

### 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 "liquid crystals", which is 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<sub>2</sub>, Si<sub>3</sub>N<sub>4</sub>, MoSi<sub>2</sub>, 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)**