Module 2.2: IC Resistors and Capacitors

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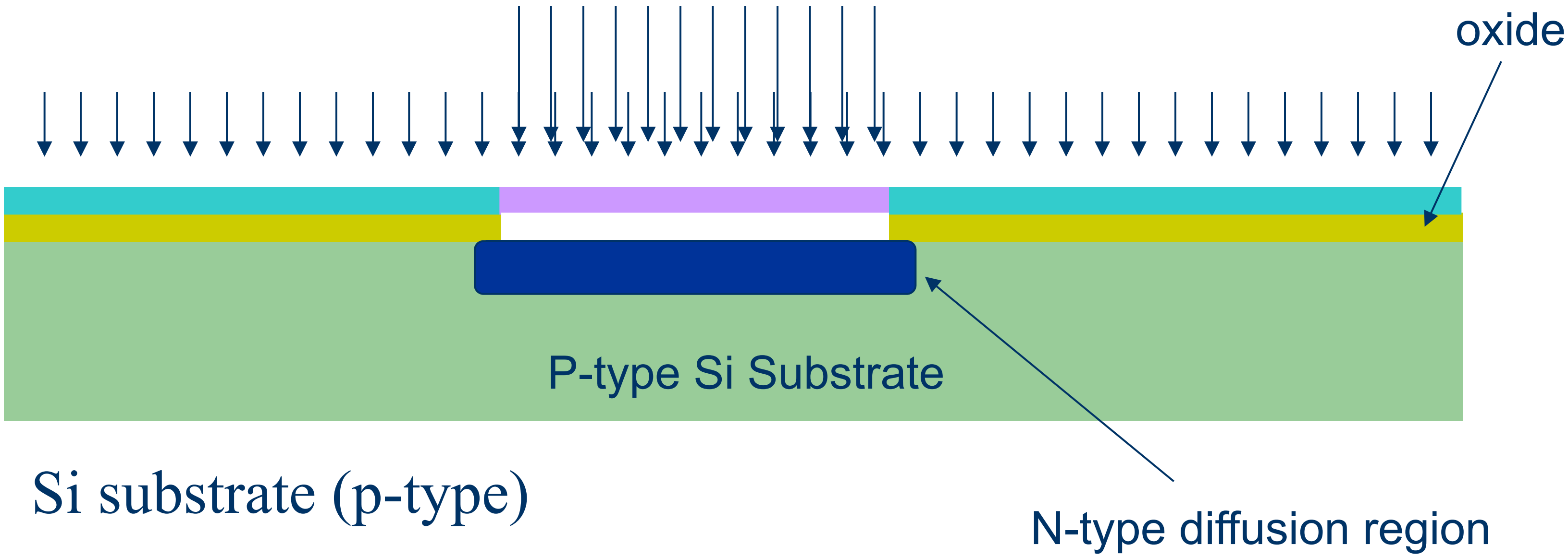
IC Fabrication: Si Substrate

- Pure Si crystal is starting material (wafer)
- The Si wafer is extremely pure (~1 part in a billion impurities)
- Why so pure?
  - Si density is about 5 10^22 atoms/cm^3
  - Desire intentional doping from 10^14 – 10^18
  - Want unintentional dopants to be about 1-2 orders of magnitude less dense ~ 10^12
- Si wafers are polished to about 700 μm thick (mirror finish)
- The Si forms the substrate for the IC

IC Fabrication: Oxide

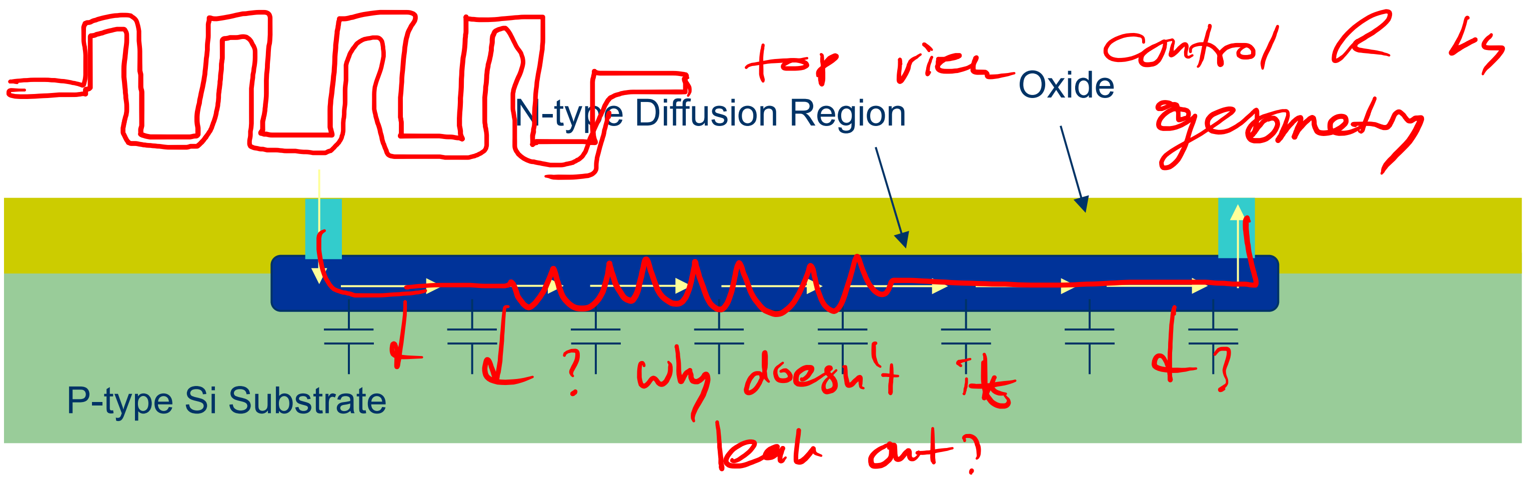
- Si has a native oxide: SiO_2
- SiO_2 (Quartz) is extremely stable and very convenient for fabrication
- It's an insulators so it can be used for house interconnection
- It can also be used for selective doping
- SiO_2 windows are etched using photolithography
- These openings allow ion implantation into selected regions
- SiO_2 can block ion implantation in other areas

IC Fabrication: Ion Implantation



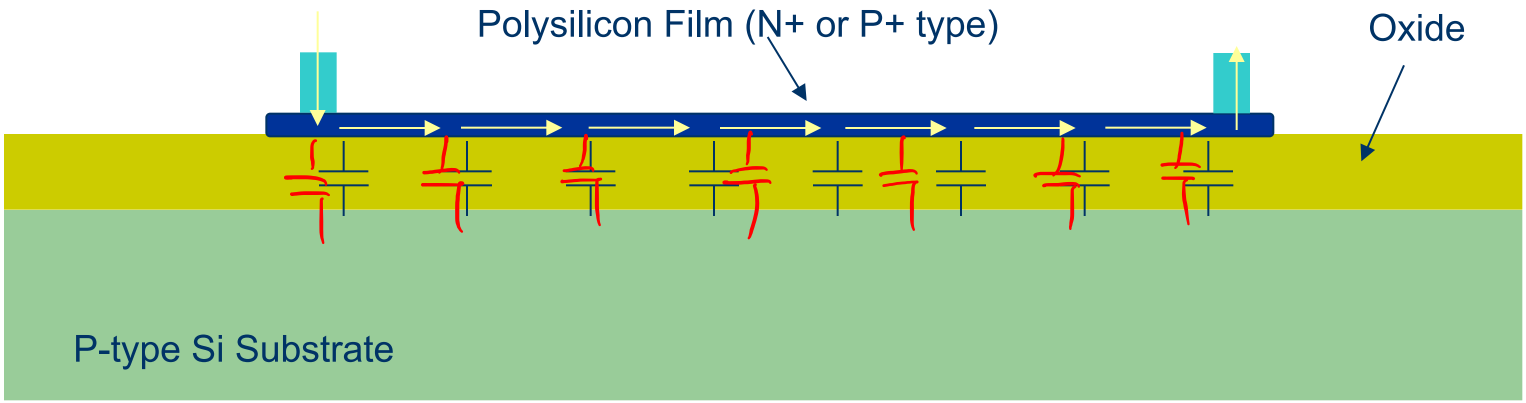
- Si substrate (p-type)
- Grow oxide (thermally)
- Add photoresist
- Expose (visible or UV source)
- Etch (chemical such as HF)
- Ion implantation (inject dopants)
- Diffuse (increase temperature and allow dopants to diffuse)

"Diffusion" Resistor



- Using ion implantation/diffusion, the thickness and dopant concentration of resistor is set by process
- Shape of the resistor is set by design (layout)
- Metal contacts are connected to ends of the resistor
- Resistor is capacitively isolation from substrate
  - Reverse Bias PN Junction!

Poly Film Resistor



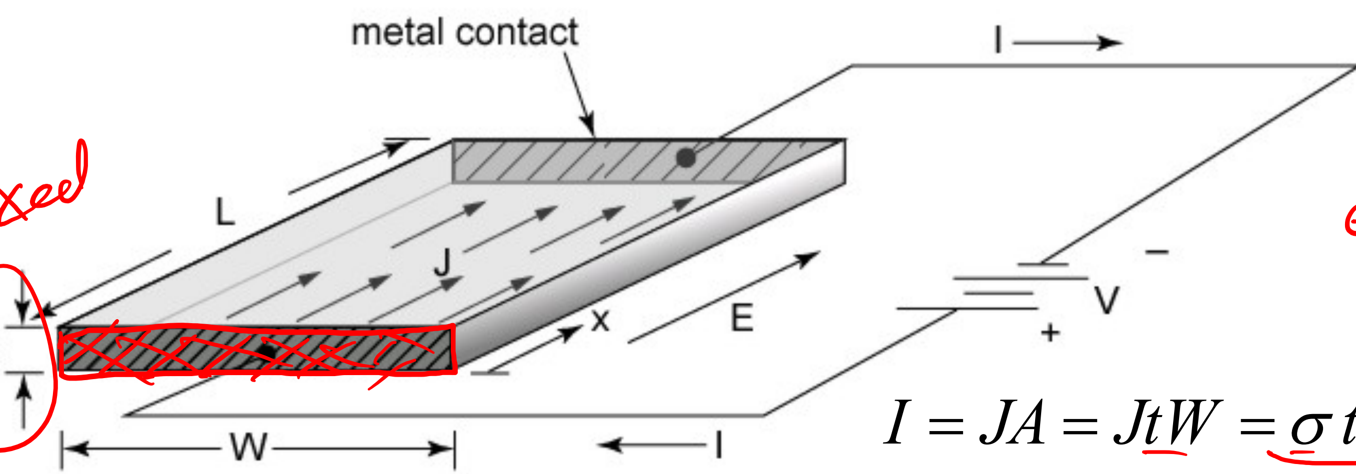
- To lower the capacitive parasitics, we should build the resistor further away from substrate
- We can deposit a thin film of "poly" Si (heavily doped) material on top of the oxide
- The poly will have a certain resistance (say 10 Ohms/sq)

Ohm's Law

- Current I in terms of J_n
- Voltage V in terms of electric field

$$V = IR$$

$$I = JA = JtW$$



$$I = JA = JtW = \sigma t W E$$

$$E = V / L$$

$$I = JA = JtW = \frac{\sigma t W}{L} V$$

– Result for R

$$R = \left(\frac{L}{W}\right)\left(\frac{1}{\sigma t}\right) \qquad R = \frac{L}{W}\frac{\rho}{t}$$

Sheet Resistance (R_s)

- IC resistors have a specified thickness – not under the control of the *circuit* designer
- Eliminate *t* by absorbing it into a new parameter: the *sheet resistance (R_s)*

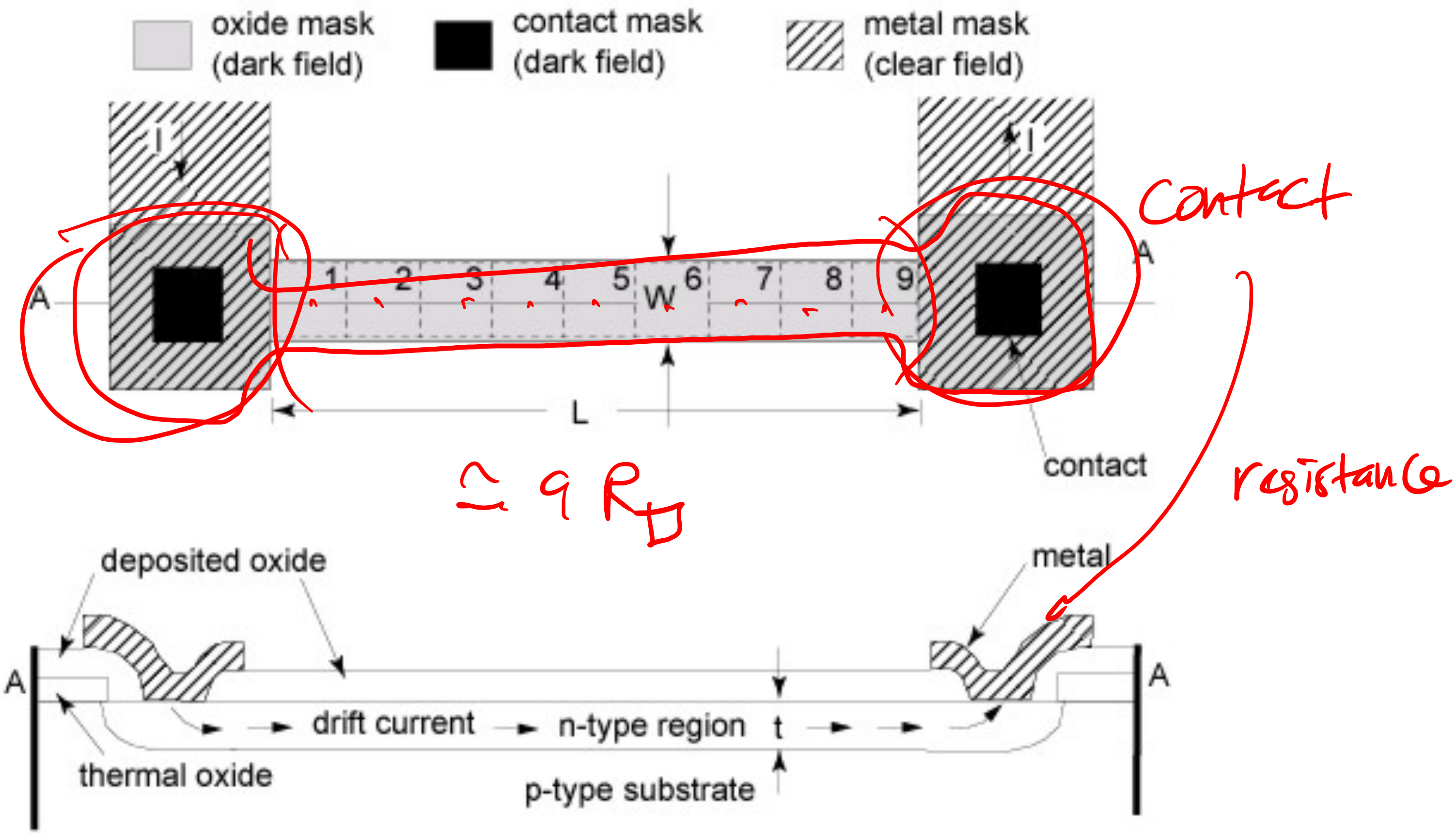
AKA $R_\square$, R_s (sheet resistance)

$$R = \frac{\rho L}{Wt} = \left(\frac{\rho}{t}\right)\left(\frac{L}{W}\right) = R_{sq}\left(\frac{L}{W}\right)$$

"Number of Squares"

Using Sheet Resistance (R_s)

- Ion-implanted (or "diffused") IC resistor



Idealizations

- Why does current density J_n "turn"?
- What is the thickness of the resistor?
- What is the effect of the contact regions?