Viscosity and structural studies of ternary silicate bioactive glasses

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Abstract

While bioactive glasses typically contain small amounts of phosphate as a second network former, *in vitro* and *in vivo* studies (Fujibayashi *et al.* 2003) have shown that even simple soda-lime silicate glasses can be bioactive, i.e. stimulate and enhance bone formation. Bioactivity, however, decreases with increasing silica content in the glasses. Here, we are trying to get an insight into structural changes with changes in silica content. We were also interested to see the effect on viscosity, to provide us with information as to how the processing of these glasses (sintering, fibre drawing etc.) can be expected to change with composition. As expected, Raman spectroscopy on melt-derived soda-lime silicate glasses with silica content varying between 70 and 50 mol% showed decreasing contributions from Q3 and increasing ones from Q2 groups. This agrees with decreasing network connectivity values calculated from the composition, i.e. a more depolymerised silicate network owing to larger network modifier contents. Viscosity was investigated using a creep apparatus and rotating crucible viscometer for the high and low viscosity regions, respectively. Results were fitted using the Adam and Gibbs equation considering the configurational entropy. With decreasing silica content, the viscosity at a given temperature decreased, owing to an increased mobility of the more disrupted silicate network. Essentially, at 50 mol% SiO2, the silicate structure consists of chains rather than the network present at higher silica contents, resulting in a rather low viscosity. This was also reflected in the fragility of the glasses, which increased with decreasing silica content, suggesting that these glasses would be much more difficult to process without crystallisation occurring. Taken together, as with more conventional phospho-silicate bioactive glasses, there is a trade-off between high bioactivity (at low silica content and network connectivity) and good processing (at higher silica content and network connectivity). So, while we cannot optimise both simultaneously, knowing the relationship between them allows us to select the best-suited composition depending on the intended use and necessary processing of the glass.

Reference

Fujibayashi, Shunsuke; Neo, Masashi; Kim, Hyun-Min; Kokubo, Tadashi; Nakamura, Takashi (2003): A comparative study between in vivo bone ingrowth and in vitro apatite formation on Na2O-CaO-SiO2 glasses. In *Biomaterials* 24 (8), pp. 1349–1356. DOI: 10.1016/s0142-9612(02)00511-2.

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