Intelligent glass ceramic materials

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Some specific properties of crystals can constitute an excellent base to justify the production of glass ceramic materials. In this way, the paper demonstrates the possibility of attaining “intelligent materials” from glasses. Intelligent materials can be defined as materials that respond to environmental changes, relatively to the excellent conditions imposed by the environment, and manifest its functions in accordance with these changes. In this way and with one extra view, the versatility of the glass processing and the unqualified possibilities for the crystals attention, by the controlled crystallization of these glasses, insert the glass ceramic process in a special form as one new kind of intelligent materials attaining. Intrinsically to the glass ceramics use are the benefits of the general properties inherent to ceramics (for example, abrasion resistance and the high temperatures resistance). This aspect also favors the magnifying of the area of intelligent materials application. Experimental results base the proposal and possible uses are discussed.

Word key: intelligent materials, glass, glass ceramic.

Introduction

Intelligent materials can be defined as materials that respond to environmental changes, relatively to the excellent conditions imposed by the environment, and manifest its functions in accordance with these changes. Thus, studies correlating ceramic properties, until then considered disadvantageous, with the “intelligent” functions of materials, constitute an innovation in the scientific field and suggest a new approaching to some of these properties. Anorthite Crystals ($CaAl_2Si_2O_8$) attained by controlled crystallization of glass can be cited as an excellent example. These crystals present low corrosion resistance when in acid environments, what, in a first view can seems as a problem, is discussed in this work as a property to be explored, associated or not to other properties, as resistance to high temperatures and abrasion. It can magnify considerably the use possibilities of this material.

X-ray difraction (XRD) was used to determine the crystalline phases of the glass ceramic, disclosing the presence of anorthite and ortoclase. The viscosity reduction of the base glass due to the addition of a small quantity of potassium caused the sprouting of the ortoclase phase. The ortoclase phase interacts with anorthite crystals forming a solid solution [1]. The Scanning Electron Microscopy (SEM), had been used to evaluate the microstructure morphology.

The methodology described in literature for evaluation of the chemical resistance of glass ceramics derived from the ternary system CaO - Al_2O_3 - SiO_2 was considered for the tests [2]. The material behavior in function of the environment pH changes was analyzed. A discussion of the “material intelligent behavior” is carried out.

Bibligraphic Review

The intelligent material is a newly created concept and is a complex science, which is based on the contemporary materials science and the information science [3]. This concept describe the design of a material, so-called "Tailored Material", capable to play several functions by its own nature, as a sensor, a processor or, in other words, as a carrier of feedback/feedforward functions in combination with the material remainder properties. The proposal of establishment of this new scientific field is to assemble smarter structures and achieve high performance systems related to the recognition potential, discrimination, adjustability, etc. The intelligent materials are related to a wide area of researches, an interdisciplinary field related to the technology, involving medicine, pharmacy, chemistry and engineering (materials, mechanical, electronics) in the most diverse areas of science and technology (biomateriais, polymers, metals, semiconductors, ceramic).

Until now, the intelligent materials field has been coursed to the medicine, pharmacy and biomateriais with the development of artificial skin, or encapsuladores of drugs that they need to act in specific regions of the human body, and others. Researches also has been developed in the field of mechanical engineering with the shape memory alloys, and in electronic engineering using smaller and more efficient integrated circuits and semiconductors. However, almost nothing was developed using ceramic materials in the scope of intelligent materials. In this way, this work suggests and exemplify that intelligent materials can be generated from the glass controlled crystallization. The identification of "intelligent properties" of crystals that are possible to be attained from glasses designates a new application line for glass ceramic materials.

The crystal formation and growth from glasses are only possible if the chemical composition of the start mixture carries an adequate amount of a forming glass agent mass. Thus, a formularization based on the ternary system CaO - Al_2O_3 - SiO_2 was prepared [4]. The selected region was of the Anorthite due to a particular feature of its crystals: to reply the pH environment changes. Its crystalline nature has triclinic symmetry ($a \neq b \neq c$ $\alpha \neq \beta \neq \gamma \neq 90°$), Figure 1(a) [5]. The crystal has ten plans, Figure 1(b). However, it is known that Anorthite can crystallize following other symmetries, as pseudo-ortorrombic, ortorrombic and hexagonal [6].

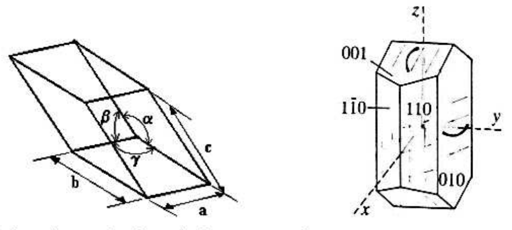


Figure 1 - Typical Anorthite ($CaAl_2Si_2O_8$) features: (a) triclinic system unit cell and (b) crystal shape.

Basically, the Anorthite physical and chemical properties are of the plagioclase [1]. This mineral category describes a solid solution between Anorthite ($CaAl_2Si_2O_8$) and Albite ($NaAlSi_3O_8$) or Ortoclase ($KAlSi_3O_8$), with the following theoretical properties: hardness of 6 to 6.5 Mohs, b) white, grizzly, bluish, reddish or greenish color, c) glass brightness, d) very good clivage in {001} and {010}, e) density of 2.6 to 2.76, f) crystals with prisms or plate shape. The Anorthite presents a divergent feature of the rest materials of this mineralogical sub-group (plagioclase), this crystal is vulnerable to acid environments.

Experimental Procedure

The raw materials had been homogenized and casting in Al_2O_3 crucible at 1550°C for 2 hours. Rutille (TiO_2) was used as nucleating agent [7]. The resultant glass was quenched in air and, later, nucleated (830°C per 15 minutes) and crystallized (1130°C per 20 minutes). Glass ceramic powder was prepared with particle size inferior of 45 mm for the XRD analysis. Other samples had been submitted to the chemical resistance testes, remaining for 24 hours to 90ºC in acid, basic or neutral solutions, concentrated or diluted. Due the glass had presented indications of the occurrence of different orientations of the crystallization, in according to previous papers [6], being able to present different unit cell features in the surface and in the volume, tests have been executed for samples with the superficial layer and samples that had this layer removed. Glass ceramics samples had been prepared and evaluated in a Scanning Electron Microscope (SEM).

Results

The X-ray diffraction analysis of the glass ceramic disclosed that Anorthite crystals ($CaAl_2Si_2O_8$ - JCPDS 41-1486) had been formed from the glass. Ortoclase crystals ($KAlSi_3O_8$ - JCPDS 09-0462) and Rutille (TiO_2 - JCPDS 21-1276) also had been developed, Figure 2.

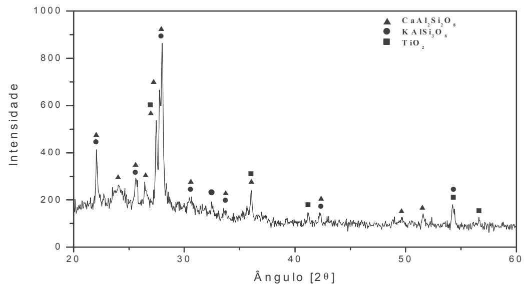
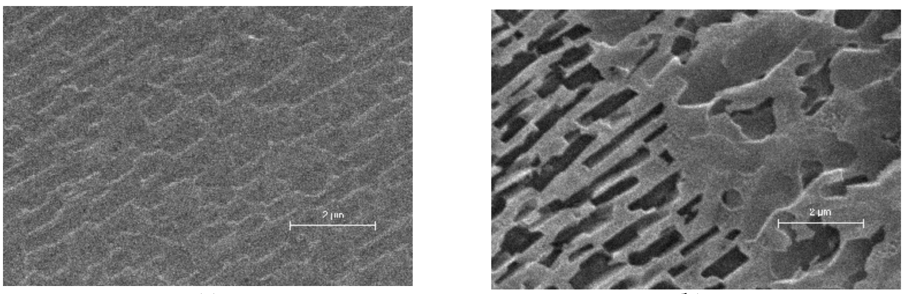


Figure 2 – X-ray diffraction identifying the glass ceramic crystalline peaks.

Figure 3(a) shows the microstructure morphology, detaching the chemical attacked (1% HF, 15 seconds) crystals area, lowered. Figure 3(b) shows a vigorously attacked region of the superficial and volumetric growth interface, where it has a clear change of orientation.



(a) (b)

Figure 3 – Glass ceramic micrograph disclosing the crystallized area: (a) lightly attacked and (b) superficial and volumetric crystallization interface vigorously attacked.

Tables 1 and 2 present the results obtained from the chemical attack resistance testes of the samples with and without the superficial layer, respectively.

Table 1 - Samples with the superficial layer

Solution	Loss of Massa (%)	Initial Mass (g)	Final Mass (g)
10% H_2SO_4	9,15	0,0820	0,0745
HNO_3 conc.	6,12	0,0572	0,0537
10% HNO_3	15,37	0,0735	0,0622
HCl conc.	7,25	0,0676	0,0627
10% HCl	4,64	0,1184	0,1129
NaOH conc.	-0,16	0,0645	0,0646
NaOH 5%	0,90	0,0776	0,0769
Na_2CO_3 10%	0,32	0,0627	0,0625
H_2O destilada	0,15	0,0655	0,0654

Table 2 - Samples without the superficial layer: volume.

Solution	Loss of Mass (%)	Inicial Mass (g)	Final Mass (g)
10% H_2SO_4	15,625	0,0320	0,0270
HNO_3 conc.	19,362	0,0470	0,0379
10% HNO_3	21,543	0,0311	0,0244
HCl conc.	13,65	0,0315	0,0272
10% HCl	12,86	0,0412	0,0359
NaOH conc.	1,26	0,0318	0,0314
NaOH 5%	2,81	0,0320	0,0311
Na_2CO_3 10%	-1,68	0,0417	0,0424
H_2O destilada	0,63	0,0316	0,0314

Discussions

Micrographs of previous papers had presented the same microstructure morphology of the obtained material [8]. Anorthite crystals ($CaAl_2Si_2O_8$) had been formed from the glass, with the presence of $KAlSi_3O_8$ e TiO_2 crystals too.

The acid attack low resistance of the material is attributed to the $CaAl_2Si_2O$ crystals, as cited in literature [1]. The loss of mass was more accented for the samples that had the superficial layer removed, which indicate a particular difference between superficial layer and the volume [6].

The molding glasses versatility allied with the good abrasion resistance and the high temperatures resistance of the Anorthite phase, according to literature [1, 10], suggests that glass ceramics riches in this crystal constitute an differentiated intelligent material being able, inclusively, to be used in environments that offer work conditions under upper-class attrition and/or temperatures above of the environment temperature.

Conclusions

Taking as an example the glass ceramic material of this paper, it can be affirmed that is possible to attain a material with properties that characterize "intelligent materials" from glass crystallization.

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