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# Bone bonding ability behavior of some ternary borate glasses by immersion in sodium phosphate solution

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## Abstract

Some ternary borate glasses of varying compositions were prepared and corrosion behaviors of such ternary borate glasses after immersion in aqueous dilute phosphate solution were studied using different immersion times. Fourier transform infrared (FTIR) absorption spectral measurements were done before and after immersion in the mentioned solution for extended times up to 3 days to justify the appearance of the characteristic FT infrared bands due to calcium phosphate (hydroxyapatite (HA)) which is considered as the potential indication of bone bonding ability.

Experimental IR data confirm the beginning of the appearance of FTIR bands at about 580 and 650 $\text{cm}^{-1}$ after 1 day and the complete resolution with its characteristic split form after 3 days and more.

The corrosion behavior of the studied borate glasses is explained in relation to a suggested hydrolysis and direct dissolution mechanism. The ease of dissolution of all the borate glasses constituents explains the rapid conversion and formation of hydroxyapatite within the borate glass matrix as indicated and confirmed by X-ray diffraction.

*Keywords:* Borate glass; IR spectroscopy; Corrosion weight loss; Sodium phosphate solution; Hydroxyapatite; Bone bonding ability

## 1. Introduction

Borate based glasses have been prepared and developed for a variety of scientific and engineering applications. These include low temperature sealing components [1], fast ionic conductors for use in solid state lithium batteries [2–4], radiation and thermoluminesence dosimetry devices [5,6], and even they have been considered for radioactive wastes immobilization [7].

Day et al. have explored in 2003 [8] and then afterwards extensively studied [9–11] the use of borate glasses in biomedical applications. Recently, the potential bioactivity of borate glasses comes from their lower chemical durability and hence converts faster and almost completely to hydroxyapatite (HA) than the widely studied modified soda lime silicate Hench's patented bioglass (45S5) when placed in a dilute potassium phosphate solution replacing the simulated body fluid (SBF). Studies have shown that some borate glasses have the ability to support the growth and differentiation of human inesenchymal stem cells, and to promote bone formation more rapidly than silicate based 45S5 glass in a rat tibial defect model [12]. Based on its rapid conversion to HA and oesteoconductivity, borate glass can thus be considered as an attractive bone substitute material which needs further extended studies.

The present work reports the preparation of three selected ternary borate samples of varying compositions including compositions of soda lime borate, lithia lime borate, potash lime borate and also binary calcium borate glasses to find out the effects of the mentioned different alkali or modifier species on the bone bonding ability behavior upon immersion in a sodium phosphate solution. The corrosion weight loss data of the prepared samples in the sodium phosphate leaching solution were estimated. Also, a comparative characterization through Fourier transform infrared (FTIR) spectroscopic technique was carried out to follow up the formation of hydroxyapatite within the studied glasses.

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## 2. Experimental details

### 2.1. Preparation of the glasses

The glasses were prepared from chemically pure grade materials with the compositions shown in Table 1. The materials include $H_3BO_3$ for $B_2O_3$, while $Na_2O$, CaO, $Li_2O$ and $K_2O$ were introduced in the form of their respective anhydrous carbonates.

The weighed batches were melted in platinum crucibles at 1050 °C for 2 h. The melts were rotated at intervals of 30 min apart to ensure homogeneity of the melts. The homogenized melts were cast into warmed stainless steel molds of the required dimensions. The prepared samples were immediately transferred to a muffle furnace regulated at 380 °C for annealing and removing thermal stresses. The muffle was switched off after 1 h and left to cool to room temperature at a rate of 25 °C/h.

### 2.2. Solubility test

Evaluation of solubility of the studied borate glasses was achieved by measurements of their weight loss in aqueous sodium phosphate solution at human body temperature (37 °C) in the incubator. Samples were polished and refined with 600 girt polishing papers. The sample dimensions were measured accurately and washed ultrasonically in acetone for a few minutes and then placed in polyethylene beaker containing pre-calculated volume of phosphate solution (ratio between geometric area of the glass samples and volume of the solution was fixed as $0.075\ cm^{-1}$ in all cases for comparison and to avoid defects resulting from volumetric differences [13]. Samples were removed and excess moisture was removed by tissue paper at various time intervals and then reweighed. The percent changes of weight loss were correlated to glass solubility or corrosion. Solubility measurements were carried out in triplicate for obtaining acceptable weight loss measurements.

A regression method used for data fitting and dissolution rates in $g\ m^{-2}\ h^{-1}$ was calculated according to the formula: $D_{rate} = (\text{slope} \times m_i/A)$, where $D_{rate}$ is the dissolution rate, $m_i$ is the initial weight of the sample and $A$ is the surface area of the specimen. The pH value was measured at fixed time intervals during the solubility test using a pH meter (Model HANNA pH211 Microprocessor pH meter, Romania) with an accuracy of ±0.01 pH and calibration of the electrode against buffer solution was performed every 12 h. The same procedure was adopted by [14].

Table 1
Chemical compositions of the prepared glasses (wt%).

| Glass no. | $B_2O_3$ | CaO | $Na_2O$ | $Li_2O$ | $K_2O$ |
|---|---|---|---|---|---|
| G100 | 70 | 15 | 15 | – | – |
| G200 | 70 | 15 | – | 15 | – |
| G300 | 70 | 15 | – | – | 15 |
| G400 | 55 | 45 | – | – | – |

### 2.3. Chemical durability by the grain method

The chemical durability of the prepared bioactive glasses was carried out using the grain method which was adopted by several authors [15–21] and recommended by ASTM specifications. Glass grains (0.3–0.6 mm in diameter) were immersed in a disodium hydrogen phosphate ($Na_2HPO_4$) solution (0.025 M) for 1 h at 95 °C.

1 g of the sample grains was placed in a sintered glass crucible G4 (Jena type) which was placed in a 250 ml polyethylene beaker situated in the water bath regulated at 95 °C. 150 ml of the attacking solution was introduced to cover the grains. After 1 h, the beaker was removed from the bath and the sintered glass crucible was fitted on a suction pump and the whole solution was pumped through it. The sintered glass crucible was transferred to an air oven at 120 °C for 1 h. Then, the crucible with its content was reweighed and the total loss was calculated. An empty sintered glass crucible of the same type (G4 Jena) was subjected to the same corrosion test and the obtained result was taken into consideration.

### 2.4. Structural analysis of bioactive glasses using FTIR analysis

Fourier transform infrared absorption spectra of the studied borate glasses were measured at room temperature (~20 °C) in the wavelength range 2000–400 $cm^{-1}$ using FTIR spectrometer (type Mattson 5000, USA). Fine powder of the samples mixed with KBr in the ratio 1:100 for quantitative study and the mixture was subjected to a load of 5 $tons/cm^2$ in an evacuble die to produce clear homogeneous discs. Then, the IR absorption spectra were immediately measured after preparing the discs to avoid moisture attack. The measurements were taken for the studied samples before and after immersion in the phosphate solution.

### 2.5. Structural analysis using scanning electron microscopy

Scanning electron microscopic (SEM) investigations were performed on glass samples at room temperature using an SEM Model Philips XL 30 attached with EDX Unit, accelerating voltage 30 kV, magnification 10× up to 400,000. All samples were coated with gold for morphological investigations.

### 2.6. X-ray diffraction analysis

The composition and crystallinity of the samples were analyzed by X-ray diffraction in order to identify the structural changes after immersion in the phosphate solution. The glass samples were ground and the fine powder was examined using a diffractometer adopting Ni-filter and Cu-target. The X-ray diffraction patterns were obtained using a Philips PW 1390 X-ray diffractometer. A computer software (Materials studio 4.4) programs was employed to calculate the degree of crystallinity of the treated glass samples after immersion in the phosphate solution.

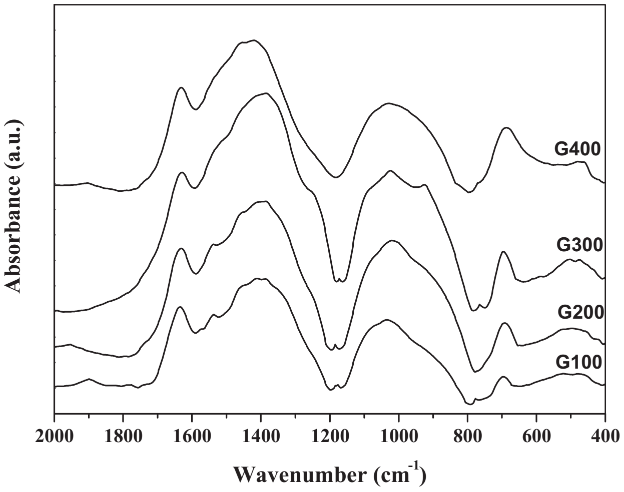

Fig. 1. FTIR of borate bioactive glass before immersion.

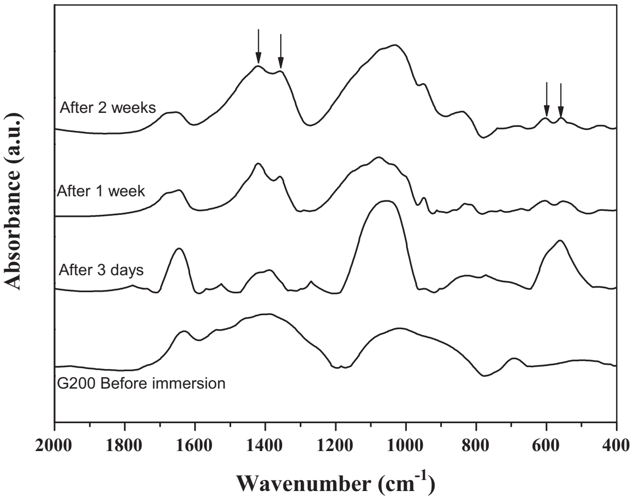

Fig. 3. FTIR Bio200 Glass before and after different immersion times.

## 3. Results

### 3.1. Infrared absorption spectra of glasses before immersion

Fig. 1 reveals the FTIR absorption spectra of the studied four borate glasses and the IR data can be summarized as follows:

(a) The first ternary borate (soda-lime-$B_2O_3$) glass shows an infrared spectrum characteristic for combined triangular and tetrahedral borate groups.

(b) The FTIR spectrum consists of the following spectral features:

1. A first small broad band with two small peaks at about 460 and 530 $cm^{-1}$.
2. A small rounded peak at about 700 $cm^{-1}$.
3. A small kink at about 780 $cm^{-1}$.
4. A broad middle band with a curvature at 900 $cm^{-1}$ and a peak at about 1040 $cm^{-1}$.
5. A small kink at about 1180 $cm^{-1}$.
6. A very broad band extending from 1200 to 1700 $cm^{-1}$ with 6 small peaks at 1260, 1330, 1380, 1420, 1460, and 1520 $cm^{-1}$ followed by a medium peak at 1640 $cm^{-1}$.
7. Two final small peaks at 1780 and 1900 $cm^{-1}$.

(c) All the other two ternary glasses ($Li_2O$–CaO–$B_2O_3$) and ($K_2O$–CaO–$B_2O_3$) and even the binary (CaO–$B_2O_3$) glass generally reveal the same IR spectral features as that obtained from the first glass. The $K_2O$-contaning glass shows more resolution or splitting of some peaks.

### 3.2. Infrared absorption spectra of borate glasses after immersion

Figs. 2–4 illustrate the IR absorption spectra of the studied borate glasses after prolonged immersion times (3 days → 2 weeks) in a sodium phosphate solution. The FTIR data indicate the following characteristics (Fig. 5):

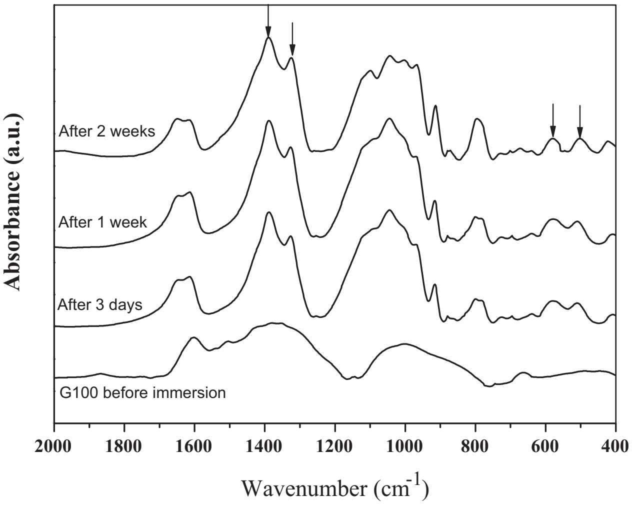

Fig. 2. FTIR Bio100 Glass before and after different immersion times.

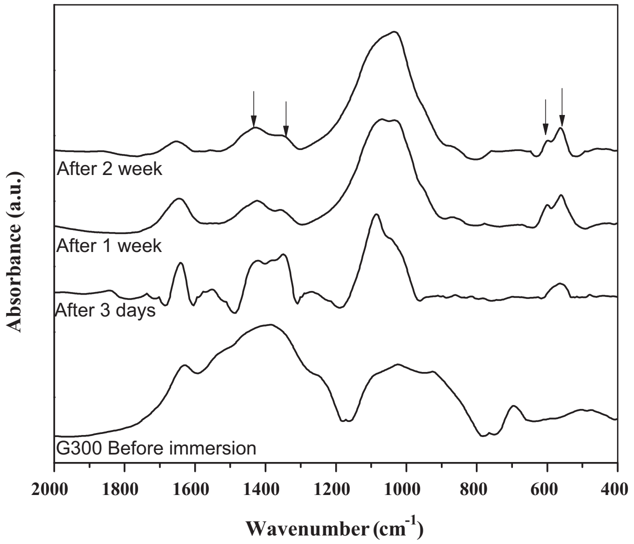

Fig. 4. FTIR Bio300 Glass before and after different immersion times.

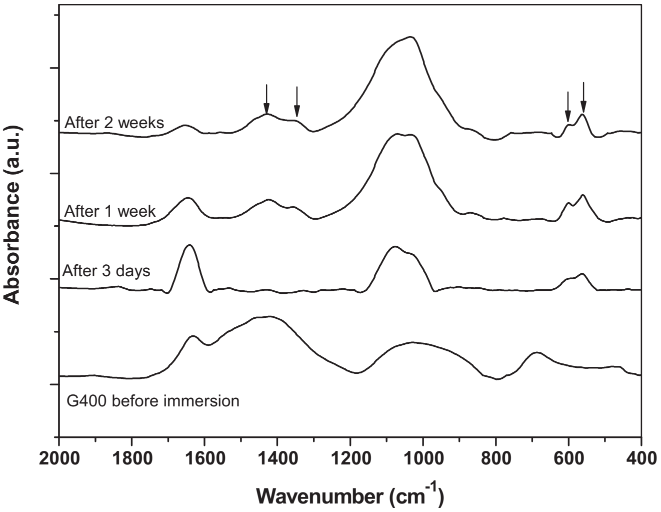

Fig. 5. FTIR Bio400 Glass before and after different immersion times.

1. The first (soda-lime-$B_2O_3$) glass shows after immersion marked variations after 3 days. The characteristic IR spectra due to triangular and tetrahedral groups are clearly identified. The main distinctive features of variations are represented as follows:
    1. The resolution of two new connected peaks at about 540 and 610 $cm^{-1}$.
    2. The resolution of a distinctive medium band at about 800 $cm^{-1}$.
    3. The resolution of a medium sharp band at about 910 $cm^{-1}$.
    4. The resolution of a very broad high intense band extending from 950 to 1200 $cm^{-1}$ with four peaks at about 980, 1030, 1080 and 1130 $cm^{-1}$.
    5. The resolution of a broad intense band extending from 1280 to 1500 $cm^{-1}$ with two distinct peaks at about 1330 and 1400 $cm^{-1}$.
    6. The resolution of a medium band with two closely connected peaks at 1630 and 1680 $cm^{-1}$.
2. On prolonged immersion to a week, the same IR spectral features are retained.
3. The other ternary or binary samples show the same distinctive IR spectral features but with lesser extent after immersion for 3 days.

### 3.3. SEM of glass samples before and after immersion

SEM micrographs of the powdered glass surfaces before and after chemical treatment with phosphate solution are shown in (Fig. 6a and b).

Fig. 6a shows the glass G300 as a representative before immersion in phosphate solution which is characterized by a nearly smooth surface but contains some undefined grains.

Fig. 6b shows large cotton-like growths or nodules on the surface of the sample after immersion in a phosphate solution for 1 week. These cotton-like growths or nodules are due to the formation of apatite crystals as identified by X-ray diffraction.

### 3.4. pH measurements

Fig. 7 reveals the change in pH of phosphate leaching solution at different time intervals after the immersion of the borate bioactive glass. The data show that the pH approaches a higher value of almost 8.00 from a starting value of 7.10 after about 480 h for all the studied samples except G400 (binary glass).

### 3.5. Weight loss measurements

The percentage weight losses of all prepared samples immersed in phosphate solution at 37 °C as a function of time are shown in Fig. 8. Sample weight measurement provides a better idea of sample dissolution and the least durable glass exhibits the highest weight loss. Solubility of a material plays an important role and significantly affects its stability in vivo because resorption or biodegradation of a material in vivo is a very complex process, where physiochemical mechanisms interact with the biological mechanisms in protein and cell-mediated processes and therefore, it is not exclusively controlled by its physiochemical properties such as solubility. It can be seen that G100 glass is the least durable glass. Further, glass compositions show decrease in solubility.

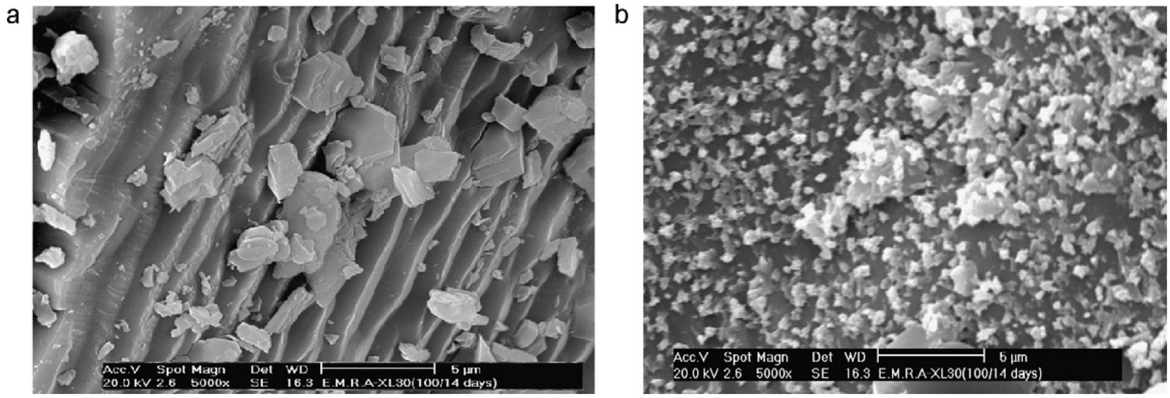

Fig. 6. SEM micrographs of glass G300 (a) before and (b) after immersion in phosphate solution.

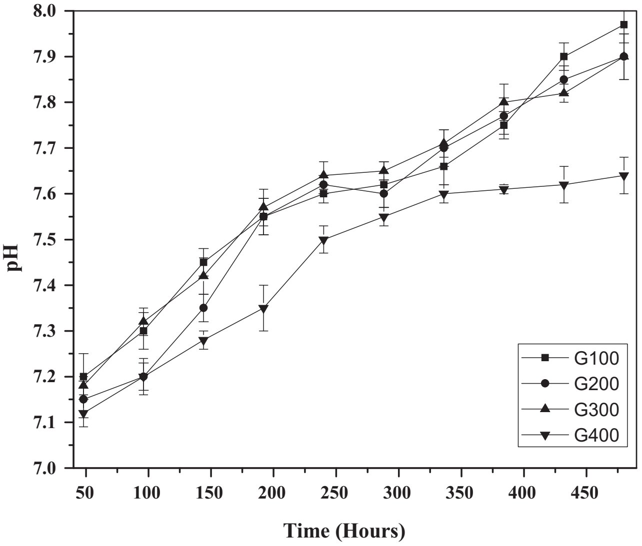

Fig. 7. Variation of phosphate solution pH with different time intervals.

Nevertheless, it can be observed that improvement of the chemical durability of the glasses in phosphate solution in the initial stages was more pronounced between the glass G300 and G400. Manupriya et al. [14] noticed that within the degradation process, the CaO content was the most influential controlling factor. The more CaO incorporated in to the system the lower is the solubility of the glass samples. The mechanism behind the glass durability improvement with CaO substitution for $B_2O_3$ is that CaO strongly increases the coupling of the vibrational modes of the boron–NBO-modifier bonds to bridging B–O–B network. The result of this coupling is that during aqueous attack, loss of calcium ions from the calcia-containing glass becomes slow. These results are completely in agreement with the weight loss results. The increase in dissolution with the addition of sodium ions is due to the fact that sodium enters the binary borate glass as a network modifier and all sodium salts are rapidly and easily dissolved in aqueous solution.

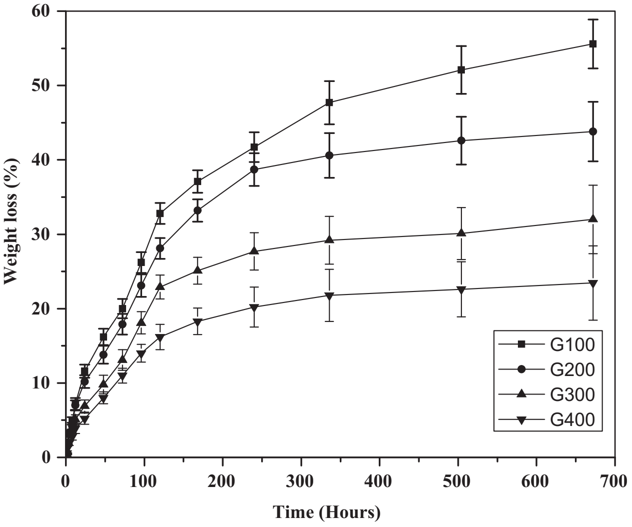

Fig. 8. Percentage weight loss of bioactive glass with different time intervals.

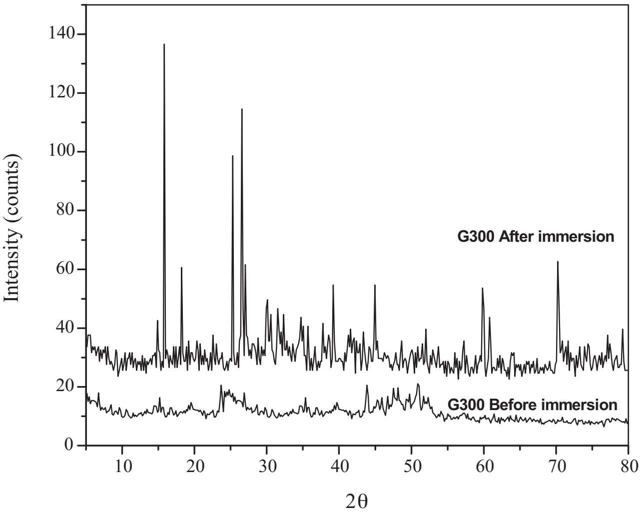

Fig. 9. XRD pattern of glass G300 before and after immersion in phosphate solution.

### *3.6. X-ray diffraction analysis*

Fig. 9 presents the XRD pattern of G300 bioactive glass before and after being immersed in a phosphate solution for 1 week.

These patterns show that the as prepared glassy material was amorphous in nature which was transformed to a material containing three different crystalline phases; orthorhombic potassium borate hydrate $KB_5O_8(H_2O)_4$, monoclinic borax $B_4O_5(OH)_4(Na_2(H_2O)_8$ and hydroxyapatite phases with crystallinity of about 65% as calculated using a computer program (Materials Studio 4.4). This result was supported by the SEM micrographs.

The former is characterized by both an obvious katabatic tendency in the base-line and diffusive peak bottoms, which are caused by the short-range ordering of the borate structure in the glass [14].

## 4. Discussion

### *4.1. Infrared spectra in relation to glass composition and constitution*

Infrared spectroscopy is a very sensitive method in various aspects of glass science. It can be used for the characterization of the local order and type of building structural units in oxide glasses [22]. Also, it is a valuable tool for studying the bioactivity of glasses [23,24]. A further application of the method includes justifying the corrosion mechanism in glasses [15,16,25,26] and identification of radiation damage in irradiated glasses [27].

Borate glasses are very interesting materials as shown by various diversed applications mentioned in the introduction and because of their rich chemistry. The boron has the ability to change easily its coordination with oxygen between three and four and hence can form variable structural units in borate glasses and crystals [28,29]. A second interest comes because boron has the smallest mass compared to other network forming elements (e.g. Si, P or Ge). Also, the main IR vibrational modes associated with the glass network appear well above 500 $cm^{-1}$ [22,29], and thus they are clearly separated from the metal ion sites vibrational modes, active in the far-infrared region.

Recently, infrared absorption spectroscopic studies of various borates [30,31], silicates [15,16] and phosphate glasses [32,33] with variable compositions have been employed through the KBr disc technique and the IR data have been found to be in complete agreement with previous reference IR absorption spectral measurements by reflectance or transmission methods by various scientists [25,29,34–37].

The borate glasses originate from boron oxide ($B_2O_3$) which was considered in 1932 by Zachariasen [38] as one of the first recognized oxides which are capable to form glass by themselves. Boron oxide was early assumed [38,39] to consist of boron–oxygen triangles [$BO_3$]. Later, Krogh-Moe [40] assumed that the structure of $B_2O_3$ consists of large concentration of an intermediate unit, consisting of 3 boron–oxygen triangles joined to form a structure known as boroxol ring or boroxol groups ($B_3O_6$). Some recent studies [41] indicate that the fraction of boroxol groups in $B_2O_3$ is 0.8, while others [42,43] claim that only 0.3–0.6 is the probable ratio limit.

The addition of alkali oxide (alkaline earth oxide or other divalent oxides such as PbO, $Bi_2O_3$) causes some of the borons to change from triangular to tetrahedral coordination, while non-bridging oxygen are not formed. This process of the conversion of borons from 3- to 4-fold coordination only occurs until the network reaches some critical concentration of tetrahedrally coordinated borons (originally believed to occur at 16–20 mol% alkali oxide ($R_2O$)), after which any additional alkali oxide causes the formation of non-bridging oxygen (NBO) which results in reversal in some property/composition trends. This simple explanation was widely accepted for the so-called borate anomaly for many years. However, some authors have introduced other explanations for the variations of physical properties in relation to composition and constitution of alkali borate glasses:

a) Shelby [44] has associated the minima of properties with the disappearance of boroxol groups, maxima in tetraborate and appearance of diborate groups.
b) Bray [45] has related the anomaly to the appearance of large awkward space-filling tetraborate groups and not to sudden change of tetrahedral coordination.

Concerning alkaline earth oxides with $B_2O_3$, the combinations of these oxides with $B_2O_3$ are limited to certain limiting compositions. The alkaline earth oxide shares also in the transformation of borons from triangular to tetrahedral coordination. Hence, the studied ternary soda lime borate glasses exhibit the two coordination states for borons and the formed tetrahedral coordinated borons are the outcomes of the action of both $Na_2O$ and CaO on the triangular borons.

### *4.2. Suggested corrosion behavior in the studied borate glasses*

The first patented modified soda lime silicate Hench's bioglass is agreed upon [23,24] to corrode in an initial step by the formation of a thin $SiO_2$-rich gel layer (a few micrometer thick) on the 45S5 glass surface by ion exchange reactions. Further dissolution of ions from this patented glass and their diffusion through the $SiO_2$-rich gel layer, followed by the reaction between $Ca^{2+}$ ions from the glass and $PO_4{}^{3-}$ ions from the surrounding fluid or solution, leads to the formation of an amorphous calcium phosphate (ACP) layer on the $SiO_2$ gel layer. The reaction between the Hench glass and SBF solution continues, and at the same time the ACP converts to hydroxyapatite giving a structure consisting of an unconverted glass core, an $SiO_2$-rich layer, an ACP layer, and a growing outer layer of HA [46]. Eventually, the reaction stops and, with the completion of the ACP conversion to HA, a composite structure consisting of an HA layer surrounding a $SiO_2$-rich core is produced.

The conversion of some borate glasses to useful biological crystalline compounds, such as HA ($Ca_{10}(PO)_4(OH)_2$) has been explored by Day and co-workers [47–49]. They have recently assumed [50] that the process of conversion of the silicate 45S5 bioactive glass to HA in SBF shows some similarities to the conversion of borate glasses in an aqueous phosphate solution [49] but there are also some important differences. Because of their low chemical durability, some borate glasses unlike silicate 45S5 glass, can be converted more rapidly, as well as almost completely to HA in aqueous phosphate solution.

Studies on the corrosion of borate glasses have arrived to several important parameters [46–51]:

a) $B_2O_3$ is a hygroscopic oxide and highly dissolves in water.
b) The addition of alkali oxide slightly improves the corrosion of $B_2O_3$ and this improvement is correlated with the formation of stronger tetrahedral ($BO_4$) units. After the saturation and the formation of non-bridging oxygens, the corrosion saturates or increases again.
c) Experiments by Velez et al. [51] showed that rotation of the borate glass specimens during the corrosion study did not alter the corrosion results.
d) As the corrosion continues, the pH increases with the dissolution of alkali oxide and the formation of the respective hydroxide and the pH reaches 9–10 and the corrosion increases with increasing pH, unless an insoluble hydroxide is formed.
e) The mentioned behavior cited for corrosion of alkali borate glasses seems to reflect fundamentally different phenomenon or behavior than in the case of silicate glasses. Although dissolution in both cases involves hydrolytic product in the case of silicate glasses can undergo polymerization and gel formation. In alkali borate glasses, the corrosion is continuously and completely performed unless supersaturation is reached. Velez et al. [51] have assumed that the results of corrosion of borate glasses suggest that dissolution takes

place by a reaction-controlled mechanism and not by ion-exchange process.

f) The introduction of lime (CaO) to the composition of glass is accepted to improve the chemical durability of binary alkali silicate or alkali borate glasses. The presence of (5–8 wt%) in ordinary sheet and tableware glasses produces an improvement of the chemical corrosion due to several reasons.

1. The double charge of $Ca^{2+}$ ions makes the ion exchange process more slowly with $H^+$ or $H_3O$ than single charge $Na^+$ ions when glass is exposed to aqueous solution.
2. The presence of mixed modifier ions ($Na^+ + Ca^{2+}$) during the corrosion process and subsequent diffusion through specified channels or pathways within the glass network causes interference and retardation of this corrosion process.
3. Clark et al. [52] have attributed that the improvement in the chemical durability with the introduction of CaO to binary sodium silicate glass to the formation of a $Ca^{2+}$ enriched zone ~1500 Å thick within the Na-deplated layer.
4. Budd and Frackiewicz [53] have assumed that this behavior associated with high (CaO) content may be either due to microphase separation and/or the activity of CaO in silicate glasses which may be disproportionately higher than other glasses.
5. The assumption of the tendency to phase separation or immiscibility with the presence of CaO in silicate glasses is supported by the work of Hudon and Baker [54] who agrees to this postulation. The same behavior is also expected with CaO in borate glasses [54]. The very narrow limits of the formation of stable glasses by conventional melting and annealing are observed with the alkaline earth oxides CaO, SrO, BaO when any of them is melted with $B_2O_3$ to form a binary glass. Also, the formed glasses of alkaline earth oxide with $B_2O_3$ possess the ability to be converted to transparent glass–ceramics through controlled heat treatment and this is due to the presence of phase separation in the original glasses.

Based on all previous considerations, the corrosion behavior of soda lime borate glasses is suggested to proceed in the following ways [46–51]:

1 All the glass constituents, namely $B_2O_3$, $Na_2O$, CaO are released in the leaching solution but it is assumed to be with different degrees. $B_2O_3$ and $Na_2O$ are easily released and rapidly dissolved because of their strong ability to dissolve by a measurable degree.

2 CaO when contaminated with aqueous solution, it forms sparingly soluble ($Ca(OH)_2$) which is not easily dissolved as NaOH and seems to prefer to be in the contact with acidic phosphate anions to form calcium phosphate with the final pathway to be converted to hydroxyapatite.

3 The proposed previous suggested dissolution processes are believed to proceed rapidly than that which occurs in silicate Hench's bioglass. This explains the complete transformation to HCA and not just forming a surface HCA layer covering the $SiO_2$–gel layer as frequently obtained in bioactive 45S5 glass.

4 Thus, it can be concluded that the corrosion mechanisms of silicate glasses in aqueous environments, generally undergo hydration, hydrolysis, and ion exchange reactions [55]. The hydrolysis products of silicate glasses can undergo polymerization and gel formation on glass surfaces, unlike borate glasses [51,56]. The corrosion of borate glasses is controlled directly by hydrolysis reaction and dissolution kinetics rather than diffusive transport.

5 Referring to the chemical composition of the studied glasses, it is evident that the modifier oxides ($Na_2O$ + CaO) are in the constituent percent more than necessary to give the maximum percent of tetrahedral $BO_4$ units and the excess modifier oxides form non-bridging oxygens with nearby modifier cations to achieve neutrality and the rest of borons remain in triangular coordination.

The easily and primarily dissolved species in the studied soda lime borate glasses are assumed to be as follows:

a. Borate species in trigonal sites are electrophilic and thus readily attacked by water.
b. Borate species with loose non-bridging oxygens.
c. Modifier ions which are not attached to $BO_4$ groups for balancing the excess charges.

These specific species can be checked and confirmed by FTIR spectral measurements of borate glasses after immersion in the sodium phosphate solution. The IR results show the decrease in the intensities of the bands within the region (1250–1500) $cm^{-1}$ which are correlated with the borons in triangular coordination. This supports the first assumption that $BO_3$ groups are readily and primarily dissolved in the sodium phosphate leaching solution. Previous studies on alkali borate glasses [57] support this postulation.

### 4.3. Interpretation of the pH measurements

The mechanism of interaction between the glasses and phosphate solution suggests that species such as $H^+$, $H_3O^+$ and $OH^-$ from the solution attack the glass constituents and are ion-exchanged with $Ca^{2+}$/($Na^+$, $Li^+$, $K^+$) ions from the glass network. The observed increase in pH value may be attributed to the continuous leaching process of alkali and alkaline earth ions from glass to solution. This may be supported by the lower value of pH change in case of the binary CaO–$B_2O_3$ system. These results may be of a great interest for researchers as it gives an idea about the environment produced by implants in active systems.

## 5. Conclusions

The corrosion behavior of some ternary borate glasses with variable modifiers together with a binary calcium borate glass was studied by both the solubility and the grain method. The conversion of the prepared borate glasses to hydroxyapatite after the immersion in a sodium phosphate solution was described and confirmed by measuring FTIR absorption spectra after immersion in this specified solution for prolonged times. Experimental IR data indicate the resolution of a characteristic split band with two peaks at about 580 and 650 $cm^{-1}$ after 3 days. This result represents an indicator for the potential bone bonding ability of the studied borate glasses which is seen to depend on the glass composition and type of modifiers. The studied ternary and binary borate glasses show varying degrees for the corrosion behavior and all the specimens reveal the appearance of the characteristic split peaks due to hydroxyapatite after 3 days. All the results are interpreted on the basis of current views on the subject of corrosion and bone bonding ability of glasses.

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