Intrinsic fiber spinnability of glass melts

An invited talk

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Published in:
The 24th International Congress on Glass - Abstracts

Publication date:
2016

Intrinsic fiber spinnability of glass melts

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The melt spinnability is the ability or suitability of a glass-forming melt to be steadily stretched or spun into defect-free fiber filaments. Fiber spinning is a complicated process since it is controlled by both melt intrinsic factors (e.g., liquid fragility, liquid cohesive strength, surface tension, liquidus temperature, crystallization temperature) and extrinsic factors of fiberizing processes (e.g., fiber spinning parameters and bushing material's properties, and melt-die contact surface). The intrinsic fiber spinnability of a melt is determined by its intrinsic properties, and hence by its chemical composition.
In this paper we attempt to understand and quantify the intrinsic fiber spinnability. To quantify fiber spinnability, we consider two crucial aspects, namely, fiberizing viscosity window and melt stability region. Melt stability region is characterized by the width of the supercooled region, which is inversely correlated with crystallization tendency and melt fragility. Fiberizing viscosity window is defined by both the upper and lower viscosity limits. Above the upper limit, fiber ruptures due to large drawing stress,[1)] whereas below the lower limit a continuous flowing stream cannot form. We propose a simple index (f_s) to quantify the intrinsic fiber spinnability, which is the ratio between the viscosity of a melt at liquidus temperature (η_L) and the lower viscosity limit (η_{limit}), η_L/η_{limit}. For continuous fiber spinning, the spinnability index is suggested to be $f_s = \eta_L/30$. If a melt has $f_s > 1$, it is spinnable. In contrast, for the centrifugal force fiber spinning, the ratio of $\eta_L/10$ is suggested. Determination of f_s is helpful for designing fiberizing process and optimizing glass compositions suitable for fiberizing, and thereby producing high quality fibers in an energy- and cost-effective manner.

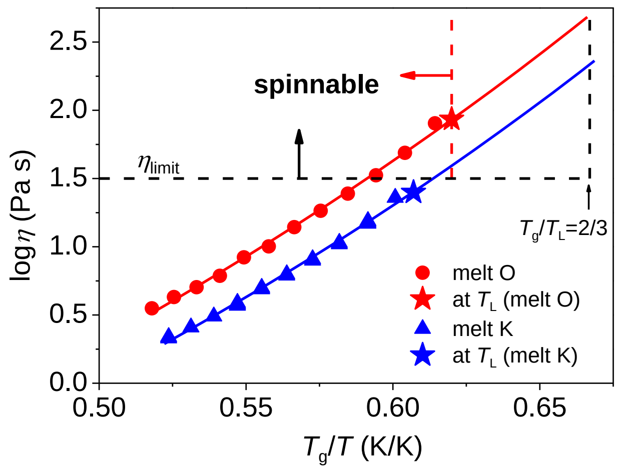

Figure 1. The fragility plot of basaltic melts O and K above the liquidus temperature (T_l). T_g is the glass transition temperature. The viscosity values of both melts at their respective liquidus temperatures are given. The fiber spinnable region is indicated for the continuous fiberizing process of melt O. The horizontal black dashed line is the lower limit of viscosity (η_{limit}) for continuous fiber drawing. The vertical red dashed line is the location of the liquidus temperature of melt O. The vertical black dashed line is the T_g/T_l=2/3 line. The solid lines are the fitting curves of the Mauro-Yue-Ellison-Gupta-Allan (MYEGA) model to the viscosity data.[2)]

Using the fragility plot (Fig. 1) we demonstrate the sensitivity of the intrinsic fiber spinnability to chemical composition of basaltic melts for continuous fiberizing process. Melt O has a much larger MgO/CaO ratio than melt K. In Fig. 1, it is seen that the viscosity curve of melt O passes through the spinnable region, whereas that of melt K is beyond its spinnable region. From Fig. 1 the spinnability indices f_s of melts O and K were calculated to be 1.8 and 0.8, respectively. This indicates that melt O is spinnable, but melt K is not. This conclusion is confirmed by the continuous fiber drawing experiments. We have never been able to draw continuous fibers from melt K, but we have easily succeeded in drawing fibers from melt O.

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