

# Study on Infrared Radiation Coating and its Application in Glass Furnace

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**Abstract.** A new type of infrared radiation coating for glass furnace without pollution was studied and prepared, and sprayed the coating onto the inner surface of the siliceous refractory in the melting end of glass furnace. The phase composition and microstructure were characterized by XRD and SEM, and the normal spectral emittance of coatings and thermal data of the glass furnace were measured. The results showed that the main phase of the coating was SiO<sub>2</sub>, and the coating firmly combined with the siliceous refractory at high temperature. The infrared spectral emissivity of the coating can reach as high as 0.92 at 1600°C. When the melting end of glass furnace was sprayed by infrared radiation coating, resulting in 7.75% energy efficiency.

## 1. Introduction

Infrared radiation coating is a kind of inorganic coating with high absorption and high radiation characteristics on infrared radiation spectrum. Spray the infrared radiation coating on the inner wall of the furnace or the heat-absorbing surface can effectively enhance the radiation heat transfer in the furnace. Then the energy efficiency and productivity of furnace can be improved, to achieve the purposes of energy-saving, emission reduction and cost reduction.

In the glass industry, glass furnace has many special working conditions. Such as high temperature (about 1600°C), complicated combustion atmospheres (oxidation, reducing and neutral atmosphere segmented coexistence), long continuous working time (5 to 10 years) and the liquid glass is sensitive to impurities. These put forward high request for the research and application of infrared radiation coating on glass furnace.

The effective radiation of the inner wall of glass furnace is divided into spontaneous radiation and reflection, the spontaneous radiation spectrum is a continuous spectrum with a peak value of 1.5μm (at 1600°C), and the reflection spectrum is a band spectrum with peak values of 2.7μm and 4.3μm. According to Wien displacement law, the absorption spectrum of glass liquid at temperature of 1000°C -1600°C is a continuous spectrum with peak values between 1.5μm and 2.2μm, which matches the spontaneous radiation spectrum of the glass furnace wall. Therefore, the glass liquid can effectively absorb the spontaneous radiation heat of the furnace wall. The absorption spectrum of the flue gas in glass furnace is a band spectrum with peak values of 2.7μm and 4.3μm, which can absorb the reflected heat from the furnace wall [3].



After the inner surface of the siliceous refractory in the melting end of glass furnace is coated with infrared radiation coating, the infrared spectral emissivity of the inner wall at 1600°C (the highest working temperature of glass furnace) is increased to 0.92. For the furnace inner wall, on one hand, the spontaneous radiation heat transferred to the glass liquid increased, thereby improve the heating efficiency. On the other hand, the reflection heat transferred to the low temperature flue gas is reduced, and the heat loss of the discharged flue gas is reduced.

The new type of infrared radiation coating can be sprayed on the surface of all the siliceous refractory inside the melting end of glass furnace, include main arch, front wall, breast wall and straight wall section of L-shaped suspended wall. The coating forms a solidified coating on the inner surface of the siliceous refractory during the heating process of the glass furnace, and infiltrated into the siliceous refractory. The SiO<sub>2</sub> content of the coating is close to the composition of the siliceous refractory, so the swelling property is consistent with that of the siliceous refractory during the sintering process at high temperature. In the production of glass furnace, the coating will not drop, peel off or fall off, and there is no potential pollution effect on glass liquid or glass product. The new type of infrared radiation coating can produce considerable energy savings while effectively protecting refractory linings and extending the life of refractory materials.

## **2. Text Materials preparation and measurement**

### *2.1. Materials preparation*

The infrared radiation coating was made of self-made composite radiation base material, quartz powder, silica sol, pure water and other auxiliary agents. The above components were weighed according to the proportion and well mixed, then the nano sand mill process was applied to make the coating particles reach the level of micro-nano, and the infrared radiation coating for glass furnace was prepared.

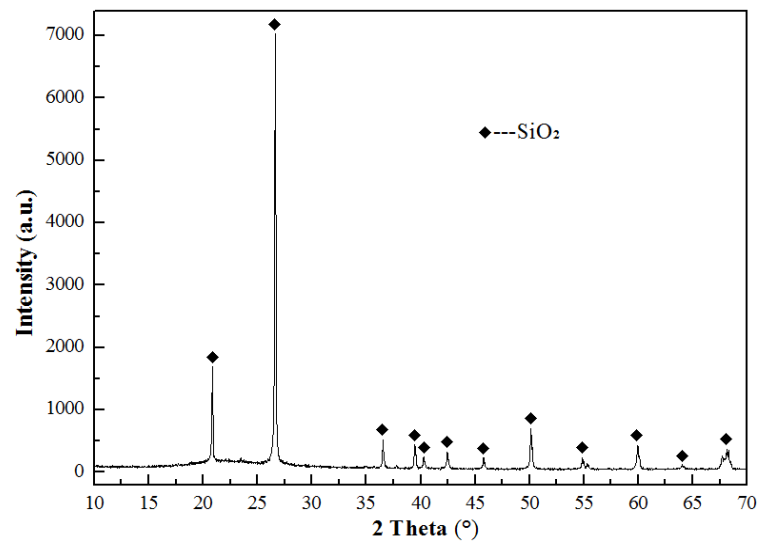
### *2.2. Measurement*

The crystal structures were examined by X-ray diffraction (XRD, Bruker D8). The cross section morphologies were observed by scanning electron microscope (SEM, FEI Nova450). The normal spectral emittance in wavelength range from 1μm to 15μm were examined by emittance measurement apparatus for high temperature (EMMA-HT) at 1500°C, 1600°C and 1700°C. The thermal balance parameters were examined by platinum and rhodium thermocouple, armored thermocouple, infrared thermometer, digital temperature display, heat flow meter, hot ball anemometer, S-type pitot tube, digital micro pressure meter, integrated flue gas analyser, wet preservative gas flow meter, ceramic tube, etc.

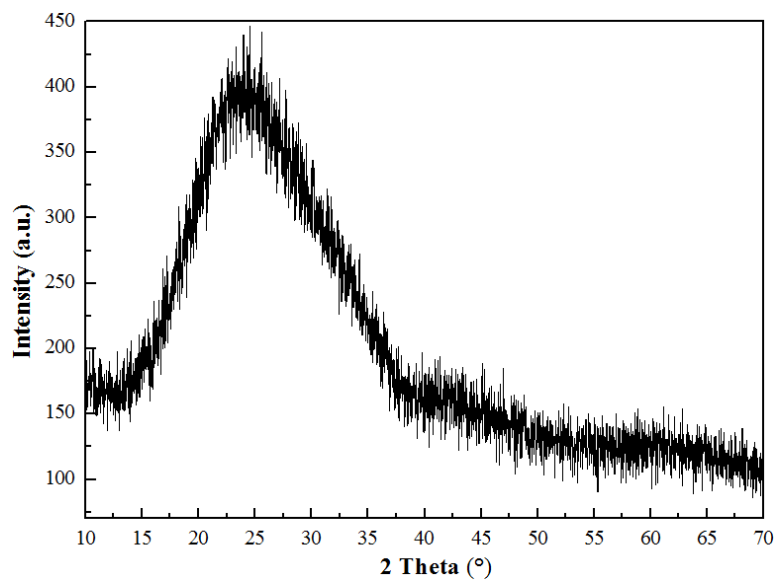
## **3. Results and discussion**

Figure 1 shows the XRD patterns of the infrared radiation coating. As shown in the figure, all diffraction peaks are corresponding to SiO<sub>2</sub>, and also shows that the coating does not pollute the glass.

The dry coating and glass batch were mixed according to 1:50 weight ratio, then melted at 1550°C, finally got molten glass sample. Figure 2 shows the XRD patterns of the glass sample, and it's showed that the diffraction peaks are the typical glass amorphous diffraction peaks, indicated that the coating will not have a crystallographic effect on the glass.

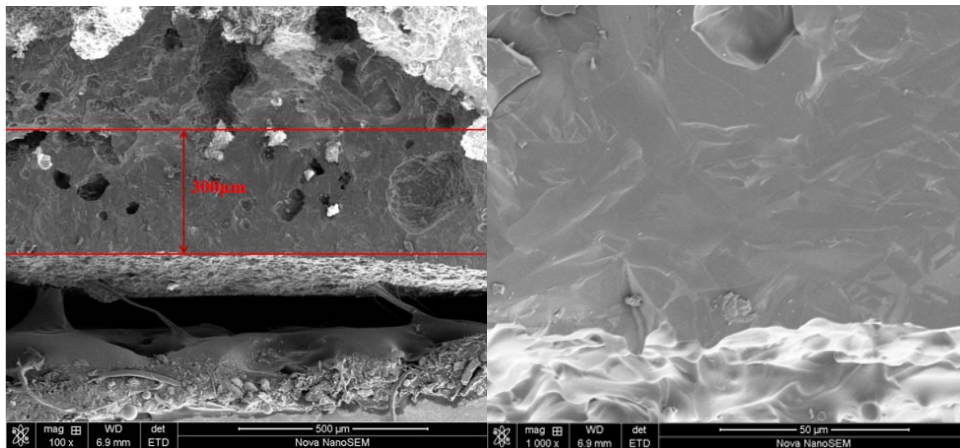


**Figure 1.** XRD patterns of the infrared radiation coating

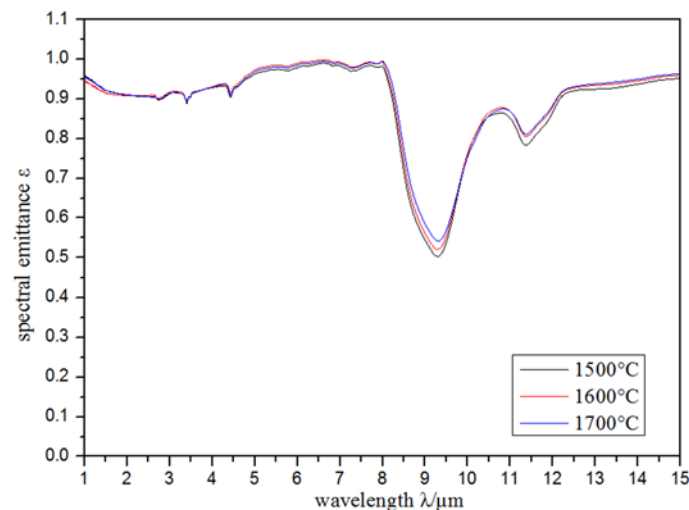


**Figure 2.** XRD patterns of the glass sample

From the SEM image at 100x magnification, it can be seen that the coating forms a dense coating of about 300 $\mu$ m thick on the surface of the silica brick, and has a tendency to penetrate into the loose internal structure of the silica brick. From the SEM image at 1000x magnification, it can be seen that the sintered coating is very dense, so it has a certain protective effect on silica brick.



**Figure 3.** Cross-section SEM of the coating after sintering on silica brick surface, left: 100x magnification, right: 1000x magnification



**Figure 4.** Spectral emittance  $\epsilon_\lambda$  of the coating in the wavelength range between  $1\mu\text{m}$  and  $15\mu\text{m}$ , measured at  $T = 1500^\circ\text{C}$ ,  $T = 1600^\circ\text{C}$  and  $T = 1700^\circ\text{C}$ .

The normal spectral emittance of the coating measured at  $T = 1500^\circ\text{C}$ ,  $T = 1600^\circ\text{C}$  and  $T = 1700^\circ\text{C}$  in air is plotted in figure 4 in the wavelength region between  $1\mu\text{m}$  and  $15\mu\text{m}$ . It can be seen from the figure that as the test temperature increased, the radiation intensity curve of the sample slightly increases. The shapes of the three radiation intensity curves are similar, and the wavelength corresponding to the maximum intensity is the same. At the test temperature of  $1500^\circ\text{C}$ ,  $1600^\circ\text{C}$  and  $1700^\circ\text{C}$ , the spectral emittance of the coating in the infrared range of  $1\mu\text{m} \sim 5\mu\text{m}$  is greater than 0.90, in the infrared range of  $5\mu\text{m} \sim 8\mu\text{m}$  is greater than 0.95. Absorption peak of glass liquid and glass batch at high temperature is  $1.5\mu\text{m}$ , and well matched with the infrared radiation band of the coating. The spectral emittance of the coating in  $8.5\mu\text{m} \sim 12\mu\text{m}$  is less than 0.85, which is outside the effective absorption band of glass liquid and glass batch materials. As a result, the utilization of heat is increased, resulting in energy saving.

**Table 1.** Normal and hemispherical thermal emittance of the coating measured at temperatures of  $T = 1500\text{ }^{\circ}\text{C}$ ,  $T = 1600\text{ }^{\circ}\text{C}$  and  $T = 1700\text{ }^{\circ}\text{C}$ , spectral range from  $1\mu\text{m} - 15\mu\text{m}$ .

name	normal thermal emittance $\epsilon_{\text{IR}}$ at $T=1500^{\circ}\text{C}$	normal thermal emittance $\epsilon_{\text{IR}}$ at $T=1600\text{ }^{\circ}\text{C}$	normal thermal emittance $\epsilon_{\text{IR}}$ at $T=1700^{\circ}\text{C}$	hemispherical thermal emittance $\epsilon_{\text{h}}$ at $T=1500\text{ }^{\circ}\text{C}$	hemispherical thermal emittance $\epsilon_{\text{h}}$ at $T=1600\text{ }^{\circ}\text{C}$	hemispherical thermal emittance $\epsilon_{\text{h}}$ at $T=1700\text{ }^{\circ}\text{C}$
infrared radiation coating	$0.92 \pm 0.02$	$0.92 \pm 0.02$	$0.92 \pm 0.02$	$0.86 \pm 0.02$	$0.86 \pm 0.02$	$0.86 \pm 0.02$

The resulting normal thermal emittances  $\epsilon_{\text{IR}}$  (thermal radiation that is emitted by the surface perpendicular to its orientation) and the hemispherical thermal emittance  $\epsilon_{\text{h}}$  (thermal radiation that is emitted by the surface in the whole front hemisphere), which were calculated in accordance with DIN EN 673, are given in table 1 at temperature  $T = 1500^{\circ}\text{C}$ ,  $1600^{\circ}\text{C}$  and also at  $1700^{\circ}\text{C}$ . It is known that at  $1500\text{ }^{\circ}\text{C} \sim 1700\text{ }^{\circ}\text{C}$  the normal thermal emittance is 0.92, and the hemispherical thermal emittance is 0.86. Shows that the coating has stable infrared radiation property at high temperatures.

#### 4. Application and Discussion

##### 4.1. Application

The coating was applied in a 450t/d float glass furnace, sprayed on the inner surfaces of all the siliceous walls of the melting section and clarification section, included the crown, the breast wall of the clarification section, the back wall of the melting section, and the vertical wall section of the L-shaped suspended wall. While another 450t/d float glass furnace that was basically consistent in structural design, construction, production operations, and production was used as a blank comparison, unsprayed the infrared radiation coating. The firing time of these two glass melting furnaces is one month apart.

**Figure 5.** The infrared radiation coating sprayed on the inner surfaces of glass furnace

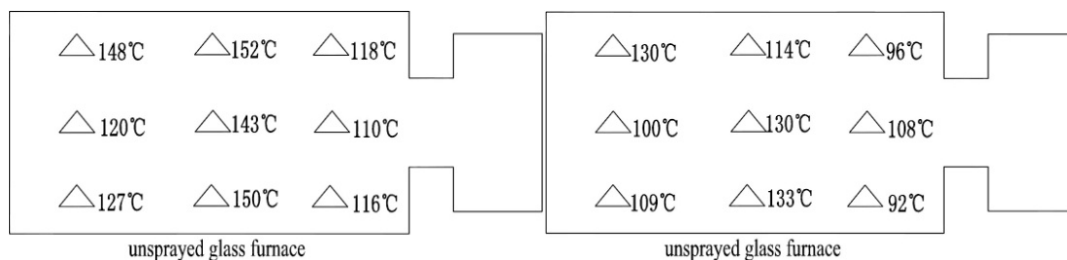
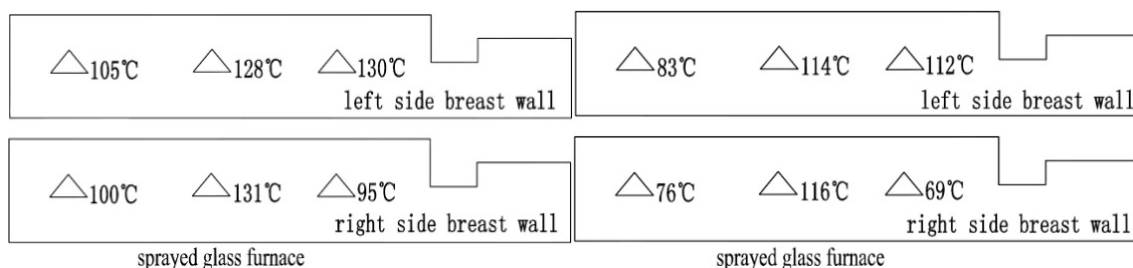
##### 4.2. Discussion

When the above two float glass furnaces were put into production for more than half a year, the thermal balance test is conducted, and then the test results are correlated and the following results are obtained:

**Table 2.** Calculation results of thermal balance tests

name	unsprayed	sprayed
Material balance error ( $<\pm 5\%$ )	-2.93%	-3.66%
Thermal balance error ( $<\pm 5\%$ )	4.96%	2.49%
glass liquid weight(kg)	19921	19880
fuel combustion heat( $\text{kg}\cdot\text{h}^{-1}$ )	159410142	146522010
explicit heat of fuel( $\text{kg}\cdot\text{h}^{-1}$ )	11689326	10987235
glass consumption( $\text{kJ/kg}$ )	8589	7923

Thermal balance test results shows that the tests meets the thermal balance test standard. The calculation results show that the glass consumption of the sprayed glass furnace is 666 kJ/kg lower than that of the unsprayed glass furnace, resulting in a 7.75% energy-saving effect.

**Figure 6.** Temperature measurement position and measured temperature of outer surface of the crown**Figure 7.** Temperature measurement position and measured temperature of outer surface of the breast wall

From the test results in figure 6 and 7, it can be seen that the outside surface temperature of the crown has been reduced by an average of 19°C, the external surface temperature of the left and right side of the breast wall was reduced by 18°C and 22°C, respectively. This also shows that after the infrared radiation coating was sprayed, the temperature of the refractory in glass furnace was significantly reduced, which can effectively prolong the service life of the refractory material of the glass furnace.

## 5. Conclusion

Infrared radiation coating has high infrared spectral emissivity at high temperature and can be used in glass furnace. It can effectively reduce the consumption of glass liquid, reduce the temperature of the crown and the external surface of the breast wall, and has a significant effect on strengthening the radiant heat transfer in glass furnace and improving the thermal efficiency of the furnace.

## References

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