Residual stresses in Bi2O3-B2O3-ZnO-SiO2 partially crystallizing glass-enamel

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Abstract

Bi2O3-B2O3-ZnO-SiO2 partially crystallizing glass-enamel is used as a protective and decorative coating in various applications, such as glassware, automotive and architectural glass. Technical requirement for such enamel coatings are low glass transition temperature with excellent chemical durability and compatible thermal expansion coefficient.
The main drawback of this glass-ceramic system is their weakening effect on the mechanical strength of the glass substrate.One of the mains root causes of this weakening are the internal residual stresses arising upon cooling.These internal residual stresses are induced by the thermal and elastic mismatch between the different crystalline and amorphous phases. Therefore, the degree of crystallization influences the thermo-mechanical properties of the glass-ceramic.Investigation of the microstructure evolution at different sintering temperatures can provide insight into the state of internal residual stresses of the microstructure at different sintering temperatures.

In this work, the formation of Bi4(SiO4)3 and Zn2SiO4 crystals structures with different temperature profiles have been investigated by X-Ray Diffraction. The crystallinity ratio was quantitatively determined by implementing the external standard method while the crystalline phases were quantified using Rietveld refinement method. Additionally, the crystals diameter and volume fractions crystallized materials were assessed with the aid of SEM cross section images and EDX analysis.

Finally, internal residual stresses are measured using focused ion beam ring core milling and digital image correlation (FIB -DIC).The internal residual stresses are then correlated with the microstructure and compared to calculated theoretical residual stresses.
An optimization of the enamel internal residual stresses by modifying the microstructure enables to reduce the weakening effect on the mechanical strength of the glass substrate, while fulfilling the technical requirements of the product.

Keywords: Residual stress, Glass enamel, Glass ceramic

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