Silicon in Circuitry

Silicon is paramount to our 21st Century lives: as the key building block for glass, ceramics, cement - furthermore buildings in general, some explosives, silicones and of course the feature of this report, electronics.

Introduction

Electronics have shaped our world for better and for worse, though their development is reliant upon silicon. With that in mind, thankfully silicates comprise over 90% of the weight of the Earth's crust [1], which can be purified to Silicon.

Production

This video [2] of the production process serves as good introductory device, showing a little of the history, the immense care required and the difficulty of manufacture.

Semiconductivity

The main property of property of silicon that is a necessity for circuitry is semiconductivity, or more generally as an insulator. Semiconductors are useful for circuitry because it allows the voltage flow to be controlled and can be used as logic gates in computers.

Required Properties

They are so important as they can vary between being a conductor and an insulator, reacting to environmental changes like temperature. The combinations of different semiconductors allows circuits to be designed to have desired electrical properties.

Hard

It is also important that the circuits are resistant to scratches and dents as to preserve the circuitry against damage, as silicon is commonly used as the supporting structure of microelectromechanical systems (obviously for this purpose it also has to be an insulator).

Macroscopic Properties

Strong

Circuit boards are often found in technology that undergoes harsh treatment: cars, phones. For this reason it would be disadvantageous for a small stress to crack the chip, though it does not necessarily need to be tough.

Silicon is a metalloid with properties similar to that of regular metals and nonmetals [3]

It is an opaque material and shiny in appearance in its crystalline form.

Heating

Silicon has a high melting point of 1414°C [4] due to the strong covalent structure, but more of that to come. This high melting point makes it ideal for use in hot environments, like space shuttles and ovens, which is over 30 times that of phosphorus (next to silicon in the periodic table) [5], and over double that of aluminium (other side of silicon on the periodic table) [6].

One of the most important reasons for its use is that it is one of the most abundant element in the Earth's crust, comprising 25.7 percent of Earth's crust by weight [9], making it cheaper to produce in large quantities, also, as said in the introduction, silicate minerals comprise over 90% [1]. Though this is not a property per-say, it is an important factor to consider when producing.

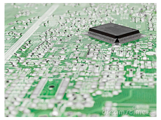
Hard & Stiff

It is relatively hard, with a rating of 7 on the Mohs scale, similar to Quartz, meaning it resists scratches well, which suits its purpose. [7]

With a Young's modulus of 130 - 185 GPa, it is twice as stiff as gold or aluminium, operating well for supporting microchips. [8]

Microscopic Properties

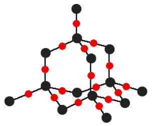
Insulator



The insulator in many circuits is silicon dioxide as it has a high resistivity, 10^{14} - 10^{16} Ωcm at room temperature [10]. Not only that, but it is very cheap and fairly easy to produce as it is essentially sand.

[11] http://thumbs.dreamstime.com/z/circuit-board-one-silicon-chip-12188837.jpg

Covalent Structure



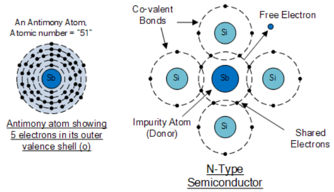
Also known as silica, sodium dioxide has a giant covalent structure, with the silicon atoms covalently bonded to four oxygen atoms and each oxygen atom covalently bonded to two silicon atoms. With the ratio of 4 to 2, thus simplifying to SiO_2 [12]

[13] Image: http://www.chemguide.co.uk/inorganic/period3/sio2struct.gif

There are no free electrons in this structure so does not conduct electricity. With such strong covalent bonds, it explains the macroscopic properties of hardness and high melting point. [12]

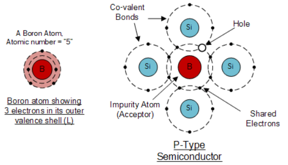
Silicon has the same behaviour, until doped when it becomes a semiconductor. In doping, small amount of an impurity is mixed into the silicon lattice. Making the silicon extrinsic by adding Antimony or Phosphorus allows a current due to the free electron. [14]

As there is an overall negative charge from all of the free electrons, this is known as an N-type semiconductor



[15] Image: http://www.electronics-tutorials.ws/diode/diode2.gif

P-type conversely uses an impurity with 3 electrons in its outer shell, such as boron or gallium, compared to N-type where the impurity has 5 in the outer shell.



This forms holes in the lattice, thus creating a mobile positive charge [21] and allowing a charge to pass through it. [14]

[16] Image: http://www.electronics-tutorials.ws/diode/diode3.gif

History of Silicon

As seen in the introductory video [2], chips are made in sterile environments, as to ensure the silicon giant covalent structure. Within the integrated circuit there are semiconducting, conducting and insulating areas.

The aforementioned silicon dioxide provides insulator, simply by oxygenating that area. The semiconducting areas are produced by the doping process, with current flowing when holes move from positive to negative, and areas that must conduct are coated with a substance such as gold. [21]

1787

Antoine Lavoisier listed silicon as one of the five "salifiable earths", recognising the material's potential.

[17]

1811

Impure amorphous silicon discovered by Gay Lussac and Louis Jacques Thénard

[18]

1854

Henri Etienne Sainte-Claire Deville was the first to prepare crystalline silicon, in the more common allotrope of the element

[20]

1823

Jöns Jacob Berzelius is the first to produce pure silicon with an amorphous structure. He used a similar technique to Gay Lussac and Thénard, though purified it by repeatedly washing it, thus is accredited the element's discovery.

[19]

Sociological Impacts

Manufacturing Issues

Whilst sand causes no immediate health problems - beaches would be far less popular if it did - though when mining sand, particulates smaller than 100 microns can be inhaled. This can be detrimental to health, leading to silicosis, obstructive lung disease, increased risk of lung infections and lung cancer. [22]

Locations

With the key role silicon plays in technology, it comes as a given that many geographical places bear its name

Is it worth it?

Undoubtedly so, yes. To expand, whilst mines and manufacturing plants cause a slight eyesore, the benefits are far greater. Silicon is the cornerstone of our society - glass, building, electronics and much more is reliant on it.

[23] Image: http://www.geokem.com/images/scans/Macraes-mines.jpg

Most obviously and perhaps famously: Silicon Valley, California [24]

Silicon Roundabout, London: due to the large number of web firms operating close to the Old Street Roundabout [25]

Locally: Silicon Fen, Cambridge: also known as the Cambridge cluster, where many hi-tech companies are located around Cambridge [27]

Silicon Border, Mexico: located on the western border between Mexico and the US, they specialise in semi-conductors [26]

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Bibliography Evaluation

Overall I feel the sources are of high quality, showing a breadth of genres and mediums.

There are plentiful reputable references, such as the BBC, Live Science, Britannica, as well as respected journals. There were some websites I found that had facts and statistics that did not agree with the others and figures in books, so did not use them in my website.