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Glass-ceramics prepared by waste fluorescent glass

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Abstract

To prepare glass-ceramics reinforced by β-wollastonite, fluorescent glass and calcium carbonate were used as starting materials. β-Wollastonite, gehlenite and sodium calcium silicate were observed by X-ray diffraction analysis, and surface morphology and chemical composition were evaluated by field emission-scanning electron microscopy and energy dispersive X-ray spectrometer. © 2002 Published by Elsevier Science Ltd and Techna S.r.l.

Keywords: Fluorescent glass; β-Wollastonite; Glass-ceramic

1. Introduction

So-called synthetic wollastonite, known in art, is made by thermal interaction of CaO and SiO_2 and comprises either predominantly a glass phase consisting of cristobalite and quartz [1–3]. As known in art shaped products composed of wollastonite have excellent properties exhibiting no deterioration at high temperatures of above 1000 °C. Therefore, the products are expected to be useful as thermal insulating materials and refractories, and in road construction compositions, but there has been no useful and economical method of preparation [4].

Moreover, approximately, above 0.6 million ton of glass waste are generated in South Korea on an annual basis including glass containers, light bulbs, plate glass and automobile glass [5]. Thus, a huge opportunity exists to convert this glass waste from an environmental and economic burden to a profitable, value-added resource. In this paper, to utilize waste fluorescent glass and resolve environmental problems, we prepared glass-ceramics reinforced by β-wollastonite.

2. Experimental

Fluorescent glass and calcium carbonate ($CaCO_3$) were used as starting materials. Waste fluorescent glass cullet was carefully washed, and dried at 110 °C for 24 h. The composition of the mother glasses of the glass-ceramics used in this work were fixed at glass cullet: $CaCO_3 = 4{:}1$ in weight ratio. About 30 g powder mixtures of these compositions were put in an alumina crucible and melted at 1300 °C for 1 h. To quench, the melts were rapidly poured into a water bath and dried at 110 °C for 24 h. The quenched glass was ground and pressed into disks 0.5 cm thick.

The formed glass disks were heated up to 800, 900 and 1000 °C at a rate of 5 °C min^{-1} for 1 h, respectively, and allowed to cool inside the furnace. The heat-treated glass-ceramic specimens were cleaned with ethyl alcohol in an ultrasonic cleaner and dried at 110 °C for 24 h in air.

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Crystallinity of the specimens was analyzed by X-ray diffraction (XRD, D-Max-1200, Rigaku Co., Jpn.). The morphology and composition of the surface of the specimens were evaluated using field emission-scanning electron microscopy (FE-SEM, S-4700, Hitachi Co., Jpn.) equipped with an energy dispersive X-ray spectrometer (EDX).

3. Results and discussion

The XRD results on the glass-ceramics showed that a mixture of phases, such as β-wollastonite ($CaSiO_3$), gehlenite ($Ca_2Al_2SiO_7$) and sodium calcium silicate (SCS, $Na_2Ca_3Si_6O_{16}$) appeared. Peak intensities corresponding to the SCS ($2\theta = 18\sim19°$ and 32°) and the gehlenite ($2\theta = 31°$) decreased with increase of heat-treatment temperature, as clearly shown in Fig. 1. On the contrary, with increase in heat-treatment temperature, peak intensity at $2\theta = 30°$, corresponding to β-wollastonite, increased. At 1000 °C, we confirmed the highest crystallized β-wollastonite reinforced glass-ceramic appeared.

Fig. 2 shows the polished surface morphology of the glass-ceramics at various heat treatment temperatures. Morphological analysis of the glass-ceramics heat-treated at 800 and 900 °C shows some well-crystallized round-shaped grains in the matrix. However, as the heat treatment temperature was increased to 1000 °C, the round-shaped crystal decreased from about 30∼35 μm to about 15∼20 μm in size. To more clearly investigate crystal composition, we performed EDX analysis for the same area used in morphological analysis. EDX analysis of the breakage-part (denoted B in Fig. 2) of the round-shaped crystals indicated the presence of gehlenite in glass-ceramics, whereas the hollow-part (denoted H in

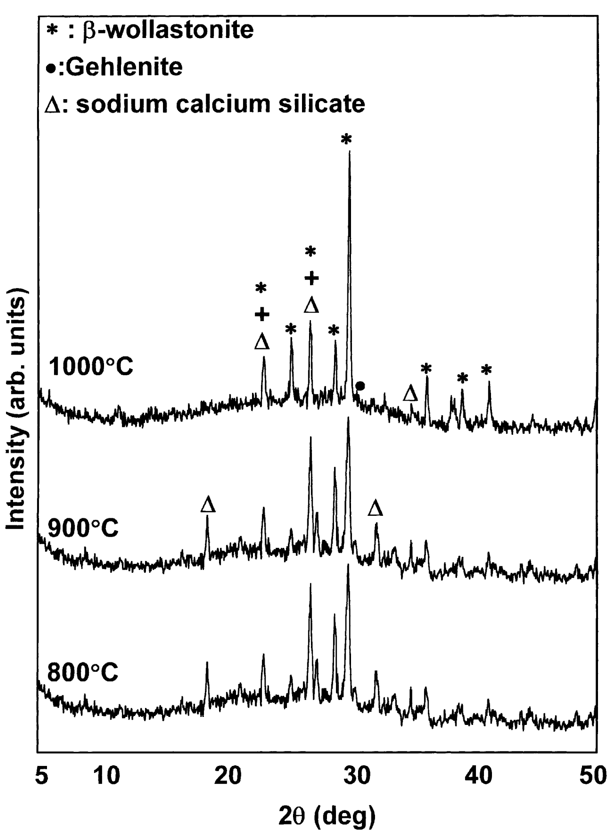

Fig. 1. XRD patterns for the glass-ceramics heat treated at various temperatures.

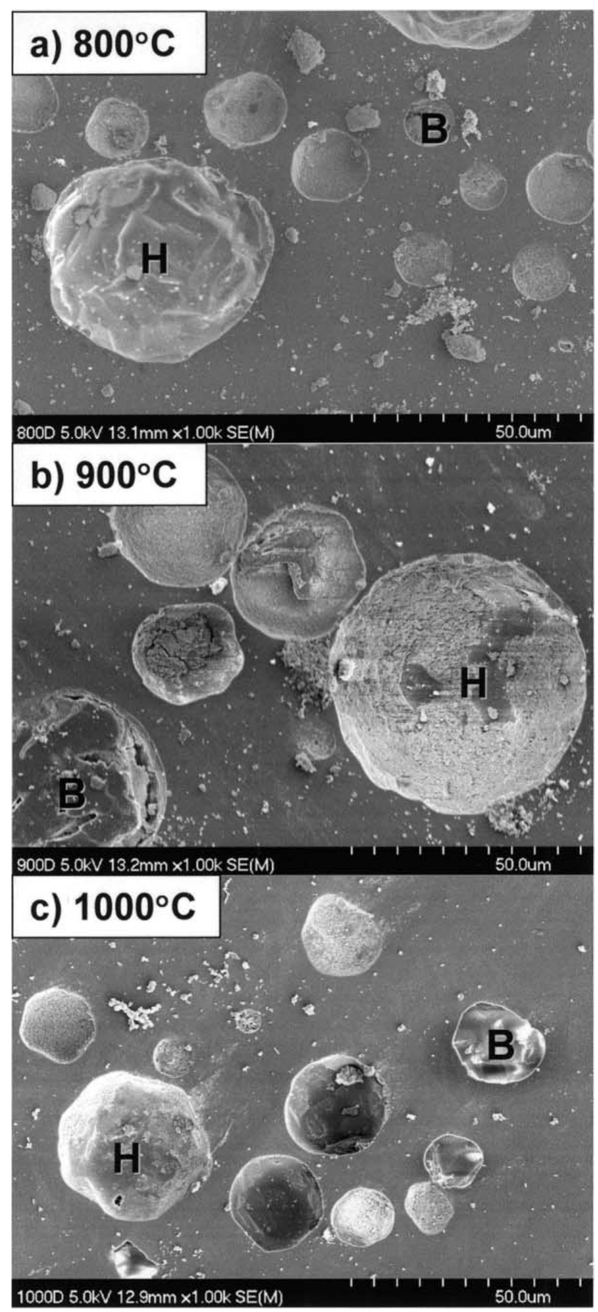

Fig. 2. Surface morphology of the glass-ceramics heat treated at various temperatures.

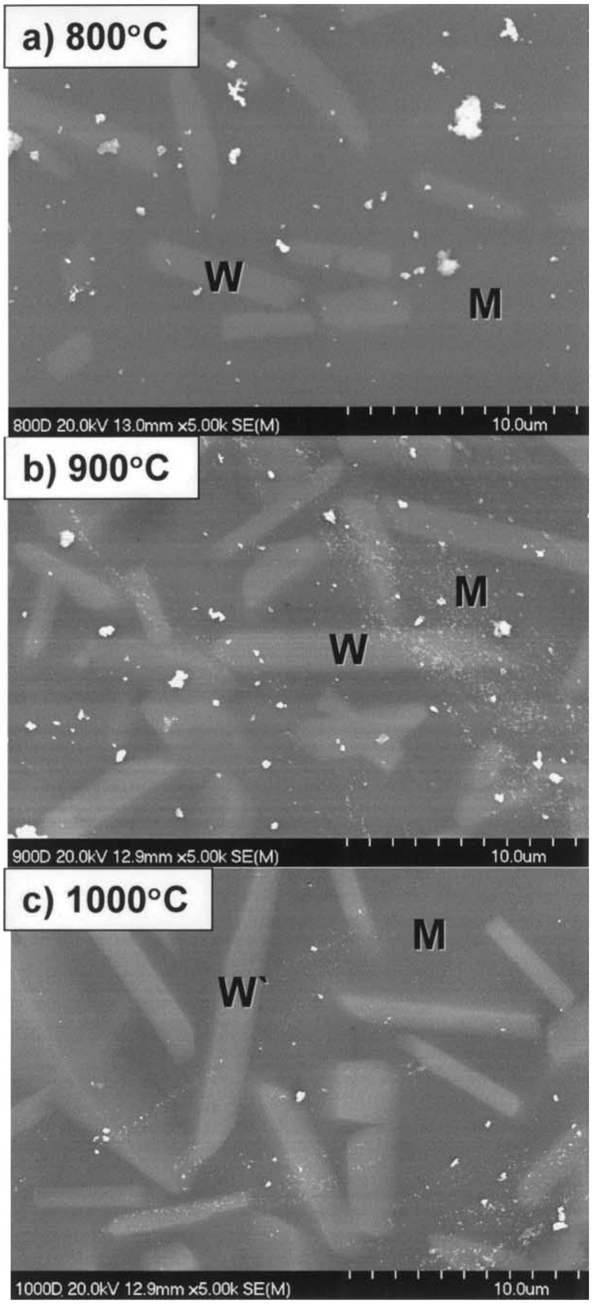

Fig. 3. Surface morphology at higher magnification of the glass-ceramics heat treated at various temperatures.

Fig. 2), probably due to the detachment of gehlenite grains in the matrix, was composed of a mixture of gehlnite and SCS.

However, there is no morphological data of the β-wollastonite for our specimens, although previous XRD exhibited the presence of the β-wollastonite. Thus, to detect the β-wollastonite, we performed FE–SEM analysis at higher magnification. As shown in Fig. 3, whisker-type β-wollastonite (denoted W) in SiO_2 glass matrix (denoted M) confirmed by EDX, not shown here, were observable. Similar to previous XRD, heat-treatment temperature increased from 800 to 900 and 1000 °C, the β-wollastonite significantly increased.

Further experimental study is needed to investigate the relationship between the mechanical strength and the chemical durability, in order to apply for practical usage.

4. Conclusion

To utilize waste fluorescent glass and to resolve environmental problems, we have prepared β-wollastonite glass-ceramics. With increase of the heat treatment temperature, the round-shaped crystals composed gehlenite and SCS in the matrix decreased. Whisker-type β-wollastonite in SiO_2 glass matrix significantly increased, with the increase of the heat-treatment temperature.

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