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THE TECHNOLOGICAL ROLL OF SILICON METAL PRODUCTION

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The silicon metal is one of the most abundant elements in the earth's crust and one of the most important for many industries. The use of silicon in the technologic world have been increasing gradually, since this element has become the base raw material for many products that today are essential for everyday life and for the technological advancement.

The silicon metal can be found and marketed in a variety of ways. Each purification method and raw material used generates a different final product, with different composition and utility. In industry silicon is marketed mainly in three molecular compositions, namely crystalline, polycrystalline and monocrystalline.

The silicon production cycle for the solar and electronics industry is usually not done since the exploration of raw element. Monocrystalline silicon companies generally buy polycrystalline silicon as a raw material and then market it to the solar and electronics industries.

Silicon production begins with its exploitation in crude form. Silicon is excavated and extracted from the ground in the form of quartz crystals, known as rock crystals, or even in the form of sand. [1] The sand used in these processes basically consists of silicon dioxide. When found in the form of quartz crystals, the physical treatment process is required, where manual selection, washing, crushing, grinding and particle size separation processes are performed. [2]

The first step of the silicon purification process begins with the metallurgical method. When processed and already in grains (sand), silicon is heated in an electric arc furnace at a temperature of 2000ºC, where it is transformed into liquid state and reduced from SiO to Si. In this process (metallurgical) silicon still has a low content purity (from 98 to 99.9%). In the final stage of this process there is the accumulation of liquid silicon in the bottom of the oven, where it is extracted and subsequently cooled. (OLIVEIRA, 2008, SERODIO, 2009).

On cooling, this SiO is oxidized to silica or micro silica (SiO2) with an average size of 0.15 mm (GASIK, 2013; SERODIO, 2009). Due to this particle size, the silica cannot be used again for carbothermal reduction. However, it is an important byproduct and can be consumed in the cement industry (GASIK, 2013; SERODIO, 2009).

The silicon obtained through the metallurgical process is the base raw material for the production of polycrystalline silicon. In this phase, the Siemens method is mainly used, which consists of the passage of the hydrochloric gas (HCl) heated to 300 ° C through granulated metallurgical grade silicon, producing chlorosilanes which are then separated by fractional distillation. [7] Fractional distillation of SiHCl3 results in a significant increase in Si purity with a concentration of electrically active impurities of less than 1.0 ppb (RECAMÁN PAYO, 2008). This process is performed by the chemical route, and the final product is the polycrystalline silicon bars which are subsequently broken into many pieces called “Chunks”.

The electric arc furnace carbothermal reduction process is the most common and cheapest way to produce SiGM. [3] After this stage of production, silicon is generally marketed to other industries such as solar, electronics, glass, ceramics, automobiles, among others. Crystalline or metallurgical silicon is the raw material used by the polycrystalline silicon producing industries, which is then used for solar cell production or marketed for the monocrystalline silicon industry.

The most commonly used purification process for the solar and electronics industry is the Czochralski or Float Zone (FZ) method. Currently, the Czochralski process is more widely used than the FZ process (MARQUES, 2013). In this process the final processing to obtain the single crystalline silicon (Silicon metal electronic grade - SiGE) is presented. For this, polycrystalline silicon in chunks, obtained by the Siemens method or by the metallurgical silicon purified, is used as raw material.

The Czochralski method is done through a puller oven. The furnace column is 4 to 5 meters high, which determines the final size of the ingots produced. In the CZ method the chuncks are melted at a temperature of 1400 ° C in a pan (crucible) and slowly rotated for the solidification process. Polycrystals transformed into monocrystalline ingots are formed from a single silicon crystal with a shiny, non-machined tip that is dipped in molten silicon and acts as a crystal seed [2]. This pen-shaped crystal at controlled temperature, pressure, and time develops a crystallization process, creating the monocrystalline silicon ingot.

After the melting process, the crystal seed, which is attached by a rod, is dipped into the molten silicon. When the silicon (seed) sample touches molten silicon, the surface of the molten silicon cools down and the crystallization process begins. Right after the beginning of crystallization [3]. In the crystallization process, the forming silicon is pulled and rotated very slowly by the stem, in the opposite direction to the rotation of the crucible, forming a monocrystalline ingot.

This step of pulling the monocrystalline crystal out of the crucible is performed, because when the liquid silicon solidifies, its volume increases by about 9%, generating tensions that would cause the crucible to rupture if the silicon solidified inside (MOREIRA, 2009). If the temperature gradient at the seed - fused silicon interface is gradual and well controlled, the atoms are solidified following the same atomic arrangement as the seed crystal (SWART, 2003). In order to maintain the homogeneity of radial thermal gradients in this process, the crucible and seed rotation in opposite directions is slowly performed (MOREIRA, 2009).

The CZ and FZ directional solidification processes aim to obtain homogeneous and defect-free monocrystalline Si ingots, as these characteristics are required in both the electronics industry and the photovoltaic industry [3]. The ingots produced have a unique and regular crystalline pattern and cylindrical shape.

In the composition of monocrystalline silicon, all silicon atoms have to be perfectly aligned within the crystal lattice. The purity is extremely high: in a billion atoms we can only find one exotic atom [2].

With this process it is possible to produce monocrystalline silicon ingots with a length between 1 and 2 meters and diameters from 200 to 300 mm. Although the largest silicon ingots produced today reach 400 mm in diameter the standard crystal in industrial processes is 200 and 300mm. The quality of the ingots depends directly on their cooling rate and their size is controlled by temperature and speed of lift and rotation.

With the ingots obtained by the CZ process, single crystalline cells are manufactured. Circular blades or wafers are obtained by means of a cross section of the ingot [7]. Wafers obtained from the cutting of these ingots range in thickness from about 0.2 - 0.75 mm. After cutting, the wafers are polished, reaching a very flat condition to make integrated circuits, or to be textured for the production of solar cells.

Conclusion. In recent years the demand and production of silicon has grown abundantly due to its effectiveness, both for technological development and for other industries that already used it in lower purity levels for their productions. Silicon has become so essential that it is now part of many industrial branches, including solar, electronic and space energy.

As it is the main raw material for the production of solar panels, integrated circuits and others, its exploration and production directly affect the technology. Without it, it would not be possible to produce chips, processors, solar boards and various other products that today are considered essential for society. For this reason, it is understood that this element not only accompanies technological development, but is the key for this development to happen in various industrial branches [8].

The production and implementation of the technologies necessary for the production of silicon still have a very high cost, however, it is estimated that in a few years these technologies and production will be more accessible.

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THE IMPACTS OF GOLD MINING IN GHANA: THE GOOD AND THE BAD

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Ghanaians are legally and illegally engaged in mining. In Ghana, the mining sector account for 41% of the country's foreign exchange and it is the leading foreign exchange earner. Gold now accounts for over United States $600 million and 90% of all mineral productivity annually and has replaced cocoa as Ghana's principal foreign exchange earner [1]. Increased investments in the mining sector resulting from Ghana's economic reforms have several benefits. Mining is the principal earner of foreign exchange in the country, providing a large amount of government revenue, a source of income and social infrastructure to the population, creating direct and indirect employment and contributing to community development in mining areas There is evidence of gold extraction activities in Ghana as far back as the 7th and 8th centuries A.D., as gold deposits attracted Arab traders into the country. These activities were strategically located along rivers where sediments believed to contain deposits of gold were washed constantly to separate the gold grains. This was a source of wealth for these communities and individuals engaged in mining. As time went on, it was revealed