

## 4. Getting Started

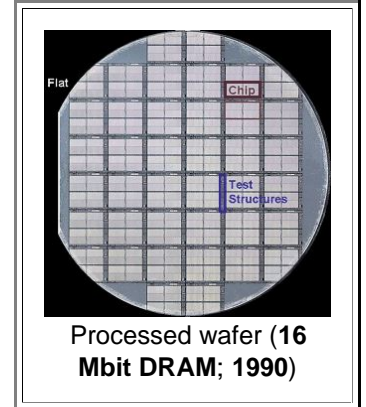
### 4.1 Input to Si Processing in an Industrial Environment

#### 4.1.1 The Factory

##### A Chip Factory

Let's have a quick look a factory where *semiconductor technology* is used to make a **product**. Behold the basic law of semiconductor processing in this context:

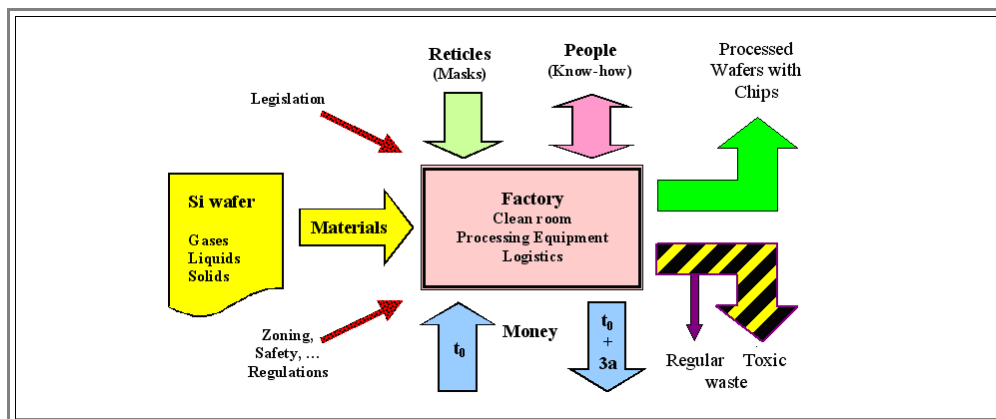
**Semiconductor  
Technology  
is for making Products**



Let's pick the most advanced product, a **Si** microelectronic circuit - a **chip**, in other words.

- There are several factories involved before you get a packaged chip that you can solder on a circuit board (actually you, personally, would have a hard time doing that, but some machines can). Here we look at the most expensive and complex part of the production chain: the huge **cleanroom** where **Si wafers** go in - and **Si wafers** come out, but now with completed chips on them.
- The processed wafers as shown in the picture will be turned into packaged chips somewhere else - often somewhere really else, like **8.000 km** away.
- We can look at the factory as a kind of a ( $3 \cdot 10^9 \text{€}$ ) **black box** and just look at inputs and outputs.

Severely simplified, here is the basic semiconductor technology plant with its inputs and outputs:



Let's look at the boring to annoying factors first:

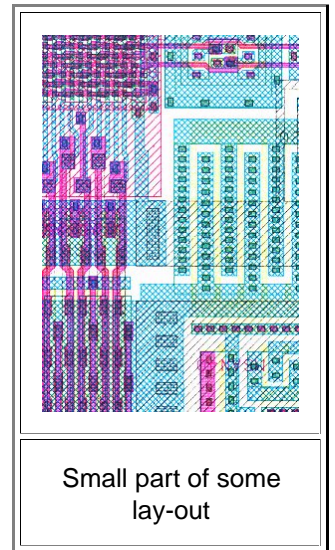
- You need a hell of a lot of **money** as **input** to get going and to keep going. Cost of building and equipping the factory (**some  $10^9 \text{€}$** ), of developing the product and technology needed, paying the **2.000 - 3.000** people working there (it's running **24 hours** a day, **7** days a week), paying for the input, and paying taxes etc. simply adds up. You can not reasonably expect the factory to actually sell anything and create money as an **output** before 3 years or so are over.
- You need to know federal law, state law, local (zoning law), safety regulation, working condition regulation and so on, and you must strictly comply - otherwise you will be in deep trouble. Are you allowed to do you **24 hours / 7** days shift? Overtime regulations? Safety issues?

- Obviously you need people - from lowly operators, via process engineers, team leaders, group leader to high-up management. You need people able to keep sophisticated equipment running, and you need people able to buy sophisticated equipment without getting over-charged and running up trouble with tax and custom authorities, and people able to sell your chips with a profit, if that is possible. They must bring in a lot of know-how, and they take out a lot of know-how by learning on the job.

Now let's look at the more interesting input. Large groups of extremely knowledgeable and sophisticated people have defined what the product should be, what kind of performance it should have, and based on this, came up with the circuit diagrams and its transformation into a layout, the precise structure in space that this or that layer is supposed to have on your wafer.

- This is encoded into a set of "reticles" or masks - a kind of slide. One state-of-the-art reticle may cost several **10.000 €** to make; you need about **20** for a product. So your box full of reticles is not exactly cheap, but the total costs of just making a set of reticles pales compared to the costs already incurred for coming up with the lay-out.

- This is essentially the basic product input coming from your colleagues from electrical engineering and computer science, who have learned how to do this.



Small part of some lay-out

Now let's look at the materials input side.

- Foremost you need **Si** wafers; several **100** to several **1.000** per day; depending on the size of your factory and the complexity of your product. If your chip takes **500** processing steps before it is finished (normal number for normal chips) you cannot process as much per day compared to a more simple chip (e.g. power chips) needing only **300** process steps.

- We skip the solid materials (the [link](#) provides some examples) and turn to liquids. You need large quantities of simple liquids like water, except that you need it ultrapure (the factory will have a rather large water processing plant in the basement), and extremely dangerous liquids like (ultrapure) hydrofluoric acid (**HF**) as well as other dangerous acids and bases.

- Then you need a lot of special gases, in particular the most toxic inorganic gases known to mankind: Arsine (**AsH<sub>3</sub>**) and Phosphine (**PH<sub>3</sub>**). Other (ultrapure, of course) gases needed in high volume are merely explosive, e.g. Silane (**SiH<sub>4</sub>**) or quite uncommon outside of semiconductor technology (e.g. **WF<sub>3</sub>**). More about that in the [link](#)

We will encounter most of these materials when we look at processes, so we will not go into any more details here.

On the output side we produce wafers containing fully processed, but not yet measured and packaged chips. Some of the chips on a wafer may be fully functional, some may be faulty. The percentage of "good" chips is called the (wafer) **yield**  $\eta$  of your factors. It is the most important single number characterizing your factory, and it should be **100 %**, of course.

- Haha! When you start to mass produce a new chip generation, you will be lucky if you make  $\eta \approx 20 \%$ . From then on it's hard work to get it up to **80 %**, maybe **90 %** over the next few years before your chip is completely outdated anyway.

In any case, you ship your finished wafers to a place where they get measured (a pretty complex task). The good ones (after slicing the wafer to separate them) then get packaged (you need another not too small factory for that - and plenty of know-how and specialized materials)

- They get measured again and, if still working, sold - typically for a few € a few chosen ones (microprocessors) for a few **100 €**
- Do you see the (economic) problem? By the time you sell your first chip of the new generation, you have already invested a few billion € in its development and production.

**You need to sell one hell of a lot of chips  
(at a profit!) to recover your costs!**

In other words: *Semiconductor technology* always has a money aspect. It just doesn't make much sense to consider it only from a detached and purely scientific point of view.