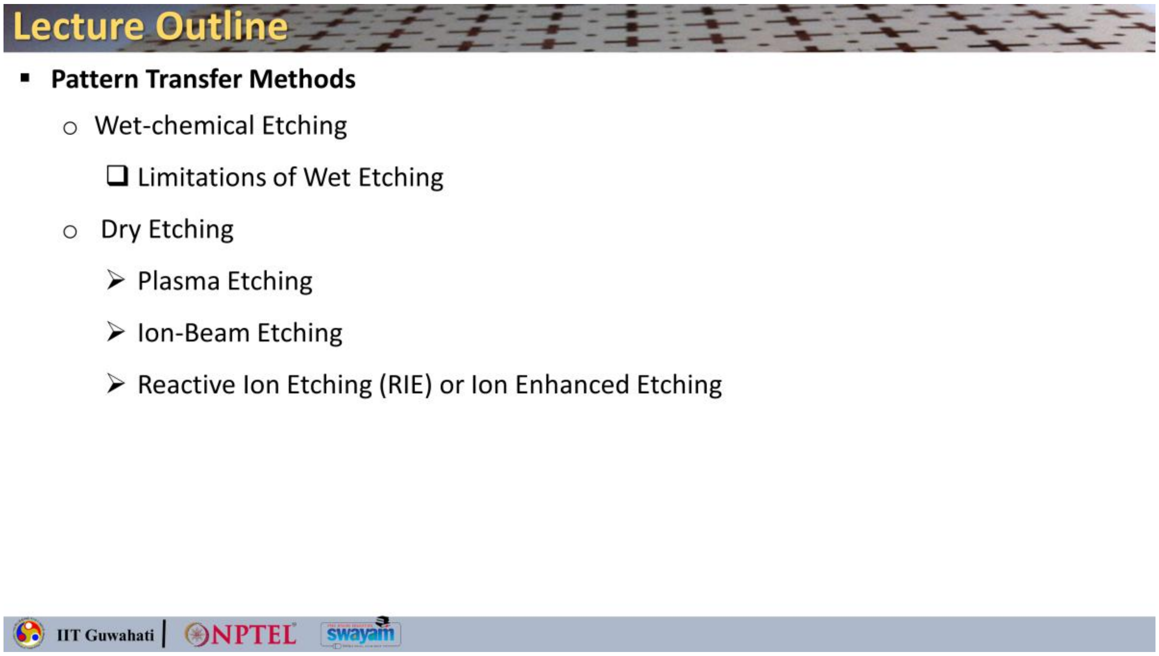
Hello everyone, welcome to Lecture 60 of the online course on Interaction with Microwave and Optical Metamaterials. Today's lecture we will be looking into metamaterial fabrication and metamaterial fabrication technique especially pattern transfer ok.

So, here is the lecture outline.



Lecture Outline

- **Pattern Transfer Methods**
  - Wet-chemical Etching
    - ❑ Limitations of Wet Etching
  - Dry Etching
    - ➢ Plasma Etching
    - ➢ Ion-Beam Etching
    - ➢ Reactive Ion Etching (RIE) or Ion Enhanced Etching

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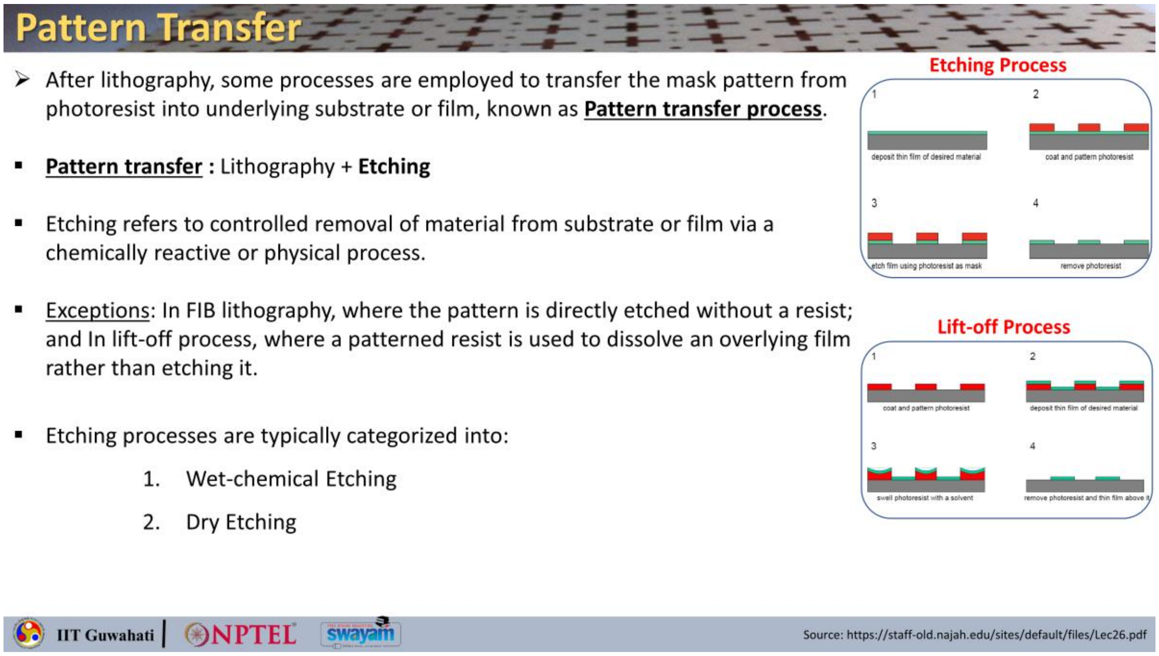
we will discuss the pattern transfer methods: wet chemical etching, we will discuss about the limitations of wet etching and then we will look into dry etching, different types of dry etching like plasma etching, ion beam etching and reactive ion etching or it is also called ion enhanced etching.

So, what is pattern transfer?



Pattern Transfer

- ➢ After lithography, some processes are employed to transfer the mask pattern from photoresist into underlying substrate or film, known as **Pattern transfer process**.
- **Pattern transfer :** Lithography + **Etching**
- Etching refers to controlled removal of material from substrate or film via a chemically reactive or physical process.
- Exceptions: In FIB lithography, where the pattern is directly etched without a resist; and In lift-off process, where a patterned resist is used to dissolve an overlying film rather than etching it.
- Etching processes are typically categorized into:
  1. Wet-chemical Etching
  2. Dry Etching

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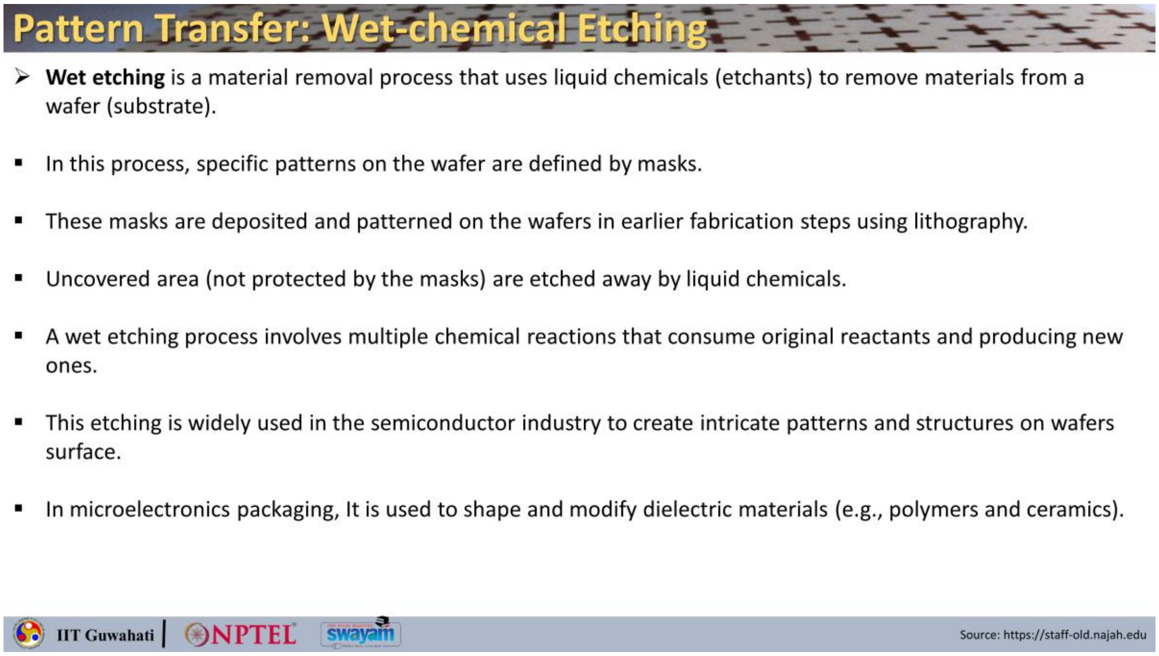
Source: https://staff-old.najah.edu/sites/default/files/Lec26.pdf

After lithography, some processes are basically applied to transfer the mask pattern from the photoresist into the underlying substrate or film, known as pattern transfer. So, pattern transfer basically requires lithography and etching.

So, here etching process is basically referring to the removal of it is called controlled removal of the materials from the substrate or film via a chemically reactive or physical process. So, some exceptions, like in FIB lithography, exist where the patterns are basically directly etched without a resist and in the lift-up process where a pattern resist is used to dissolve an underlying film rather than to etch it. So, etching process typically can be characterized into chemical or wet chemical etching and dry etching. So, here is a brief schematic of the etching process.

First, you deposit a thin film of the desired material, then you coat and pattern the photoresist. You etch your film using photoresist as the mask, and then you finally remove the photoresist, and you get the pattern. The lift-up process is like this: you coat and pattern photoresist first. And then you deposit the thin film of the desired material so films get deposited here as well. Then you swell the photoresist with a solvent and remove the photoresist and thin film above it.

So let's look into wet-chemical etching.



Pattern Transfer: Wet-chemical Etching

- **Wet etching** is a material removal process that uses liquid chemicals (etchants) to remove materials from a wafer (substrate).
- In this process, specific patterns on the wafer are defined by masks.
- These masks are deposited and patterned on the wafers in earlier fabrication steps using lithography.
- Uncovered area (not protected by the masks) are etched away by liquid chemicals.
- A wet etching process involves multiple chemical reactions that consume original reactants and producing new ones.
- This etching is widely used in the semiconductor industry to create intricate patterns and structures on wafers surface.
- In microelectronics packaging, It is used to shape and modify dielectric materials (e.g., polymers and ceramics).

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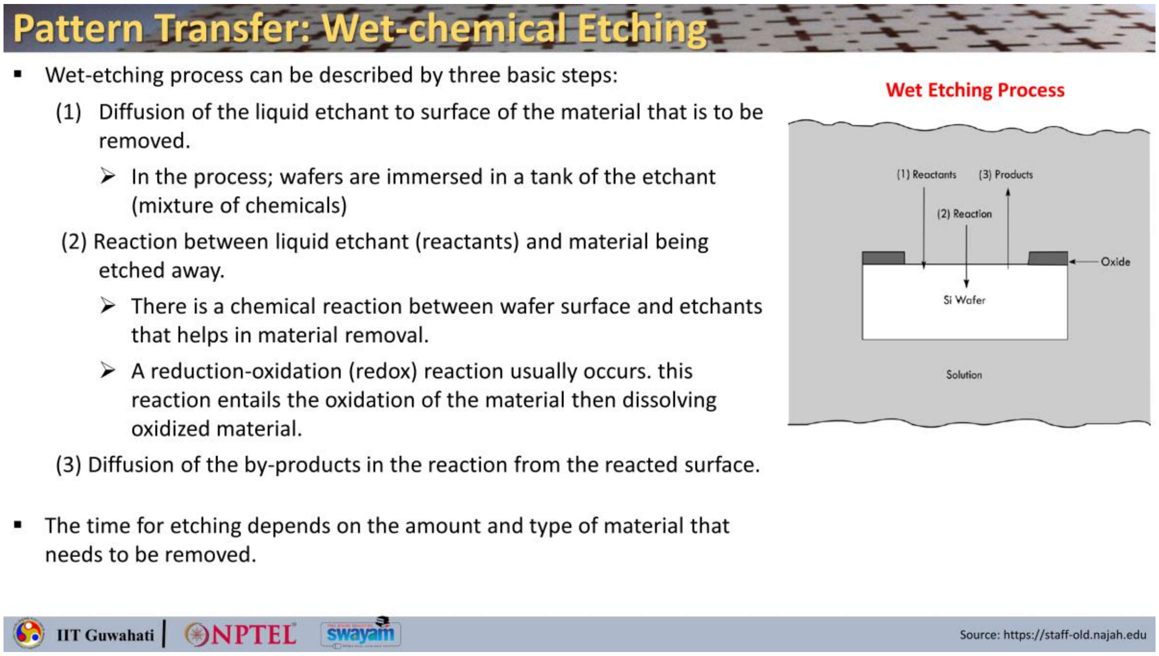
So wet etching is a material removal process that uses liquid chemicals or agents to remove materials from a wafer or substrate. So, in this process, specific patterns on the wafer are designed using the masks. These masks are deposited and patterned on the wafer in earlier fabrication steps using lithography. Now, uncovered areas that are not protected by the masks are etched away by liquid chemicals.

A wet etching process basically involves multiple chemical reactions that consume original reactants and produce new ones. This etching is widely used in the semiconductor industry to create intricate patterns and structures on wafer surfaces. In microelectronics packaging, it is basically used to shape and modify the dielectric material something like the polymers and the ceramics.



Pattern Transfer: Wet-chemical Etching

- Wet-etching process can be described by three basic steps:
  - (1) Diffusion of the liquid etchant to surface of the material that is to be removed.
    - ➢ In the process; wafers are immersed in a tank of the etchant (mixture of chemicals)
  - (2) Reaction between liquid etchant (reactants) and material being etched away.
    - ➢ There is a chemical reaction between wafer surface and etchants that helps in material removal.
    - ➢ A reduction-oxidation (redox) reaction usually occurs. this reaction entails the oxidation of the material then dissolving oxidized material.
  - (3) Diffusion of the by-products in the reaction from the reacted surface.
- The time for etching depends on the amount and type of material that needs to be removed.

Wet Etching Process

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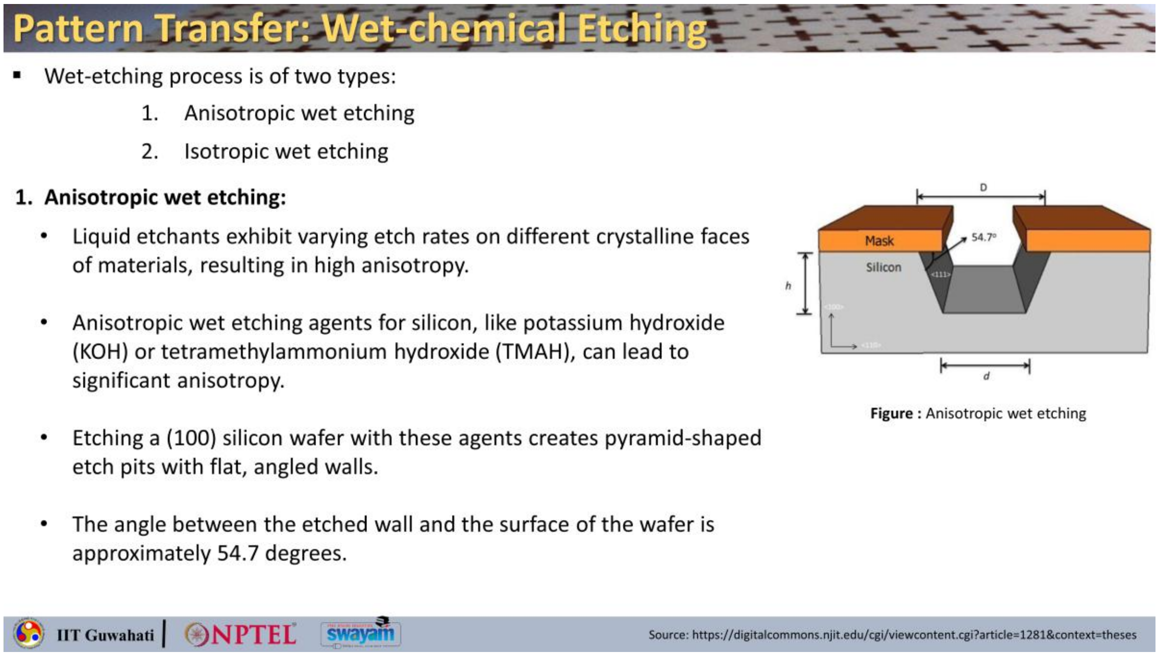
So, wet etching can be described in three basic steps. First, you have the diffusion of liquid etchant to the surface of the material that is to be removed.

So, in this process, the wafers are basically immersed in a tank of etchant, which is basically a mixture of chemicals. Then the reaction takes place between this liquid etchant and the material that is being etched away. So, there is basically a chemical reaction between the wafer surface and the etchant that will remove the material. So, reduction-oxidation, or redox, reactions basically take place. So, this reaction entails the oxidation of the material and then dissolving the oxidized material.

Diffusion of the byproducts in the reaction occurs from the reacted surface, which is the last step. So, in this way, the process works. The time for etching basically depends on the amount and type of material that you are going to remove.



Pattern Transfer: Wet-chemical Etching

- Wet-etching process is of two types:
    1. Anisotropic wet etching
    2. Isotropic wet etching

1. Anisotropic wet etching:

- Liquid etchants exhibit varying etch rates on different crystalline faces of materials, resulting in high anisotropy.
- Anisotropic wet etching agents for silicon, like potassium hydroxide (KOH) or tetramethylammonium hydroxide (TMAH), can lead to significant anisotropy.
- Etching a (100) silicon wafer with these agents creates pyramid-shaped etch pits with flat, angled walls.
- The angle between the etched wall and the surface of the wafer is approximately 54.7 degrees.

Figure : Anisotropic wet etching

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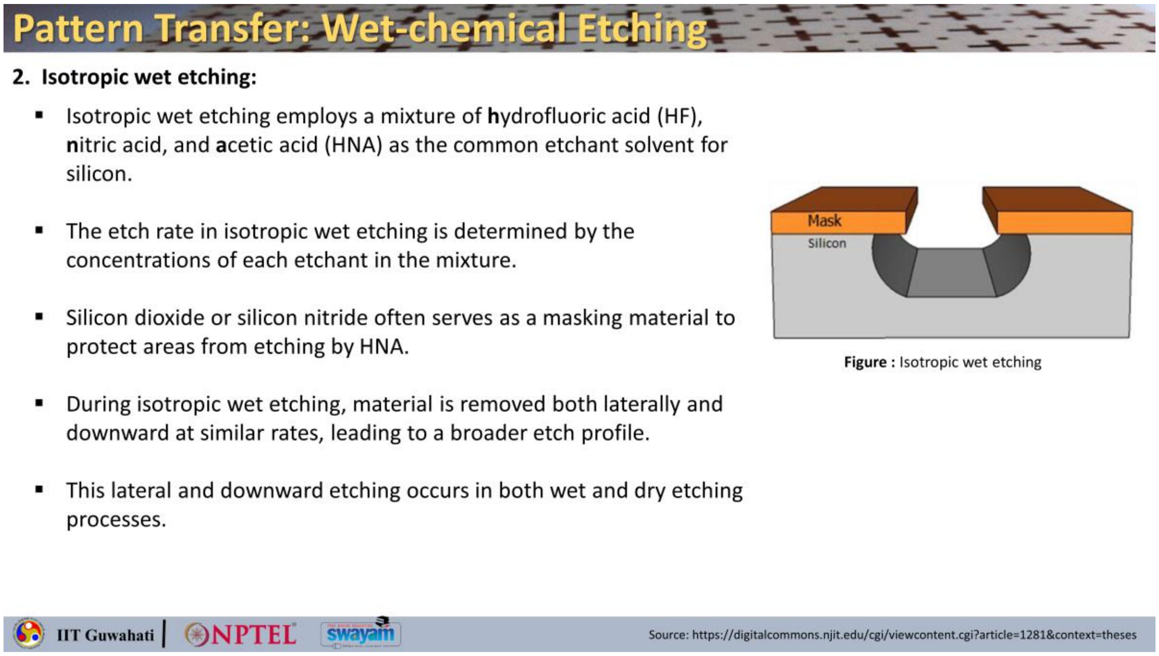
Now, the wet etching process is basically of two types: anisotropic and isotropic wet etching. So, in the anisotropic wet etching, as you can see in the figure.

Liquid etchants exhibit varying etch rates on different crystalline phases of the material that result in great or high anisotropy. So, anisotropic wet etching agents include something like silicon or potassium hydroxide (KOH). Tetramethylammonium hydroxide (TMAH) can lead to significant anisotropy. ok and etching a 100-silicon wafer with this kind of agents create a pyramid shaped etch bits with flat-angled walls. So, here you can see that the angle between the etched wall and the surface of the wafer is roughly 54.7 degrees.

Now, you can also have an isotropic wet etching.



Pattern Transfer: Wet-chemical Etching

2. Isotropic wet etching:

- Isotropic wet etching employs a mixture of **h**ydrofluoric acid (HF), **n**itric acid, and **a**cetic acid (HNA) as the common etchant solvent for silicon.
- The etch rate in isotropic wet etching is determined by the concentrations of each etchant in the mixture.
- Silicon dioxide or silicon nitride often serves as a masking material to protect areas from etching by HNA.
- During isotropic wet etching, material is removed both laterally and downward at similar rates, leading to a broader etch profile.
- This lateral and downward etching occurs in both wet and dry etching processes.

Figure : Isotropic wet etching

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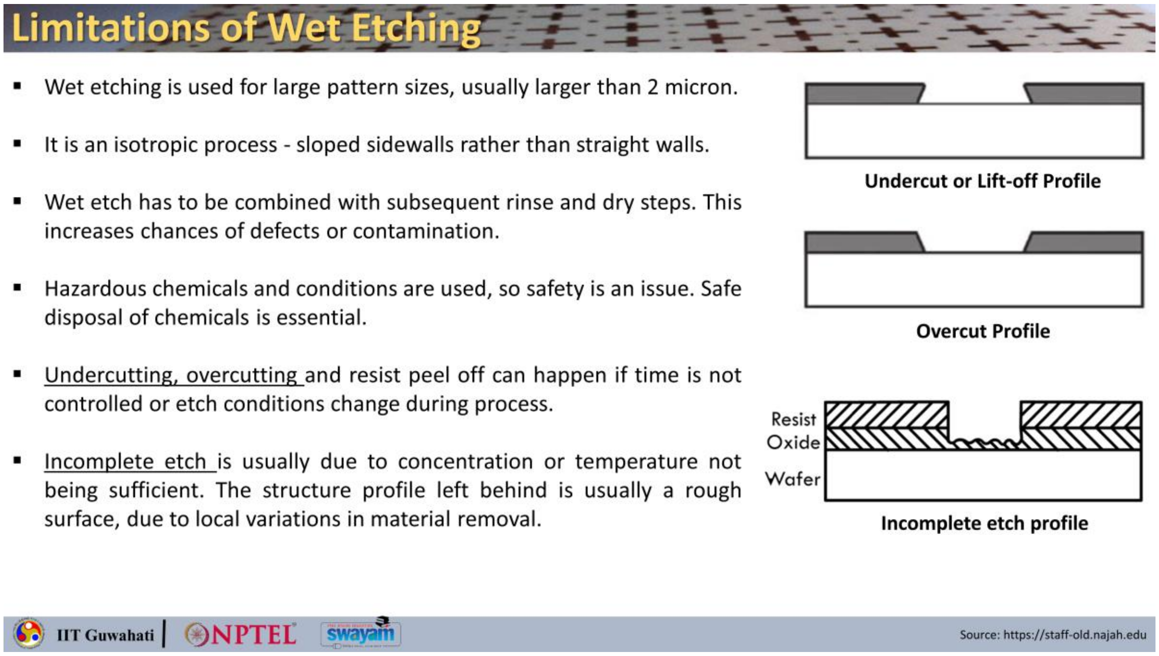
So, isotropic wet etching basically employs a mixture of hydrofluoric acid (HF), then you have nitric acid and acetic acid, all three together are called HNA, which is used as a common etchant solvent for silicon. So, this is how isotropic wet etching looks like. Here, the etch rate is basically isotropic, and sorry, here the etch rate in isotropic wet etching is basically determined by the concentration of each etchant in the mixture. Silicon dioxide or silicon nitride often serves as the masking layer that can protect the areas from etching by this HNA and during isotopic wet etching material is basically removed from both removed both laterally and downwards in the at the similar rate leading to a broader etch profile, and this lateral and downward etching occurs in both wet and dry etching processes.

So, what are the limitations of wet etching?



Limitations of Wet Etching

- Wet etching is used for large pattern sizes, usually larger than 2 micron.
- It is an isotropic process - sloped sidewalls rather than straight walls.
- Wet etch has to be combined with subsequent rinse and dry steps. This increases chances of defects or contamination.
- Hazardous chemicals and conditions are used, so safety is an issue. Safe disposal of chemicals is essential.
- Undercutting, overcutting and resist peel off can happen if time is not controlled or etch conditions change during process.
- Incomplete etch is usually due to concentration or temperature not being sufficient. The structure profile left behind is usually a rough surface, due to local variations in material removal.

Undercut or Lift-off Profile

Overcut Profile

Incomplete etch profile

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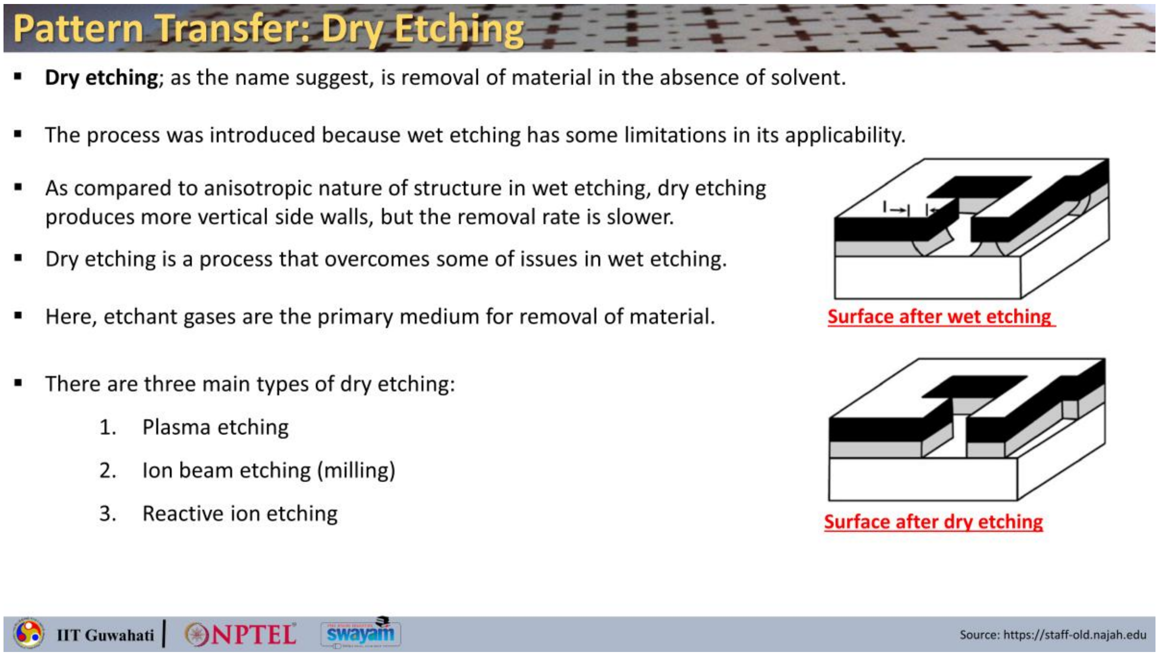
Source: https://staff-old.najah.edu

So, wet etching is basically used for large pattern sizes, typically larger than 2 microns, and as you see, it is an isotropic process. you get sloped side walls rather than straight walls. So, wet etching can be combined with subsequent rinse and dry steps, and this increases the chance of defects and contamination. Here hazardous chemicals and conditions are used. So, safety can be an issue.

The safe disposal of the chemicals becomes very essential. And then undercutting, overcutting, and resist peel-off can happen if time is not controlled or edge conditions change during the process. You may also get incomplete etch; this is usually due to the temperature concentration not being sufficient. So, the structure profile that is basically left behind is usually a rough surface due to local variations in material removal.

So, next we look into dry etching, another method of the pack and transfer.



Pattern Transfer: Dry Etching

- **Dry etching**; as the name suggest, is removal of material in the absence of solvent.
- The process was introduced because wet etching has some limitations in its applicability.
- As compared to anisotropic nature of structure in wet etching, dry etching produces more vertical side walls, but the removal rate is slower.
- Dry etching is a process that overcomes some of issues in wet etching.
- Here, etchant gases are the primary medium for removal of material.
- There are three main types of dry etching:
  1. Plasma etching
  2. Ion beam etching (milling)
  3. Reactive ion etching

Surface after wet etching

Surface after dry etching

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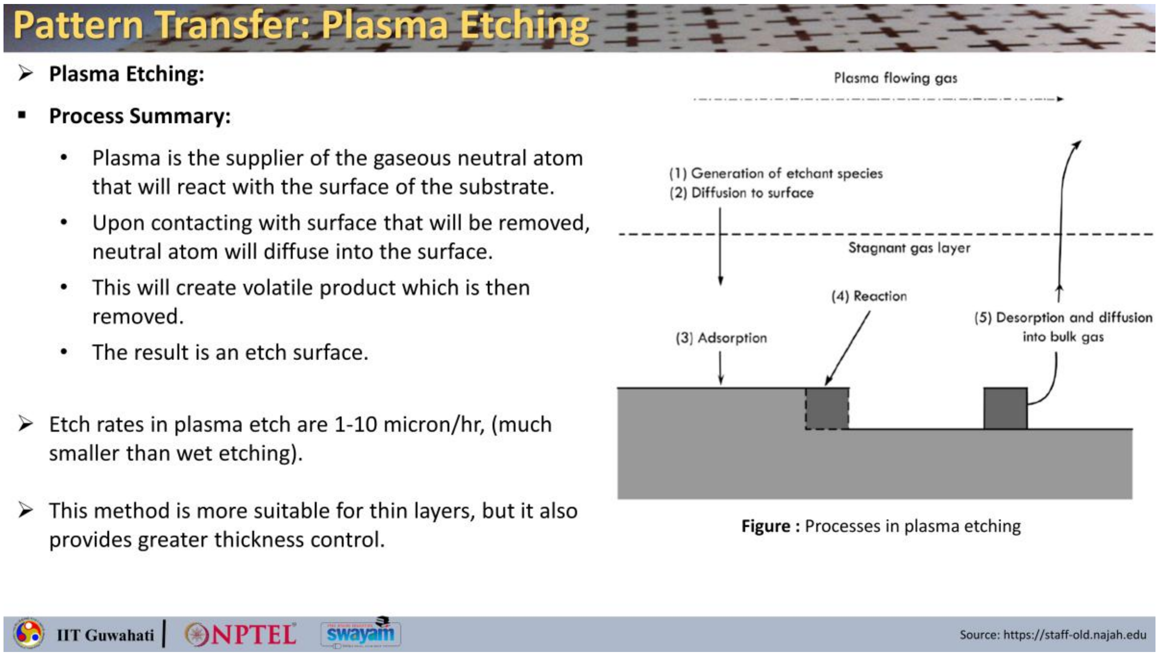
Source: https://staff-old.najah.edu

So, dry etching, as the name suggests, is basically the removal of material in the absence of any solvent. So, the process was introduced because wet etching has some limitation in its applicability. As compared to the anisotropic nature of the structure in wet etching, dry etching procedures produce more vertical sidewalls. The removal rate is slower. So, this is a typical surface after wet etching, and when you do it with dry etching, you will see that you will get straight walls and very nicely done features.

So, dry etching is basically a process that overcomes some of the issues of wet etching, as you can also see here. Here, the etchant gases are the primary medium for the removal of the material. So, there are basically three main types of dry etching. One is plasma etching, then there is ion beam etching or milling, and then there is reactive ion etching.

So, let us see how plasma etching works.



Pattern Transfer: Plasma Etching

- **Plasma Etching:**
- **Process Summary:**
  - Plasma is the supplier of the gaseous neutral atom that will react with the surface of the substrate.
  - Upon contacting with surface that will be removed, neutral atom will diffuse into the surface.
  - This will create volatile product which is then removed.
  - The result is an etch surface.
- Etch rates in plasma etch are 1-10 micron/hr, (much smaller than wet etching).
- This method is more suitable for thin layers, but it also provides greater thickness control.

Figure : Processes in plasma etching

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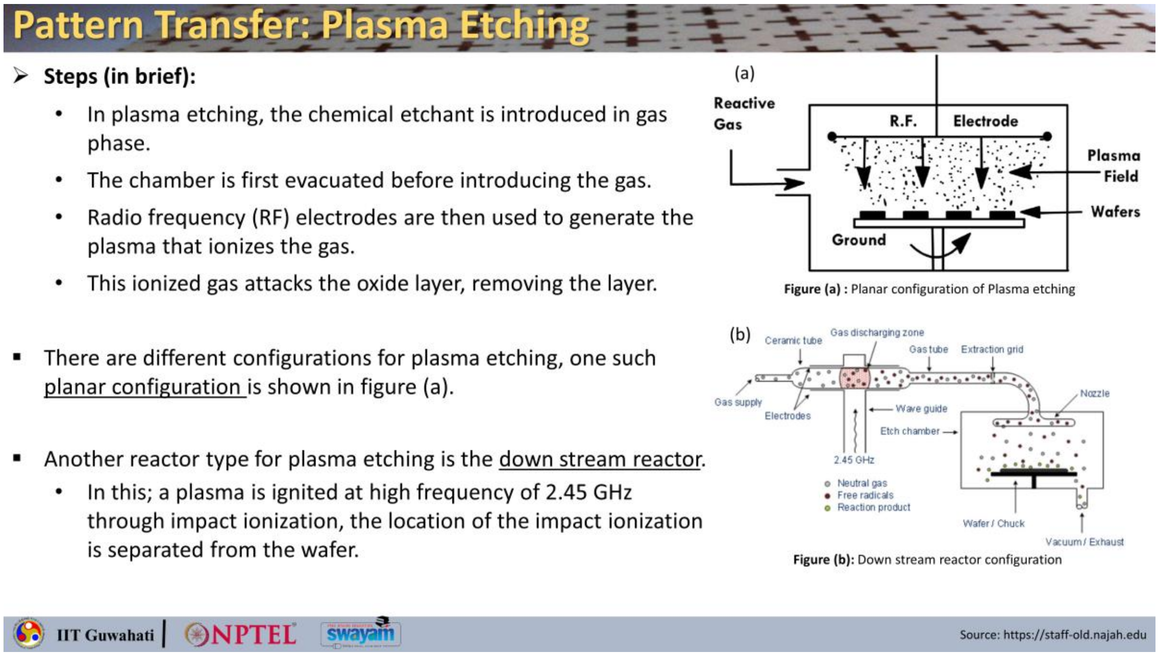
Source: https://staff-old.najah.edu

So, here the plasma is a supplier of the gaseous neutral atom that will react on the surface of the substrate. So, upon contacting the surface that is going to be removed, neutral atoms will diffuse into the substrate and this will create a volatile product which is then basically removed. So, this is the process, and finally, you will get an etched surface, and the etch rates in plasma etching are typically 1 to 10 microns per hour, which is much smaller than the wet etching. However, this method is more suitable for thin layers. but it also provides greater thickness control.

So, this is how it works.

So, you have got this material to be removed. So, you have the plasma gas flowing this way, then you have generation of the HN species, then it diffuses to the surface which get absorbed there is a reaction, after then you have desorption and diffusion of this gas into the bulk, which is basically removed by this by this gas flowing gas ok.

So, here are more details: in plasma etching, the chemical etchant is introduced in the gas phase, right.



Pattern Transfer: Plasma Etching

- **Steps (in brief):**
  - In plasma etching, the chemical etchant is introduced in gas phase.
  - The chamber is first evacuated before introducing the gas.
  - Radio frequency (RF) electrodes are then used to generate the plasma that ionizes the gas.
  - This ionized gas attacks the oxide layer, removing the layer.

- There are different configurations for plasma etching, one such planar configuration is shown in figure (a).

- Another reactor type for plasma etching is the down stream reactor.
  - In this; a plasma is ignited at high frequency of 2.45 GHz through impact ionization, the location of the impact ionization is separated from the wafer.

Figure (a) : Planar configuration of Plasma etching

Figure (b): Down stream reactor configuration

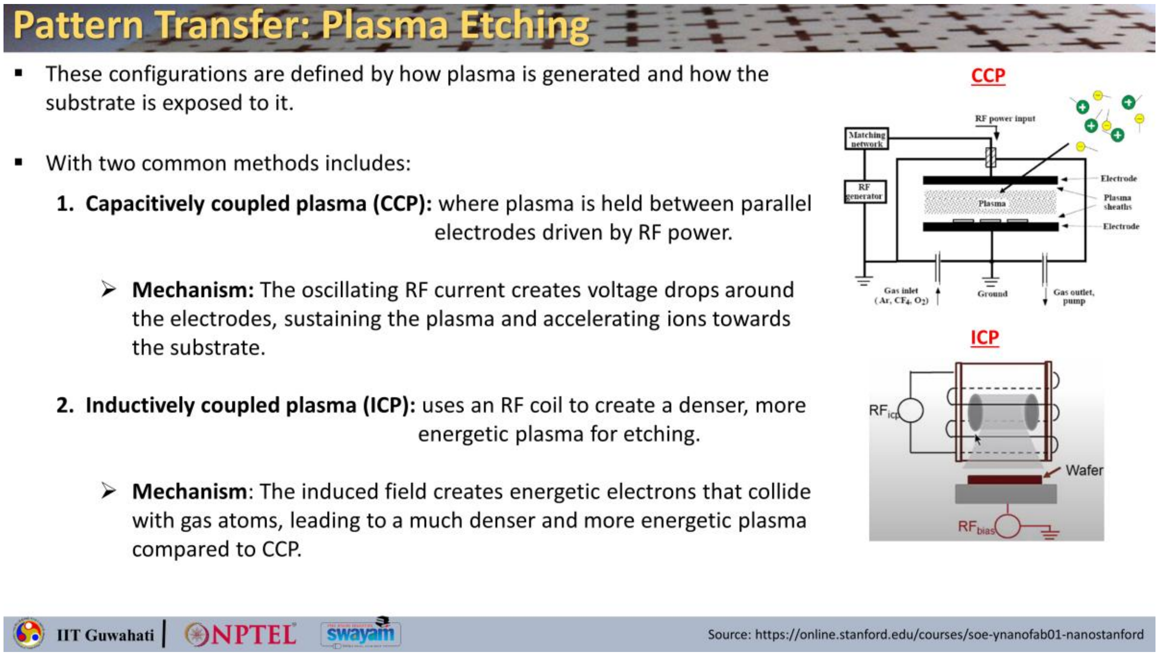
Source: https://staff-old.najah.edu

So, the chamber is first evacuated before introducing the gas and then the radio frequency electrodes are used to generate the plasma that could ionize the gas. And this ionized gas basically attacks the oxide layer; therefore, it can remove the layer.

So, there are different configurations in plasma etching. So, one is a planar configuration, which is basically shown here. Another time is another type of plasma etching is called downstream reactor which is basically shown here. So, here you see the plasma is basically ignited at a high frequency of 2.4 gigahertz, okay, through impact ionization and the location of the impact ionization is basically separated from the wafer.

So, here you do the plasma generation, and then it goes okay. So, here is a wafer that is being etched, and then it finally comes out from here, okay.

So, these configurations are basically defined by how plasma is generated and how the substrate is exposed to the plasma.



Pattern Transfer: Plasma Etching

- These configurations are defined by how plasma is generated and how the substrate is exposed to it.
- With two common methods includes:
  1. **Capacitively coupled plasma (CCP):** where plasma is held between parallel electrodes driven by RF power.
     - **Mechanism:** The oscillating RF current creates voltage drops around the electrodes, sustaining the plasma and accelerating ions towards the substrate.
  2. **Inductively coupled plasma (ICP):** uses an RF coil to create a denser, more energetic plasma for etching.
     - **Mechanism**: The induced field creates energetic electrons that collide with gas atoms, leading to a much denser and more energetic plasma compared to CCP.

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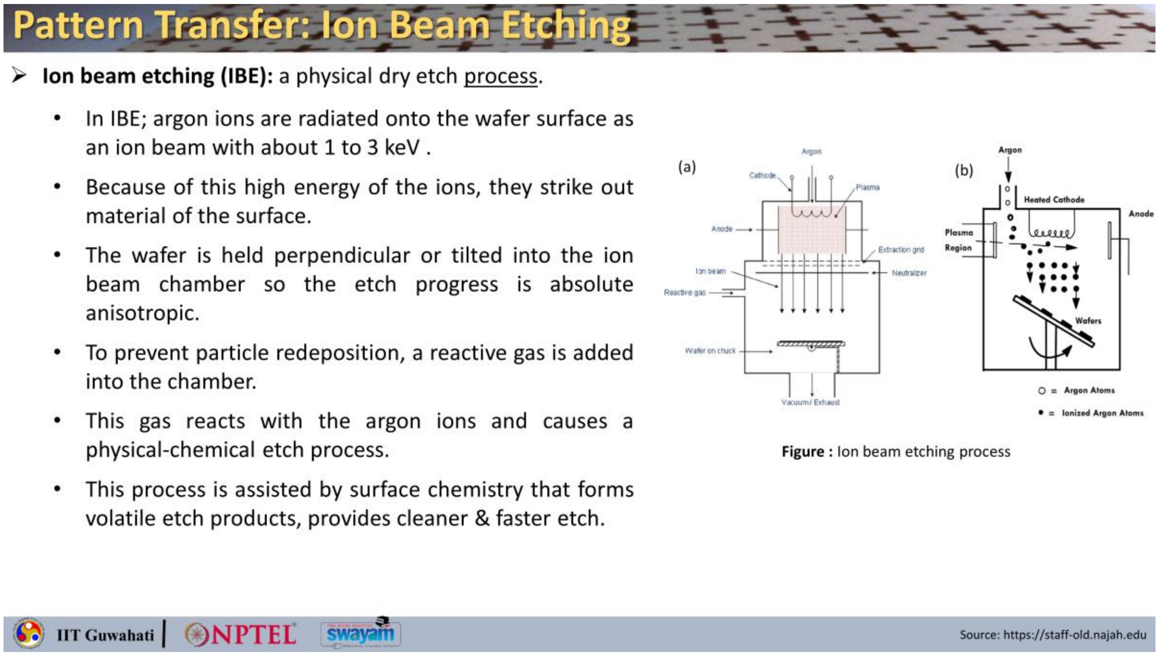
Source: https://online.stanford.edu/courses/soe-ynanofab01-nanostanford

So, two common methods here include capacitively coupled plasma. So, here the plasma is held between the parallel electrodes driven by RF power.

And here the mechanism is that the oscillating RF current basically creates voltage drops around these electrodes. and sustains the plasma, accelerating the ion towards the substrates. Another method is called inductively coupled plasma; here you have an RF coil. To create a denser and more energetic plasma that can be used for etching. So, the mechanism here involves is that you have induced field that is creating energetic electrons that collide with gas atoms leading to a much denser and more energetic plasma compared to this capacitively coupled plasma.

Then you have ion beam etching , which is also called IBE.



Pattern Transfer: Ion Beam Etching

- **Ion beam etching (IBE):** a physical dry etch process.
  - In IBE; argon ions are radiated onto the wafer surface as an ion beam with about 1 to 3 keV .
  - Because of this high energy of the ions, they strike out material of the surface.
  - The wafer is held perpendicular or tilted into the ion beam chamber so the etch progress is absolute anisotropic.
  - To prevent particle redeposition, a reactive gas is added into the chamber.
  - This gas reacts with the argon ions and causes a physical-chemical etch process.
  - This process is assisted by surface chemistry that forms volatile etch products, provides cleaner & faster etch.

Figure : Ion beam etching process

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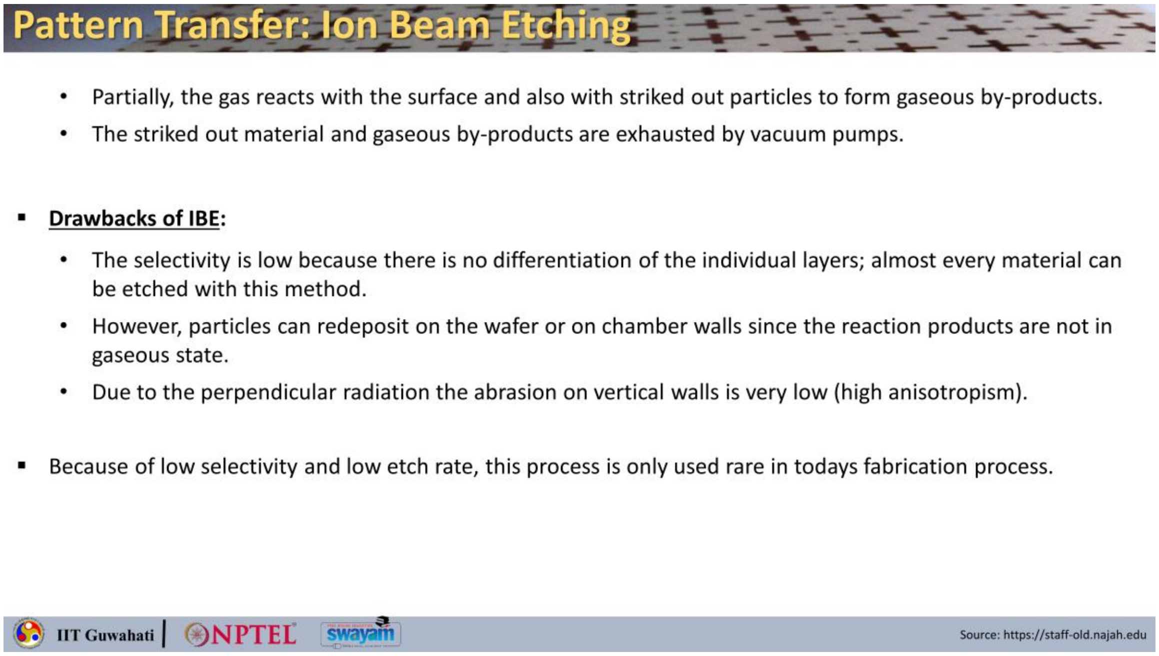
Source: https://staff-old.najah.edu

So, a physical dry etch process. So, in this IBE, argon ions are radiated onto the wafer surface as an ion beam which has an energy of around 1 to 3 kilo-electron volts. Because of the high energy of the ions, they can eject the materials from the surface. So, you can see it like this You have this wafer on the chuck.

You have some reactive gases. This is how the ion beam falls from the top. So, here the wafer is held perpendicular, or maybe tilted, to the ion beam chamber. So, the etch process is absolutely anisotropic. So, to prevent particle redeposition, a reactive gas is added to the chamber, and this gas reacts with the argon ions. and causes a physical-chemical etch process.

And this process is assisted by surface chemistry that forms volatile etch products and provides cleaner and faster etching. So, partially, the gas basically reacts with the surface, and it also reacts with the struck-out particles to form gaseous byproducts. And the stricken-out material and the gaseous byproducts are basically exhausted by the vacuum pumps that you see here, right.



Pattern Transfer: Ion Beam Etching

- Partially, the gas reacts with the surface and also with striked out particles to form gaseous by-products.
- The striked out material and gaseous by-products are exhausted by vacuum pumps.

- **<u>Drawbacks of IBE</u>:**
  - The selectivity is low because there is no differentiation of the individual layers; almost every material can be etched with this method.
  - However, particles can redeposit on the wafer or on chamber walls since the reaction products are not in gaseous state.
  - Due to the perpendicular radiation the abrasion on vertical walls is very low (high anisotropism).

- Because of low selectivity and low etch rate, this process is only used rare in todays fabrication process.

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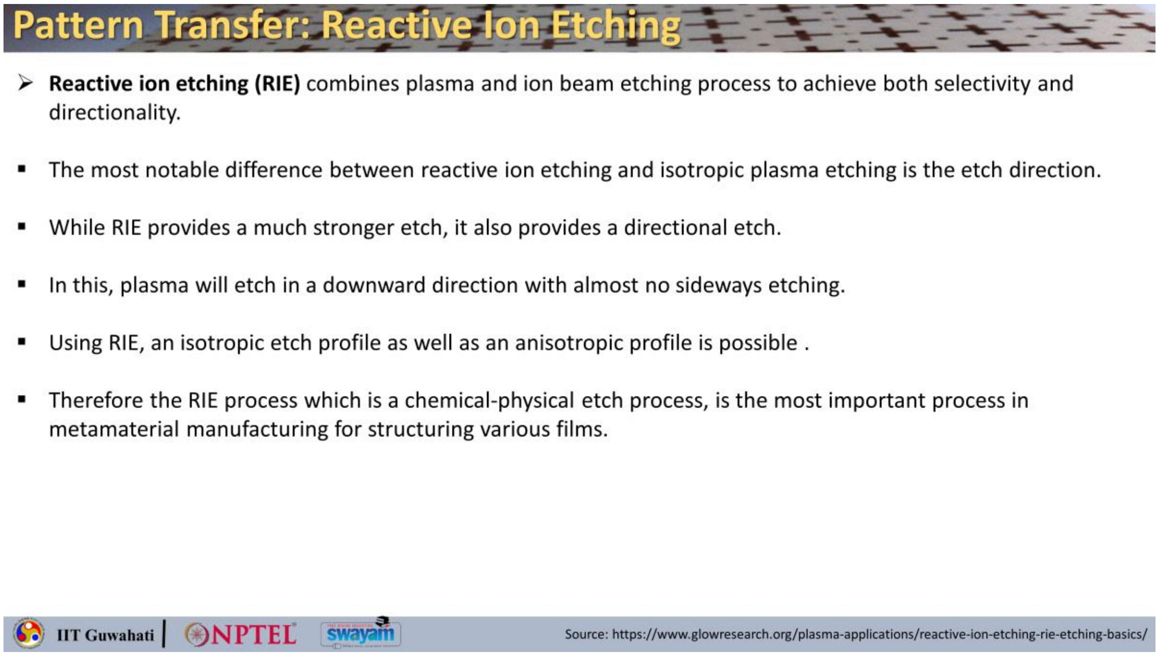
Source: https://staff-old.najah.edu

Now, what are the drawbacks of this ion beam etching?

The selectivity here is low because there is no differentiation between individual layers. Almost every material can be etched using this method. However, another problem is that the particles can redeposit on the wafer or the chamber walls.

Since the reaction products are not in the gaseous phase. And due to the perpendicular radiation, the abrasion on the vertical wall is very low. So, you get high anisotropism, and because of low sensitivity and low etch rate, so this process is not a very popular one in today's fabrication process.

Next, we will discuss reactive ion etching.:



Pattern Transfer: Reactive Ion Etching

- **Reactive ion etching (RIE)** combines plasma and ion beam etching process to achieve both selectivity and directionality.
- The most notable difference between reactive ion etching and isotropic plasma etching is the etch direction.
- While RIE provides a much stronger etch, it also provides a directional etch.
- In this, plasma will etch in a downward direction with almost no sideways etching.
- Using RIE, an isotropic etch profile as well as an anisotropic profile is possible .
- Therefore the RIE process which is a chemical-physical etch process, is the most important process in metamaterial manufacturing for structuring various films.

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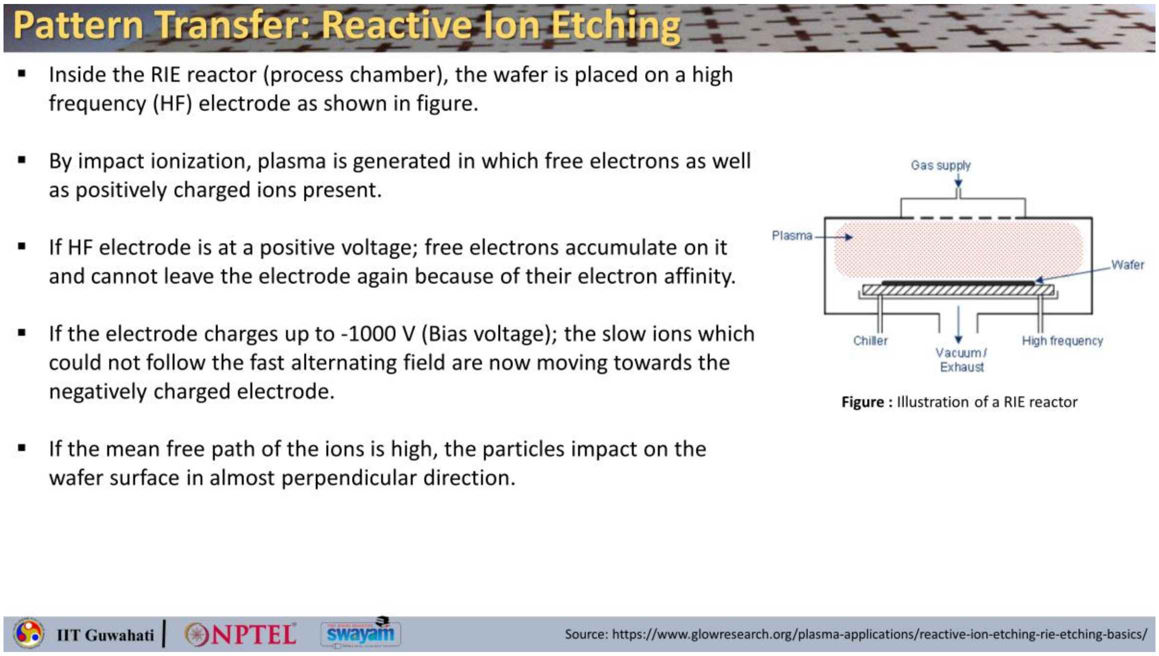
Source: https://www.glowresearch.org/plasma-applications/reactive-ion-etching-rie-etching-basics/

Now, reactive ion etching combines plasma and ion beam etching processes that allow you to achieve both selectivity and directionality.

So, there is a notable difference between reactive ion etching and the isotropic plasma etching is basically the etch direction. So, in the reactive ion etching, it is a much stronger etch and it basically provides a directional etching. In this case, the plasma will basically etch in the downward direction with almost no sideways etching. So, in reactive ion etching, both an isotropic etch profile and an anisotropic etch profile are possible. Therefore, the reactive ion etching process, which is a physical-chemical etch process, is the most important process in the metamaterial manufacturing for structuring various films.



Pattern Transfer: Reactive Ion Etching

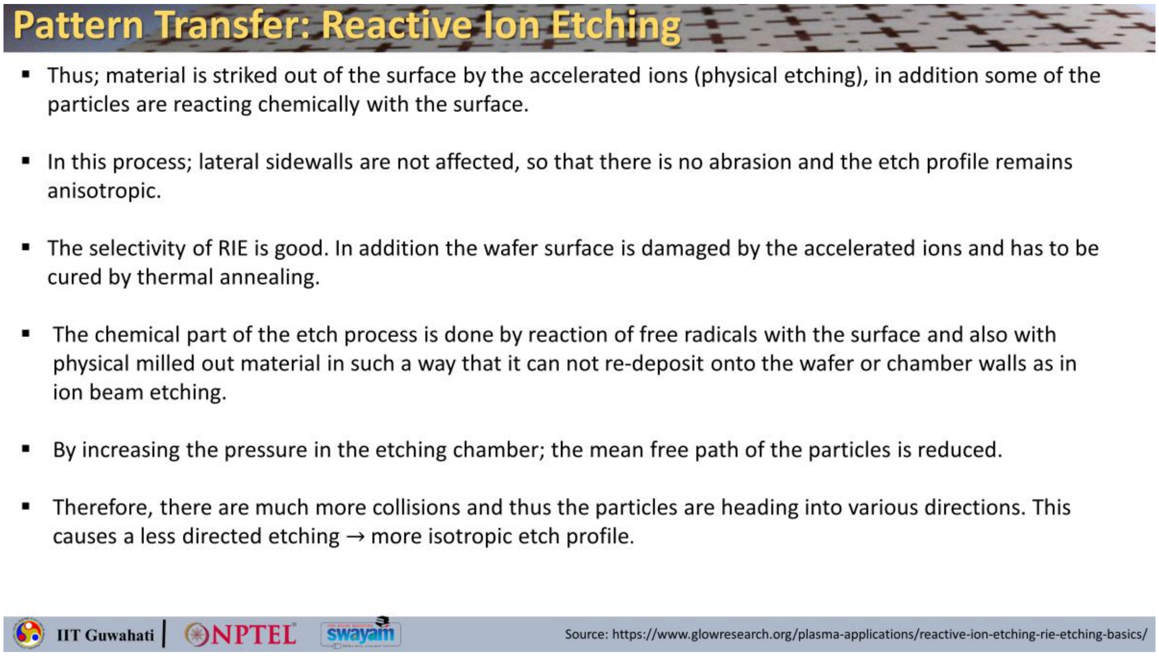
- Inside the RIE reactor (process chamber), the wafer is placed on a high frequency (HF) electrode as shown in figure.
- By impact ionization, plasma is generated in which free electrons as well as positively charged ions present.
- If HF electrode is at a positive voltage; free electrons accumulate on it and cannot leave the electrode again because of their electron affinity.
- If the electrode charges up to -1000 V (Bias voltage); the slow ions which could not follow the fast alternating field are now moving towards the negatively charged electrode.
- If the mean free path of the ions is high, the particles impact on the wafer surface in almost perpendicular direction.

Figure : Illustration of a RIE reactor

Source: https://www.glowresearch.org/plasma-applications/reactive-ion-etching-rie-etching-basics/

Reactive ion etching inside the RIE that is; there is a process chamber the wafer is basically placed on a RF or high frequency electrode as you can see here this is the high frequency electrode this is the vacuum of the exhaust okay, there is a chiller as well. Now, this is a point for gas supply, and this is where your plasma is. By impact ionization plasma is getting generated in which free electrons as well as positive charges ion charged ions are also present. Now, if the high-frequency electrode is at a positive voltage, free electrons accumulate on it and cannot leave the electrode again, because of their electron affinity.

Now, if the electrode charges up to minus 1000 volts, that is the bias voltage. The slow ions that could not follow the first alternating field are now moving towards the negatively charged electrode, right. In this case, if the mean free path of the ions is high, the particles' impact on this wafer is almost perpendicular.



Pattern Transfer: Reactive Ion Etching

- Thus; material is striked out of the surface by the accelerated ions (physical etching), in addition some of the particles are reacting chemically with the surface.
- In this process; lateral sidewalls are not affected, so that there is no abrasion and the etch profile remains anisotropic.
- The selectivity of RIE is good. In addition the wafer surface is damaged by the accelerated ions and has to be cured by thermal annealing.
- The chemical part of the etch process is done by reaction of free radicals with the surface and also with physical milled out material in such a way that it can not re-deposit onto the wafer or chamber walls as in ion beam etching.
- By increasing the pressure in the etching chamber; the mean free path of the particles is reduced.
- Therefore, there are much more collisions and thus the particles are heading into various directions. This causes a less directed etching → more isotropic etch profile.

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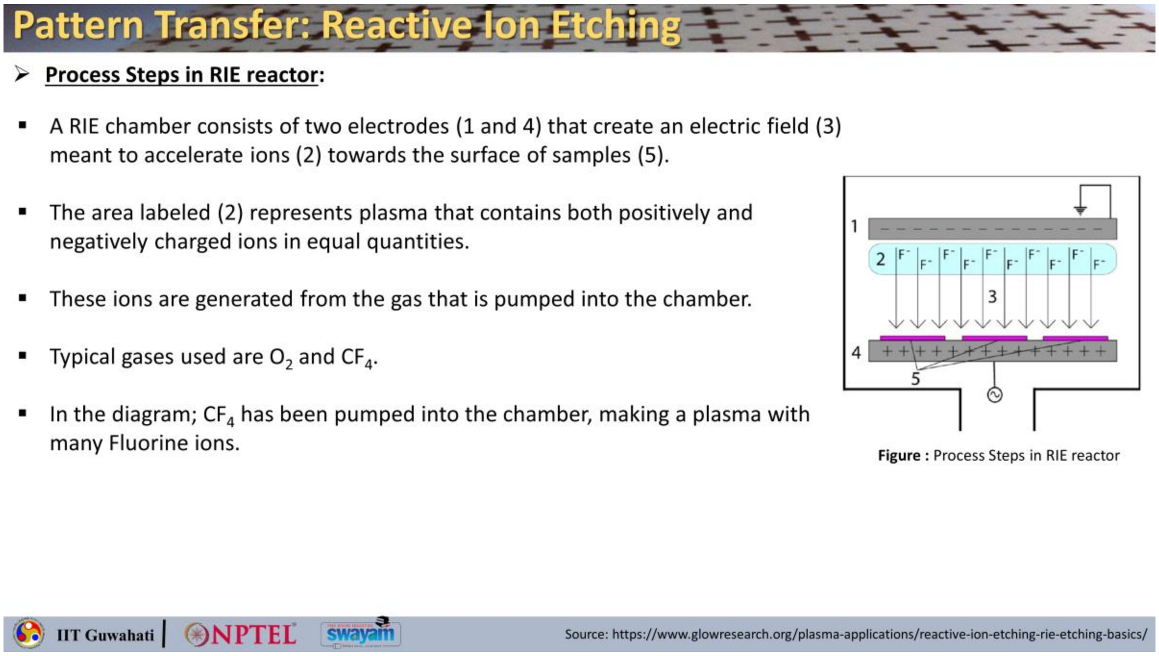
Source: https://www.glowresearch.org/plasma-applications/reactive-ion-etching-rie-etching-basics/

So, in this case, the material is basically strike out of the surface by an accelerated ion. So, it is basically a physical etching. In addition, some of the particles are reacting chemically with the surface.

So, in this process, lateral sidewalls are not affected, so there is no abrasion and the edge profile remains anisotropic. And here, the selectivity of reactive ion etching is good. In addition, the wafer surface is damaged by the accelerated ions, and that is why it needs to be cured by thermal annealing. The chemical part of the etch process is basically done by the reaction of free radicals with the surface and also with the physically milled-out material. and this is done in such a way that they cannot redeposit onto the wafer or the chamber walls as it was in the ion beam etching.

And by increasing the pressure in the etching chamber, you can reduce the mean free path of the electrons, okay. Therefore, what will happen is that there will be more collisions, and the particles heading in various directions will collide with each other. And this will cause a less-directed edge, okay. So, you can get a more isotropic edge profile if you increase the pressure.

Now, we will look into the process steps in this reactive ionizing reactor.



Pattern Transfer: Reactive Ion Etching

➢ **Process Steps in RIE reactor:**

- A RIE chamber consists of two electrodes (1 and 4) that create an electric field (3) meant to accelerate ions (2) towards the surface of samples (5).
- The area labeled (2) represents plasma that contains both positively and negatively charged ions in equal quantities.
- These ions are generated from the gas that is pumped into the chamber.
- Typical gases used are O_2 and CF_4.
- In the diagram; CF_4 has been pumped into the chamber, making a plasma with many Fluorine ions.

Figure : Process Steps in RIE reactor

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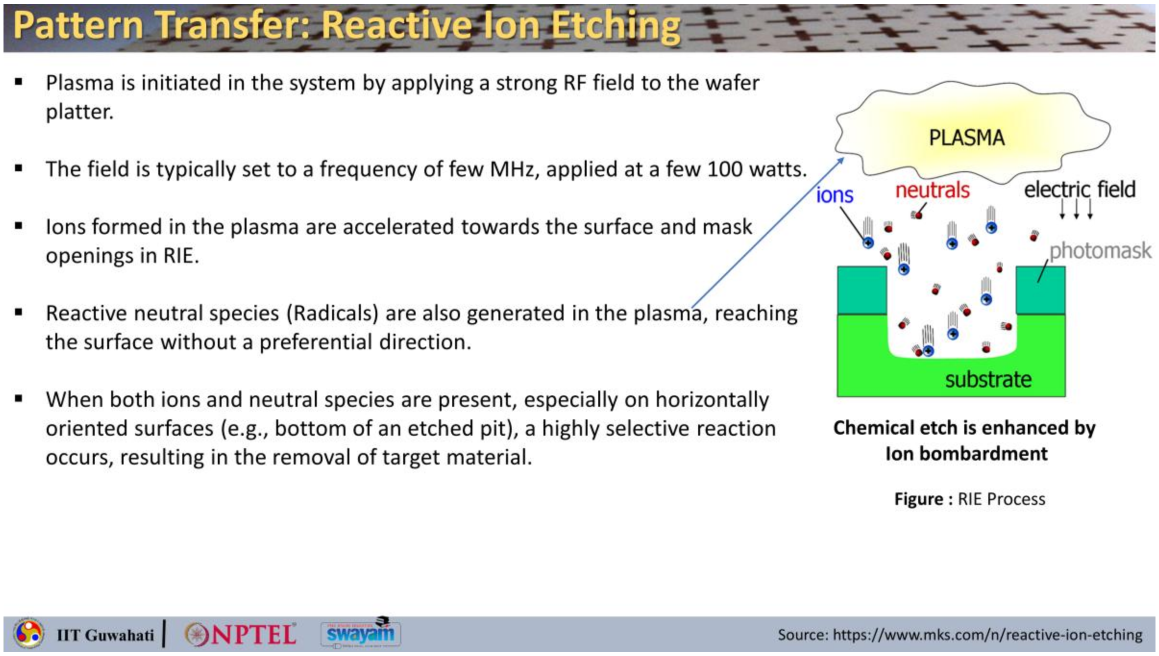
Source: https://www.glowresearch.org/plasma-applications/reactive-ion-etching-rie-etching-basics/

So, in RIE chamber, it basically consists of two electrodes. Here you can see the numbers 1 and 4. And that creates an electric field like this, which is marked as 3. That is meant to accelerate the ions.

these ones towards the surface of the sample. So, that is the sample surface. So, the area labeled as 2 basically represents the plasma that contains both positively and negatively charged ions in equal quantities. Now, the ions are generated from the gas that was pumped into the chamber. And what are these gases?

They can typically be oxygen or CF_4. So, here in this particular diagram, you can see that CF_4 has been pumped into the chamber and you are getting a plasma made of many fluorine ions.



Pattern Transfer: Reactive Ion Etching

- Plasma is initiated in the system by applying a strong RF field to the wafer platter.
- The field is typically set to a frequency of few MHz, applied at a few 100 watts.
- Ions formed in the plasma are accelerated towards the surface and mask openings in RIE.
- Reactive neutral species (Radicals) are also generated in the plasma, reaching the surface without a preferential direction.
- When both ions and neutral species are present, especially on horizontally oriented surfaces (e.g., bottom of an etched pit), a highly selective reaction occurs, resulting in the removal of target material.

Chemical etch is enhanced by Ion bombardment

Figure : RIE Process

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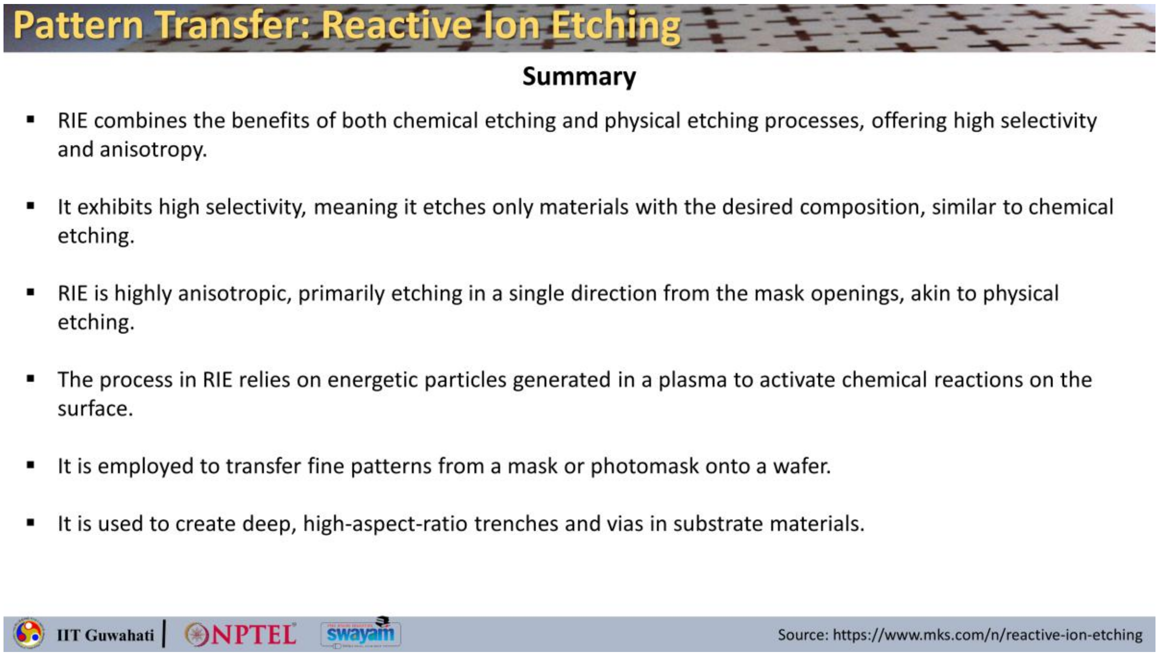
Source: https://www.mks.com/n/reactive-ion-etching

Now, the plasma is initiated in the system by applying a strong RF field to the wafer plate. Now, the field is typically set to a frequency of a few megahertz, applied at a few hundred watts. Now, ions formed in the plasma are basically accelerated towards the surface and mask openings in the RIE. The reactive neutral species, something like the radicals, are also generated in the plasma. and reaching the surface without any preferential reaction.

So, when both ions and the neutral species are present, especially on a horizontally oriented surface, something like the bottom of an etched pit. A highly sensitive reaction could occur that will result in the removal of the target material. So, here you can see the chemical etch is basically enhanced by this ion bombardment, right. So, what it shows here is basically the substrate; this is a photo mask. They have these ions that are bombarding; there are some neutrals, and this is the electric field that is working. So, what do you understand?



Pattern Transfer: Reactive Ion Etching

Summary

- RIE combines the benefits of both chemical etching and physical etching processes, offering high selectivity and anisotropy.
- It exhibits high selectivity, meaning it etches only materials with the desired composition, similar to chemical etching.
- RIE is highly anisotropic, primarily etching in a single direction from the mask openings, akin to physical etching.
- The process in RIE relies on energetic particles generated in a plasma to activate chemical reactions on the surface.
- It is employed to transfer fine patterns from a mask or photomask onto a wafer.
- It is used to create deep, high-aspect-ratio trenches and vias in substrate materials.

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Source: https://www.mks.com/n/reactive-ion-etching

To conclude, we can say that RIE basically combines the benefit of both chemical etching as well as the physical etching processes and it offers high selectivity and anisotropy, which are very good things.

It exhibits high sensitivity, making it etch only materials with a desired composition similar to that of chemical etching. Now, RIE is highly anisotropic, as we mentioned. So, it can primarily etch in a single direction from the mask opening, akin to a physical etching. And the process in the array relies on energetic particles generated in the plasma that basically activate the chemical reaction on the surface. So, it is used to transfer fine patterns from a mask or a photomask onto a wafer.

So, that is why it can be used to create deep, high-aspect-ratio trenches and vias in substrate material.

Thank You

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So, with that, we conclude this lecture. We will have a short discussion on the characterization methods of metamaterials in the next lecture, and that will also conclude the course. So, if you have any queries regarding this lecture, you can drop an email to this email address: deb.sikdar@iitg.ac.in. but make sure you mention the course title and the lecture number on the subject line, Thank you!