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The systematic analysis of present situation and future development of semiconductor

Chenyue Wang[1, *]

[1]School of British Australia and America, Shanghai, China

*Corresponding author: yusaijun@ldy.edu.rs

Abstract:

Semiconductor has a property between conductor and insulator. The property is caused by the different structure of the p-type and n-type material in the semiconductor, which only allows the current to travel in one direction. Because of this special property, semiconductor is used to design many different devices. Solar panel is an important technology to reduce pollution to the environment, with the energy generated by sunlight, the demand to fossil fuels will decrease. Therefore, global warming and air pollution will be solved by this solar panel technology. Wafer is also an important technology. It is widely used in computer and smart phones to processing complex information, many communications technology have a large demand on wafer. LED is a lighting device; its color and brightness is depended on the structure and material of semiconductor. There are many challenges and limitations in recent semiconductor industry, including its low efficiency in different scenario and high cost in production. In future, the need to semiconductor will increase a lot, like the 5G station and electric cars. The limitations of semiconductor are very important to solve by design new structure and new materials. Semiconductor will largely change the development in future technology.

Keywords: Semiconductor, solar panel, LED

1. Introduction

Semiconductor is an electronic device with a property between conductor and insulator, it works as a very important part in many electronic devices. Solar panel, wafer and LED all made by the semiconductor. Since last century the semiconductor has changed and upgraded a lot. For example, the raw material silicon was replaced by many new materials, including GaN and SiC, which are the newest generation of semiconductor [1]. This new generation of semiconductor has a better performance and more useful than the first semiconductor generation, like their better heat durability and higher power.

However, as the industry of electronic devices are increasing, the demand of semiconductor is also increased in recent years. The recent primary goal of semiconductor industry is to meet the needs of the other industry. Meeting the needs of customers starts with offering the technology to achieve ever-smaller feature sizes and higher productivity equipment solu-

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tions.

By providing enabling technologies, both at the process level and at the structure level, by putting more of an emphasis on solutions for the entire fabrication, some better materials and better production technology in needed. After the limitations in semiconductor was solved, the electronic device will meet a huge development. Those high needs of semiconductor in the future, from 5G stations and electronic cars will be satisfied by the new semiconductor.

2. Basic Theoretical Analysis of semiconductor

2.1 Definition and history of semiconductor

A semiconductor is a substance having a wide range of unique and practical qualities. It's a substance that exhibits conductivity between the conductor and the insulator. In the semiconductor one direction is where electricity is moving through more readily than the other. Additionally, it is highly susceptible to heat and light, which will affect its resistance. Devices built of semiconductors were utilized for energy conversion and switching because its electrical characteristics can be altered by doping and applying electric fields or light. The majority of electric devices, including light-emitting diodes, solar cells, and electronic circuits, depend on semiconductors as a key component [1].

2.1.1 History of Semiconductor

The beginning of semiconductor history was in the 1800s. The two-electrode vacuum tube rectifier, created in 1904 by John Ambrose Fleming, was to become a crucial component of electrical circuits in the near future. Numerous gadgets, including the first transistor radio in 1955 and the ENIAC computer in 1961 are supported by its design.

At first, silicon was the best and most pioneering material for semiconductors. Because it outperformed alternative materials like germanium, it was favored [2]. The chemical element silicon (Si) with the atomic number of 14. Research on silicon purification in the late 1950s was successful in yielding material appropriate for semiconductor devices, and starting around 1960, new silicon-based devices were produced. Another substance that can be used to create semiconductors is germanium. Nevertheless, the low heat durability of germanium prevents this semiconductor from being used over 85°C. Since silicon is found in 28.3% of the Earth's crust, it is inexpensive, easy to produce in big quantities, and can result in low prices for the finished product. This is another benefit of silicon semiconductors [3].

Figure 1 illustrates the three generations of semiconductor development.

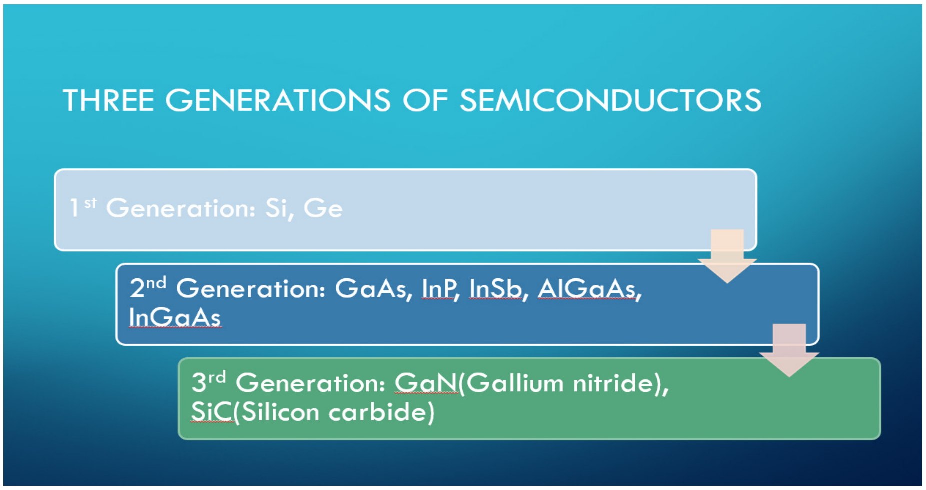

Figure 1. Three generations of Semiconductors

First generation semiconductors are silicon, and second-generation semiconductors are GaAs, InP, InSb, AlGaAs, and InGaAs. GaN and SiC are the newest semiconductors; they were developed and brought to market in 2001. GaN is an inorganic material with a direct bandgap semiconductor, along with excellent physical stability, high breakdown voltage, high critical electronic field, and high thermal conductivity. GaN is therefore thought to be among the most promising semiconductor materials and is frequently utilized in UV detectors, energy storage devices, and light-emitting diodes. Another material whose performance far outperforms that of Si semiconductors is SiC. It performs superbly at high temperatures, high frequencies, and exceptional temperature stability [4].

2.1.2 Basic working purpose of semiconductor

The p-n junction's structure affects semiconductor behavior. A structure that guarantees a semiconductor is partially conductive is the p-n junction. p-n junction is the convene of two different junctions into one single crystal. There are freely moving electrons on the negative side, and freely moving electron holes on the positive side. This material will experience a one-way current as free electrons move from the n junction to the p junction.

There is a diffusion effect happens when electrons from the n-type come into the p-type section of semiconductors, in the N and P regions come into contact, donor atoms with positive charge in this area will remain in the p-n interface near the n-zone. In the other situation, the junction besides p-zone was witnessed filled with positive atoms. By observing the significant leaps of the valence electrons, one can see a movement of the holes. A depleted zone of charge carriers known as the depletion region or space charge region will result from the happen of diffusion effect in electrons and holes, which will also produce the diffusion current. An electric field that is created sweeps all of the electrons and holes out of the depletion zone, stopping the charge carriers from flowing in a longer distance.

With the increasing of reverse-bias voltage, the depletion zone electric field becomes stronger. A break down will happen inside the p–n junction and current starts to flow when the magnitude of electric field is higher than the breaking point value, which is the avalanche breakdown processes and the Zener effect in other words.

2.2 Application

Semiconductors are present in almost every facet of people's daily lives. Since the 1948 creation of the transistor, the market demand and number of applications for integrated circuits have grown significantly. The majority of our contemporary comforts, such as televisions, personal computers, mobile phones, and cars, are powered by integrated circuits. The marketplace is now more competitive as a result of rising demand. Today, a semiconductor business needs to build the product at a fair cost and using a both cheap and efficient delivery system. It is no longer enough to simply create a good product.

2.2.1 Solar panel

As the environment problem is becoming very serious currently, the clean energy and green resources is becoming more popular. Therefore, the demand in better and higher efficiency technology is increasing. In all types of renewable energy which can be used to solve future energy supply problem, solar energy is the most abundant and reasonably priced technology. The method to use sunlight to create electricity is through solar photovoltaic (PV) effect, using sunlight to create a direct current inside solar cells and transform to other devices.

Photovoltaic cell is an electric device which can use sunlight to generate electricity in a high deficiency. A device with a p-n junction is the solar cell. The PV structure is depicted in figure 2, where n-type is the negative electrons provided by donor impurity atoms and p-type is the region below, with a positively charge empty hole inside.

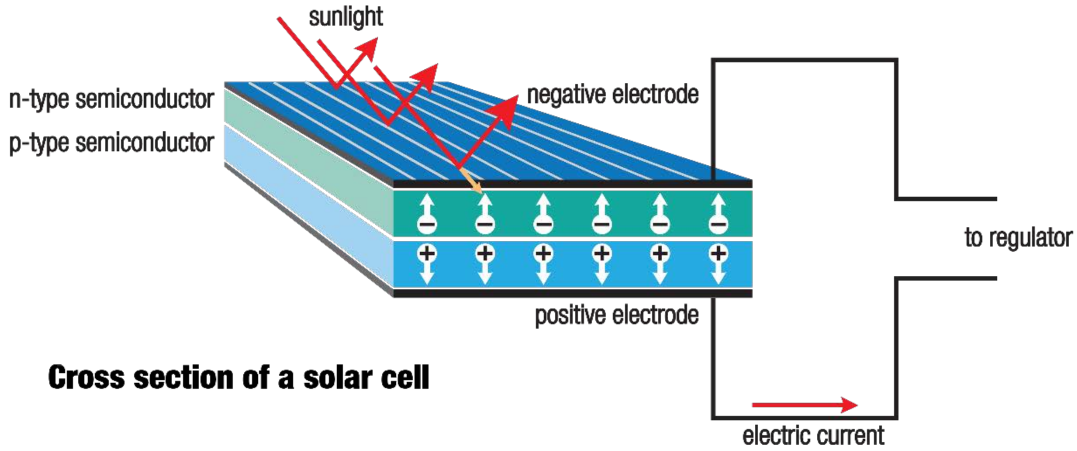

Figure 2. Structure of solar panel [5]

The photovoltaic effect is how solar energy is used to generated electricity, it has three steps to operate. While creating the charge carriers, photons was absorbed by the semiconductor. Then the electron is excited from the valence band to the conduction band, leaving an empty space at the valance level, when a photon with energy greater than the doped semiconductor material's gap energy is absorbed.

Those extra remaining photon energy provides more energies to the electrons and holes inside the components. The minimum energy or semiconductor work function required to create a pair of electrons. In this case, the work

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function represents the energy gap. The surplus energy in the semiconductor is wasted and transfer into the environment around. Secondly is ensuing division of the charge carriers produced by light. With the power from sunlight, the free electrons inside the semiconductor can escape from the p-side and going to the circuit connected to the semiconductor, and the hole in n-junction will fill with a new electron. Then, a current was generated by sunlight. Free electrons flowing though the circuit around will go back to the hole in n-junction.

However, the energy of one single solar panel is not very significant, this power can be increased by connecting more solar panels in parallel and in serious. The largest potential difference of one solar cell is below 1V, but by combining more solar cells together, the total voltage will increase and be satisfied to more using situations and energy supply [6].

2.2.2 Wafer

The process of manufacturing semiconductors is to create wafers first, which requires silicon to build its substrate. Currently, with the increasing amount of VLSI products, the requirement to a better wafer is increasing at the same time. The impurity inside a wafer is looking for a lower value and the structure must be nearly no error during production. Therefore, the process of creating silicon wafers has become extremely complex, involving many different intricate steps, like the refining of raw materials, the growth of silicon ingots, different complex steps to make a wafer from ingots, check to its environment durability including heat and waterproof, and final protection during the transport system, which is very important to prevent damage during transport. Manufacturing companies that produce chips rely heavily on yields, which are determined by the size, shape, and purity of the semiconductor die as well as the diameter and purity of the wafer. Wafer defects result in reduced final chip yields, underscoring the significance of precise control throughout the wafer production process.

2.2.3 Light emitting diodes

A diode is the semiconductor made of silicon crystal that has two doping: n-type, formed by pentavalent impurities, and p-type, formed by trivalent impurities. In each area, the doping process produces more mobile carriers known as majority carriers. LED is s kind of electrical pair made from solid-state semiconductor. In other words, it resembles a computer chip more closely than a lightbulb. It is a single-junction semiconductor device, to be more precise. The electrical characteristics of the semiconductor can be changed by purposefully adding impurities to its chemical structure. After build semiconductor with different kind of doped materials, the region between these two materials will occur [7].

Similar to a conventional diode, electrical current crosses the junction with great ease in only one single fixed way. Therefore, LED is also a device only emit light when the current flow through a fixed direction. LED has different color of light, which can be influenced by the material and structure of the raw material. Peak emission wavelengths for LEDs range from 250 nm to 1000 nm and beyond, encompassing inferred and UVC wavelengths.

2.3 Challenge and improvements in semiconductor

2.3.1 Challenge

Many gadgets use semiconductor technology, which is frequently used in them. It also confronts a lot of difficulties because there is a constant need for improved semiconductors. Furthermore, the cost and price of semiconductors remain extremely expensive; therefore, the price problem must be resolved in order to meet future demand.

The International Technology Roadmap for Semiconductors states that equipment expenses account for more than 75% of overall factory capital costs in a new wafer fab. Furthermore, a large portion of the machinery in contemporary crystal plate is “bleeding edge”, which means that the ratio of broken devices in production or substantial preventive maintenance are commonplace.

Deploying this costly equipment to its full potential will need major improvements in production scheduling and planning. Today’s fiercely competitive semiconductor markets not only face cost pressures, but also place more focus on responding quickly and consistently to customer order lead times, which are essential for effective delivery performance.

Moreover, semiconductor will become a pollution when they are broken [8]. The manage of old semiconductor need to be improved and cause no pollution to the environment.

2.3.2 Improvements

Despite several advancements, the problem in production and price is still unsolved, like the cost of broken plates during process. Although operational control theory is developing quickly, there hasn’t been much development to address real-world issues effectively and optimally.

The purpose of the proposed future development presented is to reduce the difference between theoretical advancement and real-world implementations. Research is divided into three categories: theoretical, computational, and empirical. The quantity and quality in the production are all needed to be increased.

In recent industry, the metrology is a critical component that ensures the quality and performance of semiconductor products. Metorlogy including different measurement methods, different measurements, and equipment to collect data from semiconductor. For instance, 3D NAND is a machine which can detect the data of size, thickness and accuracy. However, this technology is influenced by the difference in material and the environment [9].

Dynamic random-access memory is the developments in semiconductor technology. It has smaller design nodes and smaller error and difference in production. This higher accuracy of this technology prevents the quality of product while not influence its quantity [10].

3. Conclusion

Overall, Semiconductor is an important technology recently, and it will largely reduce the influence of global warming and other environment problems. Although many data and conclusions are discussed in this essay, there are still many limitations exist. Such as the lack of experimental data, narrow study range, and the personal research. First, many of the conclusions in the article can be supported by more diverse experimental data. Many applications of semiconductor are not discussed in this essay. Only the information from those essays my quote is not enough. The same experiment made by different people at different times may be different too. Comparing more data can make the conclusion to be more accurate. Accuracy of this essay can be improved by more research directions. The future work to prevent this limitation is to collect more information, like cost change of materials during time, or more quote resources to each conclusion.

Second, to improve the article, more different data sources can be added. More experimental methods from different directions can be used to get more accurate values and make the conclusion more precise. There is still some research directions not considered in the article, such as the development in light emitting diodes. After the materials in semiconductor is improved, the performance of light emitting diodes will also improve. To make a discussion about this change, many experimental data are needed, like the difference lightness and lifespan between new light emitting diodes and the origin light emitting diodes.

Third, is the personal experiments. Most of the data in the article is quoted from experimental data and lacks numerical values obtained from personal experiments. This may also affect the judgment of the conclusion. Due to limitations in conditions, it is not possible to obtain this part of the data. The future work is to do more personal one-hand experiment data. One-hand data is more reliable and credible.

After the future works are done, improvements in accuracy, experiment range, and more conclusions are expected to be seen. With more data support, the comparison between different devices using semiconductor will be more sufficient and more detailed supports to the final conclusion.

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