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Review

Research Status on the Structure, Performance, and Defects of Float Glass

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Abstract: Float glass is an important material widely used in fields such as construction, automotive, and electronics. Its production process employs advanced float technology, which ensures that characteristics such as a smooth surface and high transparency are fully realized. Its microstructure is similar to that of oxide glass, often exhibiting a tin streak pattern, while the surface bonds significantly influence the physical and chemical properties of the glass. In addition, float glass has certain defects that need to be identified and remedied through inspection methods. Overall, as an important material, float glass has broad application prospects and development potential. However, during use, it is necessary to carefully consider its performance and defects, selecting appropriate usage scenarios and methods to ensure effective and safe application. Furthermore, research and application of float glass need to be further deepened to continuously promote its development and innovation.

Keywords: float glass; structure; properties; defects

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1. Introduction

In order to serve as a reference for scholars and professionals in relevant sectors, the goal of this study is to investigate the properties and patterns of float glass with regard to its structure, functionality, and flaws. After that, it will assess its benefits and limitations in practical applications. This supports the study and advancement of float glass applications and has significant theoretical and practical implications for a better comprehension of the functionality and uses of float glass. In order to provide a scientific foundation for research and application in relevant domains, the study explores the structure, performance, and flaws of float glass in order to fully comprehend its properties and regulations.

2. Production Process of Float Glass

Float glass, also known as annealed glass, is made from float glass invented in the 1950s by Sir Alastair Pilkington of Pilkington Glass Company. Most flat glass in the world is produced using this method. The process involves pouring molten glass onto a bath of molten metal with a higher relative density (usually tin). The glass floats on the surface of the metal, naturally forming smooth surfaces on both sides, and slowly cools and solidifies, separating from the tin bath in sheets. After fire polishing, it becomes nearly perfectly flat glass. Float glass is usually produced in standard thicknesses, including 2, 3, 4, 5, 6, 8, 10, 12, 15, 19, and 22 millimeters. Before this manufacturing method was invented, annealed glass was also produced by blowing or rolling, but these methods made it difficult to produce perfectly flat glass unless expensive mechanical polishing was applied. Therefore, this preparation method offers advantages such as high efficiency, energy saving, and environmental friendliness.

3. Structure of float glass

3.1. Differential Structure of Float Glass

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The silicate glass system, which includes fused quartz, soda-lime glass, borosilicate glass, and others, is made up of silicon dioxide (SiO_2), the fundamental ingredient of glass. Among these, float glass is a common soda-lime silicate glass made from dolomite, sodium carbonate, and quartz sand as basic ingredients. Zachariasen's Continuous Random Network (CRN) model can be used to explain the microscopic structure of glass. The basic units are silicon-oxygen tetrahedra, which are joined by shared oxygen atoms to form a three-dimensional network.

According to experimental research, the Si–O–Si bond angle between tetrahedra varies between 127° and 160°, whereas the O–Si–O bond angle within a tetrahedron is stable at 109°. A long-range spatially disordered structure is formed by the accommodation of 3–9 uneven silicon-oxygen tetrahedra in silicon-oxygen atom rings due to this diversity in bond angles. Additionally, the theoretical maximum of 0.74 for a face-centered cubic structure is greatly exceeded by the spatial packing densities of silica and sodium-calcium silicate glass, which are 0.45 and 0.52 respectively. A theoretical structural explanation for the densification behavior of glass is offered by this reduced spatial filling rate.

3.2. Surface Structure of Float Glass

A "surface bond" is created when the surface of the float glass in the tin bath reacts with air to form a nanoscale oxide or hydrated oxide coating. The glass's chemical and physical characteristics are greatly impacted by this structure. The glass surface has very high flatness and optical homogeneity because of the balanced spreading of the liquid glass between the tin bath and the gas interface. This makes the glass surface ideal for high-precision optical and electrical components.

Microstructurally, float glass's lower surface frequently develops wavy "tin streaks" that match the flow direction. These are tiny marks that are left on the glass surface by tin bath vortices. Because of the variation in tin content between the upper and lower surfaces, these patterns can not only produce yellow fluorescence when exposed to ultraviolet light, but they also provide a crucial foundation for determining the type and orientation of glass. The gaps in the glass network can be filled by a suitable quantity of tin ions, which can also prevent crystallization and improve structural stability; However, excessive tin penetration can alter the material properties and increase production costs, so precise control of tin content is necessary.

In addition, the glass surface may also have random defects such as bubbles and scratches, which usually do not affect its overall performance.

4. Performance of float glass

4.1. Mechanical Properties of Float Glass

Zhou et al. (2020) used a TS580 tin side detector to identify the tin side and air side, mainly using 1040 g steel balls for drop impact experiments. Each experimental group consisted of 20 glass samples, and the final test result was obtained by taking the average. From the experimental results, it is clear that the mechanical performance of the tin side is far superior to that of the air side. Therefore, when we want to improve the mechanical performance of float glass, we can either change the air side composition to that of the tin side or place the tin side on the side that experiences greater impact.

4.2. Sound Insulation Performance of Float Glass

Ma (1990) used a special intermediate film inserted between two flat float glass panes to make sound-insulating glass. Liu (2019) noted that float glass has good sound insulation performance. Therefore, float glass is also used in building materials and soundproof materials, and because of these excellent characteristics, it is highly favored by designers.

5. Defects of Float Glass

5.1. Optical Distortion Points

Tiny bubbles or contaminants may show up on the surface of float glass during the manufacturing process. These microscopic bubbles or contaminants have the ability to reflect and refract light, creating optical distortion points on the glass surface. The specific causes are caused by two factors that occur simultaneously: first, the atmosphere in the tin bath contains volatile tin compounds, such as tin oxide, tin sulfide, and metallic tin vapor; second, low-temperature areas in the space above the glass ribbon or on the tin bath cover allow the tin-containing volatiles to condense into liquid or solid form when the glass ribbon has not yet hardened. These volatiles then fall onto the surface of the glass ribbon, creating contamination of the optical distortion point. (Gao and Ye, 1994)

5.2. Tin Ash

Tin oxide, also known as tin stone, mainly consists of SnO_2. When tin is added to float glass, it may not completely melt or dissolve during the manufacturing process, forming particles that fall onto the surface of the soft glass ribbon. These are usually small gray-white spots, and these particles create tin oxide deposits on the glass surface.

5.3. Iris

Iridescence is a defect on the lower surface of float glass, also known as 'tempered iridescence.' During the manufacturing process of float glass, changes in temperature and pressure can cause tiny wrinkles or undulations to form on the glass surface, which can lead to interference and diffraction of light. The formation process is as follows: substances such as SnS, Sn, and SnO_2 in the tin bath condense and accumulate in slightly cooler areas, and due to their own weight or external forces such as airflow fluctuations and changes in bath pressure, they may fall. Once they land on the glass sheet, they create point defects of optical distortion. (Gao, 2014).

In the production of float glass, besides controlling the quality of raw materials and the forming process, special attention should also be paid to the detection of glass defects. It is important to make effective use of inspection equipment, promptly identify defective glass, and analyze the causes of defects through sampling to propose reasonable and effective solutions. Glass defect detection mainly includes manual inspection and mechanical automated inspection. Currently, machine vision-based online defect detection devices are widely used to inspect various point and line defects in float glass online.

6. Conclusion

The distinct surface properties and microstructure of float glass are the foundation of its performance. The macroscopic behavior of the material is determined by its non-equilibrium surface arrangement and continuous and irregular network structure. The theoretical underpinnings of the glass's mechanical behavior are provided by the topological connections of silicon-oxygen tetrahedra and their spatial packing properties; on the other hand, the surface tin layer and tin streak pattern have a direct impact on the material's mechanical strength and chemical stability and are also important markers for determining and improving its performance. Float glass exhibits many performance advantages at the application level: its optical homogeneity satisfies the needs of precision equipment, its tin side provides high impact resistance, and structural design can accomplish good sound insulation. Nevertheless, process optimization and intelligence detection are still required to prevent flaws such optical distortion and tin slag produced throughout the production process. To broaden the range of applications for float glass in upscale industries, future studies should concentrate on the mechanisms that link microscopic structural evolution and macroscopic performance, create new surface modification technologies, and set up a more accurate defect prevention and control system.

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