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Effect of Crystallisation Degree on Hardness of Basaltic Glass-Ceramics

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Introduction

Hardness is important for wear restistance and abrasiveness in glass-ceramics

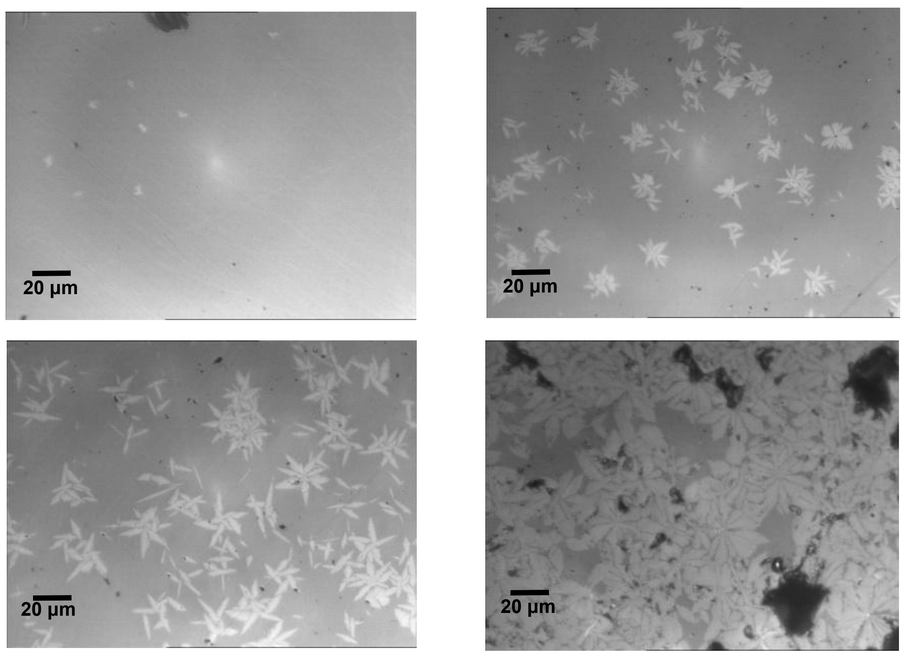
As hardness of inorganic crystals is determined by their bond strength and atomic structure[1], it is likely that hardness of glass-ceramics changes with heat treatment conditions

Measure crystallisation degree by 3 different techniques: 1) Processing of images acquired by means of optical microscopy; 2) X-ray diffraction (XRD); 3) Differential scanning calorimetry (DSC). 1 and 2 provide absolute crystallisation degree $D_{c,\,abs}$ whereas 3 gives relative one $D_{c,rel}$

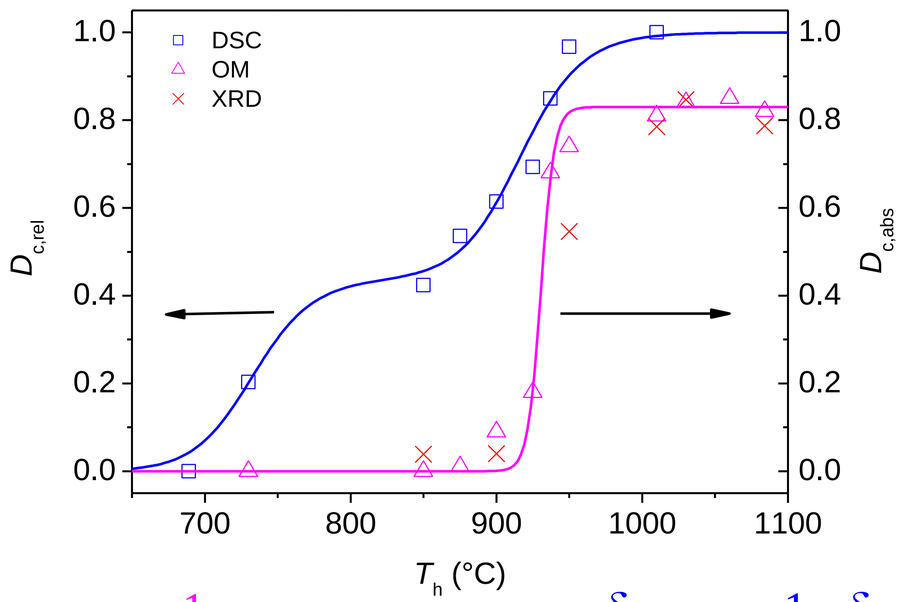
Heat treatment of the glass for 30 min at 730-1084 °C

Crystallisation Degree

Leaf-like crystals identified as augite are found. The size of the crystals increases with heat treatment temperature (T_h). After etching, traces of a mica phase were also found at T_h < 1010 °C [2].



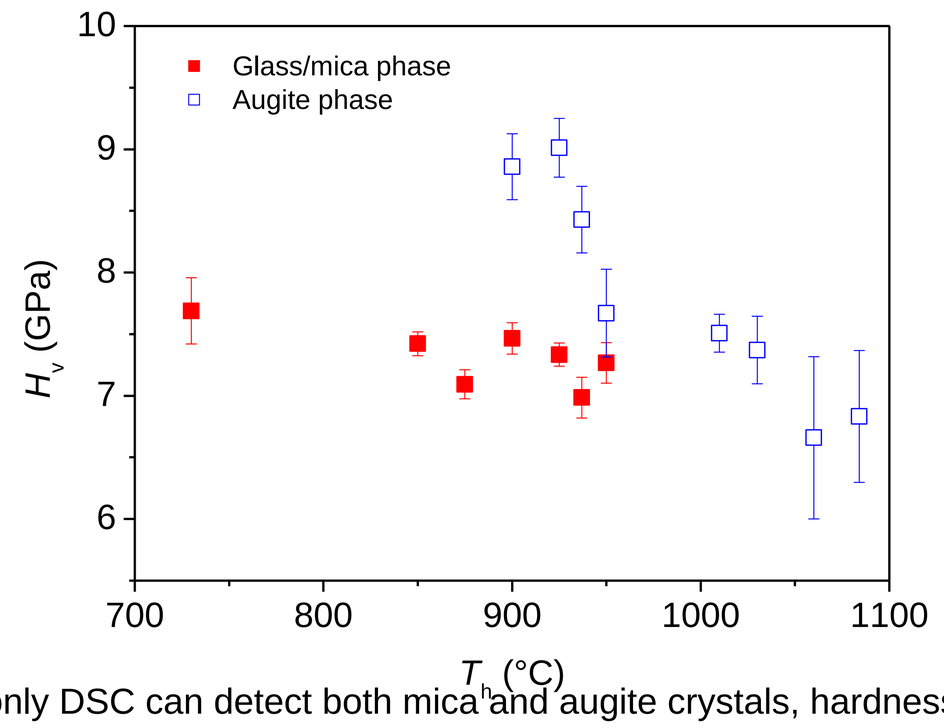
Only DSC could detect the mica crystals, which leads to the discrepancy between the curves at low T_h. Augite crystallises around 910 °C. The crystallisation degree has an S-shaped behaviour as a function of heat treatment temperature



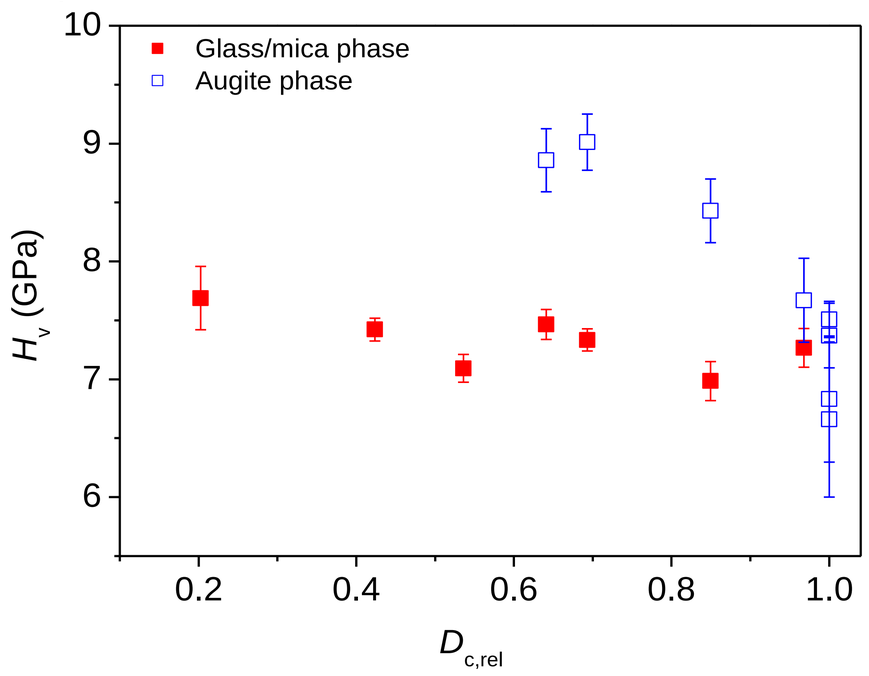
$$D_{c,OM} = \frac{1}{1+\left(\frac{T_c}{T_h}\right)^{\alpha}} \qquad D_{c,DSC} = \frac{\delta}{1+\left(\frac{T_1}{T_h}\right)^{\beta}} + \frac{1-\delta}{1+\left(\frac{T_2}{T_h}\right)^{\gamma}}$$

Hardness

Hardness measured of both glass/mica and augite phase. The hardness of the glassy phase decreases slightly whereas that of the augite phase shows a more pronounced decrease when the heat treatment temperature is elevated. The hardness of the crystal phase is higher than that of the glassy one



As only DSC can detect both mica and augite crystals, hardness is plotted against the crystallisation degree determined by DSC. The decreasing hardness of the crystalline phase as a function of heat treatment temperature can partly be described by the Hall-Petch relationship.



Conclusions

1) During heat treatment of basaltic glass both mica and augite crystals form
2) The hardness of the glass and augite phase decrease when the heat treatment temperature is increased
3) The highly crystallised glass-ceramic has a lower hardness than the less crystallised one

References

1 F. M. Gao et al. (2003) *Phys. Rev. Lett.* **91**, 015502
2 M. Jensen et al (2009) *Glass Technol.: Eur. J. Glass Sci. Technol. A*, **50**, 189