

# Review of biocompatibility behavior of bioglass as promising material in biomedical industry

## Revisión del comportamiento biocompatible de biovidrio como material promisorio en la industria biomédica

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### Abstract

This article aims to show how the bioglass has been important in the development of biomedical sciences from its applicability and versatility in its multiple uses. This review aims to show how through interdisciplinary research it has designed different processes for obtaining materials from bioactive glasses. First, we will discuss the importance of development of biomedical devices focused in bioglass as precursor material and its impact on society today. Subsequently, relevance and importance of the surface modification as mechanism to improve working.

Conditions and functionality of biomedical devices the collection of bioglass coatings by different methods will be discussed. Finally, the authors propose vacuum evaporation method as a possible technique for to obtaining bioglass coatings, as an alternative for the difficulties encountered by other deposition methods.

**Keywords:** Bioglass; Biocompatibility; Biomaterials; Ceramic materials; Bioactivity.

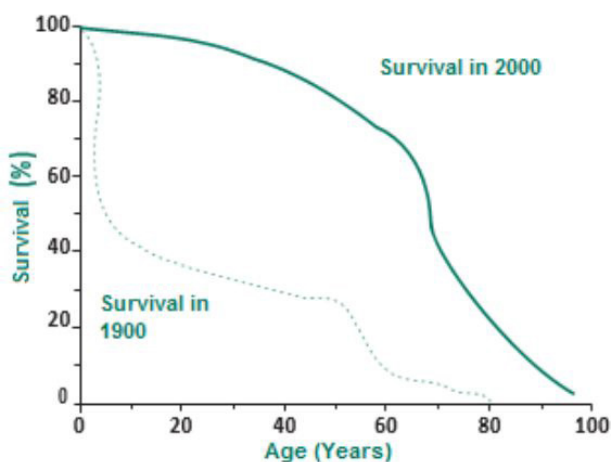
### Introduction

The term biomaterial was initially taken to describe a material that could be utilized to replace sick or damaged tissues in a living, (Williams, 1987); however the inter-behavioral work has made the definition wider; in this sense, the biomaterials can be considered as products suitable to be utilized in human beings with the purpose of treating or relieving deceases, injuries or well for substitution or modification of its anatomy or of a physiological (Enderle, 2005; Souto *et al.*, 2003); this is why there have been developed so many materials that can supply the physical, chemical and biological requirements for a perfect functioning that guarantee the best result (Geringer *et al.*, 2013; García *et al.*, 2004).

In the field of the biomaterials a primal classification can be done by the nature of the material: Biometals, biopolymers, ceramics; although their differences, their main property is that they don't produce toxic wastes in the interaction with the organism.(Liu *et al.*, 2010; Lang *et al.*, 2008); however in the case of the metals is possible that they present problems such as corrosion, fatigue, wear and combinations; in the case of polymers the chemical degradation in applications of prolonged use and the wear under mechanical conditions are high impact factors at the selection and device design time with these materials. (Vijayalakshmi *et al.*, 2012; Tiwari *et al.*, 2007).

The ceramic materials have been widely research for the use of implantable devices and the development of physiologic functions (Guo *et al.*, 2004; Lee *et al.*, 2010) Due to the high textural alike of the tissue with the conventional ceramic materials, the bioceramic have been deeply studied in oral surgery, orthopedic surgery medium ear surgery and in the coating of dental implants and joints since these materials can be classified as bioinert, bioactives and resorbable, depending in their interaction with the tissue or contact method. (Castleman *et al.*, 1976).

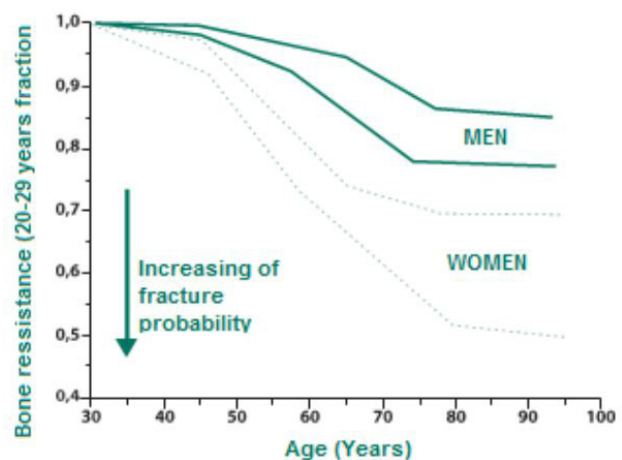
Whatever the biomedical application or the collection of the bioglass, its research has generated high impact in society, increasing life span; actually, it has been studied the increasing of the life span in US and UE during the XX century (National Research Council, 1997; FDA, 1995). La Figure 1 represents a comparison in the increasing of life span between US and UE during the XX century.



**Figure 1.** Increasing in life span in US and EU during the XX century.  
**Source:** National Research Council, 1997.

## Bioglass as application in the replacement of bone tissue

The traumas and diseases associated to ageing, produce decreasing in the properties of bone tissue; this is makes necessary the use of biomedic materials to replace and repair said tissues (Enderle, 2005). In the case of bone tissue, the decreasing in the bone density starting at the 30 years of age can be translated in a reduction of its mechanical resistance up to 40%, however in women could be even higher. The Figure 2 shows the effect of the age in the mechanical resistance of the bone and the fracture. (Hench, 1991).



**Figure 2.** Effect of age in the mechanical resistance of the bone  
**Source:** Hench, 1991.

The glasses are ceramic materials produced from the fusion and cooling of a rigid condition without crystallization of inorganic materials at high temperatures, this is why these materials are constituted by close range random structures (De aza *et al.*, 2013; Hench *et al.*, 2013). The bioactive materials are those that are in the capacity to establish a strong link with the bone tissue; wake a great interest with sights in its application in the biomedic industry in implantation for substitution and reparation of bone tissue (Ng, *et al.*, 2005; Donald *et al.*, 2011).

These bioactive materials have been researched as scaffolds that allow the formation of bone tissue and through a link between the bone and the scaffold in hydroxyapatite, the main formative bone mineral (Hench *et al.*, 1984; Hench, 1998). Other studies have demonstrated that these osteoconductive and osteoinductive also are companied with a good mechanical behavior that surpasses the one reached by the scaffolds of the polymeric type (Fu *et al.*, 2007a; Lockyer *et al.*, 1995). Some

researchers have done studies in glasses in form of particles and fibers to obtain proximal results and the formation of pre-osteoblastic cells that show a growth in these cells and a proportional increase of the bioactive character as function of the bioglass in. (Brown *et al.*, 2007; Fu *et al.*, 2007b).

Biocompatibility and biomimetic osteogenesis scaffolds, collagenous phosphatidylserine with applications in tissue engineering, though *in-vivo* and *in-vitro* it was revealed that said scaffolds had a good radiographic and histologic answer evidencing an excellent behavior osteogenic and osteoconductive. (Xu *et al.*, 2011).

Another found use for this biocompatible ceramic inside in its wide specter of possible utilities have been the using as with the ones we have obtained changes in different properties in some materials that have been reinforced with bioglass. Habide *et al.* (2009) studied the effect of the addition of bioactive glass in bioceramics composed of yttria and zirconia; in this research it has been determined that there was a decrease in the cytotoxicity, but also in the hardness and resistance to the fracture. A study was done in addition of the 45S5 bioglass to hydroxyapatite with the goal to improve the proliferation and transformation apatite of the osteoblasts; in this project two compounds were synthesized and different studies at cellular level were done to measure the influence of the glass in the matrix's structure of hydroxyapatite obtaining a substantial improve in the properties of biocompatibility on other hand the compound in relation to the behavior of the hydroxyapatite..(Demirkiran *et al.*, 2010; Shirtliff *et al.*, 2013).

With the goal to know the mechanical properties of the hydroxyapatite Guo *et al.* (2004), described a process in which the mechanical properties of the hydroxyapatite compounds with AISI 316L steel fibers and an analogous compound of 45S5 bioglass with fibers of the same steel, the authors didn't find better substantial improvements between the one and the other material apart from a slight increase in the bending resistance from the bioglass compound. (Altomare *et al.*, 2011)

### **Bioglass applications in the field of coverage**

A covering is a laid material on top of another that acts as a base (substrate) and its function is to improve the properties of said base, with the use of covering chemical and physical properties can be modified, such as superficial properties, tribological, electrochemical

and biocompatibility, in this last branch are presented the branches like osseointegration, cellular proliferation, among other (Ratner *et al.*, 2003).

For the majority of the clinical appliances is required to withstand charges; taking in account this principle metallic implants are used with different metallic alloys. Although it presents high mechanic resistance, it also present difficulties such as the value difference of the elastic module between the alloy and the bone, corrosion due to body fluids and the impossibility to regenerate bone in a natural manner due to the formation of a fibrous capsule in the interface metal bone product of the organism before the metal (Vossen, 1980).

The surficial modifications are divided in two categories; the first one is the chemical or physical alteration of the atoms, compounds or molecules in the existing surface (treatments, mechanical abrasion, chemical modification), and the second one is the covering of an existing coverage with a material of different nature; in this branch can be counted with the stool of thin films, the use of grafts and the use of ticker coverings. (Abella, 2003). The grown films about the substrate can modify the mechanical and functional properties of the material, that's why the thickness must be taken in account, the very thick coverings are victims of delamination (Abe *et al.*, 1990).

Due to that the superficial characteristics of an implant are very important during the first stages of the biological response just like are decisive in relation to the course of posterior reactions and the final cell/tissues in the interface (Spencer *et al.*, 1998). The superficial modification of the orthopedic devices and implantable has been developed with the goal to grant and potentiate on or various answer properties; the Chart 1 shows the type of modifications in function of the place and the device. (Vörös *et al.*, 2001).

The bioglasses have been widely studied in the area of coverings, with the goal to improve the bioactivity conditions in the substrate, like every bioactive material in contact with the bone is characterized by a modification in the surface, in function of the contact time with the physiological fluid, that occurs after the implant, (Hench, 2005); for such reason, it has been evidence a marked tendency to develop superficial modifications in implants, due to that there are other materials that could interact way better with proteins and cells in a more efficient way than the prosthesis materials with conventional surface concepts.

**Chart 1.** Properties that characterize the surface of an implant

<b>Property</b>	<b>Description</b>
Chemical composition	Atomic composition and chemical state of the elements
Structure and flaws	crystallinity, inclusive slots and grain limits
Morphology	3D and 2D from of the surficial details
Texture	Specific area
Rigor	Porosity
Superficial energy	Wettability, absorption, superficial energy
Electric	Surface potential
Mechanic	Elasticity, plasticity, tension residual

**Source:** (Vörös *et al.*, 2001).

The bioglasses are seen from the point of view of osteogenesis as a bioactive osteoproducer, that is to say they stimulate the growth of new bone even if far of the bone implant interface (Jones, 2005). Different authors suggest that the increase of osseous cells is dependent to the morphologic characteristics of the surface of the surface of the materials and its chemical interaction (Liu *et al.*, 2010; Lamers *et al.*, 2010).

Taking in account the bioinert character of the metallic alloys, the bioactive glasses besides from developing the direct link with the tissue it allows the application of support in high stiffness., (Hench *et al.*, 1996), although there are other important factors like the metal protection against corrosion through the physiological method in contact of the corrosion products, finally optimize the fixation of the implants through the better tension distribution in the interface implant-bone. (Gross *et al.*, 1988).

Researchers have obtained glass covering through different methods that go from the electrochemical practices to coverings achieved through thermic injection, oxyacetylene combustion, according to studies about the influence of the deposition parameters in the porosity and adherence of glass coverings by this technique. (Correa *et al.*, 2013).

The dusts sintering and bioglass/Al<sub>2</sub>O<sub>3</sub> coverage is possible but the existence of aluminum oxide harms the bioactive behavior of the glass because it doesn't allow Si-OH link necessary for the formation of apatites (Sierra *et al.*, 2015; Bravo *et al.*, 2014), though other studies suggest the opposite, bioglass-silica obtained through the method sun-gel, upon the AISI 316L steel substrate, it was found out that during the exposure of the same simulated body fluids, a film is composed of amorphous apatite,

hydroxyapatite and CaSiO<sub>3</sub>.(Pourhashem and Afshar, 2014).

In done studies, thin bioglass films were obtained over titanium substrate through the sedimentation with pulsed laser, in this study the reactivity and ionic exchange between the settled layer and the simulated body fluids solution (SBF) was examined (Berbecaru *et al.*, 2009).

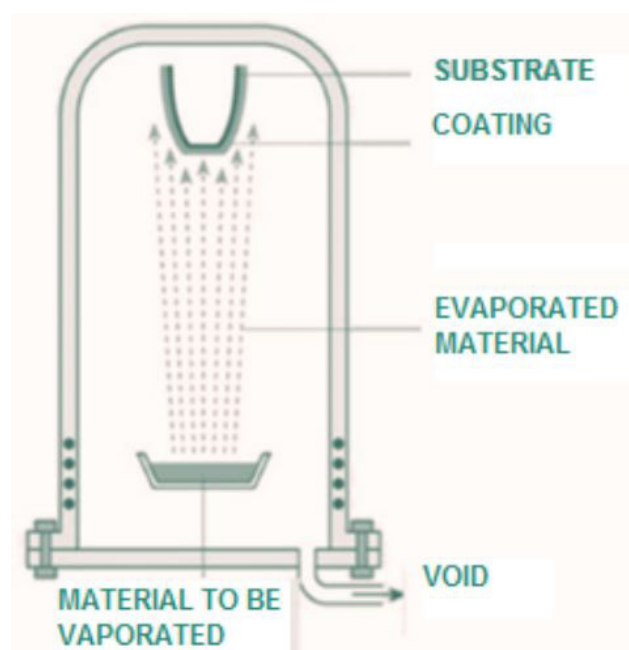
New glass families in other compositional elements have been obtained as bioactive coverage through the dip coating technique (Lopez-Esteban *et al.*, 2003; Gómez-Vega *et al.*, 1999), these coatings showed to be promising materials for the application in orthopedic implants.

### **PVD application with evaporation to the vacuum as possible collection method of bioglass layers over metallic substrates**

Deposition techniques as flame spray, thermal spraying immersion and the aforementioned can preset problems associated with the residual tensions generated by the difference in the coefficients of thermal expansion generated between the glass and the substrate, (Gómez-Vega *et al.*, 1999) on the other hand, in some of these techniques due to the high reactivity is probable the bubble formation and fragile stages in the interface, can bring adhesion and fissure issues (Andrews,1961). The PVD deposition has had great reception in the superficial modification due to the purity of the coatings, the possibility to cover complex geometric pieces (Wasa *et al.*, 2005). The physical deposition in the steam stage also allows the technological transfer to the industry, proof of this are the decorative and semiconductors coatings, this technique characterizes itself for producing films with good adherence to the substrate and a density near to the

substrate's (Surmenev, 2012). Around the world authors have proposed different research revolving around the structural, chemical and biological structures of the bioactive glass coatings, although the information is few and is rather weak. (Tang *et al.*, 2006).

The PVD technique with vacuum evaporation has been used in the obtention of commercial coatings; it basically consists in evaporating a material in high vacuum conditions (in the range of  $10^{-5}$  to  $10^{-9}$  Torr) thus producing a steam flux that deposits and condensates in the substrate surface (Mattox, 1998). The figure 3 shows the main scheme of this technic's functioning.



**Figure 3.** Scheme of the operative process in the process of vacuum evaporation.  
**Source:** Mattox, 1998.

Studies showed that the coatings obtained by this technique well have a crystallographic orientation it depends in the ions flux, that at the same time affect properties like roughness, corrosion resistance by the current residual efforts and mechanical properties (Ceh *et al.*, 2002; Sue *et al.*, 1989). Said this, the study of the thin glass bioactive film layers formation through vacuum evaporation, could be seen as a new opportunity to obtain coatings with better features with the simplified steam stage deposition.

Starting from the described in the current work, it's evident the need to perform studies in the bioactive glass coatings obtained by evaporation as deposition method in the steam stage, because it corresponds to an innovative method of fabricating biocompatible coatings and can generate a new wide study field in the wide specter of application possibilities if these ceramic materials. Besides, taking in account the biological point of view of ceramic glasses and the increasing need to improve the processes and collection methods of biocompatible materials more body-friendly and that improve the recovering condition of the patients. Results in great interest to the possibility to obtain and characterize bioactive glass coverings, collected through the PVD method about used alloys by the biomechanics industry to improve the time and quality of patient recovering.

## Conclusions

Without doubts, the biomaterials design, biomedic devices and the superficial analysis have achieved a great positive impact in the increasing of life span, these has influenced in the development of new techniques and new knowledge areas. On other hand, the bioglass has been highly used in the field of biomaterials due to its bioactive feature and its capacity to encourage the osteogenesis.

Part of the great advance in the biomedic industry is that in what refers to the development of implantable devices, it corresponds to the advance in analysis and superficial characterization of the base materials and the application of deposition techniques of better biocompatible behaved materials. The evaporation technique can be seen as a new opportunity inside the biomaterials field to generate more knowledge and higher advance in the PVD deposition.

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