Analysis Of Silicon Crystal Materials: Meeting Growing Demands Across Industries

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Abstract. The demand for silicon crystal materials is poised for continued growth across diverse sectors in the upcoming years. In the realm of computers and communication, silicon single crystal wafers and chips are in high demand, fueled by the increasing adoption of communication equipment and the essential requirement for memory and control chips in information processing systems. Beyond the electronics domain, silicon crystals find applications in various industries, including environmental protection, new energy, and construction. In the field of environmental protection, silicon crystals play a vital role in denitrification and dust removal devices. In the new energy sector, they contribute to solar photovoltaic power generation systems and geothermal power generation systems. In construction, silicon crystals find their place in the production of building glass and semiconductor building materials. As China's economy continues to evolve and environmental concerns gain prominence, the demand for semiconductor materials, including silicon crystal materials, is anticipated to rise. This underscores a bright market outlook for silicon crystal materials in the foreseeable future.

Keywords: Silicon Crystal Materials, Growing Demand, Diverse Applications, Industry Trends.

1. Introduction

In recent years, remarkable advancements in science and technology have catalyzed significant progress and achievements across various sectors. In this dynamic landscape, silicon crystal has emerged as a pivotal material in the Chinese market, holding a position of utmost importance. Beyond its intrinsic properties, which render it indispensable in domains like semiconductors and solar energy, silicon crystal's potential extends far and wide, spanning a multitude of applications within the Chinese market [1].

The inherent versatility of silicon crystals opens doors to an array of possibilities, underscoring their significance as a focal point of study. As we delve deeper into understanding the myriad applications of silicon crystals across diverse sectors, this paper not only gain insight into the future trajectory of this invaluable material but also unearth the extensive value it brings to the ever-evolving Chinese market.

This exploration into the multifaceted applications of silicon crystals within the Chinese context is poised to shed light on emerging trends and the expanding scope of their utilization. Moreover, it underscores the pivotal role silicon crystals play in shaping the future landscape of technology and industry, affirming their status as a crucial and invaluable resource.

2. Semiconductor industry analysis

Silicon crystal is a new kind of semiconductor material synthesized by high temperature diffusion method. It has the characteristics of low resistance, high thermal conductivity, high stability, and has the advantages of large size, high specific capacity, high-cost performance, etc., which is unmatched by other materials [2]. The structure of Silicon crystal is shown in figure 1.

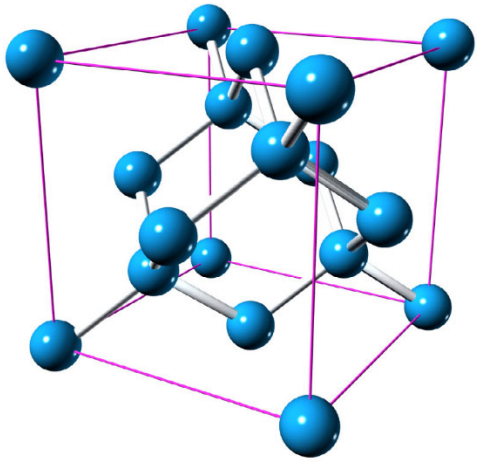

Fig. 1 The structure of Silicon crystal [2]

At present, most of the silicon crystal materials in the world come from developed countries. In China, because silicon crystal materials are an emerging industry that has been developed in recent years, the demand for silicon crystal materials in the Chinese market is still relatively small, and there are currently four major domestic companies that can produce silicon crystal materials.

2.1. Semiconductor field

Silicon crystals can be widely used in various semiconductor devices, such as semiconductor diodes, transistors, integrated circuits, LED and so on. Among these semiconductor devices, silicon crystals are the most widely used and occupy the vast majority of the market. China's semiconductor industry started late, and silicon crystal materials mainly rely on imports [3]. In recent years, with the rapid development of China's economy and the country's increasing attention to environmental protection, domestic silicon crystal materials have gradually replaced imported products, and the market size has gradually expanded.

2.2. Solar energy field

At present, China's solar energy industry is developing rapidly, and has made major breakthroughs in photovoltaic power generation, wind power generation and other fields, which has promoted the progress of solar power generation technology, greatly reduced the cost of solar power generation, and began to enter thousands of households. In 2016, China's photovoltaic module production was 23.1 GW, an increase of 65.3%, accounting for 59.6% of global production [4]. It is expected that by 2020, China's photovoltaic module production will reach 42.8 GW, an increase of 8.7 GW over 2016. At present, the development of China's solar energy industry is in a stage of rapid growth and will become a key development industry in China in the future. Silicon crystals can help in the field of solar energy.

With the increase of annealing time, the Voc and Isc of (non-I-layer) heterojunction cells increased first and then decreased. They reached the maximum value at 60min and 30min, respectively, and η increased at 60min [5]. This is because the appropriate annealing time can produce thermal effect inside the battery, reduce the density of the interface defect state, and optimize the structure of the film. At the same time, each layer of film can be recombined to improve battery contact and improve battery performance. The optimized annealing time (60min) is applied to the heterojunction battery (plus i layer). Although the treatment has a heating effect on the aluminum back electrode of the battery, the battery contact is improved, Rs is reduced, Isc is increased. However, if this time is too long, not only the crystallization rate of the intrinsic amorphous silicon film is increased, but also the hydrogen precipitation in the film is intensified, and the interfacial suspension bond cannot be saturated effectively, which affects the passivation effect of the intrinsic layer.

In order to improve FF, the battery preparation process was explored. They are1) The P-type window layer and the ITO front electrode are deposited successively on the front of the silicon wafer,

and the aluminum back electrode is steamed on the back of the silicon wafer. 2) Change the sputtering power of ITO electrode in 1). 3) Before the evaporation of the aluminum back electrode, a layer of ITO film with a thickness of about 50nm is sputtered to form a double-sided ITO battery. 4) Change the electrode deposition sequence in 1), plating Al back electrode first and then ITO front electrode. 5) Increase the battery area to 2*2 cm2, and the aluminum gate wire is introduced on the ITO front electrode. After comparative analysis, it is found that the battery prepared by process 1) has the highest FF and the best performance [6].

2.3. Radio frequency field

Silicon crystal materials are mainly used in semiconductor filters in the field of radio frequency. Semiconductor filter is a device that can limit the electromagnetic wave signal of a specific frequency to a specific range and can realize the cancellation of signals of different frequencies, different amplitudes, and phases, so as to achieve the purpose of filtering. Silicon crystal materials are the main materials of RF filters, which can provide higher isolation than quartz filters in high frequency bands, so as to ensure that the filter can maintain a good match with the circuit at high frequencies [7].

At present, in China's semiconductor market, the largest proportion of silicon crystal materials in the application field is RF filters. Silicon crystal material is the most important material in the field of radio frequency, it can be used as a medium in the filter, but also as a medium in the resonator, is an indispensable part of the radio frequency filter.

2.4. Power electronics field

The field of power electronics is the most important application field of silicon crystals in the Chinese market, because the demand for silicon crystal materials in the field of power electronics is relatively large, so the demand for silicon crystal materials in China is also large.

Polysilicon is the use of industrial silicon as a raw material, after a series of physical and chemical reaction purification to reach a certain purity of electronic materials, in the silicon product industry chain is a very important intermediate product, is the manufacturing of silicon polishing, solar electromagnetic and high-purity silicon products important raw materials. Therefore, the development of electronic grade polysilicon industry has a very important significance [8].

From the industry application point of view, silicon crystals are mainly used in the field of power electronics. With the continuous progress of China's power electronics technology, as well as the development of photovoltaic, wind power and other new energy industries, the demand for silicon crystal materials is also increasing.

According to the statistics of the Silicon-based Semiconductor Branch of the China Semiconductor Industry Association, China's grid-connected photovoltaic installed capacity reached 15.89GW in 2019, an increase of 7.95%. The installed capacity of photovoltaic connected to the grid reached 3.79GW, an increase of 5.35% [9]. It is expected that in the next few years, China's photovoltaic industry will maintain a good development trend, and the demand for silicon-based semiconductor materials will also increase.

2.5. Computers and communications field

The computer and communication field is one of the most important application fields of silicon crystal materials. With the rapid development of computer technology and communication technology, more and more silicon crystal materials are used in electronic products. For silicon crystal materials, their quality plays a decisive role in the performance of the entire electronic product, so the requirements are becoming higher and higher. Because of its excellent optical waveguide characteristics, high mechanical strength, operational flexibility and easy integration, microfiber devices have received more and more attention, and have been widely used in sensing, laser, biochemistry and other fields. However, the relatively large size of silicon dioxide microfiber devices and the low refractive index of materials make their application in gas and liquid environments at micro and nano scales extremely challenging. The emergence of one-dimensional nanomaterials

makes up for this deficiency. Because of its smaller size and higher refractive index, microfiber devices based on single nanowire integration can achieve higher sensitivity and higher spatial resolution in some special environments and have broad application prospects [10].

At present, the demand for silicon crystal materials in the field of computer and communication in China is mainly concentrated in three aspects: first, a large number of silicon single crystal wafers are needed in communication equipment; Second, computers need a large number of silicon single crystal chips; Third, it is used for memory and control chip in information processing system. Among them, the demand for silicon crystal materials in computers is the largest, accounting for more than 50% of the demand in the entire computer and communication field.

2.6. Other fields

Silicon crystals have a wide range of applications, in addition to the field of electronics, but also used in environmental protection, new energy, construction and other fields. Among them, in the field of environmental protection, it is mainly used in denitrification and dust removal devices of environmental protection industry. In the field of new energy, it is mainly used in solar photovoltaic power generation systems, geothermal power generation systems, etc. In the field of construction, it is mainly used in building glass and semiconductor building materials [11].

In the next few years, with the further development of China's economy and the increasing attention of the country to environmental protection, China's demand for semiconductor materials will be increasing. Therefore, the future market prospects of silicon crystal materials are very broad.

3. Challenges and prospects

Silicon crystal materials have undoubtedly revolutionized various industries, but they are not without their unique set of challenges. One of the foremost challenges lies in the quest for ever-higher purity levels. As technology advances, there is a growing demand for silicon crystals with fewer impurities to meet the stringent requirements of modern electronics and semiconductor manufacturing. Achieving higher purity levels while maintaining cost-effectiveness remains a delicate balance that researchers and manufacturers continually strive to address.

Looking ahead, the prospects for silicon crystal materials are promising. With the relentless advancement of technology and the increasing emphasis on sustainability, silicon crystals are poised to play a pivotal role in renewable energy solutions. Solar photovoltaic systems, in particular, hold enormous potential, and as the global shift towards clean energy intensifies, silicon crystal materials will be instrumental in harnessing and storing solar power efficiently [12]. Moreover, the application of silicon crystals in emerging fields like quantum computing presents exciting opportunities for groundbreaking innovations. The journey ahead involves overcoming challenges while leveraging the inherent versatility of silicon crystals to shape a more sustainable and technologically advanced future.

4. Conclusion

In conclusion, silicon crystal stands as a fundamental raw material at the heart of the semiconductor industry, commanding a substantial share within this pivotal sector. The quality of silicon crystals bears direct influence over semiconductor performance, thereby underscoring the pivotal role that the advancement and application of silicon crystals hold in propelling the broader semiconductor industry forward. China, as the world's leading producer of silicon crystals, has exhibited rapid growth in this industry in recent years. While acknowledging that disparities persist between China and other nations in the silicon crystal sector, it is firmly believed that, fueled by the ongoing growth of China's economy and its continuously evolving technological prowess, the nation will steadily bridge this gap. As the demand for semiconductor materials continues to surge within

China, the country is poised to progressively master silicon crystal production technology, ultimately achieving a position of leadership in this crucial domain.

5. References

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