

5.4 Summary

5.4.1 Summary to 5: Integrated Circuits - Process Integration

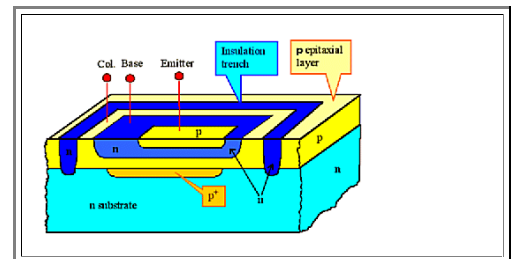
Integration means:

1. Produce a large number (up to **1.000.000.000**) of transistors (bipolar or **MOS**) and other electronic elements on a **cm²** of **Si**
2. Keep those elements electrically insulated from each other.
3. Connect those elements in a meaningful way to produce a system / product.

It ain't easy!

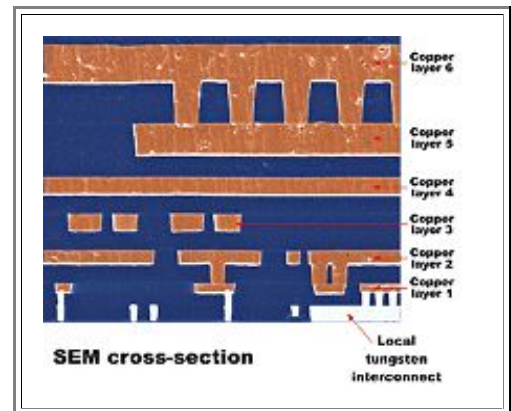
An integrated bipolar transistor does not resemble the textbook picture at all, but looks far more complicated \Rightarrow .

- This is due to the insulation requirements, the process requirements, and the need to interconnect as efficiently as possible.
- The epitaxial layer cuts down on the number of critical diffusions, makes insulation easier, and allows a "buried contact" structure.



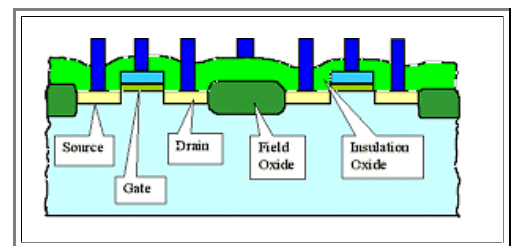
Connecting transistor / elements is complicated; it has to be done on several levels

- Materials used are **Al** ("old"), **Cu** ("new"), **W**, (highly doped) poly-**Si** as well as various silicides.
- Essential properties are the conductivity σ of the conductor, the dielectric constant ϵ_r of the intermetal dielectric, and the resulting time constant $\tau = \sigma \cdot \epsilon_r$ that defines the maximum signal transmission frequency through the conducting line.



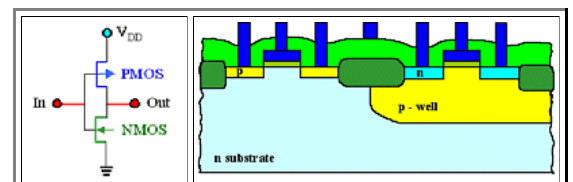
Integrating **MOS** transistors requires special measures for insulation (e.g. a field oxide) and for gate oxide production

- Since a **MOS** transistor contains intrinsically a capacitor (the gate "stack"), the technology can be used to produce capacitors, too.



CMOS allows to reduce power consumption dramatically.

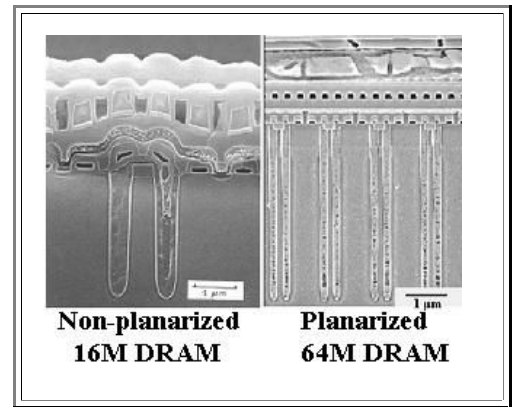
- The process, however, is more complex: Wells with different doping type need to be made.



Using the third dimension (depth / height) might become necessary for integrating "large" structures into a small projected are (example: trench capacitor in **DRAMs** ⇒).

Unwanted "topology", however, makes integration more difficult.

Planarized technologies are a must since about 1995! ⇒



It ain't neither easy nor cheap!

Questionnaire

Multiple Choice questions to 5.

Exercise 5.4-1

All Questions to 5.

| Property | Number |
|----------------------------------|-----------------------------------|
| Feature size | 0,2 μm |
| No. metallization levels | 4 - 7 |
| No. components | > 6 · 10 ⁸ (Memory) |
| Complexity | > 500 Process steps |
| Cost (development and 1 factory) | ca. \$ 6 · 10 ⁹ |