From Solid Inclusions to Sustainable Glass: Understanding Alumina Dissolution

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Abstract

Commercial glass manufacturing faces the challenge of avoiding the presence of solid (mineral) inclusions that affect mechanical, processing, and aesthetic properties. The development of sustainable glass technologies that reduce primary (raw materials) and or secondary (heating process) CO2 emissions must comply with quality constraints and avoid mineral defects originating from refractory phases.
This problem requires a thorough understanding of the dissolution kinetics of typical refractory phases such as alumina in the context of an industrial furnace. Existing studies on alumina corrosion offer empirical laws, but their application to real-world problems remains challenging. At the scale of glass melting furnaces Computational Fluid Dynamics (CFD) is a promising tool but requires precise physicochemical data to complete quality index submodels.

In this context, alumina dissolution in an industrial soda-lime-silica glass melt has been studied at different temperatures of interest for glass fusion in static conditions (without convection). Employing a cylindrical slab approach inspired by methods developed in the geoscience literature, the effects of critical variables are isolated, bridging the gap to industrial applications.

The experimental setup involves stacking glass and alumina disks, encapsulated in a platinum-gold foil, subjected to temperatures ranging from 1300 to 1450 ◦C. Quenching and subsequent analysis through scanning electron microscopy (SEM) and electron probe microanalysis (EPMA) provide insights into dissolution behavior.

Glass compositional profiles exhibit uniform behavior across the studied temperature range, suggesting a diffusive control mechanism. On the other hand, strong coupling between

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elements is observed requiring the use of a multi-component diffusion approach to model alumina dissolution.

Eigenvalue analysis of diffusion matrices reveals two distinct exchange reactions: alumina with alkaline earth oxides and alumina with silica and alkalis. Activation energy calculations show Arrhenian behavior, offering insights into underlying energetics.

Combining our results with literature data for alumina dissolution for a range of melt compositions and temperatures, we find that the effective binary coefficient of diffusion (EBCD) for alumina is very well correlated with viscosity, indicating an important control of atomic mobility in the liquid that may be related to Eyring-type diffusivity of networking-forming ions.
In summary, this study unravels mechanisms governing alumina dissolution in industrial glass melts, providing essential insights for optimizing glass quality. The findings contribute to the understanding of dissolution kinetics, refractories corrosion, and offer a basis for optimizing glass manufacturing processes for a more sustainable future, in the context of current incentives and the urgent need to use alternative raw materials and increase use of cullet, whose composition can be more variable than current raw materials.

Keywords: dissolution, alumina, digestion, diffusion, soda, lime silica glass