

# **THE POTENTIAL OF THE METALLURGIC INDUSTRY IN BRAZIL, AIMING THE PRODUCTION OF SILICON METAL IN SOLAR GRADE**

**P. da Fonseca Freire**  
Supervisor E.A. Efimova

Metals are a key part in contemporary life and your use is indispensable. They are present in the daily life of all, since the use of small objects like keys, even in large market sectors, such as construction, medicine, transportation, communication, power generation, production of appliances, etc. and the use of these metals is possible only because of the metallurgy.

Within the various branches of metallurgy, there is the production and treatment of Silicon Metal. It is used in the production of metal alloys, in the preparation of silicones, in the ceramics industry and for being a very abundant semiconductor material, has a very special interest in the electronics and microelectronics industry, as basic material for the production of transistors for chips, solar cells and in several varieties of electronic circuits. [1]

Silicon (Si) is a chemical element of the metalloid group and the second most abundant element in the earth's crust, just being behind the oxygen. [2] At room temperature it is found in the solid state and appears in clay, granite, quartz and sand, usually in the form of silicon dioxide (also known as silica) and silicates (compounds containing silicon, oxygen and metals). [3] It is the main component of glass, cement, ceramics, most semiconductor components and silicones.

In your crystalline form the Silicon is very hard and slightly soluble, showing a metallic sheen and a grayish color. It is a relatively inert element and resistant to the action of most acids; reacts with halogens and alkalis.

It is an essential component of the vast majority of rocks that form the earth's crust. Sandstone, clay and granite are examples of rocks that contain silicon compounds. Almost pure silica is known as quartz or simply crystal. Purple or lilac quartz are known as amethyst, yellow crystals are known as citrine.

Silicon is vital element in many industries, since it is used for the production of metal alloys, in the preparation of silicones, in the ceramics industry, in the automobile industry, aeronautics among others. [4] By a reason of being a very abundant semiconductor material, has a special interest in the electronics and microelectronics industries, as a basic material for the production of transistors to chips, solar cells and in several varieties of electronic circuits.

In the chemical industry Silicon Metal is used in the manufacture of countless resins, silicones and lubricants. It is also used in the production of high purity silicon, either chemically or metallurgically, for electronic components used in fields of advanced technology such as computing, space communication, defense systems, photovoltaic panels, etc.

In the Silicon Metal industry, we can find mainly three kind of silicon, named by level of purity. The first is the Silicon Metallurgical Grade that has very low levels of impurity and is used in the production of aluminum alloys, mainly in the manufacture of parts for the automotive sector. It is obtained from high purity silica in electrical arc by the reduction of silicon dioxide ( $\text{SiO}_2$ ) with carbon at a temperature above  $1900^\circ \text{C}$ . [3] The liquid silicon accumulates in the bottom of the furnace, from where it is extracted and cold. It has a purity of up to 99.5%. The Silicon Solar Grade is the raw material used in the manufacture of solar cells, whose market has been growing exponentially around the world as an alternative to a new energy matrix, and has 99,9999% of purity. The Silicon Electronic Grade is the most pure silicon, with 99,9999999% to 99,999999999% of purity. [2] This Silicon is used in the semiconductor industries; the silicon electronic grade is the main raw material in the production of trichlorosilanes, which are transformed into diodes and high-performance processors (computer chips).

Brazil is among the world's largest producers of metallurgical grade silicon, with a production capacity of approximately 200 thousand t/ year. [5] With such development, it opens doors to the industry, to add value to the product currently commercialized, investing in the improvement of information, processes and technological renovation for the production of silicon in higher level of purity.

Currently the production of silicon in solar and electronic grade in Brazil is almost non-existent and has a high cost due to the lack of technology and preparation for the processes of treatment and refinement of this element. [2] However, investment in this sector is a great opportunity for Brazilian industries, since Brazil already has large production of silicon grade and large reserves of quality quartz for the exploitation and production of silicon grade solar.

The silicon industry is growing and the expectation is that it continues to advance, as the product is being increasingly used and recognized as an essential element for various industries and sectors of production. [2] Moreover, when produced in solar grade, silicon becomes the base element for the production of solar panels, which are already widely used in several countries, by reducing abundantly the greenhouse effects and environmental impacts caused by other sources of electricity. The growth in the demand for solar grade silicon is due to the need to replace energy based on fossil fuels by cleaner and renewable energies, in the sense of meeting the goals of reducing CO<sub>2</sub> emissions.

The dominating countries of the solar grade silicon metal market are mainly China and Germany. The high added value is also present in the purification of silicon, since the solar grade comes to be worth more than 100 times the price of the metallurgical grade silicon currently exported by Brazil.

According to data reported by CGEE "Silicon Solar Grade in Brazil - Technical Note", Brazil, despite being among the dominant countries in the silicon industry, still has great need to import the solar and electronic grade, as well as various products that have these elements as a production base, such as solar panels, computer chips and electrical and electronic materials.

According to Ricardo Campos Mascarenhas, a researcher at Petrobras, the inclusion of the silicon purification industry (electronic / solar) as beneficiary of the legislation to stimulate the production of semiconductors in Brazil is fundamental. The production of purified silicon should take into account strategic objectives, such as the development of the semiconductor industry in Brazil and the production of silicon derivatives for various applications (eg high performance

electrical insulating oils with low environmental impact, fine chemicals, petrochemicals and pharmaceuticals).

According to Izete Zanesco and Adriano Moehlecke, researchers at CB-Solar of PUC-RS, understand that, like any established industry, the production of solar silicon in Brazil will generate jobs, wealth and will drive the economy.

According to Marcelo Poppe, CGEE consultant on energy issues is of the opinion that the eventual national production of solar grade silicon will add value to an abundant mineral in the country and will allow access to an international consumer market with high growth rate. The investment could also place Brazil in the international dynamics of the development of the markets for the manufacture of cells and other supports, components and systems, as well as the generation of electricity based on renewable energy sources.

The study realized shows that Brazil has the potential to produce silicon in solar grade of lower cost. In the meantime, currently, it should invest in new technologies and information (knowhow) with the intention of participating in the competitive market of purified silicon (electronic / solar).

In addition, the insertion of the Brazilian industry in the solar grade silicon market will bring value to silicon industries, reduce import costs and the opportunity to insert new production sectors (such as photovoltaic solar panels, chips, computers, etc.), the use of solar energy at reduced costs (generating significant environmental impacts), the generation of jobs and specialization and the insertion of the country into one or more international industrial sectors.

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## **CLASSIFICATION OF ROBOTS IN MANUFACTURING**

**D.K. Sergeeva**

Supervisor E.A. Efimova

According to the recent data, the application of robots has drastically increased around the world. About 5,4 million were sold in 2015, and that number doubled in 2016 to more than 10 million units. The top applications are in manufacturing, construction, rescue operations, and personal security.

The use of industrial robots deployed in factories has also expanded. Figure 1-1 shows the number of these devices in operation globally; as is evident from the figure there has been a substantial increase in the past few years. In 2013, for instance, an estimated 1,2 million industrial robots were in use. This figure rose to around 1,5 million in 2014 and to 1,9 million in 2017. Japan has the most, at 306700, followed by North America (237,400), China (182,300), South Korea