International Journal of Engineering Research and Development
ISSN: 2278-067X, Volume 2, Issue 1 (July 2012), PP. 46-49
www.ijerd.com

Infrared transparent glass ceramic as per ancient Indian text '*AMSHUBODHINI'*

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Abstract—*This paper deals with the synthesis of novel infrared transparent, non-hygroscopic glass as per the ancient Indian text 'AMSHUBODHINI' of Maharshi Bharadvaja with a commentary by Bodhananda.*

The constituent raw materials were mixed together in the ratios mentioned in the text. This mixture was melted in a graphite crucible at a temperature of 265 KAKSYA on an ancient temperature scale (about 950°C) and was then rapidly poured into a fireclay dye, which was then cooled very slowly in the muffle furnace to produce a new material which was a non-hygroscopic, non-opulent greenish yellow calcium glass. The physical characterization of this material was carried out in the department of Metallurgical & Materials Engineering VNIT, Nagpur. The transparency test was carried out at Central Glass and Ceramic Research Institute, Kolkata. The test results revealed that this new glass could be compared with Calcium Fluoride Glass , with a transparency in the wavelength range of 5000cm-1 to 1200 cm-1(2 to 8.33 µ). It is important to note that, this material is novel in the sense that the most of the known infrared transparent materials used for prisms and windows for cells, are highly hygroscopic in nature such as LiF (up to 6 µ) ,CaF_2 (2 to 8.5 µ), NaCl (up to 15 µ) etc; requiring dry air environment for their working while the new glass is non-hygroscopic in nature, can be used under any environmental conditions with a very high average life.

I. INTRODUCTION

Prakasha Stambhanabhid Lauha i.e. this glass ceramic is described by BHARADWAJA in his Sanskrit text 'AMSHUBODHINI'[1]. The terminological words in the text were interpreted by Dr.Dongre et al[2,3] Various materials described in AMSHUBODHINI of Maharshi Bharadwaja with an equivalent material at present,are as follows.

(1) KHACHARA LAUHA(SILICA-SiO_2)--8Parts
(2) BHUCHAKRASURAMITRADIKSHARA (LIME–CaO)---------------------------5Parts
(3) AYASKANTA (LODESTONE/MAGNETITE – Fe_3O_4)------------------------------4Parts
(4) RURUKA (DEERBONEASH—Calcium diphosphate $Ca_3P_2O_8$)--------------------6Parts

Hence, the empirical formula of this glass ceramic is--**5 ($CaO.SiO_2$). (Fe_3O_4). ($Ca_3P_2O_8$).**

This suggests that the melted final glass is a silico-phosphate glass with a coloring agent as ferreso-ferric silicates &forming a clear emulsion with tricalcaum phosphate. It is known from the phase diagram that the eutectic mixture has the composition of 63%SiO2 & 37%CaO.Thus the final product is a solution of ferresoferric silicate in metacalcium silicate and uniformly mixed with calcium diphosphate in their liquid phases to produce a clear liquid and subsequently gradually cooled to a solid mass.

II. LABORATORY EXPERIMENTAL TRIALS

(1) Silica & Calcia are substituted by ready lime glass in bead form to facilitate fusion .
(2) Calcium Diphosphate is substituted for DEER-BONE-ASH, acting as stabilizer, colouring agent & inhibitor for the conversion of ferric oxide. It also acts as a flux.
(3) Slow cooling of the final liquid was carried out to avoid internal stresses. Preheated fireclay mould was used, which was placed in a separate muffle furnace at 600^0 C.
(4) A molybdenum silicide muffle furnace and a graphite crucible was used for the melting purpose to attain a temperature of about 1400^0C.
(5) The sample size was selected as 100 gms.

Composition of the raw materials

Lime glass beads (AR Grade) was used as a source of Silica and Calcia. A high purity magnetite(96%LRGrade) was used in place of lodestone. Calcium diphosphate (86% LR Grade) was used as phosphate source.[Raw Materials: M/s Arex Chemicals, Mumbai-2.]All these raw materials in appropriate proportions were ground to less than 100 microns and

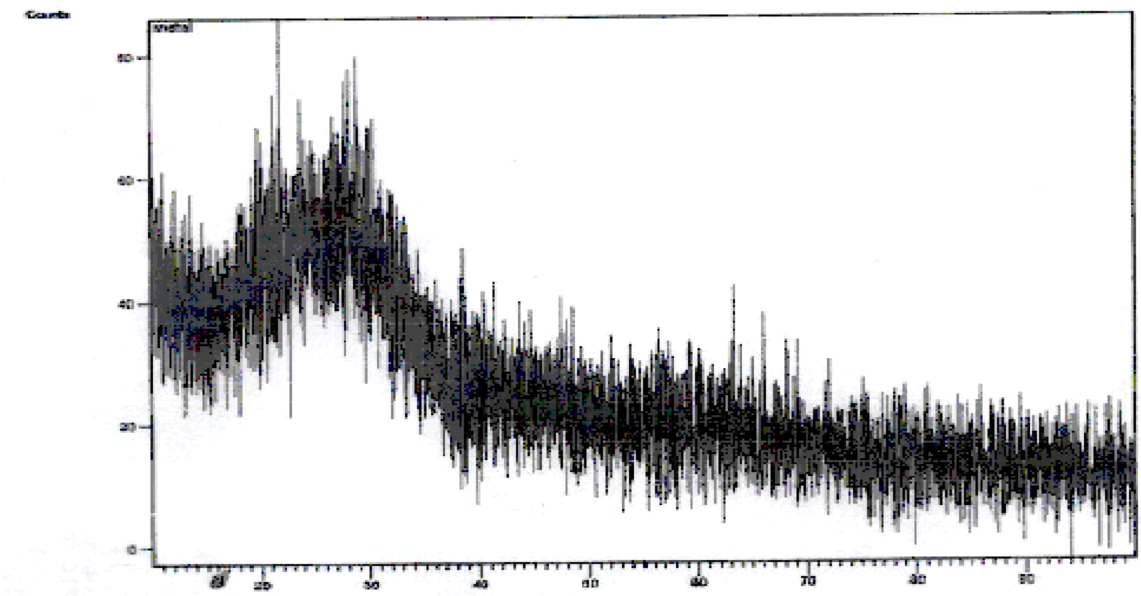
S.No.	Materials (composition)	Composition By Parts. (by weight)	Actual Weight Taken. (gms.)
1.	**Glass Beads (SiO_2+CaO)**	**13 (58.5)**	**58**
2.	**Lodestone (Fe_3O_4)**	**4 (17.7)**	**18**
3.	**Calcium Diphosphate ($Ca_3P_2O_8$)**	**6 (23.8)**	**24**

then thoroughly mixed. This mixture was loaded to a standard graphite crucible which was heated in a molybdenum silicide muffle furnace. For removing the internal stresses programmable heating technique was used, in which the rate of heating was very slow up to 300°C followed by a moderate rate of heating up to 1400°C subsequently. After about 3 hours, the sample started melting, forming a clear greenish-yellowish brown liquid. The liquid was stirred continuously and was then instantaneously transferred to a preheated fireclay refractory mould of the size (1cm x 4 cm x1mm) in dimensions.

III. CHARACTERIZATION OF THE GLASS PRODUCT, RESULTS & DISCUSSIONS

The product piece was sent to Central Glass &Ceramic Research Institute, Kolkata for the I.R. Spectroscopy and Hygroscopic Test and the results obtained are as follows –

(1)XRD results



Position (2θ)

Fig.1: **position (2θ) vs. counts.**

This graph shows the amorphous nature of the sample as there is no peak found in the XRD pattern of this sample. This indicates that the sample is a glass.

(2).DTA Results

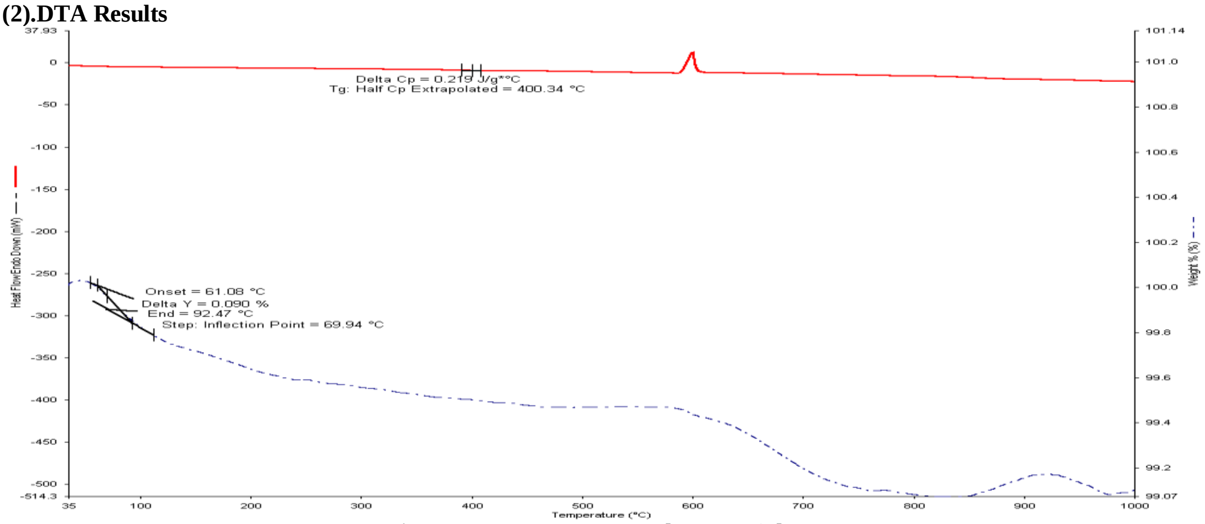


***Fig2:*Temperaturevs.HeatFlowvsWeight%**

This graph shows that, the glass transition temperature of the sample is 400.34°C. And the second weight percent curve shows that, there is a very negligible (0.09%) weight reduced in the sample in DTA testing. This indicates that, the glass is perfectly non-hygroscopic in nature.

(3) FTIR Result:

Spectrum is recorded from 7000 cm-1 to 1200cm-1 wavelength range, with the 4cm-1 resolution.

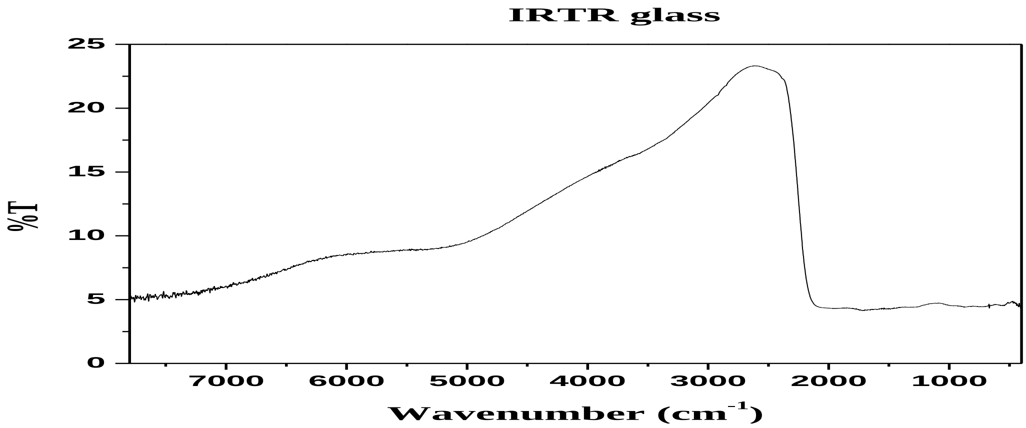


***Fig.10:* IR spectrum of percentage transmittance vs. wavelength range**

This graph shows that, the material shows a transmittance nearly 7% at 5000cm-1(2µ) and steadily rises to 24% at about 2500 cm-1(4µ) and then falls to 3% nearly up to1200 cm-1 i.e.(8.33µ).

(4).Density & Colour of the Glass:

The density of the IR transparent glass was found to be 6.791 g/cm^3.by displacement method. The colour of the glass was observed as greenish-brownish yellow.

Discussion

1]. XRD graph shows the amorphous nature of the material, since there is no peak found in the graph. This type of graph is obtained generally for the amorphous glass material. Thus, it is confirmed that the product obtained is a GLASS.

2]. The DTA graph shows the non-hygroscopic nature of the glass, since average weight loss percent as per the graph is 0.09 percent which is assumed to be negligible. Hence, this glass is non-hygroscopic in nature and can be used in any environment.

3]. The DTA graph also indicates about the glass transition temperature (Tg) as 400.34°C or 400°C approximately. From the FTIR of the sample , the transmittance of nearly 7% at 5000 cm-1 (2µ) and steadily rises to 24% at 2500cm-1(4 µ) and finally drops very sharply to3% at 2200cm-1(4.55 µ) and remains steady up to 1200cm-1 (8.33 µ).

4]. The resulted colour of the glass is found to be greenish yellow, because of the colouring effects shared by both the forms of iron silicates i.e. the ferrous and ferric silicates.

5]. This range of colours of the glass is varying from green to greenish yellow as the proportion of the ferric to ferrous salt increases.

6]. The final glass is found to be 'A solution of ferrosoferric silicate in metacalcium silicate uniformly mixed with calcium diphosphate in their liquid phases to produce a clear transparent liquid and subsequently gradually cooled to a solid mass.

IV. CONCLUSIONS

1. This newly formed IR transparent glass having wavelength range 5000cm-1 to 1200cm-1 (2 to 8.33µ) may be compared with known IR transparent CaF2 glass with a wavelength range of 5000 to 1175 cm-1(2 to 8.5µ)and the salient difference between THESE two glasses is that this IR material is perfectly non-hygroscopic, while CAF2 is highly hygroscopic.
2. Infrared spectra or signals of these materials is proved ideal in the range of 5000cm-1 to1800cm-1 (2 to 5.56µ) and is used for windows and prisms materials without the danger of the presence of the water vapor into the atmosphere. This glass ceramic can be used in any environment with very high average life.

V. ACKNOWLEDGEMENTS

We are thankful to the scientist Dr. Ranjan Sen.& his team of Central Glass and Ceramic Research Institute, Jadhavpur, kolkata.We are specially thankful to Mr.M.K.Kawadkar & the entire team of the scientists of Vijnana Bharati, Nagpur & Varanasi chapters.Thanks are also due to the Director, V.N.I.T. and the faculty members & supporting staff of the department of Metallurgical & Materials Engineering,V.N.Institute of Technology,Nagpur, for the permission to present this research work.

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