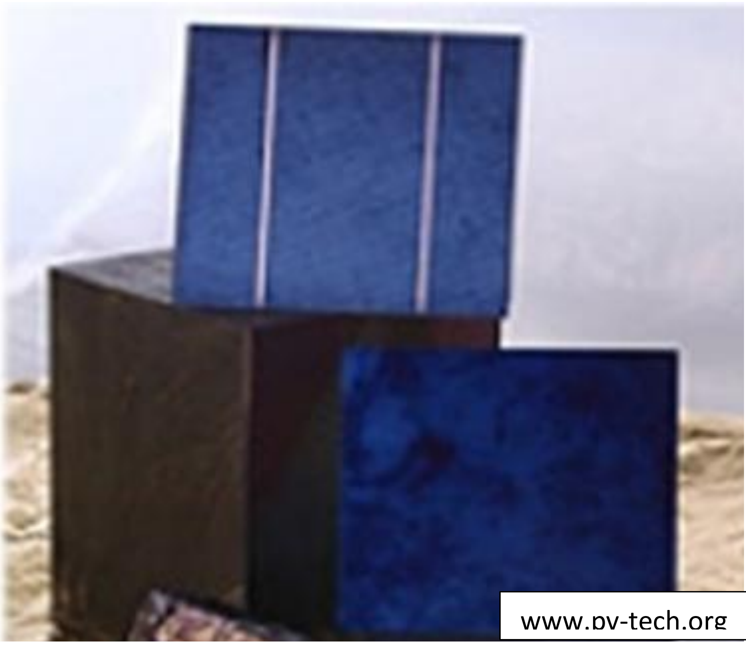
MANUFACTURING SILICON



www.pv-tech.org

MANUFACTURING SILICON

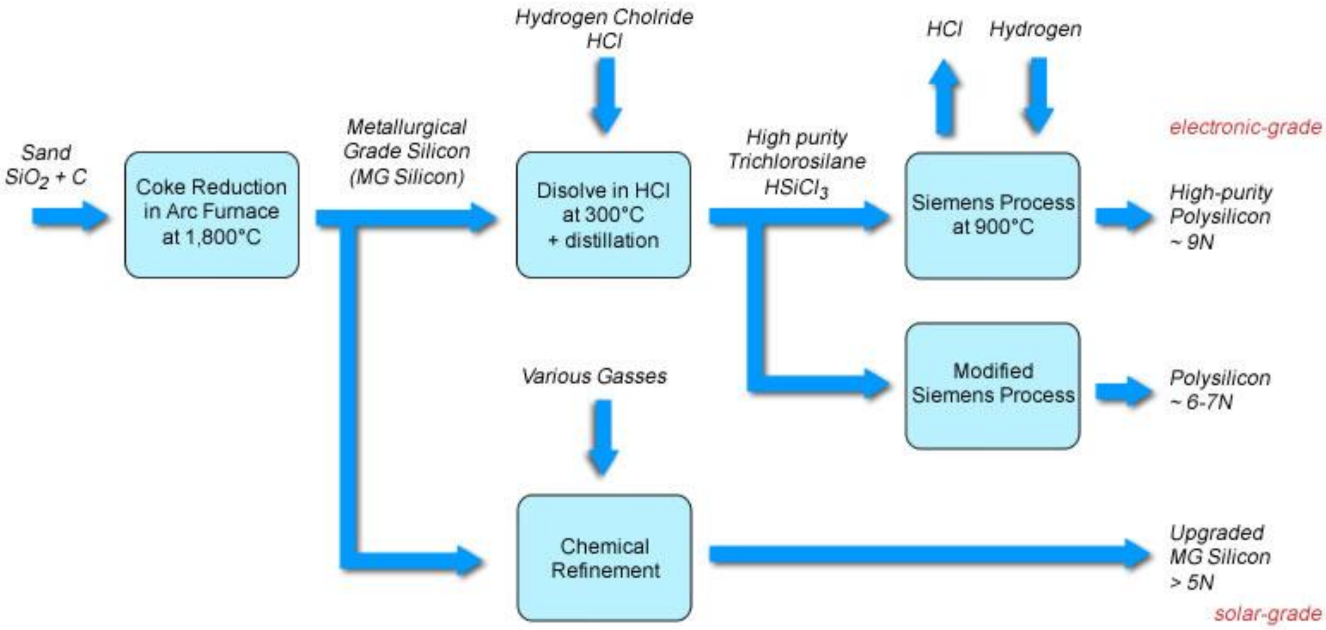
http://www.greenrhinoenergy.com/

PV MANUFACTURING

Some of the manufacturing processes and resources for photovoltaics are shared with other applications, especially electronic chips for computers, mobile phones and any other electronic device. This competition has caused a shortage in supply of crystalline cells.

MANUFACTURING SILICON

The raw material of most solar cells today is crystalline silicon. Luckily, silicon is one of the most widely available elements in the form of sand. Before silicon can be cut into thin wafers, however, it has to be purified, as otherwise the photoeffect will not be very efficient. Purity levels for solar cells do not have to be as high as in chip applications. Solar-grade purity is 99.999% (5N) as opposed to electronic-grade silicon purity of up to 99.9999999% (9N).



There are three main categories of manufacturing processes, resulting in different purity levels:

Electronic-grade Silicon: 9N

There are three main steps to produce high-purity polycrystalline silicon.

1. **Coke reduction:** Metallurgical-grade silicon with 98.5% purity is produced from quartz sand in an arc furnace at very high temperatures.

2. **Distillation:** In a second step, the metallurgical grade silicon powder is disolved in hydrogen chloride and subsequently distilled to form a silane gas. In most instances, this is the trichlorosilane, but could be others.

3. **Siemens Process:** In the so-called *Siemens Process* the polycrystalline silicon is grown at very high temperatures. It requires hydrogen and produces more hydrogen-chloride as a by-product.

Medium-grade Silicon: 6-7N

The big drawback of the standard process as above is that a Siemens reactor is very expensive and the Siemens process itself requires a lot of energy. A number of new proprietary processes reduce the energy consumption and the capital costs for silicon production, though they are still similar to the traditional Siemens process.

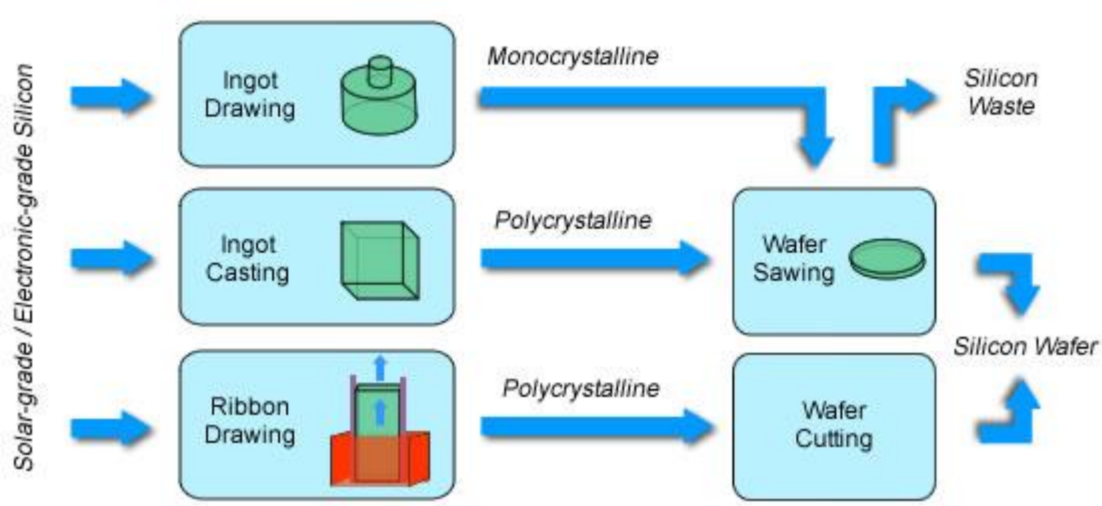
- Fluidized Bed Reactor (Renewable Energy Corporation): operates at much lower temperatures and does not produce by-products.

- Vapour to liquid deposition (Tokuyama): similar to Siemens, but faster extraction.

Upgraded Metallurgical-grade Silicon (UMG): > 5N

In an altogether different process, metallurgical-grade silicon is chemically refined. By blowing gasses through the silicon melt, the boron and phosphorous impurities are removed, followed by directional solidification. Companies like Timminco, Arise or RSI Silicon all have their own proprietary processes. However, they all have in common that by avoiding high purification, manufacturing costs are reduced significantly

MANUFACTURING WAFERS



There are mainly three different silicon wafer types of different qualities:

- **Monocrystalline wafer:** Silicon with a single, continuous crystal structure is grown from a small seed crystal that is slowly pulled out of a polysilicon melt into a cylindrical shaped ingot (Czochralski process). The ingot is cut into wafers using a diamond saw. Silicon waste from the sawing process can be re-cycled into polysilicon.
- **Polycrystalline wafer:** Polycrystalline silicon consists of small grains of monocrystalline silicon. Cube-shaped ingots can be made directly by casting molten polysilicon, which are then cut into wafers similar to monocrystalline wafers.
- **Silicon ribbons**: This is a continuous process whereby thin ribbons or sheets of multicrystalline silicon are drawn from a polysilicon melt. The subsequent cutting into wafers does not produce waste, as the drawn sheets are already wafer-thin. Silicon ribbons require around 5g of silicon per Watt rather than 8g/W using crystalline wafers.

MANUFACTURING CELLS AND MODULES

- **Crystalline**

  Crystalline cells are made from silicon wafers by cleaning and doping the wafer. In a separate manufacturing process, a number of cells are wired up to form a module. As such the manufacturing process of crystalline modules consists of four distinct processes: Polysilicon production,
  Ingot & Wafer manufacturing, cell manufacturing and module manufacturing

- **Thin-Film**

  "Thin" means that the semiconductor layer is about 1/100th times "thinner" than in crystalline cells. The manufacturing process starts by depositing the thin photoactive film on the substrate, which could be either glass or a transparent film. Afterwards, the film is structured into cells similarly to the crystalline module. Unlike crystalline modules, the manufacturing process of thin-film modules is a single process that can not be split up.

  For CdTe - thin-film, 220kg are required for 1MWp, which is 36 times less weight per kWp than crystalline silicon.

THE PROBLEM:

The sand used in the construction industry is usually yellow, orange or red due to impurities, but the type chosen for the manufacture of pure silicon is a form known as silica sand.

a) Helping you from the text, write the three chemical reactions to obtain electronic grade-silicon (EG-Si) from sand. And give the name of all compounds.

b) Calculate the amount of metallurgical grade silicon (MG-Si) obtained from 155 kg of silica sand composed of nearly 98 % quartz.

c) At the laboratory 90g de MG-Si (98% pure) reacts with 5, 00 dm^3 w/HCl 2,00 M obtaining 40,0 dm^3 of H_2 (g) at 25 ºC and 1,60 atm. Calculate the reaction yield.

The relative atomic mass of H = 1, C = 12, 0 = 16, Si = 28, Cl = 35,5