ORIGINAL ARTICLE

Determining the Thermal Behaviour of Bioactive Glasses in Dentistry by using Differential Scanning Calorimetry

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ABSTRACT

Background: The structural transformations of the bioactive glass ICI16M has been discussed during thermal treatments.The most common use of Differential scanning calorimetry is to find out the glass transition (Tg) range and the temperature of crystallization for both ceramic and glass.
Method: Stanton Redcroft, DSC 1500 Rheomatric Scientific, Epson, UK) was used to measure glass transition temperature and crystallisation behaviour of the glasses using thermal analysis soft ware (TAS- infinity pro soft ware).
Results: The glass transition temperatures for ICIE16M can be seen at 560˚ , 670˚ and peak of crystallization could be seen at 860˚.The two glass transition temperatures present indicate that the glass has a two phase system which means a silicate phase and other is a phosphorus phase.
Conclusion: The DSC traces further show that the crystallization phases only used a small amount of the total volume of glass powder and the less than 38 micron particle size glass powder showed reduced crystallization phases and more bioactive nature.. Further future work is required in order to get glasses with more bioactive properties and compressive strength in order to diversify its usage in bone replacement scaffolds and dental implants.
Key words Silicates, Crystalliazation, Differential scanning calorimetry, Bioactive glasses

INTRODUCTION

It is a method of determining the properties and characteristics of polymers when they are heated. The most common use of DSC is to find out the glass transition (Tg) range and the temperature of crystallization for both ceramic and glass. Glass transition temperature could be defined as a certain temperature at which the viscous liquid changes to a glass state when cooling is done or we could also say that above the glass transition temperature it is a viscous liquid and when temperature falls below it then it is changed into a glass structure. For the formation of three dimensional objects from the ceramic powders an information about the sintering window is very important which lies between the both key values[1].

Bioactive glasses are biocompatible and make a strong bond with bone. Their bioactivity could be determined by the formation of hydroxycarbonated apatite layer (HCA) which resembles largely to the mineral part of the bone. The rate of HCA formation plays a vital role in tissue bonding between the implanted material and the surrounding tissue and physiological fluids[2]. Hench proposed a three step procedure in the formation of HCAion exchange, dissolution and precipitation[3]. The process of ion exchange occurs at the bioactive glass surface. Cations such as Na and Ca are exchanged with H from the surrounding solution. The breakage of Si-O-Si bonds occur by the action of hydroxyl ions (OH-) in the process of network dissolution. The hydrated silica (SiOH) formed on the surface of the glass goes rearrangement and results in silica rich gel layer. Calcium- phospahate- rich layer (CaP) on the surface due to the precipitation of calcium and phosphate ions released from the glass and as well from the solution[4,5,6]. Different compositions of 45S5 glasses showed that it is themost bioactive glass and it is used successfully in middle ear and dental implants[7]. The thermal treatment of the bioactive glass 45S5 above 600˚ results in the formation of the main crystalline phase[8,9,10,11,12,13].

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MATERIAL AND METHODS

(Stanton Redcroft, DSC 1500 Rheomatric Scientific, Epson, UK) was used to measure glass transition temperature and crystallisation behaviour of the glasses using thermal analysis soft ware (TAS- infinity pro soft ware)

Both glasses ICIE16M and QMNR2 were weighed in a dry platinum crucible for (0.05) grams then the crucible was tapped to prevent flow of glass into the diagnostic head of the machine. A fifty microgram of alumina powder was weighed in a separate aluminium crucible and here alumina was used as a reference. The crucibles were placed on the diagnostic head of the DSC machine. The flow of water was checked to ensure temperature control. The DSC machine and the head of the machine were then turned on. Head then sets itself over the samples. Data acquisition software was then turned on and the standards of the test were adjusted into it. The starting temperature of the experiment was 50˚C and the final temperature was 1100˚C. The heating rate was maintained at 10˚Cmin $^{-1}$ and the gas used was Nitrogen (N_2).The weight of the sample was 50 micrograms. Cycle was then allowed to run and the data was collected using TAS Infinity Pro.

RESULTS

In this figure two glass transition temperatures could be seen, Tg1 is present at 590˚C and Tg2 could be seen at 670˚C. Also this indicates the glass has two phases one is silicate glass phase and other is phosphate glass phase. The peak of crystallization is at 860˚C. The trace has been shortened to include glass transition point and peak of crystallization.

The trace shows two glass transition temperatures Tg1 590˚C and Tg2 680˚C. The peak of crystallization is at 860˚C. The trace has been shortened to give a clear picture of glass transition temperatures and the crystallization peak.

Fig. 1: DSC trace for ICIE16M bioactive glass (particle size more than 38 microns)

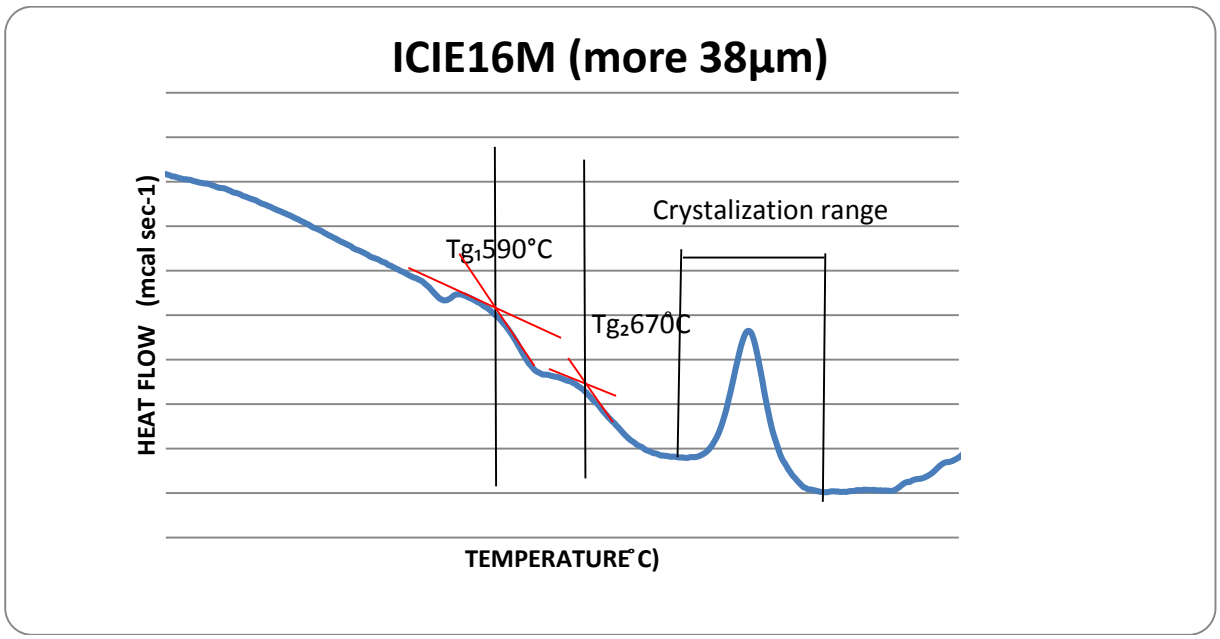
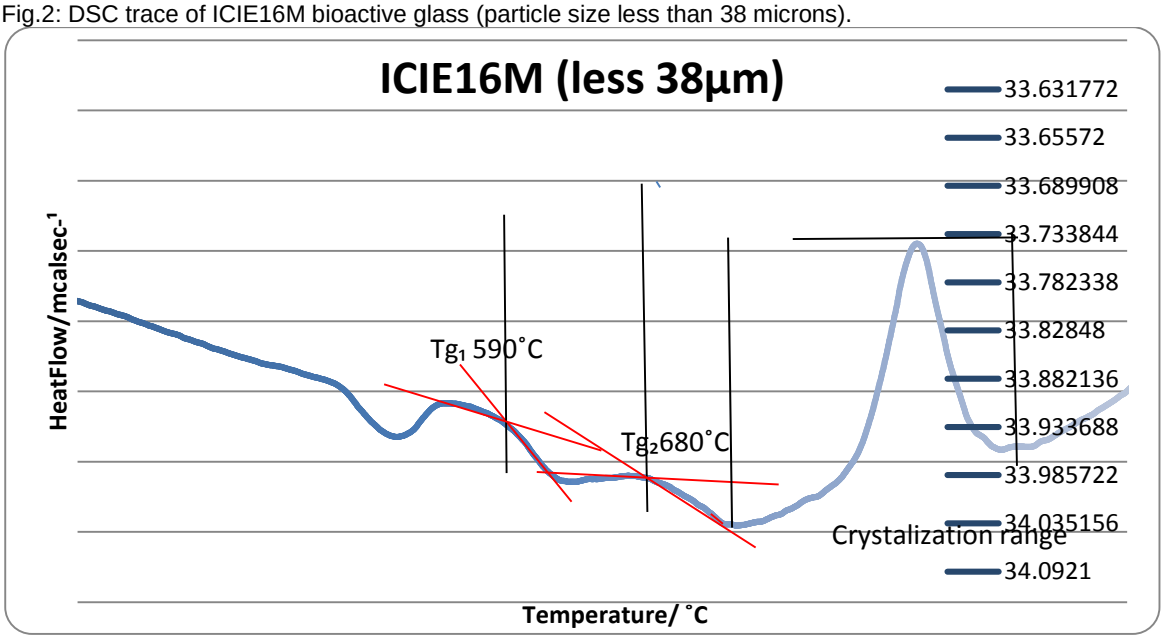


Fig.2: DSC trace of ICIE16M bioactive glass (particle size less than 38 microns).



DISCUSSION

The two glass transition temperatures present indicate that the glass has a two phase system which means a silicate phase and other is a phosphorus phase. The glass ceramics which are obtained from glasses containing phosphorous show the formation of apatite layer when they are soaked in simulated body fluid[14]. The DSC traces which are included in the results show that ICIE16M glass more and less than 38 micron have two glass transition points. A glass transition temperature could be defined as a specific point that below which the glass behaves as glassy solid and above this point the glass enters the liquid phase and the viscosity is increased. When the state of glass is changed from a solid to the liquid transition energy is released and it could be seen in the form of a bump on the trace. By comparison between the two traces of ICIE16M more and less than 38 microns particle size the glass transition temperatures appeared to be almost same.

The high number of ICIE16M forming glass components would give rise to greater number of crystal phases. The amount of components in the glass could be reduced to form less number of crystal phases. The peak for crystallization is caused by latent energy transfer in the system and this occurs when the atoms change from an irregular pattern to an ordered arrangement. When comparing both traces of ICIE16M glass the peak of crystallization appears to be on the same temperature.

CONCLUSION

The DSC traces further show that the crystallization phases only used a small amount of the total volume of glass powder and the less than 38 micron particle size glass powder showed reduced crystallization phases and more bioactive nature. Further future work is required in order to get glasses with more bioactive properties and compressive strength in order to diversify its usage in bone replacement scaffolds and dental implants.

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