1.2. Introduction to the Course

1.2.1 Motivation for the Content

General Remarks

- The course will first take a look at **products** containing semiconductor technology. Analyzing this products leaves us with **components** and finally with materials and processes for semiconductor technology.
  - *Products* we define simply as something you and I *do* buy or at least *could* buy. We also include services in this category.
  - *Components* are whatever one finds inside a product, e.g. "**Chips**", but also **light emitting diodes** (***LED***'s) or **liquid crystal displays** (***LCD***'s)
  - At least some components of our products of interest are made from **semiconductors**. What we want to learn in this course then is simply
    - What Semiconductors do we use?
    - How do we make the component we want?
- These questions go deeper then it may appear on first sight. Let's look at two examples:
- So we use **Si** for our component. But just saying **Si** is not good enough.
  - Do we use single crystalline **Si**, poly crystalline **Si** or amorphous **Si**? Or perhaps nanocrystalline **Si** with some amorphous regions?
  - If we use single crystalline **Si**, do we go for **Czochralski**-grown (***CZ***) or **float zone** (***FZ***) crystals, or possibly an *epitaxial layer*?
  - OK - we take the **CZ** wafer. What doping type would you like? **p** - or **n**-type? All right, we take the **n**-type, well done - thank you very much.
  - Would you prefer **P**-doping or **As**-doping? Or may we recommend today's special: **Sb**-doping? And what kind of interstitial oxygen concentration may I offer to you? We have a large selection for every taste.
  - You get the drift. And as in any good restaurant, you will "taste" the difference. What you get as a component depends on your detailed specification.
- No let's make a solar cell. From **Si** or from something else?
  - In fact, we make (and you and I can buy it) from all kinds of **Si** mentioned above, from **GaAs**, from **$CuInSe_2$**, from **CdTe**, from **TiO_2** and from a growing number of other semiconductors and combinations of different semiconductors,

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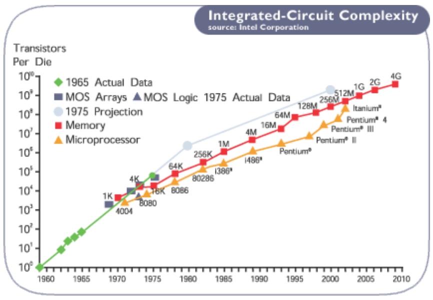
- Why, oh why are we doing this? It seems to make life so complicated. Can't we decide on the best material and process for solar cells and be done with it?
  - Well, being the boss of a large solar cell company, you actually must make this decision - you can not possible run a multitude of factories, each with its own materials and processes. **You** must make a choice for one, or maybe just two basic product lines.
  - The same is true for your competitor. If his choice is different from yours, time and in particular the market will tell, which one of you guys made the *better* choice.
- In other words: if we look at products, we do not just look at technical topics, we actually look at economical issues! **Money**, not Nobel prizes is the decisive factor in the end!

Products, Components and Materials

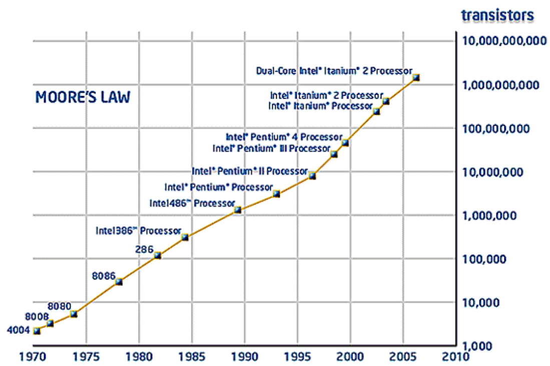
- As a human being, you encounter all kinds of products and services all the time - and you rarely think about what is hidden behind the obvious. You pick up your (cell)phone, dial a number or press a button, and expect that within seconds you will be able to talk to the person of your choice - whoever and wherever that person might be.
  - If a regular human being gives the "behind the obvious" any thoughts, he or she will probably conclude, in the words of **Dave Barry**, "that cell phones are operated by **magic**".
  - As a (budding) Materials Scientist and Engineer, you know better. Behind the obvious is semiconductor technology. Not exclusively, and not always, but "immer öfter" (ever more often).
- Note that not all that long ago (for elderly professors) - in the **1950** ties - the number of semiconductor products was exactly zero.
  - Now we have such a large diversity of products, components and semiconductors all around us that we can hardly do more than scratch the surface in this course.

Markets and Growth

- The very first semiconductor products intentionally made (i.e. based on understanding what is going on) hit the market in the late fifties / early sixties of the **20**th century - in the form of "transistors", a word not used for a transistor per se, but for a **transistor radio**.
  - This was an unbelievable big *product* achievement because, for the first time in human history, it enabled everybody, not just skilled muscians, to make loud noises in public. Of course, the transistor radio was an instant success.
  - A portable, battery-run "transistor" contained about **20** (**Ge**) transistors, already some progress in comparison to your big and heavy home radio, that may have contained about **10** vacuum tubes as active elements.
- Putting several transistors on *one* piece of **Si**, i.e. making an **integrated circuit** (***IC***), was the next big (double) step in technological development; it consisted of switching to **Si** as base material and in finding ways for integration.
  - Since then semiconductor technology is an unprecedented success story - it is now (**2007**) arguably the world-wide biggest industry with respect to product penetration.
- The key word in this respect is "**Moore's law**", simply stating that any quantitative measure of progress in **IC** technology grows exponentially "forever" with growth rates in the **30 %** range.
  - Typical measures are, for example, the number of transistors on one chip, almost the same as the number of bits one can store in one memory chip. What that looks like is shown in the figure below - note the logarithmic scale



Memories and micro processors



Intel processors
Courtesy of Intel Corp.

- The implications of exponential growth for by now more than **40**years are staggering - use the [link]() if you want to have just a flavor of this. We will just look at two points in this context:
  - The world has changed in a major way in the last **20** years or so because of semiconductor technology. Think about this yourself. *Hint:* Consider what hides behind catch words like "Internet", "electronic warfare", "Resonance tomography", "globalization", "energy crisis", ..., in technical, social and political terms.
  - Exponential growth *never* continues forever. In fact, since about **1985**, serious people believed (or actually tried to prove) that it will be over soon. When it will be over, meaning that growth rates come down to "normal", all kinds of problems might occur - witness the bursting of the (stock market) "Internet bubble" in **2000** or the bursting of the USA real estate bubble right now (Aug. **2007**) - all caused by the sudden end of exponential growth. If we are lucky, we will have a "soft landing" in the **IC** business; if we are even luckier, the foreseeable slack in the **IC** business will be compensated for by growth in other areas of semiconductor technology, e.g. **solar cells**.
- Where does this leave *you*? If the **30%** per year growth rate peters off, will there be jobs? Is it sensible to learn about semiconductor technology now when it soon will be "over"?
  - For an answer, look at the German car industry. Seen with semiconductor industry eyes, technical progress in making cars during the last **40** years or so was close to zero - compared to semiconductor products. A factor of two in total performance progress (top speed, gas consumption, ..) in these **40** years is already seen as enormous achievement. Compare with memory chips: **1978: 16 kbit**, **2007: 16 Gbit**; improvement factor **10^{6}**.

- Yes - but:. The car industry is still the largest industrial branch in Germany with lots of jobs....