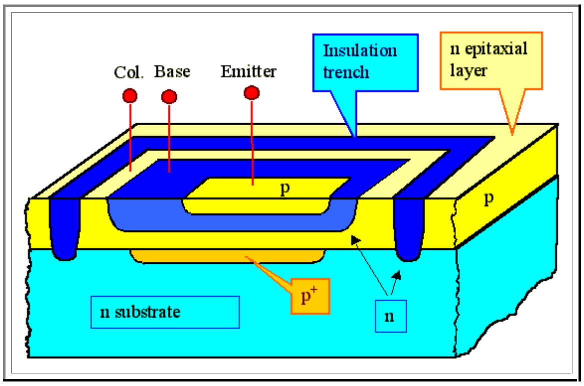
Passivation of Interface States

This module will expand with time; here are a few basic informations

Illustration

- A case could be made that passivation of surfaces (for the early bipolar devices) and of the **Si/SiO_2** interface in **MOS** technology, was the *key process* in the beginning of semiconductor technology.
  - The reason was that early devices simply did not work - the electrical function of properly made **pn**-junctions and so on was overwhelmed by the surface states. To understand that, consider that every **pn**- junction in a real device will come out at the surfaces somewhere:



  - The picture shows a typical bipolar transistor in an integrated circuit (from around **1990**), and you see a lot of **pn**-junctions coming out at the surface.
  - The solution was simple (but took a while to find): in the old days it consisted of simply oxidizing the whole device; taking advantage of the low interface state density in a **Si/SiO_2** interface obtainable with a "good" thermal oxide.
- Modern solar cells, just consisting of the yellow and light blue layer in the schematic drawing above, still have this problem: The **pn**-junction comes out at the side, with all kinds of problems.
  - The good old oxidation recipe, however, cannot be applied anymore - it is simply too expensive.
- But now we have **MOS** devices, and interface states are crucial - even at the low density obtained with good oxides. "Passivating" the remaining interface states in the critical **Si/SiO_2** interface of a **MOS** device is necessary and calls for a different technology.
  - Here we use as the *last* process step, never abandoned, the annealing of the whole wafer for half an hour or so at typically **450 ^{0}C** in a **H_2** or **H/N_2** ("forming gas") atmosphere. Higher temperatures would probably be better, but after the **Al** deposition, **450 ^{0}C** is the highest temperature you may use without degrading the **Al**.
- All these (and other) processes are generally called **passivation**, and they all have in common that "somehow" hydrogen atoms bind to the disturbed atom configurations that cause the deep levels in the band gap with the effect that the level disappears.
- Passivation is still a critical process. A little anecdote to this:
  - Back in the days of the **16 Mbit DRAM** development (around **1989**), the process engineers started to wonder if the **H**-annealing at the end is still necessary. It has betwen kept as a matter of course throughout the years, was never questioned, and always applied (Its easy and doesn't cost much).
  - It was decided to do a few experiments. But this proved not to be necessary, because actually the production unit (making **4 Mbit DRAMs** at this time), independently (and quite involuntarily) performed the experiment - on large scale: Somebody accidentally hooked up a *wrong* gas bottle to the **H**-annealing station containing only **N_2**.
  - This mistake was quickly discovered, because from this day on the factory only produced junk - the devices did not work This is the biggest disaster imaginable, so people started to move quickly, and the mistake was discovered.
- This "experiment" thus proved that **H_2** -passivation still was essential. It proved even more:
  - After the defunct wafers were annealed again - this time in the proper atmosphere - the devices came back to life. Everything was as it should be.

What do we learn from, this?

- Don't take interface and surfaces states lightly. The recombination or generation velocity associated with these deep levels or states are important parameters that can easily control the function of your device.
- All semiconductor technology starts with controlling these states. If you are lucky and you can use mono-crystalline material, you do not have to worry about grain boundary states (a grain boundary, after all, is an internal interface), but most semiconductors come as poly-crystals. And it is often the inability of dealing with the surface recombination velocity of these materials that makes them useless for technical application.
- And if you think that we do not need new semiconductor - after all we have **Si**, **GaAs**, etc. - think again. What humankind would need quite desperately is a *cheap* (= polycrystalline) semiconductor for making *cheap and good* solar cells. Finding this magic material includes control of its interface recombination velocity.