1.1.3 Electronic Materials and Products

- So what are "Electronic Materials"? Ask Google and you get an answer!

- Progress in Electrical Engineering was always dependent on progress in materials. For quite some time, electrical engineering meant electro*mechanical* engineering, and electrical products were made from "trivial" materials, as seen from a modern point of view. What was needed were cables, insulators, ferromagnetic sheet metal for transformers and generators, and a lot of metal for the general mechanics. A few applications centered around some mysterious materials - out of that grew *electronics* and electronic materials. But even then there were key materials:
  - *Cu wires* of all kinds. Not so trivial - how do you make a insulated but still flexible wire?
  - Insulating materials - plastics didn't quite exist yet. ***Mica*** was one of the key materials - there were mines for it!
  - *Graphite* and ***tungsten*** were important, whenever things got hot, like the filament in the light bulb or in a **vacuum tube**.
  - The "tube of **Braun**" - the "*Braunsche Röhre*" as it was known in Europe - the first **cathode ray tube** (***CRT)*** in other words - needed complicated glass work and some *ZnS* as electroluminescent material
  - Strange compounds like "*phosphor bronze*" were developed for contacts.
  - And **Selenium** (**Se**) was important for rectifiers, although nobody quite understood how it worked.
- The essential break through in the thirties was the **vacuum tube**; with it came electronics: Rectifiers, amplifiers, radio, black-and white **TV**, colour **TV**. It's not that long ago, but obviously long enough for some not to remember!
- The next break-through was called **transistor**; it happened in **1947**. **Integrated circuits** followed around **1970**, and since then we witness exponential growth with growth rates in the complexity of electronics (at constant prices) of up to **40%** a year!
  - A good (german) book covering this development in some detail is Hans **Queissers** "*Kristallne Krisen*".

1.2.2 Electronic Materials and Electronic Products

Electronic Products

- *Electronic Materials* are what you find inside the *components* making up *electronic products*. They consist of some stuff that you cannot easily exchange with something else - not even in principle - without losing the function.
  - What you *can* change easily for example, is the material for the box, the housing. Use *Al* instead of plastic or vice versa for your video recorder - it would still work, needing at most some minor adjustments.
  - You also may change (in principle) the metal for real wires. Using *Au*, *Ag*, or *Al* instead of - let's say - *Cu*, makes little difference for the function.
  - But exchange *any* material in a "chip" (i.e. in an **integrated circuit**) with something else (even allowing for minor adjustments) - and that definitely will be the end of your product.
- Let's look at some typical products or product groups that contain electronic materials:
  - *Electronics* in general (Computer, **TV**, Radio, Radar, Microwave, ...).
  - **Flat panel displays** (***FPD***).
  - **Micromechanics** and **Microsystems** (***MEMS***).
  - **Solar cells**.
  - **Lasers** (in particular semiconductor Lasers).
  - **Batteries**, **Accumulators**; energy storage systems in general.
  - **Sensors**, in particular solid state sensors, that convert whatever they sense directly into a current or a voltage.
  - **Fuel Cells**.
  - **Magnetic Memories**.

Looking at Components

- Consider, e.g., a **laptop** or **notebook** in more detail. If you take it apart, you find the "high tech" stuff:
  - Any number of *chips*, i.e. integrated circuits.
  - Some **quartz oscillators**.
  - A **hard disc**, i.e. a magnetic memory for the bulk memory.
  - A reading head for the hard disc that uses the "**giant magnetoresistance effect**"
  - A ***CD ROM***, i.e. an optical memory and a semiconductor ***Laser***
  - A **flat-panel display** (**FPD**) using "liqiud crystals", whichis pretty big as a single component, but cannot be subdivided in smaller pieces.
- But there is also "low tech" - or so it seems:
  - **Capacitors** and **inductors**.
  - *Switches*, connectors, the keyboard as a unit.
  - *Insulation*.
  - Mechanical stuff like the disk drive, but also the *housing.*
- Some components betray their key material in their name ("*quartz*" oscillator) or by common knowledge (who, besides some so-called intellectuals, does not know that the word "chip" is almost a synonym for Silicon?), but for most components we have to look deeper - we must open them up (which will almost always destroy them). What do we find?

Electronic Materials

- Lets open up a chip. We find
  - **Packaging material** - either some *polymer* blend or *ceramics*.
  - A "chip" mostly consisting of **Si**, but interlaced in an intricate pattern with other materials like **P**, **B**, **As**, **SiO_2**, **Si_3N_4**, **$MoSi_2$**, **W**, **TiN**, **Al**, **Cu**….
  - A **lead frame** - the little pins sticking out of the package - made of some *metal alloys*.
  - Tiny **wires** connecting the leads to the chip or some pretty sophisticated stuff doing this job.
- Now open up the **FPD**. You will find many materials, the most suspicious beyond what we already found in chips are:
  - **Liquid crystals**, some strange liquid stuff.
  - **Amorphous Si**.
  - **Indium tin oxide *ITO***, a transparent electrode.
  - *Plastic foils* acting as *polarizers*.
  - A plastic (or *glass*) front and end plate.
- Now lets look at the **Laser** coming with the **CD** drive :
  - You find a complex mix of **GaAs**, **GaAlAs**, some other elements, as well as wires and packaging materials.
  - And all of this is quite different from what you find in the **Si** chips!
  - Soon you would find **GaN** in your Laser diode - and the capacity of your **CD** memory will quadruple!
- We could continue this, *but by now you got the idea*:

Progress in Electronic and Communication Technology is driven by
Progress in Material Science
(and almost nothing else)