Dry Etching Profile Simulation

Simulated profile evolution in anisotropic vs isotropic etch processes.

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Objective

The objective of this project is to simulate the evolution of etch profiles in microfabrication using dry etching techniques. Specifically, the simulation compares:

- **Anisotropic dry etching**, where material is etched primarily in the vertical direction.
- **Isotropic dry etching**, where material is removed equally in all directions.

The project involves implementing both processes in MATLAB, generating visual profiles over multiple etch steps, and creating animations to visualize trench evolution. The goal is to understand the differences in etch behavior and resulting geometry under each condition.

Background Theory

In semiconductor fabrication, **etching** is a process used to selectively remove material from the wafer surface to form devices and circuits. There are two broad classes:

- **Wet etching** (using liquid chemicals)
- **Dry etching** (using plasma or gas-phase reactions)

This project focuses on **dry etching**, which uses plasma to remove material more precisely. Depending on the directionality of etching, dry etching can be:

- **Anisotropic**: Directional etching, primarily vertical, due to ion bombardment.
- **Isotropic**: Uniform etching in all directions, due to chemical diffusion.

Etch profile geometry plays a critical role in determining device dimensions, functionality, and yield.

Simulation Methodology

A 2D simulation is performed on a square grid representing a material block with a mask layer on top.

- The grid values represent:
  - **0**: Etched (air/vacuum)
  - **1**: Material (e.g., silicon)
  - **2**: Mask (photoresist/hardmask)
- A mask opening is created in the center of the top row.
- For each time step:
  - In **anisotropic etching**, material is removed only if the pixel above is air.
  - In **isotropic etching**, material is removed if any of the 4 neighbors is air.

- Each step is saved as an image. After 90 steps, these frames are compiled into mp4 movies.

Results and Discussion

The following visualizations and movies show the trench profiles after 90 steps of etching.

Anisotropic Etching Profile

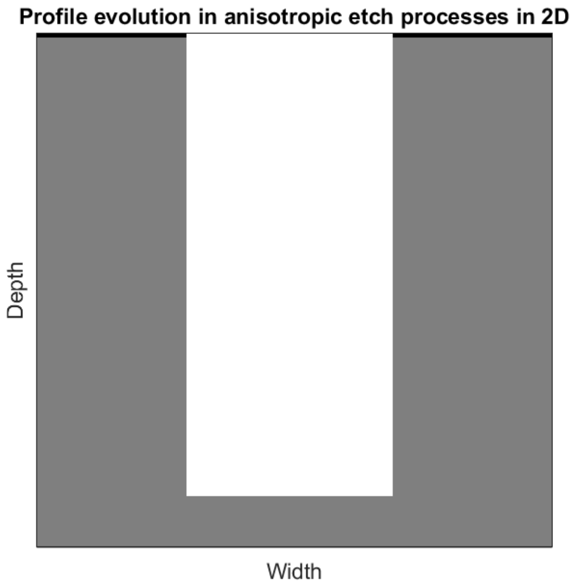

Figure 1: Final etch profile after 89 steps — Anisotropic

- The trench profile is narrow with **vertical sidewalls**.
- Etching occurs only in the vertical direction under the mask opening.
- No lateral undercut is observed.

Isotropic Etching Profile

- The profile expands sideways with **rounded sidewalls**.
- Etching spreads laterally beneath the mask visible **undercutting**.
- Matches real-world isotropic behavior caused by chemical species.

Simulation

Both etching processes were simulated over 90 steps and exported as animation videos:

- `anisotropic_etching.mp4`
- `isotropic_etching.mp4`

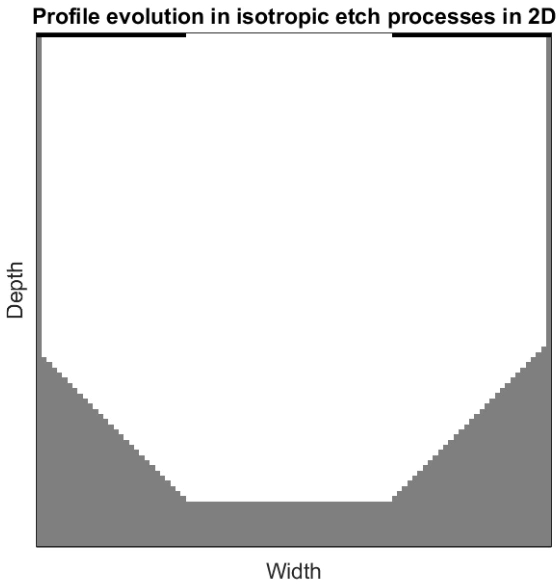

Figure 2: Final etch profile after 89 steps — Isotropic

To watch the anisotropic etching simulation, please click **here**.

To watch the isotropic etching simulation, please click **here**.

Conclusion

This project successfully simulates the evolution of etch profiles in dry etching for both anisotropic and isotropic cases using MATLAB. The results match expected physical behavior:

- Anisotropic etching results in **straight, vertical trenches**.
- Isotropic etching results in **rounded and undercut profiles**.

This simulation highlights the importance of etching directionality in semiconductor manufacturing and helps visualize microscopic process effects at a macro level.