Chapter

Introductory Chapter: Silicon

Beddiaf Zaidi and Slimen Belghit

1. Introduction

Silicon (Si) is a member of Group 14 (IV_A) in the periodic table of elements. Si is also part of the carbon family. This family elements include C, Ge, Sn, and Pb. Silicon is a metalloid, one of only a very few elements that have properties of both metals and non-metals. Si is the second most abundant element in the Earth's crust, apart from oxygen.

2. Energy bands

Silicon is a semiconductor whose number of free electrons is less than conductor but more than that of an insulator. Two kinds of energy band which are conduction and valence. Series of energy levels having valence electrons forms valance band in solid. At 0°K, the energy levels of valence band are filled with electrons. This band contains maximum of energy when the electrons are in valence band. Conduction band is the higher energy level band, which is the minimum of energy. Conduction band is partially filled by the electrons, which are known as the free electrons as they can move anywhere in solid. These electrons are responsible for current flowing. There is a gap of energy. The difference between the conduction band and valence band is called energy gap. For semiconductors, the gap is neither large nor the bands get overlapped (**Figure 1**).

3. Basic material

Apart from the oxygen, silicon is most commonly occurring element on the Earth. Silica is the dioxide from silicon and occurs mostly as quartz. Its synthesis has been familiar for many decades. It is extracted from (mainly) quartzite reduction with carbon in an arc furnace process [1]. The pulverized quartz and carbon are put in a graphite crucible. An arc causes them to melt at approximately 1800°C. Then, the reduction process takes place according to the formula:

$$SiO_2 + 2C \rightarrow Si + 2CO_{(g)} \quad (1)$$

The liquid collected at the bottom of crucible can then be drawn off. Its purity can be approximately 97.9%. This is called metallurgic grade silicon (MG-Si). However, for silicon to be used in the semiconductor industry, the impurities must be removed almost completely by further processes. For such a high purity grade, multistage processes must be implemented.

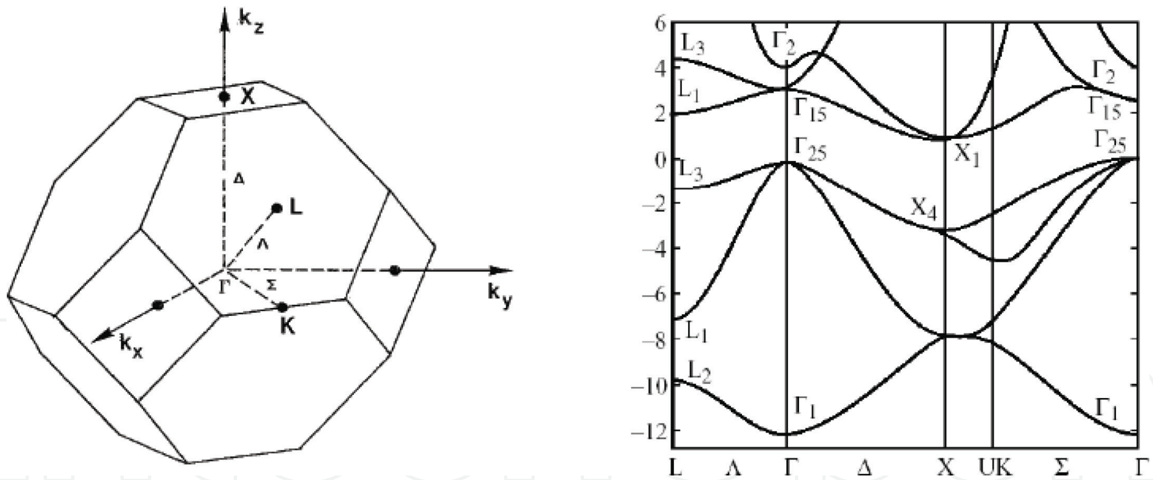

Figure 1.
E(k) for the conduction and valence bands of silicon.

4. Silicon thin film

Silicon thin-film cells are mainly deposited by chemical vapor deposition (typically plasma-enhanced, PE-CVD) from silane gas and hydrogen gas. Depending on the deposition parameters, these silicon thin films can be based on one or a combination of these materials [2–5]:

1. Amorphous silicon (a-Si or a-Si:H) or polymorphous silicon

2. Microcrystalline silicon

3. Polycrystalline silicon (poly-Si).

These silicon thin film materials can be characterized by their grain sizes ranging from none (amorphous) to large silicon (~100 μm) for polysilicon. The crystalline silicon thin films present dangling bonds, which result in deep defects (energy levels in band gap) as well as deformation of the conduction and valence bands. The solar cells made from thin films tend to have lower energy conversion efficiency than silicon bulk but are also less expensive to produce (**Table 1**).

Type of silicon	Abbreviation	Crystal size	Deposition method
Single-crystal silicon	Sc-Si	>10 cm	Czochralski, Float zone
Multicrystalline silicon	Mc-Si	1 mm–10 cm	Cast, sheet, ribbon
Polycrystalline silicon	Poly-Si	1 μm–1 mm	Chemical-vapor deposition (at high temperature ≥ 1000°C)
Microcrystalline silicon	μc-Si	10 nm–1 μm	Ex.: Plasma deposition (at low temperature < 600°C)
Nanocrystalline silicon	nc-Si	1–10 nm	

Table 1.
Grain size range depending on the type of the silicon [6–8].

5. Application

Silicon materials are used in components of electronic devices. It is also used to make solar cells [9–13] and parts for computer circuits [14]. Solar cell is a device that converts sun light into electrical energy [15–23]. A rectifier is an electrical device that converts alternating current to direct current. The most important silicon alloys are those made with Fe, Al, and Cu. When silicon is produced, in fact, scrap iron and metal are sometimes added to the furnace [24, 25].

Author details

Beddiaf Zaidi* and Slimen Belghit
Department of Physics, Faculty of Material Sciences, University of Batna 1, Batna, Algeria

*Address all correspondence to: zbeddiaf@gmail.com

References

[1] Deal BE, Grove AS. General relation for the oxidation of silicon. Journal of Applied Physics. 1965;**36**:3770

[2] Zaidi B, Hadjoudja B, Chouial B, Kamli K, Chibani A, Shekhar C. Impact of hydrogen passivation on electrical properties of polysilicon thin films. Silicon. 2018;**10**:2161

[3] Zaidi B, Shekhar C, Hadjoudja B, Chouial B, Li R, Madhava Rao MV, et al. Dopant segregation and heat treatment effects on the electrical properties of polycrystalline silicon thin films. Silicon. 2016;**8**:513

[4] Ghitani HE, Pasquinelli M, Martinuzzi S. Influence of dislocations on photovoltaic properties of multicrystalline silicon solar cells. Journal de Physique III. 1993;**3**(19):41

[5] Zaidi B, Shekhar C, Hadjoudja B, Chouial B, Chibani A, Li R, et al. Optimum parameters for obtaining polycrystalline silicon for photovoltaic application. American Journal of Nanosciences. 2015;**1**(1)

[6] Jellison GE, Modine FA, White CW, Wood RF, Young RT. Optical properties of heavily doped silicon between 1.5 and 4.1 eV. Physical Review Letters. 1981;**46**:1414

[7] Zaidi B, Hadjoudja B, Chouial B, Gagui S, Felfli H, Magramene A, et al. Effect of secondary annealing on electrical properties of polysilicon thin films. Silicon. 2015;7:293

[8] Zaidi B, Hadjoudja B, Chouial B, Gagui S, Felfli H, Chibani A. Hydrogenation effect on electrical behavior of polysilicon thin films. Silicon. 2015;7:275

[9] Moller HJ. Semiconductors for Solar Cells. Norwood, MA: Artech House. Inc.; 1993

[10] Zaidi B. Introductory chapter: Introduction to photovoltaic effect. In: Solar Panels and Photovoltaic Materials. London, UK: InTech Open; 2018. pp. 1-8

[11] Zaidi B, Hadjoudja B, Felfli H, Chouial B, Chibani A. Effet des Traitements Thermiques sur le Comportement Électrique des Couches de Silicium Polycristallin pour des Applications Photovoltaïques. Revue de Métallurgie. 2011;**108**:443

[12] Goetzberger A, Knobloch J, Voss B. Crystalline Silicon Solar Cells. England: Wiley; 1998

[13] Zaidi B, Hadjoudja B, Felfli H, Chibani A. Influence of doping and heat treatments on carriers mobility in polycrystalline silicon thin films for photovoltaic application. Turkish Journal of Physics. 2011;**35**:185

[14] Mathieu H. physique des semi-conducteurs et des composants électroniques. Paris: Masson; 1987

[15] Zaidi B, Saouane I, Shekhar C. Electrical energy generated by amorphous silicon solar panels. Silicon. 2018;**10**:975

[16] Zaidi B, Saouane I, Shekhar C. Simulation of single-diode equivalent model of polycrystalline silicon solar cells. International Journal of Materials Science and Applications. 2018;7(8)

[17] Conibeer G. Third-generation photovoltaics. Materials Today. 2007;**10**:42

[18] Zaidi B, Belghit S, Shekhar C, Mekhalfa M, Hadjoudja B, Chouial B. Electrical performance of $CuInSe_2$ solar panels using ant colony optimization algorithm. Journal of Nano- and Electronic Physics. 2018;**10**:05044

[19] Haddad A, Inokuma T, Kurata Y, Hasegawa S. Characterization of structure and role of different textures in polycrystalline Si films. Journal of Non-Crystalline Solids. 2005;**351**:2107

[20] Zaidi B, Saouane I, Madhava Rao MV, Li R, Hadjoudja B, Gagui S, et al. Matlab/simulink based simulation of monocrystalline silicon solar cells. International Journal of Materials Science and Applications. 2016;**5**(11)

[21] Jayawardena K, Rozanski LJ, Mills CA, Beliatis MJ, Nismy NA, Silva S. Inorganics-in-organics': Recent developments and outlook for 4G polymer solar cells. Nanoscale. 2013;**5**:8411

[22] Zaidi B, Belghit S, Shekhar C, Houaidji N, Hadjoudja B, Chouial B. Impact of anti-reflective coating on the characteristics of a-Si: H solar cells. Nanosistemi, Nanomateriali, Nanotehnologii. 2018;**16**:713

[23] Zaidi B, Hadjoudja B, Belghit S, Chouial B, Mekhalfa M. Annealing effect on grain boundary width of polycrystalline silicon for photovoltaic application. Revue des Energies Renouvelables. 2018;**21**:397

[24] Sigfússon T, Helgason Ö. Rates of transformations in the ferrosilicon system. Hyperfine Interactions. 1990;**54**:867

[25] Waanders FB, Mans A. Characterisation of ferrosilicon dense medium separation material. Hyperfine Interactions. 2003;**148**:325