Lecture 18
Ion implantation, part 3

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Reading:
Chapter 5, Fabrication Engineering at the Micro- and Nanoscale, 4th edition, Campbell

Channeling

- If the incoming beam is aligned with a crystallographic axis, channeling can occur

To Reduce Channeling

- Ion implantation at an angle can essentially eliminate channeling
- The critical angle at which channeling begins:
  \[ \Psi \approx 9.73\degree \frac{Z_i Z_f}{E_d d} \]
  - \(Z_i\) = ion, \(Z_f\) = target
  - \(d\) = atomic spacing
- Typically, \(7\degree\) is used, which works well for everything except very low energy Boron

Shadowing

- A consequence of angle implantation is shadowing
- Solutions
  - Use \(\pm 7\degree\) implants, both left/right and top/bottom
  - Rotate the wafer

Implant Masking

- Selective doping requires the use of implant masks
  - The gate acts as a mask for source/drain implants (which are thus self-aligned)
  - Photoresist and field oxides are often used
  - Typical rule of thumb: the mask must be thick enough to stop 99.99% of the ions from penetrating
Implant Damage

- Above a certain dose, ion implantation leaves the substrate amorphous
- To regrow the crystal and activate the dopant, an anneal step is used
  - If the temperature/time is too low, defects remain in the crystal (up to 1000°C is required)
  - If the temperature/time is too high, too much diffusion occurs
  - Best compromise requires the use of Rapid Thermal Annealing (RTA)
- Note that ion implantation allows dopant concentrations above the solid solubility limit

Lecture 18: What have we learned?

- How and why does channeling occur?
- What is the most common remedy for channeling?
- Explain shadowing and how it is mitigated
- What is required of an implant mask?
- How is implant damage repaired?