

DECOLORATION OF HIGH-IRON SODA-LIME SILICATE GLASS BY CARBON

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Abstract- High-iron soda-lime silicate glass exhibits characteristic greenish-yellow coloration arising from the Fe²⁺/Fe³⁺ redox equilibrium. Decoloration aims to increase visible transmittance, improve aesthetic neutrality, and reduce solar heat gain. High-iron soda-lime silicate glass contains up to 0.09–0.15 wt% Fe₂O₃, resulting in strong absorption in the blue and near-infrared regions. The color arises from the coexistence of Fe²⁺ (strong NIR absorber) and Fe³⁺ (strong visible light absorber). Decoloration strategies include redox modification, chemical additives, oxidizing agents, or refining conditions.

Keywords- Decoloration, transparent soda-lime silicate float glass, colorants, reducing agent, CIE L*a*b* system.

I. INTRODUCTION

High-iron soda-lime silicate glass (0.15–0.25 wt% Fe₂O₃) exhibits a characteristic greenish-yellow coloration caused by the mixed-valence states of iron:

- Fe³⁺ → strong visible (blue) absorber → yellow/brown tint
- Fe²⁺ → strong near-infrared (NIR) absorber → greenish tint

Decoloration refers to reducing the intensity of this coloration by modifying the Fe²⁺/Fe³⁺ ratio or by trapping chromophoric species in non-absorbing forms.

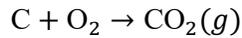
Among industrial decolorants, carbon (C)—used in the batch as coke, graphite, or organic carbon—plays a subtle but important role.

Carbon does not act as a classical decolorizer (like selenium, cerium, or cobalt).

Instead, carbon indirectly influences color through redox control.

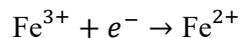
Carbon as a Reducing Agent

During melting:



Carbon consumes oxygen in the melt atmosphere, thereby lowering the oxygen partial pressure (p_{O_2}).

Lower p_{O_2} shifts the equilibrium:



Thus, carbon increases Fe^{2+} content in the melt.

Effect on color:

Fe^{3+} (brown/yellow) decreases

Fe^{2+} (green/NIR absorbing) increases

Visible coloration typically reduces because Fe^{3+} is a stronger chromophore in the visible band than Fe^{2+} .

Therefore:

Carbon reduces the brownish-yellow tint by lowering Fe^{3+} content.

II. WHY INCREASING Fe^{2+} SOMETIMES IMPROVES DECOLORATION

This seems counterintuitive because Fe^{2+} is also a colorant.

Key point:

- Fe^{3+} absorbs strongly at ~ 380 nm, affecting visible blue \rightarrow produces a yellow-brown tint
- Fe^{2+} absorbs mainly in the NIR region (~ 1000 – 1100 nm) \rightarrow minimal visible color impact

Thus, converting $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}$:

- reduces visible color
- increases clarity
- decreases SHGC (solar heat gain), due to higher NIR absorption

III. CHEMICAL REACTIONS INVOLVED

3.1 Carbon removes oxidizing species

In a glass batch containing sulphates or nitrates, carbon reacts:



Removal of oxidation sources \rightarrow Favors Fe^{2+} formation.

IV. INDUSTRIAL USE OF CARBON IN DECOLORATION

4.1 Controlled Low-Level Carbon Additions

Carbon is added in small quantities (0.05–0.07 wt% of batch) as:

- Pet coke
- Organic carbon (coal, sugar, cellulose)

Purposes:

- Soft reduction → promote Fe²⁺ from Fe³⁺
- Improve melting fining by enhancing gas evolution
- Reduce yellow-brown tint caused by excess Fe³⁺
- Improve optical neutrality (a* and b* values approach zero)

1. Over-Reduction Risk

Excess carbon → too much Fe²⁺ → deep green tint (not desirable)

Balanced redox is essential.

V. QUANTITATIVE EFFECTS ON OPTICS (TYPICAL TRENDS)

Fe Redox Ratio	L* (Lightness)	a*	b*	Result
High Fe ³⁺	↓ 85–88	+0.5 to 5	+3.5 to +7.5	Yellow-brown tint
Balanced	↑ 86–89	-1.5 to 0	+2.0 to 0	Neutral color

Fe ²⁺ /Fe ³⁺			+3.5	
High Fe ²⁺	84–88	-2 to -1	+1 to +2	Greenish tint

Carbon shifts the spectrum toward the center row (ideal condition).

7. UV-Visible Behaviour

With carbon treatment:

- Decrease in Fe³⁺ absorption at **380–420 nm**
- Limited effect on Fe²⁺ NIR absorption
- Increased overall transmittance in visible (400–700 nm)

Carbon-treated glass typically shows:

- Lower b* (less yellow)
- Higher L* (brighter)
- More neutral appearance

VI. CONCLUSION.

Decoloration of high-iron soda-lime glass depends strongly on Fe oxidation-state control.

Optical data confirm that higher Fe²⁺ ratios reduce visible coloration, increasing L* and improving neutrality. This study demonstrates how spectral and colorimetric evaluation can guide industrial optimization.

Carbon acts primarily as a **reducing agent**, indirectly causing decoloration by:

- Lowering melt oxygen potential
- Converting $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}$
- Reducing yellow-brown visible absorption
- Improving neutrality (lower a^* and b^*)
- Increasing L^* (lightness)

REFERENCES

- [1] Brow, R. K. (2000). *The structure of simple phosphate glasses*. Journal of Non-Crystalline Solids, 263–264, 1–28.
- [2] Duffy, J. A. (1993). *Optical basicity: A functional property for oxide glasses*. Journal of Non-Crystalline Solids, 159(1–2), 176–189.
- [3] El-Batal, F. H., Hamdy, Y. M., & Ezz-El-Din, F. M. (2017). *Reduction–oxidation behaviour of iron ions in silicate glass melts*. Ceramics International, 43(2), 1780–1788.
- [4] Frantz, P., & Shelby, J. E. (1997). *Effects of carbon and other reducing agents on iron redox in soda–lime glasses*. Journal of the American Ceramic Society, 80(6), 1433–1438.
- [5] Fuxi, G. (1992). *Optical and Spectroscopic Properties of Glasses*. Springer.
- [6] Hench, L. L., & Clark, D. E. (1978). *Glass and ceramic technology*. Wiley.
- [7] Karakassides, M. A., Saranti, A., & Kordas, G. (2004). *Spectroscopic investigation of $\text{Fe}^{2+}/\text{Fe}^{3+}$ balance in silicate glasses*. Journal of Non-Crystalline Solids, 347(1–3), 37–43.
- [8] Paul, A. (1990). *Chemistry of Glasses* (2nd ed.). Springer.
- [9] Pourzare, K., Sangpour, P., & Ghollasi, M. (2019). *Redox chemistry of iron in soda-lime-silicate glass melts under reducing atmospheres*. Journal of Materials Science, 54(12), 8975–8985.
- [10] Shelby, J. E. (2005). *Introduction to Glass Science and Technology* (2nd ed.). Royal Society of Chemistry.
- [11] Smedskjaer, M. M., Mauro, J. C., & Yue, Y. (2010). *Prediction of glass color from redox state of transition metal ions*. Journal of Non-Crystalline Solids, 356(41–42), 2352–2358.
- [12] Takahashi, S., Yoshida, M., & Oka, Y. (2010). *Influence of melting atmosphere on Fe oxidation state in silicate glasses*. Physics and Chemistry of Glasses: European Journal of Glass

Science and Technology B, 51(3), 133–138.

[13] Varshneya, A. K., & Mauro, J. C. (2023). *Fundamentals of Inorganic Glasses* (3rd ed.). Elsevier.

[14] Worrell, W. L. (1997). *Transition metal ions in oxide glasses*. *Journal of Non-Crystalline Solids*, 223(1–2), 57–66.

[15] Zhang, H., Li, P., & Luo, X. (2014). *Color control in high-iron architectural glass: effects of carbon-based refining*. *Journal of Applied Glass Science*, 5(3), 305–315.