Patterning

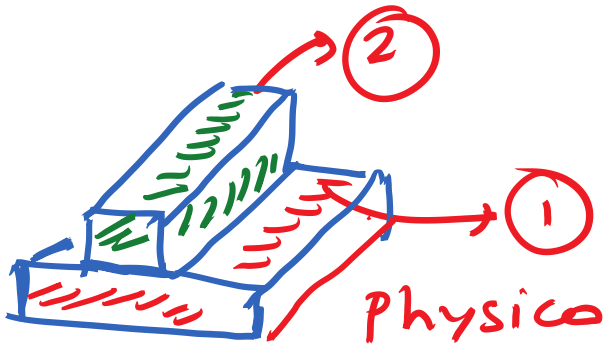
What exactly is a Topographically Patterned Surface?

Photolithography

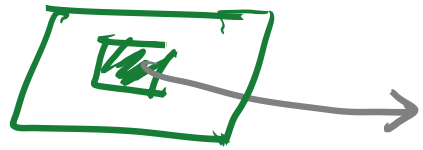
↓

Chemical Patterns

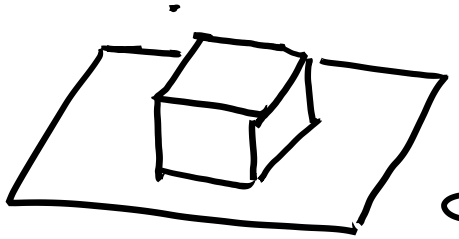
Topographic Patters



Physico-Chemical patterns



→ Different Chemical Properties.



or

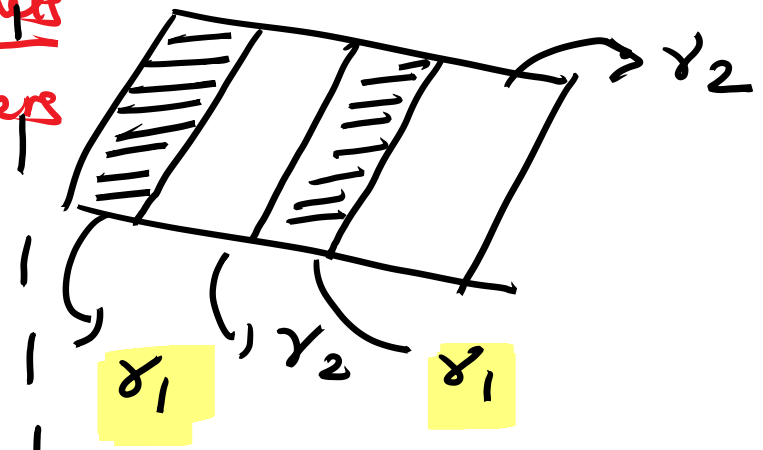
(No topographic contrast)

→ Flat

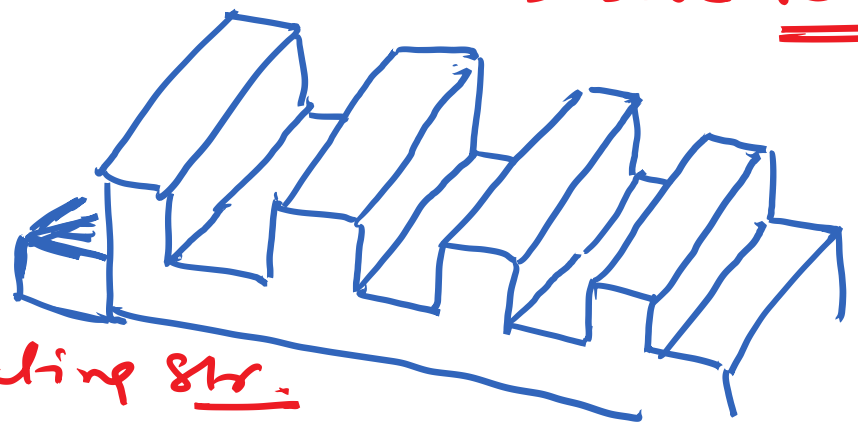
↓

Dewetted Droplets

Disordered Patters



Chemically Homogeneous



Line Grating str.

Top Down Approaches:: Lithography

- Photolithography
- **Soft Lithography**
  - **Micro contact printing**
  - **Nano Imprint Lithography group of methods**
  - **Capillary Force Lithography**
  - **Micro Molding in Capillaries**

(1) How do you make such Topographic Patterns.

(2) What are the potential applications of such patterns.

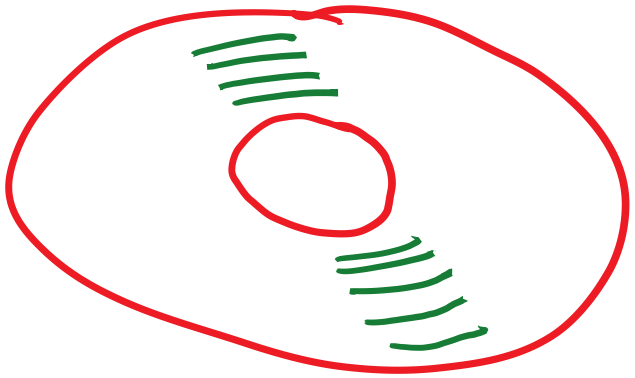
→ Structural Superhydrophobicity

→ Self Cleaning Surfaces.

→ Diffraction of Light → Rainbow Color on the back side of a CD.

→ Insect Vision / Change of Color like

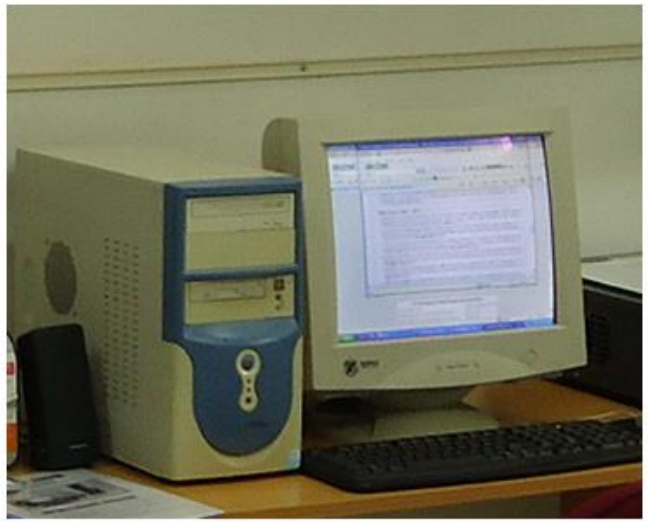
Back Side of a Compact Disc.



Some Topographic Patterns → Which have feature size Comparable to the WL of Visible Light →

Structural Color

The BIGGEST application area of Patterning



Pentium II processor

200 M Hz Clock Speed

500 MBHDD

1999

Intel Core i9-9980XE

4.5 GHz speed

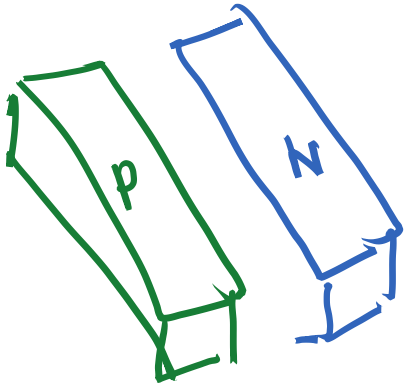
5 TB HDD

2019

To what is this change attributed to?

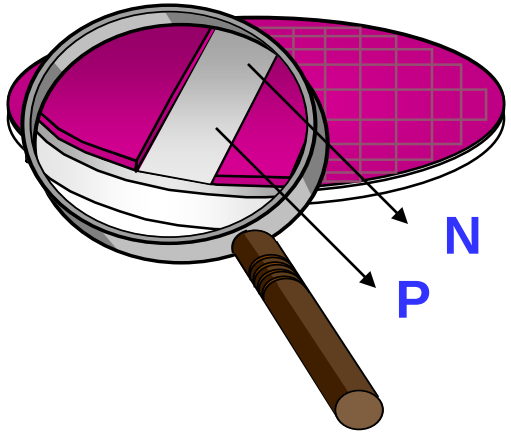
Patterning in Micro Electronics

The micro electronic industry
PC, Laptop, Cell Phone, i-pod ….

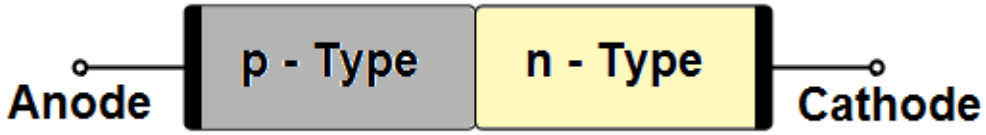


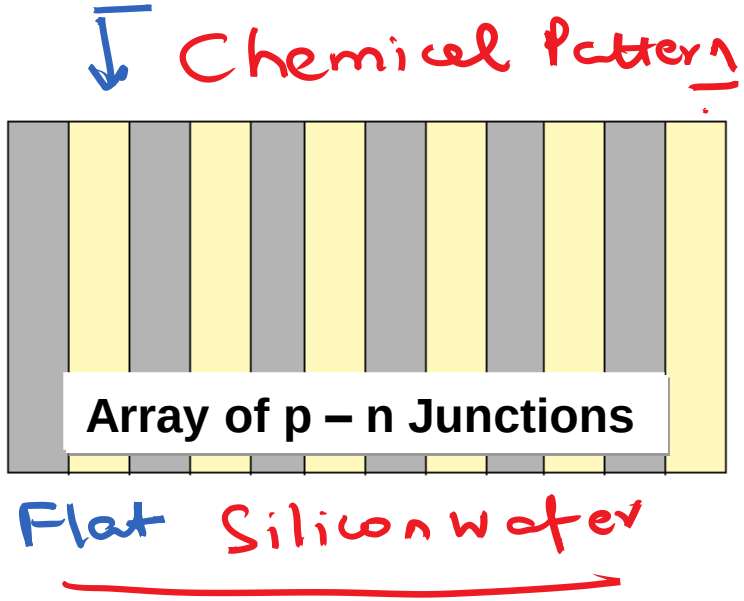
Have you ever thought how every year the speed of the computer processor becomes faster or how the memory sizes increases?

Reality is the tremendous progress in the field of micro electronics industry is attributed to the progress of a specific patterning technique, which is known as photolithography.

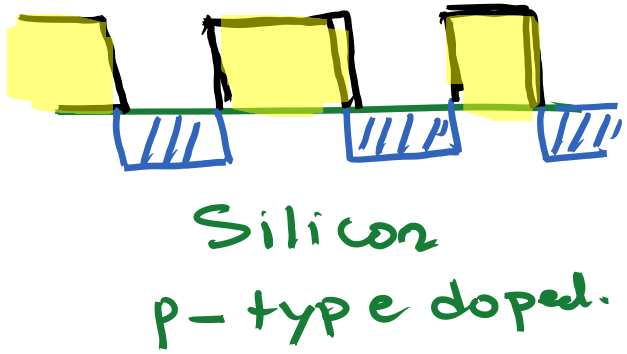


The p – n Junction

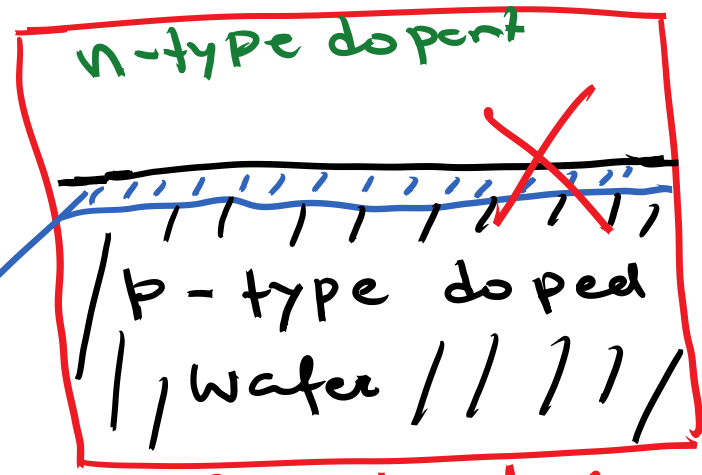




Some Pa

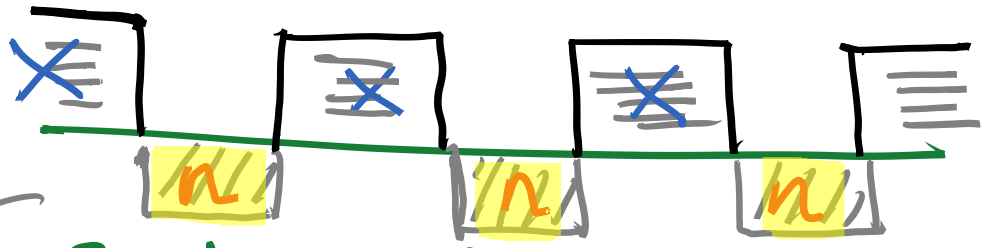


- A p–n junction is formed at the boundary between a p-type and n-type semiconductor.
- If two separate pieces of material were used, this would introduce a grain boundary between the semiconductors which severely inhibits its utility by scattering the electrons and holes.
- so p–n junctions are created in a single crystal of semiconductor by doping
- P–N junctions are elementary "building blocks" of many semiconductor electronic devices such as diodes, transistors, solar cells, and integrated circuits



n-type doping over the entire surface.

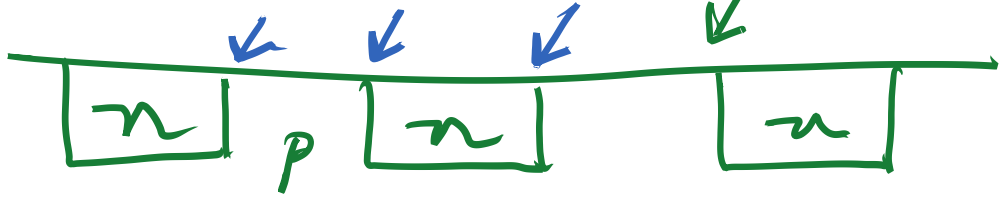
↓ n-type doping Chamber



Doping of the exposed areas only.

Remove the Strips also

p-n junction

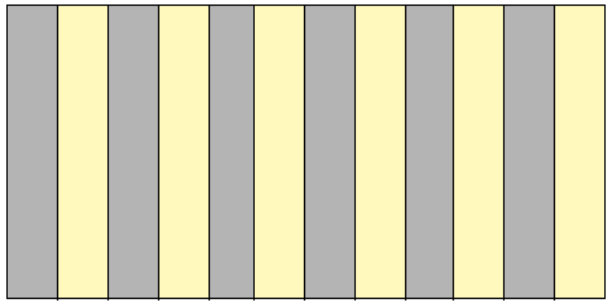


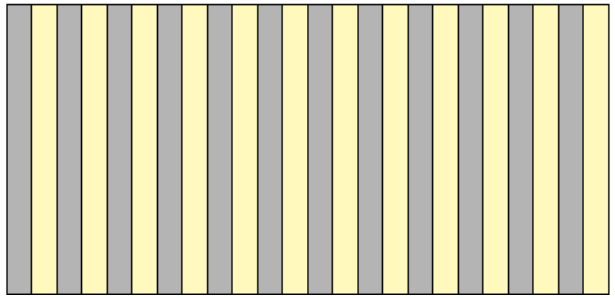
(1) Some Topographic features on the wafer (of a material that does not react/degrade and prevents diffusion of the dopant)

(2) Place in n-type doping chamber.

These strips or patterns prevent the n type dopant from reaching the surface of the wafer.

The p – n Junction



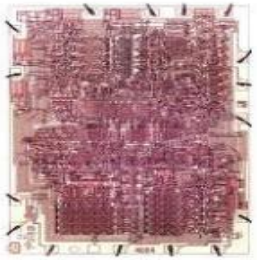


Keep making the domains smaller and smaller → so you can put more p-n junctions.

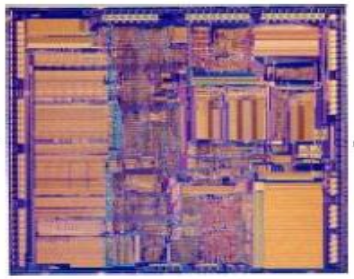
Line width in a computer chip.

- So simply put if your lines become narrower, you can have more number of p – n junctions on a chip whose physical dimensions are the same.
- These lines are created by the method of Photolithography.
- For example while a Pentium II processor had lines which are 300 nm wide, the lines are about 32 nm wide in a i-core 5 processor.
- Similarly progress in patterning is also responsible for higher capacity memories.

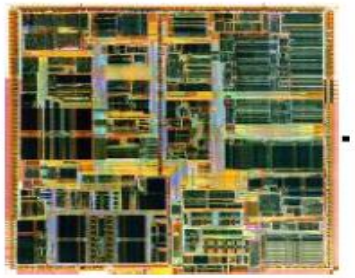
Intel Microprocessors – Brief History



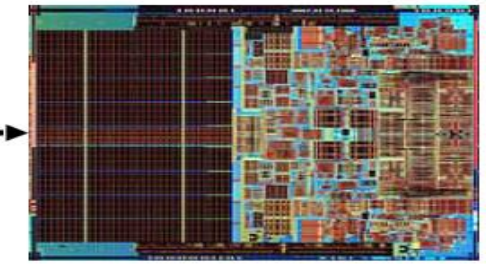
1971
Intel 4004 µP
2,300 transistors
108 KHz
10 µm linewidth



1985
Intel 386 µP
275K transistors
33 MHz
1.5 µm



1997
Intel PII µP
7.5 M-transistor
300 MHz
0.25 µm



2006
Intel Core 2 Duo
291 M-transistor
2.4 GHz
0.065 µm

Historically, advances in microelectronics have been due to ability to making smaller and denser patterns.
→Photolithography has been the workhorse of the semiconductor industry.
→ Lithography is key technology pacing Moore's Law

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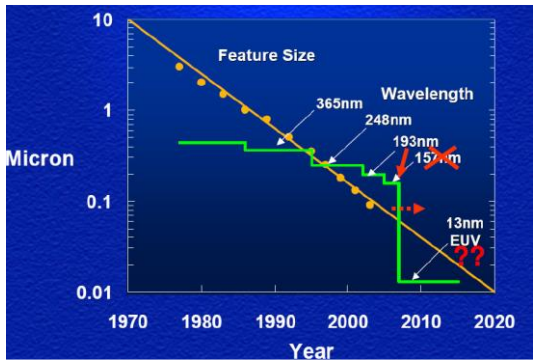
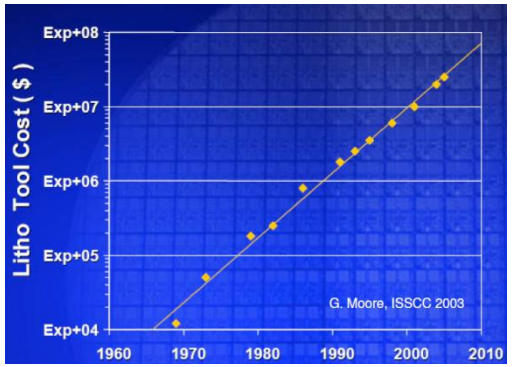
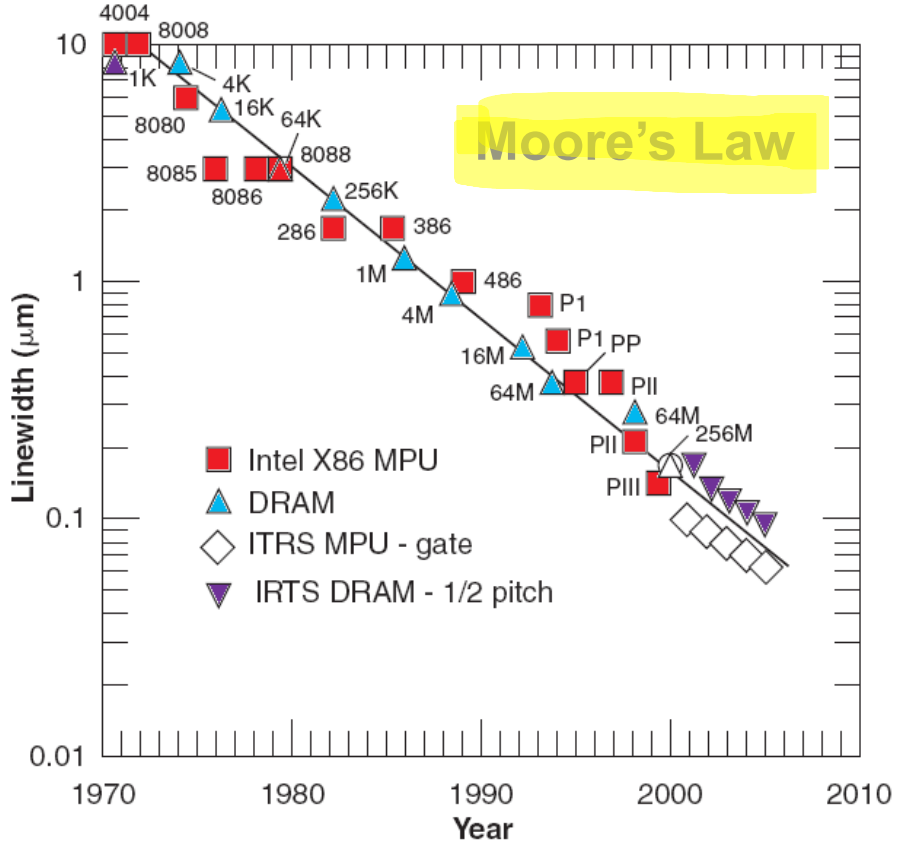
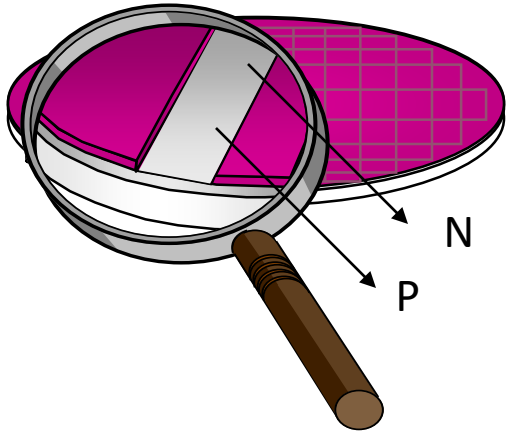


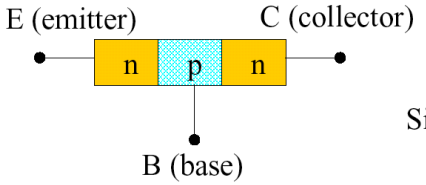


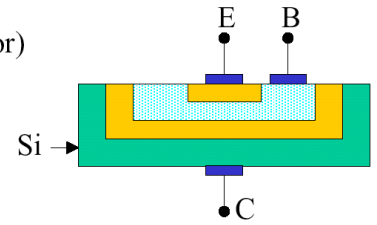
Photolithography

- Innovations in the integrated circuit industry is the main motive force for the tremendous advance in the field of surface patterning.
  - *Transistor invented in 1947.*
  - *The first Integrated Circuit built in 1960. The line width in integrated circuits was 5 µm.*
  - *First IBM PC (1981), 16 K Byte memory, 4.77 MHz clock speed.*
  - *Line widths of 350 nm was achieved, when 40 GB D-RAM was discovered in 1997.*
  - *Present state ~ 40 nm.*
- Narrower is the line size, closer is the packing, better is the performance of the circuit!

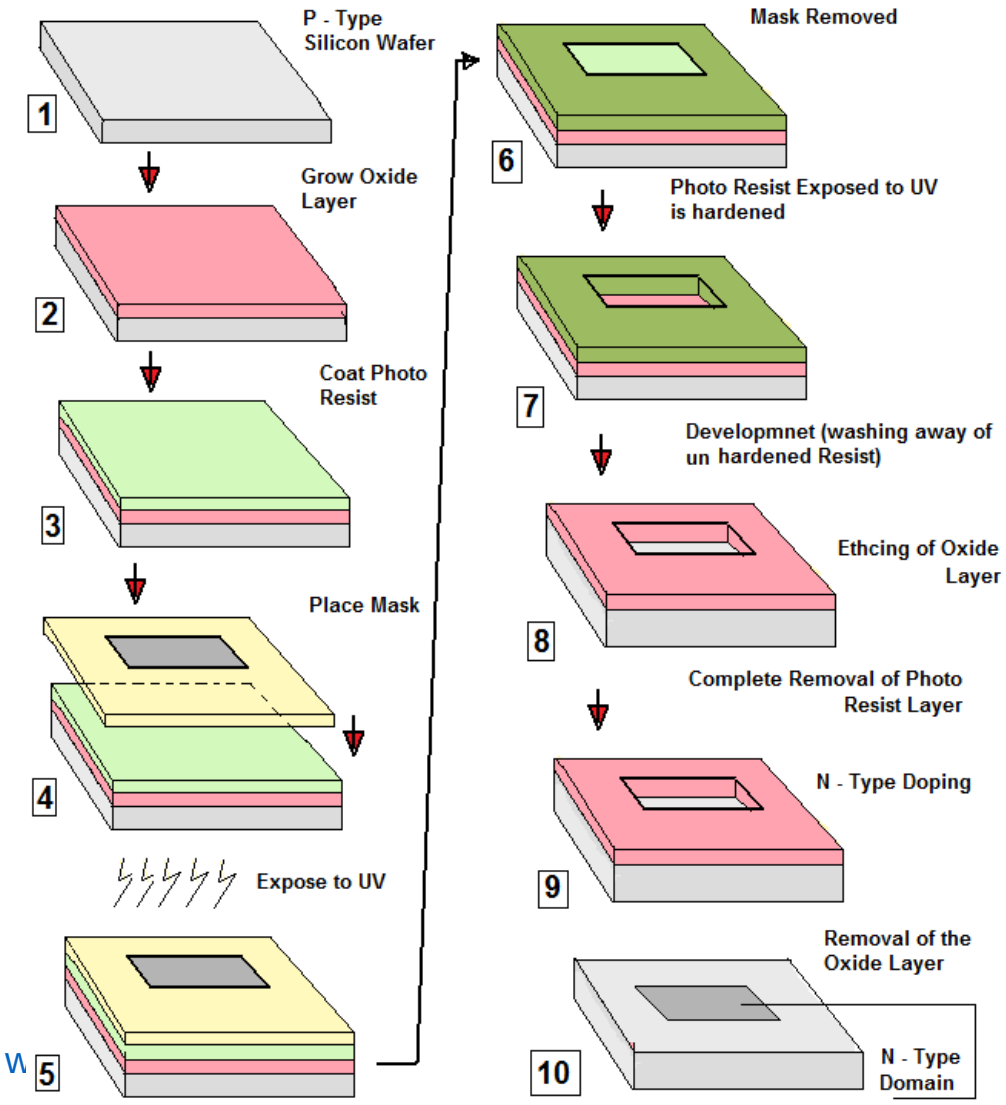








Photolithography Process: Basic Steps



- Silicon Wafer
- Photo resist
- Spin Coating
- Mask
- Optical Source
- Mask Aligner
- Developer
- Etching