EE 143
Microfabrication Technology
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Lecture Module 7: Interconnects & Contacts

Interconnects & Contacts

Outline

- Interconnects & Contacts
  - Planar Process Compatible Metals
  - Ohmic vs. Diode Contacts
  - Sintering
  - Measuring Contact Resistance
  - Electromigration
  - Space-Saving Contact Strategies
  - Silicidation
  - Lift-Off
  - Multilevel Metallization
    - Damascene Process
- Metal MEMS Surface-Micromachining

Planar Process Compatible Metals

TABLE 7.1 Bulk Resistivity of Metals (μΩ-cm)

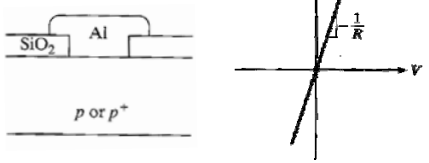
Ag: Silver	1.6
Al: Aluminum	2.65
Au: Gold	2.2
Co: Cobalt	6
Cu: Copper	1.7
Mo: Molybdenum	5
Ni: Nickel	7
Pd: Paladium	10
Pt: Platinum	10.6
Ti: Titanium	50
W: Tungsten	5

Source: WebElements (http://www.webelements.com)

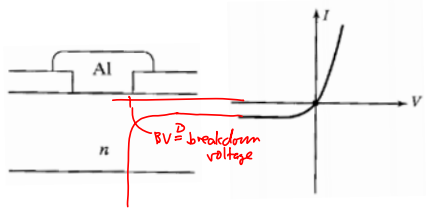
- Aluminum (Al) and gold (Au) used most in IC's before 2002
  - Al compatible with silicon IC's, so most common on chip
  - Au not compatible with silicon IC's, since it diffuses too fast and can trap charge; used mainly for bond wires

Ohmic Versus Rectifying Contact

Schottky Ohmic Contact:
- Metal work function < semiconductor work function
- For Al: $q\Phi_M$=4.1eV
- For p+-Si: $q\Phi_{Si}$~5.17eV

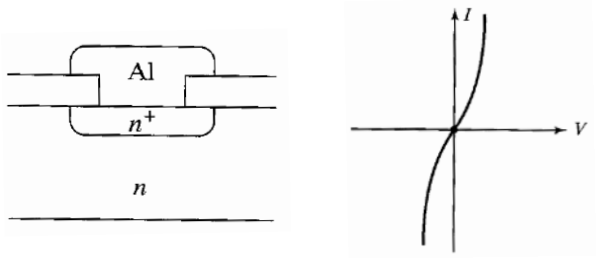


Schottky Diode Contact:
- Metal work function > semiconductor work function
- For Al: $q\Phi_M$=4.1eV
- For n-Si: $q\Phi_{Si}$~4.05eV



How to Contact n-type?

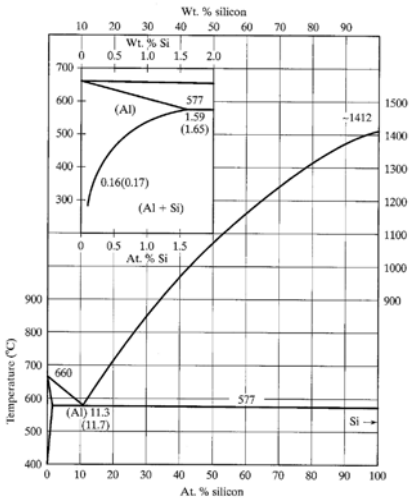
- Just dope the silicon heavily n-type; i.e., make it n+



- Depletion region between metal and silicon becomes extremely thin
  - e-'s can tunnel through it
  - Basically dope so heavily with n+ that the diode breaks down at a much lower voltage
  - Gives it an IV-characteristic similar to ohmic

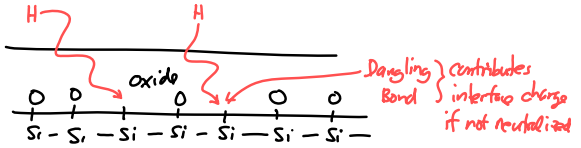
Aluminum-Silicon Eutectic Behavior

- Silicon melts at 1412°C
- Al melts at 660°C
- But when in contact, Si and Al effectively lower each other's melting temperature
- Minimum temperature is the eutectic temperature that can occur as low as 577°C, where we get 88.7% Al, 11.3% Si



Sintering

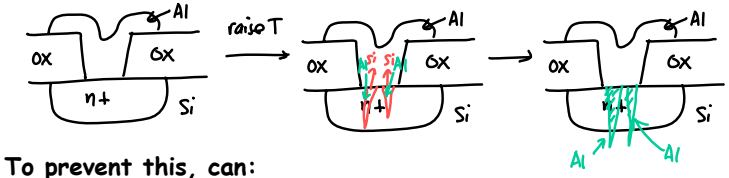
- Usually need a forming gas anneal @ 400-450°C (called sintering) at the end of an NMOS or CMOS process
  - Forming gas = mixture of H_2 and N_2
  - Improves the metal to silicon contact
  - Reduces the oxide interface charge, allowing the threshold voltage to be the right value
  - The H_2 ties up dangling bonds that would otherwise contribute fixed interface charge



- If you finish an MOS process and your thresholds are off, don't despair – just do a sintering step & this will probably fix your problems (almost like magic)

Al Spiking & Junction Penetration

- Problem: taking the temperature up too high causes silicon to diffuse into Al
  - Supply of Si tends to come from a few points, that then leave caves that Al can then go into to form spikes
  - This happens because the silicon wants to diffuse into the Al till it reaches its solid solubility limit of 0.25-1.5%



- To prevent this, can:
  - Incorporate Si into the Al so that it's closer to its solid solubility limit – usually add 1% Si to the Al target in sputtering
  - Use a barrier metal (e.g., TiW)
  - Use a barrier silicide