

INTRODUCTION TO
VLSI FABRICATION
MATERIALS
&
PROCESSES

7 Primary Chip Ingredients

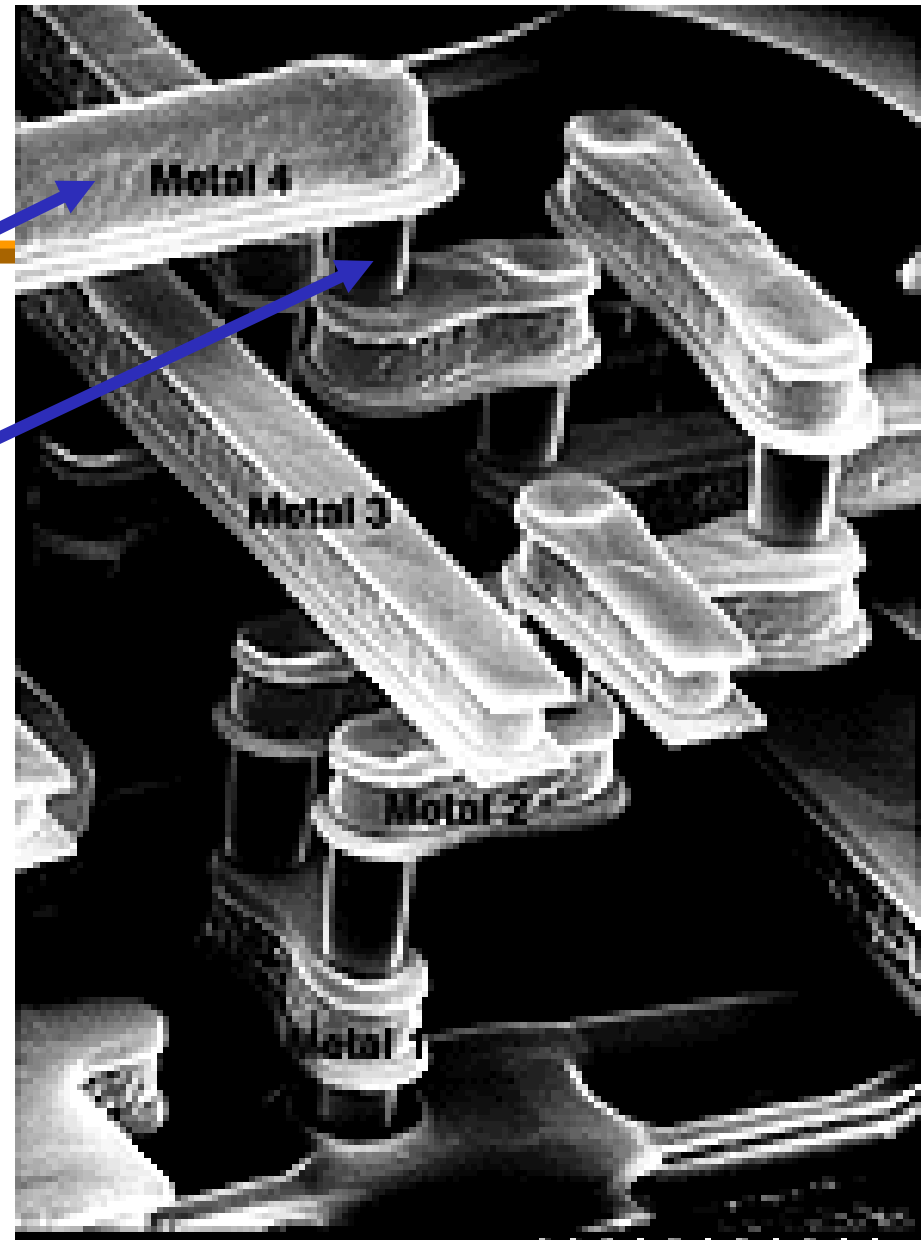
- 1) Silicon – crystalline
 - Near-perfect crystal (atoms organized in a regular, ordered lattice)
 - Semiconductor – not a conductor or insulator, but somewhere in between and its conduction can be altered significantly
- 2) SiO₂ – Silicon dioxide
 - Just like it says, made from silicon and oxygen
 - Insulator
- 3) Silicon – polycrystalline, poly, polysilicon
 - Silicon but only small regions are organized as crystalline structures. Polysilicon structures are made up of multiple small crystalline regions where the smaller regions are not aligned with each other.
- 4) n-type dopants
 - Materials that contain 5 outer electrons
 - “donors”
 - Examples: phosphorus, arsenic

7 Primary Chip Ingredients

- 5) p-type dopants
 - Materials that contain 3 outer electrons
 - “acceptors”
 - Examples: boron, gallium
- 6) Metal wires
 - In older technologies, made of aluminum. Now copper is commonly used because of its lower resistivity.
 - Conductors
- 7) Contacts/vias
 - Tungsten and aluminium commonly used
 - These are “vertical” connections between layers

The 3D Nature of Chips

- 6) Metal wire layers
- 7) “vertical” contacts/vias
- By convention we typically describe chips as being in the orientation with the substrate “horizontal” and interconnect layers placed on top of the substrate



5 Primary Fabrication-Materials and Fabrication-Processes

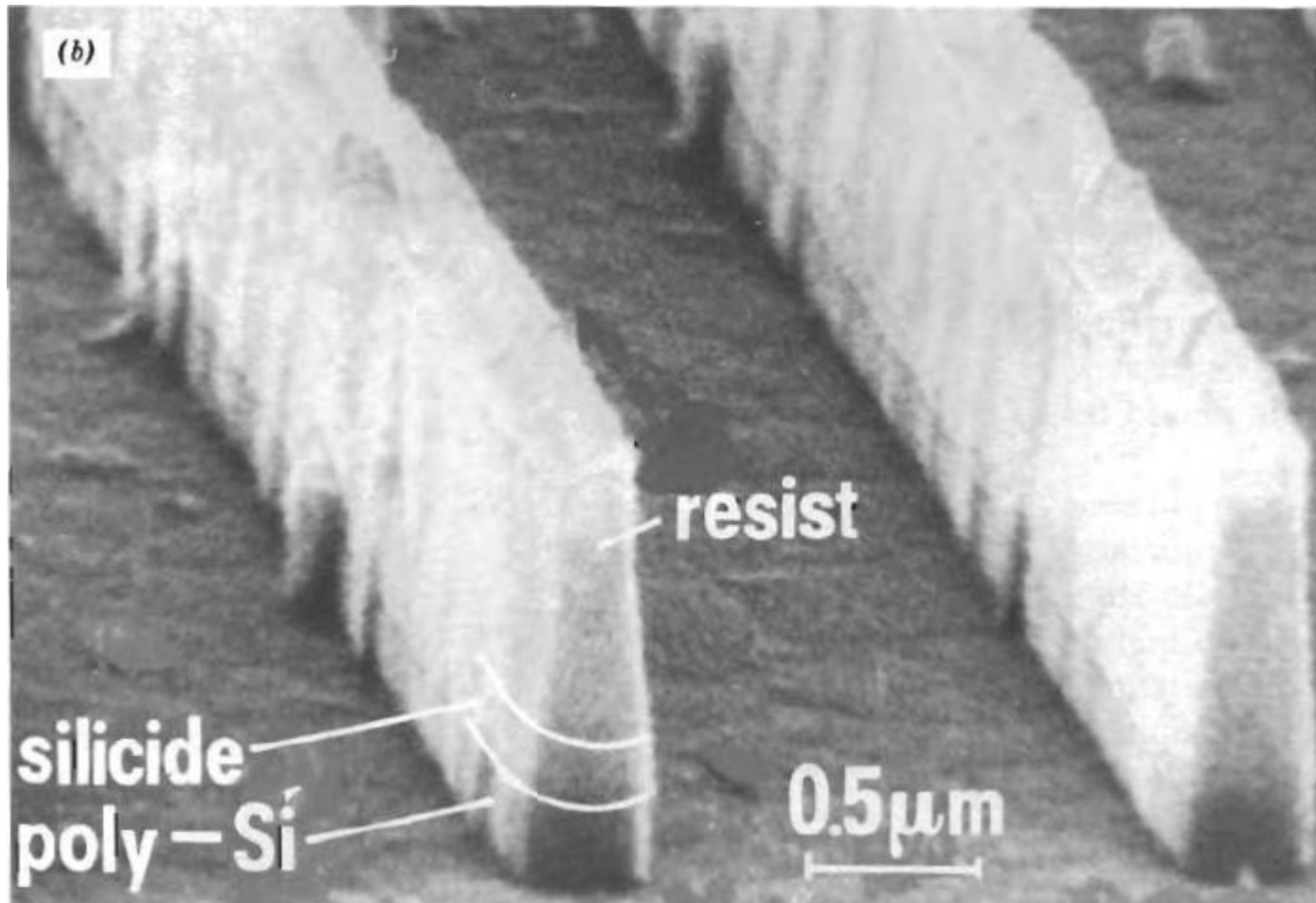
1) Photoresist

- *Positive photoresist* (becomes soluble when exposed to UV light)
- *Negative photoresist* (becomes insoluble when exposed to UV light)
- Applied roughly 1 μm thick to entire wafer

2) Etching processes

- The “selectivity” of different etches varies in the sense that the materials that are etched or not etched depends on the particular etch.
- Acid (wet etching). Ex: HF acid
- Plasma (dry etching)

Etching of Polysilicon



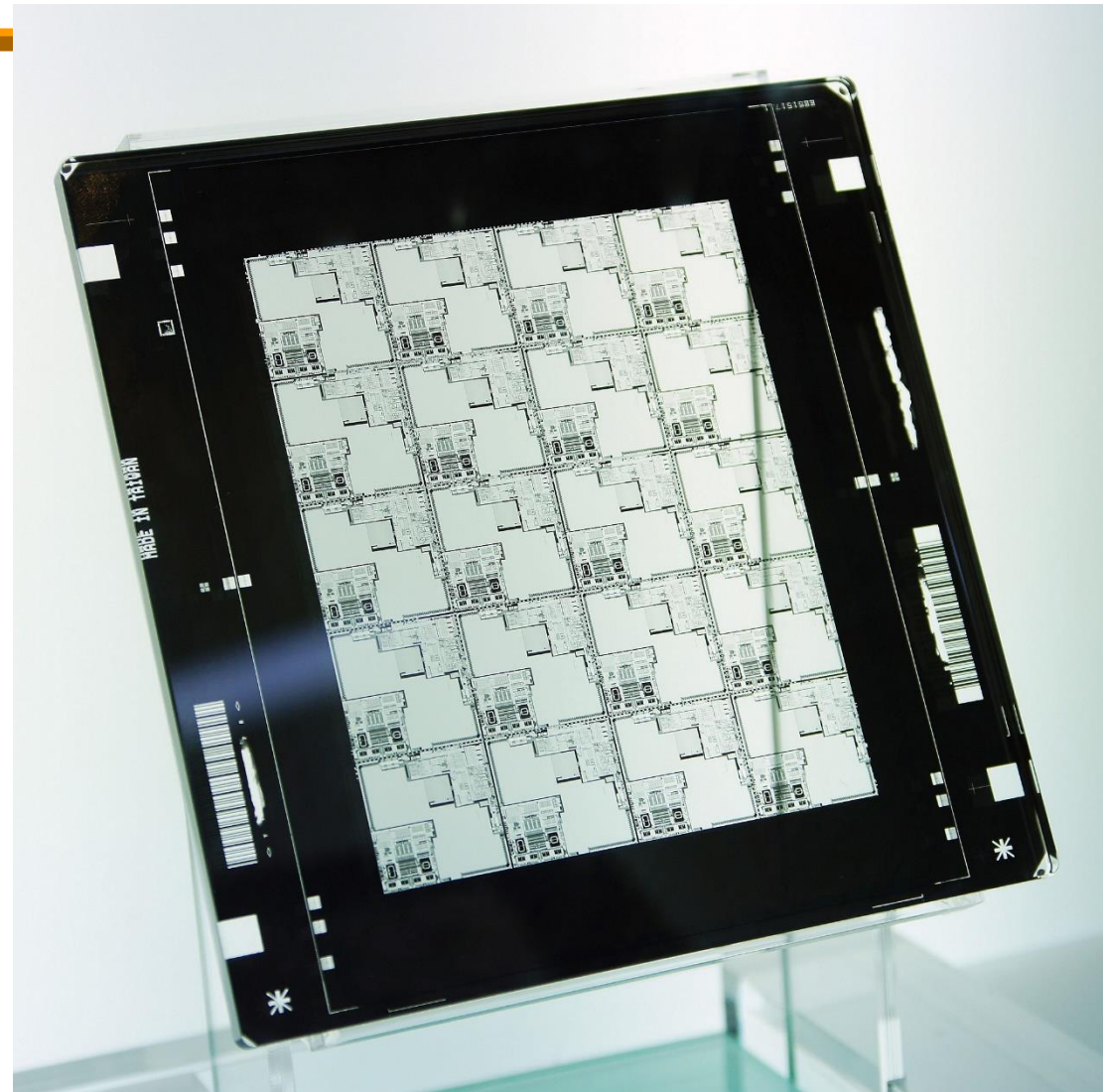
5 Primary Fabrication-Materials and Fabrication-Processes

- 3) Masks – one per patterned shape
- Picture a developed film negative used to make photograph prints; or a slide



5 Primary Fabrication-Materials and Fabrication-Processes

- 3) Masks – one per patterned shape
- The mask may contain one or more copies of the same chip (20 in this example)
 - The chip layer's image is typically several times larger in the mask compared to the final chip size



5 Primary Fabrication-Materials and Fabrication-Processes

4) Laying down material

A. Deposition

- Example method: CVD
- Example materials: SiO_2 , silicon

B. Growth

- Example materials: SiO_2 on silicon substrate

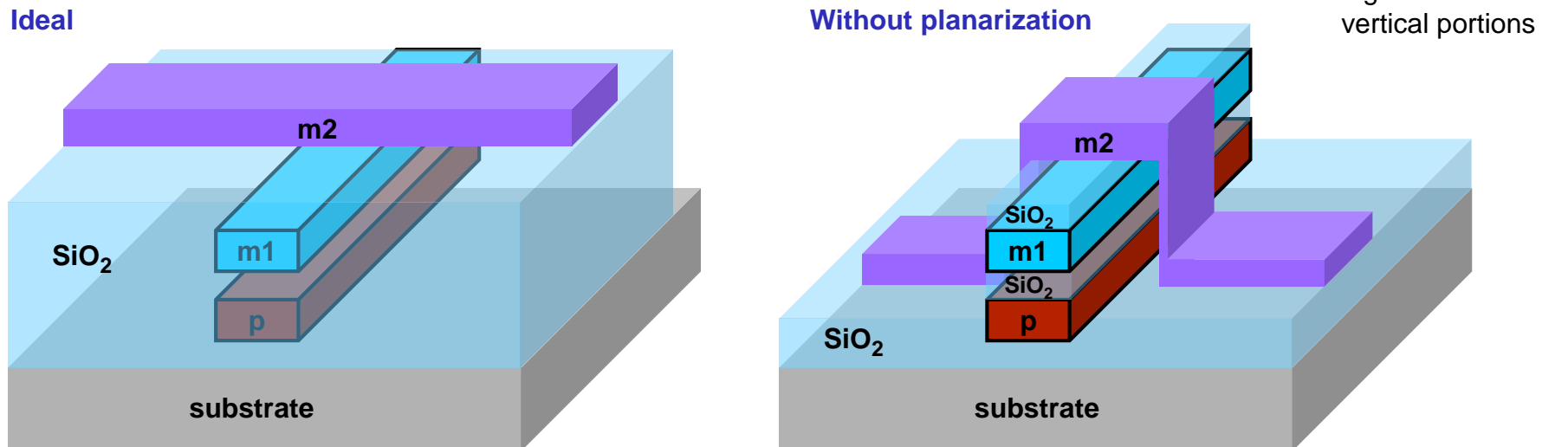
C. Implantation

- Produces high dopant concentration regions
- Diffusion implantation
 - Silicon exposed to dopant gas at high temperature
- Ion implantation
 - Dopant ions are implanted at high speed with an accelerator
 - Causes lattice damage
 - Normally followed by annealing step (short high temperature “crystal healing” process)
- Example implanted structures: source/drains, transistor channels, well and substrate contacts, polysilicon

D. Sputtering – for metals

5 Primary Fabrication-Materials and Fabrication-Processes

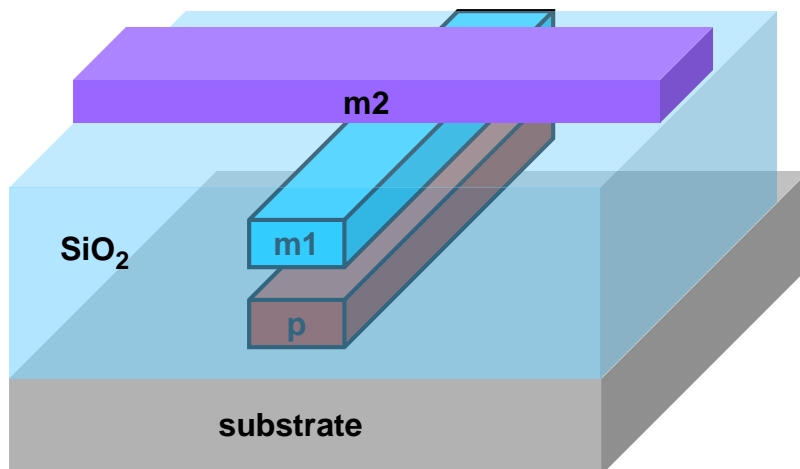
- 5) Planarization – extreme flattening of the wafer’s surface
- Suppose we have the case below where similar patterns stacked on top of each other produce large vertical features



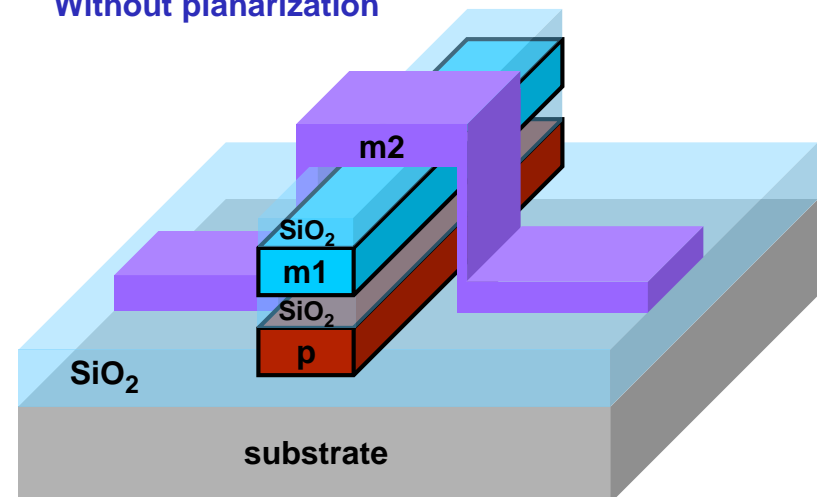
5 Primary Fabrication-Materials and Fabrication-Processes

- 5) Planarization – extreme flattening of the wafer’s surface
- CMP: Chemical Mechanical Planarization (or Polishing)
 - Needed for reliability and consistent thickness of a large number of interconnect layers

Ideal and with CMP processing steps



Without planarization



Basic repeated process

- 1) Deposit a material
- 2) Coat with photoresist
- 3) Expose photoresist to a pattern of UV light using a light source and a patterned *mask*
- 4) Remove soluble photoresist with selective etching
- 5) Remove material below photoresist with selective etching (base material only)
- 6) Remove remaining photoresist with selective etching (hardened photoresist only)

Photo-Lithographic Process Overview

