SOLAR-CITY GRADE SILICON (SGS) AND THE ELECTRONIC-CRASS GRADE SILICON (ECS) ARE TWO OF THE GRADES COMMONLY USED TO CHARACTERIZE POLYSILICON. THE PURITY OF THE POLYSILICON GRADE IS KNOWN AS SIX NINE OR ELEVEN NINE (ELEVEN ONE) (WILLIAMS, 2000).

POLYSILICON PRODUCTION IS A HIGHLY SPECIALIZED INDUSTRY AND ESSENTIALLY ITS ONLY APPLICATION IS IN PRODUCING SILICON WAFERS FOR SEMICONDUCTORS AND SOLAR CELLS. THERE ARE ABOUT 10 TO 100 MAJOR MANUFACTURERS OF POLYSILICON WORLDWIDE AND SOME small producers in the East European countries (AFOSR, 1997). USA, JAPAN AND GERMANY ARE THE MAJOR PRODUCERS OF POLYSILICON IN THE WORLD (YAMAUCHI, 1998).

TECHNOLOGIES FOR PRODUCING POLYSILICON ARE BASED ON THE FEEDBACK TECHNOLOGY. THE MAIN FEEDSTOCKS ARE LISTED AS FOLLOWS:
- Silicon tetrachloride (SiCl4)
- Trichlorosilane (SiHCl3)
- Dichlorosilane (SiH2Cl2)

I. INTRODUCTION
In the semiconductor industry, there are basically ten global industrial sectors considered in the production chain of high-quality semiconductors. These sectors are the one involved in producing quartz/silica (SiO2), coal, charcoal, silicon metal, chlorosilane compound (chemical used in purifying silicon), polycrystalline silicon (polysilicon), semiconductor devices, solar cells and optical fibers. Figure 2 shows how these industrial sectors are related to each other (WILLIAMS, 2000).

Silicon wafers are the main materials for the fabrication of integrated circuits. The production of silicon wafers starts off with polycrystalline silicon (polysilicon). The polysilicon is converted into monocrystalline silicon (monosilicon) ingot form before it can be used to make silicon wafers. Monosilicon ingots are usually produced by either the Czochralski (CZ) method, or the Float Zone (FZ) method (WILLIAMS, 2000). A simplified process flow of how integrated circuit is produced from raw materials is shown in Fig. 3.

POLYSILICON PRODUCTION OVERVIEW
The production of polysilicon requires several distillation steps and it is known that more than 98% of electronic grade polysilicon is produced by the trichlorosilane (SiHCl3) distillation method (ROGERS, 1990; FRANK ET AL., 1996). The process of obtaining electronic-grade polysilicon starts with the reduction of quartzite or silica to MGS. A summary of the process involves the steps shown as follows.

1. **Quartz to metallurgical-grade silicon:** During the process, SiO2 is decomposed into metallurgical-grade silicon and carbon monoxide, according to the carbothermic reaction (Suzuki, 1998; NAGAMU ET AL., 1986).

   \[ \text{SiO}_2 + 2\text{C} \rightarrow \text{Si} + 2\text{CO} \] (1)

2. **MGS to trichlorosilane:** Crude MGS must undergo rigorous purification to reach a purity level suitable for semiconductor device applications. The standard process used is the reaction of MGS with hydrogen chloride, HCl, to form SiHCl3. The following shows the main reaction of MGS with HCl to form SiHCl3 (CHU, 2001).

   \[ \text{Si}(s) + 3\text{HCl}(g) \rightarrow \text{SiHCl}_3(g) + \text{H}_2(g) \] (2)

3. **Distillation of trichlorosilane (SiHCl3):** Dissolved trichlorosilane at room temperature is then purified by distillation processes. This is the main purification step for the electronic grade silicon (EGS) and the resulting impurity levels are at a very low ppm level.

   \[ \text{SiHCl}_3(s) \rightarrow \text{SiHCl}_3(l) \] (3)

4. **Electronic-grade polysilicon:** Once the purified SiHCl3 is obtained, it is then used to deposit very pure polysilicon onto a thin monosilicon seed that serves as a starting material in a chemical vapor deposition (CVD) reactor. The main reaction for the production of polysilicon is shown below.

   \[ \text{SiHCl}_3(g) + \text{H}_2(g) \rightarrow \text{Si}(s) + 3\text{HCl}(g) \] (4)

**POLYSILICON GROWTH IN CHEMICAL VAPOR DEPOSITION SYSTEM**

**Figure 4** shows the polysilicon production scheme used in the actual polysilicon plant at GAO Kristall. Some other sub-plants which are not shown in **Figure 4** are the steam plant, water circulation pump plant, water treatment plant, energy block plant, air separation plant and neutralization plant. The starting raw materials which are not produced on-site are chlorine gas (Cl2) and MGS or silicon metal. Hydrogen chloride (HCl) which is produced on-site using H2 and Cl2, together with MGS are processed in the TCS (trichlorosilane) plant to produce SiHCl3 and SiCl4.

Liquid SiHCl3 which vapourise at temperatures between 30°C to 32°C (CHU, 2001) goes into a vaporizer where it will form SiHCl3 gas by boiling it at a temperature above 30°C. Hydrogen gas, H2 is usually obtained via electrolysis of water and goes through a purification process normally by using palladium (BRETSCHELDER, 2001), platinum (NRCC, 2001) or chrome nickel (GAO, 2001) filters. Both SiHCl3 and H2 gases are then channelled into a CVD reactor where the main reaction takes place. High current, up to 2 kA will flow between the cathode and anode of the silicon seed where the seed's temperature is allowed to reach between 1050°C and 1150°C. A pyrometer is used to measure the temperature of the polysilicon rod during deposition.

During the deposition process, by-products are continuously pumped out and condensed into liquid form. These by-products are directed to the purification plant where they will be separated into useful gases and recycled. Material such as SiCl4 is used for producing quartz whereas H2, HCl and other silane compounds will be refined and re-used in the plant. Marketable by-product of the polysilicon plant are the quartz tube (from SiCl4), and H2 which is also used in the fabrication of fiber optics cable.

**POLYSILICON CHARACTERISATION**

Evaluation of polysilicon rods is done by a suitable method as recommended.

**REFERENCES**


Gao: Photosensitive conversion to GAO Kristall polysilicon plant specialest (2000).


Figure 2: Production chain for high-purity silicon and its use in semiconductors, solar cells and optical fiber

Figure 3: Raw material to IC fabrication process flow

Figure 4: GAO Kristall polysilicon production scheme