

Comparative analysis of the impact on societies of silicon technology against that of steel

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Abstract. Silicon is one of the most important elements in the world today, and its content in the Earth's crust reaches 26%, second only to oxygen. Iron is the fourth most abundant element in the Earth's crust, accounting for more than 5% of the Earth's mass. It makes up most of the Earth's core. Both of them play a vital role in daily human life and economic development. Silicon electronics industry, computer, composite materials, life technology, and other important pillars. Iron is used in construction, manufacturing, transportation, and so on. This article will describe the discovery of two elements and their development history. In addition, this paper analyzes the similarities and differences between the two from different aspects, comparing their impact on society. Finally, this paper gives some prospects for them. The insight gained from this paper can reinforce the understanding of the history of its exploration and their different role in social development.

Keywords: Silicon, Iron, Social impact

1. Introduction

In this era of rapid development. The use of new materials and high technology has a profound impact on the development of society. Among them, silicon technology and steel technology have become the key pillars of social development, and have left an indelible mark in the process of human social progress. This paper attempts to comprehensively compare and analyze the impact of the two materials on social progress and development by analyzing their social impacts. Through an in-depth study of history, applications, social impact and material properties, the contrast between silicon technology and steel is revealed, ultimately contributing to a deeper understanding of the importance of both technologies in shaping our world.

2. History and Development of Silicon

2.1. Early history

Since the birth of mankind, silicon and its compounds have contributed to human civilization and are one of the material bases for human survival. At first, humans only used some natural silicates. For example, they used stones to make tools for hunting or used flint to get fire. After learning to use fire, people began to use fire to make things, creating the first substance, porcelain, which did not exist in nature. Then, the Egyptians invented glass. Although these glasses were mostly small glass beads or small glass fragments, it was a big step in the exploration of silicon.

Due to a lack of knowledge of chemical elements and the backwardness of science and technology, ancient people did not separate elemental silicon.

2.2. Discovery of silicon

In 1789, Antoine-Laurent Lavoisier (1743~1794) recognized that quartz (mainly silica) contained an element, which he included in the first list of elements, named silice according to the Latin silex(flint). In 1800, it was mistaken for one compound by a British chemist, Humphry Davy (1778~1829). After him, in 1808, Joseph Louis Gay-Lussac(1778~1850) and Louis Jacques Thenard (1777~1857) got one type of reddish- brown powder(amorphous silicon α -Si) by heating potassium and silicon tetrafluoride. However, it was impure, which means it cannot conduct further study. It was not until 1823 that elemental silicon was discovered by a Swedish scientist(Jons Jakob Berzelius,1779~1848). He reduced potassium fluosilicate with potassium to get some brown powder and then washed the powder repeatedly to get a purer amorphous silicon. Furthermore, after 31 years, Henri-Étienne Sainte-Claire Deville (1818~1881) mixed amorphous silicon with sodium chloride and aluminum chloride, and then electrolyzed it to obtain a purer crystalline silicon for the first time.

2.3. Properties of silicon

Initially, the discovery of silicon did not attract much attention, because it had a high melting point, which reached 1410 degrees Celsius. So, silicon is very stable at room temperature. Specifically, it can only react with alkalis and hydrofluoric acid. Then, scientists found that silicon will be very active at high temperatures. For example, mixed with quartz, coke and steel, heated to above 1500 degrees Celsius, ferrosilicon alloy was obtained. Furthermore, like many substances, when the purity of silicon reaches a certain level, its chemical properties will become completely different. Through the electric arc furnace, quartz and charcoal are mixed, heated to more than 1900 degrees, and electrolyzed by electricity, more than 98% silicon can be obtained, which is called metallurgical grade silicon. Metallurgical-grade silicon continues to be purified to produce purer silicon. Let hydrogen chloride and coarse silica powder react to generate chlorosilane, and then let chlorosilane be reduced and deposited in a reduction furnace in a hydrogen atmosphere, and a relatively pure silicon crystal is obtained, and the purity can reach four nines, that is, 99.99%, which were used in automotive, textile, aerospace, and other industries. A little higher than its purity is solar-grade polysilicon, which have a purity between 99.99% and 99.9999%. Further, the purity of 6 9s is electronic grade polysilicon, which is mainly used in the semiconductor industry, such as photovoltaic cells. Although these silicon crystals are very pure, there are many crystallization directions inside, not a single large crystal, called polysilicon. Moreover, when the molten elemental silicon solidifies, the silicon atoms are arranged into crystal nuclei in a diamond lattice, and its crystal nucleus grows into grains with the same crystal face orientation to form single crystal silicon [1]. As a relatively active non-metallic element crystal, monocrystalline silicon is an important part of crystal materials and is at the forefront of the development of new materials. The manufacturing of monocrystalline silicon materials goes through the following process: quartz sand - metallurgical grade silicon - purification and refining - deposited polycrystalline silicon ingots - monocrystalline silicon - silicon wafer cutting. Its main use is as semiconductor materials and the use of solar photovoltaic power generation, heat supply, etc [2].

2.4. Growth of single crystal silicon

When it comes to monocrystalline silicon, we must mention silicon crystal growth technology. Silicon crystal growth is the conversion of semiconductor-grade polysilicon into a large single crystal silicon. The most extensive method now is Czochralski (CZ) process. This method is to change the melted semiconductor-grade silicon liquid into a fixed silicon ingot with the correct crystal orientation and doped into n-type or p-type fixed silicon ingots. Semiconductor crystal growth using melt-based growth was spearheaded by Teal and Little by demonstrating the growth of single crystal Ge [3], [4]. Then, in 1959, Dash showed dislocation-free CZ silicon crystal growth through a modified seeding technique for the first time [5], [6]. Large-scale industrial production of high-quality monocrystalline silicon has a significant impact on computer communication systems, sensors, medical equipment, spacecraft, etc. So, there is a growing demand for large-diameter monocrystalline silicon, and this conduce to the Czochralski (CZ) method has become the most popular method [7].

3. The Historic Background of Steel

3.1. The Origins of Steel Technology

Steel technology has its roots in the ancient process of metallurgy, dating back about three thousand years. Many early civilizations, such as the Hittites and the Egyptians, produced their primitive forms by heating pastes over charcoal fires, a process later known as smelting. Wrought iron at the time was malleable but lacked hardness. Over time, operating in 300 BC, the Indians invented the Indian Crucible steelmaking process, which fused iron and carbon-rich materials together to produce higher quality, better performing steel.

3.2. The Evolution of Steel Technology

The development of steel technology made significant progress during the Industrial Revolution in the 18th century. Many innovative processes, such as the Bessemer process and the Siemens-Martin process, have transformed the steel industry by producing high-quality steel on a large scale and at low cost. Steel has become an important material railways, Bridges, and buildings. The development of alloy steel has further expanded its use. It can be used in automobile, aerospace, mechanical engineering, and other industrial fields.[8] After entering the 21st century, with the acceleration of industrialization and economic development in developing countries and emerging economies, the world steel industry continues to grow rapidly and the scale of the industry continues to expand. In 2000, world steel production exceeded 800 million tons. In 2004, world steel production reached 1,054.8 million tons, exceeding 1 billion tons for the first time in human history. In 2009, affected by the global financial crisis, world steel production fell by 7.9%. After a rapid recovery, 2011 reached a new record, exceeding 1.5 billion tons, reaching 1.518 billion tons. By 2018, world steel production reached 1,809 million tons, an increase of 1.1 times over 2000, with an average annual growth rate of 4.3%, compared with an average annual growth rate of less than 1% in the 1980s and 1990s. It can be seen that since entering the 21st century, the development speed of the world steel industry has accelerated significantly.

3.3. The Applications of Steel Technology

Steel's versatility and strength have made it indispensable across numerous fields. In the construction industry, steel is a primary choice for structural elements, offering both durability and flexibility. In transportation, it plays a critical role in vehicle development, providing lightweight solutions with exceptional strength. The aerospace sector relies on high-strength steel alloys for aircraft components. Additionally, steel is essential in the energy sector for the construction of pipelines and power plants, and it contributes to medical advancements in the form of surgical instruments and implants.

3.4. The Impact of Steel on Society

Because of its high strength and durability, steel has played a very important role throughout human history, especially during the Industrial Revolution. Because of these properties, steel materials are

indispensable in the construction of infrastructure such as railways, promoting the development of industrialization, and promoting economic growth and creating jobs. Today, the steel industry remains an important contributor to the global economy, providing many jobs in mining, manufacturing, and construction. Because it has an extensive supply chain including raw material suppliers, distributors, and end users all over the world, it expands its economic impact on a local, national and international scale. In addition, the application of steel has also built skyscrapers, Bridges, and various transportation networks for people. At the moment, people are moving to cities for jobs, education and a higher standard of living, and this shift has led to increased urbanization. The development of the steel industry has profoundly affected the way people live and work. The development of steel technology has provided employment opportunities for millions of people around the world, from miners to engineers

At the same time, it also promotes the development of welding, metallurgy, and structural engineering industries, and promotes economic growth. At the same time, we should recognize that steel production is a resource - and energy-intensive consumption industry, which will lead to greenhouse gas emissions and environmental degradation. Both the mining of iron ore and the discharge of steel mill waste pollute the air and water. These hazards are now recognized and efforts are being made to find new ways to reduce the environmental damage caused by industry

3.5. The impact of the steel industry on war

In the modern military war, the importance of military technology is self-evident. And the development of the steel industry has had a profound impact on the evolution of military technology. First of all, steel materials are not used in the manufacture of various advanced weapons such as the armor of tanks and various structures of aircraft. Guns need barrels that can withstand high temperatures and pressures, and some of the properties of steel are ideal for meeting these requirements. Second, the innovation of steel technology led to the innovation of military technology. Looking back at history, during the two World Wars, steel manufacturers actively cooperated to conduct research and experiments for improving weapons systems. These improvements included improved range and accuracy of the gun and increased mobility of the tank. These innovations are crucial to victory on the battlefield. Most importantly, steel technology provided the basis for the mass production required by military technology. During the war, countries needed to produce large quantities of weapons quickly to meet the needs of the war, and the expansion of the steel industry made it possible to produce weapons on a large scale, ensuring the supply of weapons.

4. Comparative Analysis: Steel Vs Silicon Technology

To truly understand the profound societal impact of steel and silicon technologies, we must integrate their historical development into our discussion. Steel, as a material with a long history, finds its earliest applications dating back over 2000 years in the Middle East and Asia. Over these millennia, continuous research and utilization have driven advancements in both the quantity and quality of steel production. Undoubtedly, throughout this period, it has a substantial influence on the way human society presents itself and how we understand the use of materials. Today, from the Eiffel Tower, the magnificent spectacle in Paris, to the intricate railway networks, steel is used in every aspect of our lives. This material, has become an indispensable cornerstone in different fields with its versatility, strength, and durability. In stark contrast, silicon technology represents an emerging frontier. Its beginning can be traced back to the late 1940s, when the transistor was invented. This monumental innovation heralded a new era in electronics and marked the dawn of the Information Age. Then the leaps in semiconductor manufacturing technology paved the path for the widespread application of silicon-based devices. Specific applications of silicon technology, such as integrated circuits and microprocessors, serving as the basis of modern computing, have thoroughly revolutionized communication, computation, and nearly every aspect of daily life.

The specific comparison of the impact of steel and silicon technology starts in the economic aspect. Steel's economic significance lies in its foundational role in heavy industries, including construction, automotive manufacturing, and infrastructure development. It's the backbone of buildings, and

transportation networks, playing an important role in job creation and the prosperity of economic. Silicon technology, on the other hand, has given rise to a dynamic and high-tech ecosystem. Driven by silicon-based microchips, the semiconductor industry has cultivated a fertile ground for innovation. It has stimulated economic expansion by producing consumer electronics, fueling the rise of data centers, and powering the global telecommunications network. Silicon Valley, the epicenter of technological advancement, stands as a testament to the economic dynamism that silicon technology has unleashed.

Beyond their economic influence, both steel and silicon technologies have left a significant mark on society. Steel, by enabling the construction of vast urban landscapes, has played a pivotal role in uniting communities and facilitating the flow of goods and people, the automotive industry which is heavily reliant on steel has revolutionized personal mobility and urban planning. Silicon technology, however, has rewritten the rules of communication and connectivity. When steel bridges and tunnels have bridged geographic divides and transformed global transportation networks, silicon technology has transcended geographical boundaries, thus redefining social interactions and defining the digital age. Furthermore, the advent of the internet and social media platforms has democratized information access and revolutionized the way people communicate, collaborate, and access knowledge. Silicon technology has also driven transformative advancements in healthcare, making telemedicine, remote patient monitoring, and precision medicine viable realities.

While in terms of environmental impact, steel technology is now facing substantial challenges. Traditional methods of steel production are resource intensive and emit significant greenhouse gases, and we are making efforts to develop cleaner and more sustainable approaches to steel production consequently. These efforts include exploring hydrogen-based reduction processes and transitioning to electric arc furnaces, which can effectively reduce the carbon footprint of steel production. Silicon technology, in a contrast, holds promise as a catalyst for energy efficiency and renewable energy sources. Silicon-based solar panels, for instance, silicon-based solar panels can contribute to the global shift towards cleaner and more sustainable energy generation by harness the power of sunlight to generate electricity.

5. Future Implications and Societal Significance

Both steel and silicon technologies are poised to continue their profound influence on society. In the future. Silicon technology, on an exponential growth trajectory, promises to redefine industries through advancements in artificial intelligence, quantum computing, and 5G connectivity. The fusion of silicon technology with healthcare, transportation, and smart infrastructure heralds the advent of smart cities, personalized medicine, and efficient transportation systems, all poised to enhance the quality of life. For steel technology, we should cast a spotlight on the sustainable practices. The development of eco-friendly production methods will be paramount in mitigating its negative environmental impact. And the steel technology will still be used in emerging industries for its adaptability and strength. For instance, it can be used in carbon capture and storage, which contribute to global efforts to combat climate change.

Besides, the societal significance of these two technologies cannot be overstated. Steel technology, as an enduring pillar of infrastructure and industry, will continue to be a bedrock for economic stability and create lots of jobs. It will remain foundational for essential sectors like transportation, energy, and construction. Nonetheless, reducing the negative environmental effects of steel production is not just a goal but a necessity for the pursuit of a sustainable and resilient future. On the other hand, when silicon technology has democratized information access, empowered individuals, and expedited scientific progress, it has also raised several ethical and social questions, spanning data privacy, cybersecurity, and the concerns about jobs being replaced by artificial intelligence. In all, how to reach a harmonious balance between technological innovation and the ethical considerations that underpin societal well-being will be a central challenge in our times.

Beyond the discussion related to economic impact, societal change, and environmental stewardship above, there exists the potential for synergy between steel and silicon technologies, and each technology has to play a significant role for a sustainable and technologically advanced future. Steel, known for its

strength and structural integrity, may find new applications in the construction of sustainable smart cities. Its adaptability can be fully used to create resilient urban environments that utilize the latest advancements in silicon technology, such as smart grids, efficient transportation systems, and data-driven urban planning. Silicon technology, with its power to connect, compute, and innovate, can further enhance the efficiency of steel production and consumption. Data analytics, IoT sensors, and automation can in turn optimize steel manufacturing processes, minimize waste, and reduce energy consumption. Together, steel and silicon can form a powerful synergy that builds sustainable, connected, and technologically advanced societies for the future.

6. Conclusion

In conclusion, our exploration of steel and silicon technologies reveals a compelling storyline involving two fundamental forces that have significantly shaped our society. Steel, with its strength, forms the bedrock of our physical world. On the other hand, silicon technology leads us the way to the digital era, embodying a pursuit of innovation and progress. What's more, when we gaze into the future, it becomes more and more evident that both steel and silicon technologies will continue to play significant roles in shaping our societal landscape.

However, the contributions of these technologies are accompanied by challenges and ethical considerations, and the paramount challenge we face on our journey into the future is to achieve a balance between technological innovation and the ethical principles that form the basis of the well-being of our society. It is the collective efforts and forward-looking perspectives of our global community that will serve as our compass through this intricate terrain.

In the era of rapid technological advancement, we are now standing at the crossroads of tradition and innovation, where the wisdom of the past converges with the promise of the future. The tale of steel and silicon is not only a story of progress but a testament of our spirit of exploration and discovery. Now, with the capability to harness the potential of these elemental forces responsibly, we can shape a future that enriches the lives of all humankind.

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