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# BIOACTIVE GLASSES – HISTORY, SYNTHESIS & APPLICATION

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***Abstract***

*Bioactive glasses were researched and developed from 1969 until now on. Many studies have been published on the physical and chemical properties and applications of these biomaterials as artificial materials in tooth filling, bone grafting, or used as additives in toothpaste or in cosmetics. This work involves the essential scientific presentations about the discovery, synthesis, and application of these biomaterials.*

***Keywords:*** *bioactive glass, bioactivity, hydroxyapatite, artificial bone, implant.*

## INTRODUCTION

Biomaterial is a natural or man-made material, consisting of all or part of a living structure or a medical device, which can perform or replace a human life function [1-2]. Today, the use of biomaterials has become familiar in human life. Some examples of biomaterials can be listed such as artificial heart valve, artificial blood vessel, leather and artificial sewing thread, screw, bone brace, prosthetic appliance, dentures, bone filler in orthopedic surgery, bone transplantation. Biomaterials can be classified into two main groups: bioactive materials and bio-inert materials [2]. Bioactive materials are materials that, when implanted in the human body, will occur chemical interactions between materials and the human humoral environment; meanwhile, bio-inert materials do not have any interactions.

In the group of bioactive materials, bioactive glasses have been studied and applied as artificial bone materials used as ingredients in cement fillings, culturing powder and bone graft in orthopedic surgery to restore and repair broken bones, diseased bones [2-3].

In terms of structure, bioactive glass materials are silicate systems based on the silica $SiO_2$ network in which the oxides such as $SiO_2$, $Na_2O$, $CaO$, $P_2O_5$, $B_2O_3$, $MgO$, $ZnO$ do not exist separately but are linked together to form into an inorganic polymer that does not recirculate. In other words, bioactive glasses are glass systems that have three dimensions (3D) silica networks in the form of an amorphous structure [4].

This work provides readers with information about the discovery of bioactive glasses, the synthesis and application of these biomaterials.

## DISCOVERY OF BIOACTIVE GLASS AND THEIR BIOACTIVITY

Professor L.L. Hench was the first to discover a bioactive glass material in 1969 [3]. The idea of the material came to L.L. Hench from the need for bone transplantation for soldiers who returned from the Vietnam War. The soldiers lost part of their limbs or had their limbs amputated due to the body's refusal to accept bone graft made from metal and plastic. Professor L.L. Hench realized that a new material is needed to form a living bond with the bone tissue in the human body. L.L. Hench's glass is designated as 45S5 with weight (%) content of $45SiO_2$ - $24.5CaO$ - $24.5Na_2O$ - $6P_2O_5$ and the commercial name as Bioglass®. Through testing, L.L. Hench

has discovered an important property of this glass material, called ''bioactivity''. The bioactivity of bioactive glass materials is the ability to form a new layer of hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ (HA) on the surface when the material is implanted at the defective bone sites, broken bones in the human body. The HA mineral is similar to the inorganic component of human bone, so it is the bridge connecting the artificial graft made of glass material and natural bone, through which the broken bones, defective bones are repaired and filled [3-4].

After the invention of L.L. Hench, many bioactive glass systems with different components are studied, synthesized and applied for ''in vitro'' and ''in vivo''. The ''in vitro'' experiment is considered to be a fast and effective method to test the bioactivity of synthetic bioactive glass materials. This is the method developed by T. Kokubo & H. Takadama, and widely applied until now [5]. Samples of bioactive glass material were immersed in the Simulated Body Fluid (SBF) - a solution with inorganic ionic components similar to the blood of the human body. After different time periods, a layer of hydroxyapatite (HA) mineral will form on the surface of the glass material if synthetic glass systems are bioactive. The HA formed-layer can be examined by the physical-chemical analysis methods such as X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Transmitted Electron Microscopy (TEM).

A typical example of glass surface observation after ''in vitro'' experiment analyzed by SEM technique is shown in Figure 1 below [6]. The analysis showed that the formation of new layer of hydroxyapatite mineral as a function of immersing times.

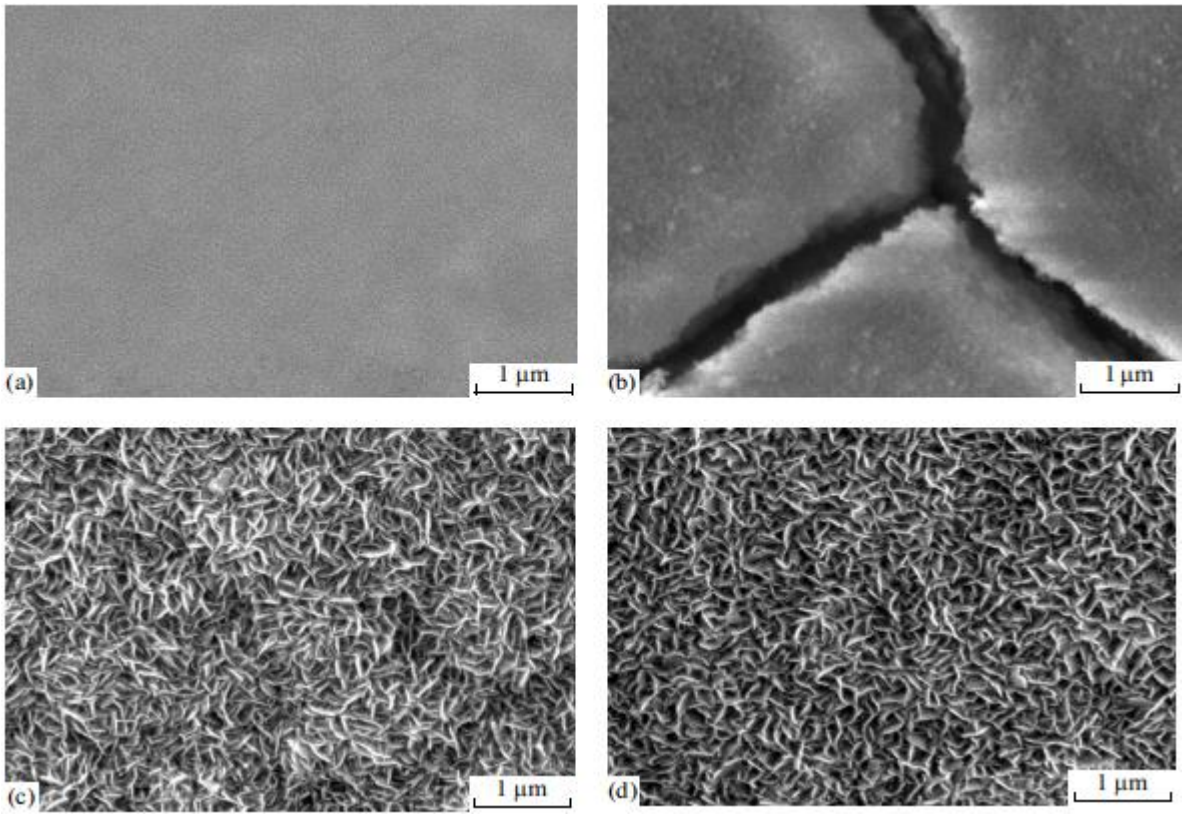


***Fig. 1.*** *SEM observations of bioactive glass synthesized by melting method before and after soaking in SBF fluid: a-initial glass, b-1 day, c-15 days, and d-30 days [6]*

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**SYNTHETIC METHOD**

There are two main methods for the synthesis of bioactive glass systems. The first method is melting the precursors at a high temperature. The second method of synthesizing the glass systems in solution is called the sol-gel method. The melting method can quickly synthesize glass systems, can synthesize a large number of products, but there are also disadvantages such as requiring a high temperature for synthesis (above 1300 °C). At high temperature, the $P_2O_5$ component is easily volatile, leading to deviation in final composition. Moreover, the resulting glass systems generally have a low specific surface area [7-8]. The sol-gel method undergoes two main steps: precursor hydrolysis to form the sol and converting sol particles into gel. Then, the gel is processed at a temperature of about 700 °C to obtain the glass systems. The sol-gel method overcomes the disadvantages of the melting method such as synthesis of materials at lower temperatures, resulting glass systems having porous structures and larger specific surface areas. On the other hand, the sol-gel method is favorable for combining bioactive glass with active organic molecules to create inorganic/organic functional composite systems with more superior properties [9-10].

Recently, we have developed a hydrothermal method to synthesize bioactive glass systems in which no acid catalysts are used [11-12]. We call it the green synthesis approach. The starting precursors were added in a hydrothermal system and heated at 150 °C for 1 day. The resulting gel was dried at the same temperature and time. After that, the obtaining dried-gel was sintered at 700 °C for 3 hours to convert into bioactive glass. The synthetic processing is presented as Figure 2.

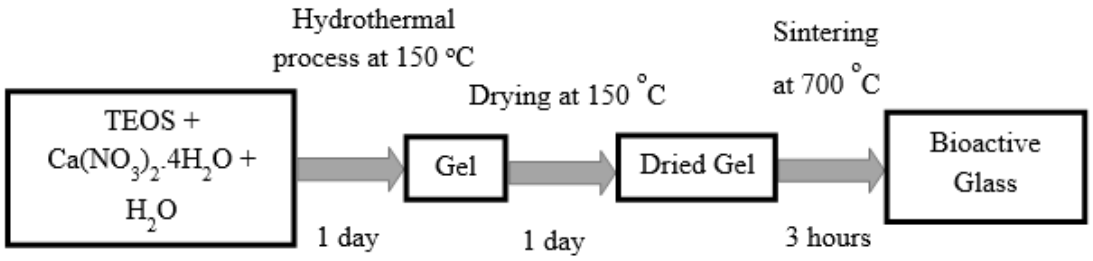


***Fig. 2.*** *Diagram of glass synthesis by hydrothermal method*

**APPLICATION**

There are many glass systems that have been studied and synthesized such as 45S5, 46S6, 58S, S53P4, 70S30C, 50S50C, 13-93…systems [13-14]. Some of them have been commercialized and applied in practice. The bioactive glass with the commercial name of Douek-Med, is the special glass used for repairing the middle ear bone. The glasses named as Perioglas and Novabone are specifically intended to replace or connect the jaw bone; orbital bone. The GlassBone is used to replace the tooth root bone. The BonAlive is designated to replace spine defect, bone defect tune, skull bone due to trauma. Besides being used as artificial bone material, powdered glass with the commercial name of Dermfactor is a typical glass, that has healing properties for soft-tissue injuries caused by surgery technique, burns, ulcers. Due to the bioactivity property, some toothpastes such as BioMin, Sensodyne contain the bioactive glass which act as intelligent agent to repair the bone defects on the tooth-surface. Recently, powdered glass is also added to cosmetics because the ions released from glass network have the ability to enhance the cell regeneration on skin, on nails. Figure 3 presents some typical images of glass application.

***Fig. 3.*** *Some application of bioactive glasses*

## CONCLUSION

This scientific paper presents the discovery, synthesis, and application of bioactive glasses which are the biomaterials used as artificial biomaterials for tooth filling, bone grafting, additive agents in toothpaste or in cosmetics. The development history of glass materials was started by Hench's research in 1969. Next is a presentation of the main methods for the synthesis of bioactive glass systems. Finally, the important applications of glass materials are presented and presented to the readers.

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