Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

The 7th International Conference on Computational Mechanics and Virtual Engineering
COMEC 2017
Brasov, ROMANIA, 16-17 November 2017

BIOCOMPOSITES: A REVIEW

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Abstract : *By definition, the biocomposite is a specific composite or a medical composite that is used exclusively in the medical or pharmaceutical field. Biocomposites are classified according to two main criteria: the form of the reinforcement material; biological compatibility. Their physical structure consists of biomaterials: metallic, ceramic; polymer; natural. Biocomposites have three main features: mechanical / structural characteristics; 2. physical characteristics; 3. chemical / biological characteristics*
Keywords : *Biocomposite, Biomaterial, Characteristics, Biocompatibility*

1. INTRODUCTION

By biocomposite is meant a specific composite material or medical composite which is limited to biomedical use. In this situation, biocomposite constituents are not necessarily biomass-based or biodegradable, but they must be biocompatible’’ [2], [1]. A similar definition is presented in the form: Biocomposites are nontoxic composite materials (medical composites) capable of harmoniously interacting with the human body in vivo and ideally contain one or more components that stimulate the healing and absorption of the implant 'and' for biocomposites, biological compatibility seems to be more important than any other type of compatibility". [1].
Biocomposites are classified according to the shape and arrangement of the reinforcement material (Fig.1) and respectively according to the biodegradability characteristic in the body.

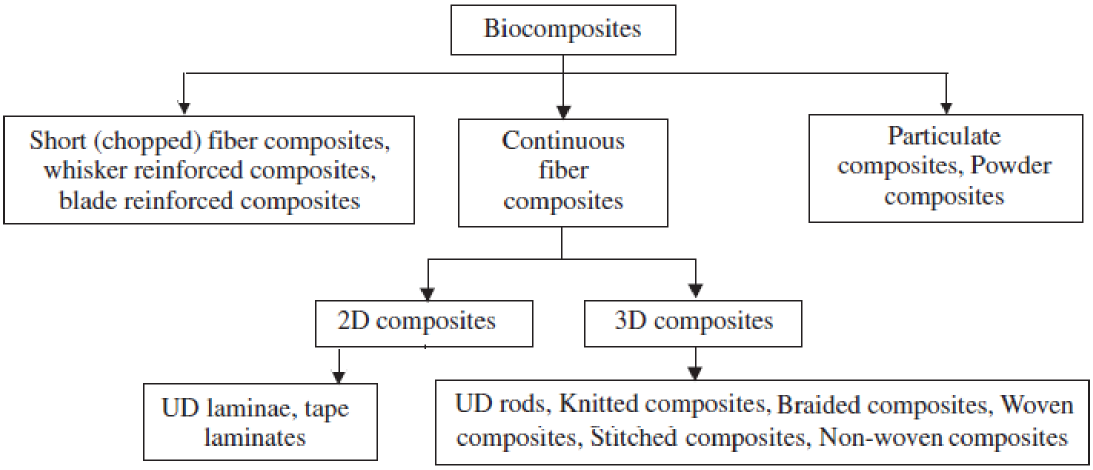

Figure 1: Classification of biocomposites based on reinforcement form, after [10]

The constituents of the biocomposite are made up of metallic, bioceramic, biopolymeric and natural biomaterials. As a result, the following categories of biocomposites are met [6], [7]: 1. metal matrix biocomposites; 2. ceramic matrix biocomposites; 3. biocomposites with polymeric matrix, thermoplastic or thermosetting such as epoxy resin; 4. carbon / carbon biocomposites. These biomaterials are used in the matrix or in the reinforcement material structure (Tab.1).

Table: 1 Constituents of medical biocomposites, after [3], [4], [5]

Matrix	Fibers	Particles
Thermosets	***Polymers***	***Inorganic***
Epoxy	Aromatic polyamides (aramids)	Glass
Polyacrylates	UHMWPE	Alumina
Polymethacrylates	Polyesters	***Organic***
Polyesters	Polyolefina	Polyacrylate
Silicones	PTFE	Polymethacrylate
Thermoplastics	***Resorbable polymers***	
Polyolefins (PP,PE)	Polylactide, and its copolymers	
UHMWPE	with polyglyocolide	
Polycarbonate	Collagen	
Polysulfones	Silk	
Poly(ether ketones)	***Inorganic***	
Polyesters	**Carbon**	
Inorganic	Glass	
Hydroxypatite	Hydroxypatite	
Glass ceramics	Tricalcium phosphate	
Calcium carbonate ceramics		
Calcium phosphate ceramics		
Carbon		
Steel		
Titanium		
Resorbable polymers		
Polylactide, polyglycolide and their copolymers		
Polydioxanone		
Poly(hydroxyl butyrate)		
Alginate		
Chitosan		
Collagen		

2. MEDICAL REQUIREMENTS

Medical biocomposites have to meet three main characteristics: 1. mechanical / structural characteristics; 2. physical characteristics; 3. chemical / biological characteristics [10], [9], [11]. Table 2 shows the influence of these characteristics on the properties of biocomposite [12], [13], [14]:

- intrinsic properties (mainly determined by the chemical composition);
- behavior;
- surface properties;
- processing.

From the point of view of biodegradability of biocomposite, in the body there are three categories of biocomposites:

- non-resorbable biocomposites, where the matrix and reinforcement material are from non-resorbable biomaterials in the body: alumina / PMMA, bone / PMMA, CF / C, GF / PP etc. They are used in rods to hip and knee prostheses, bone plaques, external fixators etc;
- partially biodegradable biocomposites. The matrix is made of absorbable material, and the reinforcement material from non-absorbable one, CF / PGA, CF / PLA, CF / PLLA, Alumina / PLLA etc;
- fully resorbable biocomposites in which both the matrix and the reinforcement material are made of body absorbable biomaterials, PGA / PGA, PLLA / PLDLLA etc.

The characteristics of biocomposite materials are highlighted by various test methods and procedures that show [14], [8]:

- biofunctionality (biocompatibility);
- Mechanical behavior at the structure level, and/or at the fiber-matrix level;
- Thermal behavior;
- Behavior (tolerance) to damage (breakage);
- aesthetic and ecological features, etc

Table 2: Biomaterials properties different categories, after [10], [9]

The properties of biocomposite	**Characteristics**		
	Mechanical	*Physical*	*Chemical/Biological*
Intrinsic properties (mainly determined by the chemical composition)	- elasticity modulus; - Poisson ratio; - flow limit; - tensile/compression resistance	-density; - form and geometry; - color aesthetics	- elasticity modulus; - poisson ratio; - flow limit; - tensile/compression resistance
Behavior	- rigidity; - breaking strength; - fatigue resistance; - shock resistance; - wear resistance; - crack resistance	- coefficient of thermal expansion; - electrical conductivity; - refractive index	- biofunctionality; - bioinert; -bioactive; - biostability; - biodegradation behavior
Surface properties	- hardness; - shearing modulus; - shearing resistance; - bending modulus; - bending resistance	- surface topology; - texture; - roughness; - hardness - coefficient of friction	- adhesion
Processing	- reproducibility; - can be sterilized; - packaging features		

The modulus of elasticity of biocomposites is a major feature. It can be estimated, based on the blend theory, with the relations [3]:

$$E_c = E_f \cdot V_f + E_m \cdot V_m, \tag{7.1}$$

with:

$$\begin{aligned} E_c &= E \cdot c' + i \cdot E \cdot c'', \\ E_f &= E \cdot f' + i \cdot E \cdot f'', \\ E_m &= E \cdot m' + i \cdot E \cdot m'', \end{aligned} \tag{7.2}$$

where E_f and E_m represents the modulus of elasticity of the fiber *f* and the matrix *m* expressed in GPa.
At present, the use of biomedical composites is directed to the following main areas [11], [3], [5]:

- general clinical use;
- bone substitutions;
- prostheses, especially in the lower limb area. In this regard, we note increasing interest in the use of polymer matrix composites and reinforcement with carbon fibers and Kevlar.
- Figure 2 shows carbon fiber composite prostheses for transtibial amputations [10], [9]..

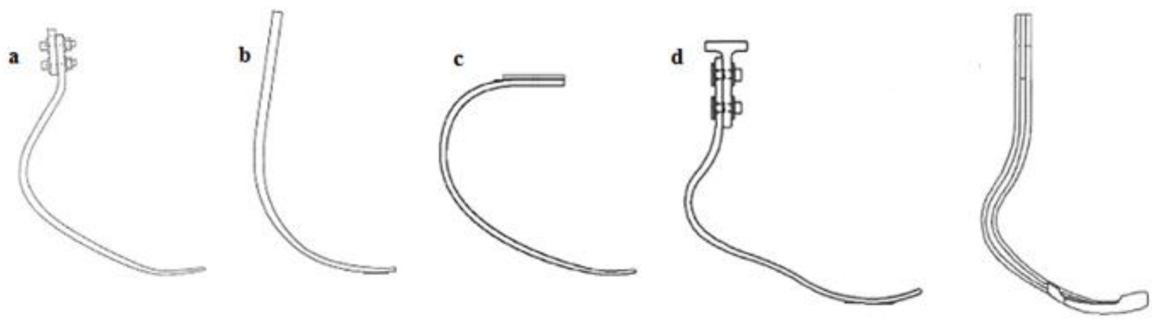

Figure 2: The different sprint foot designs: cheetah (Össur) (a); flex-sprint (Össur) (b); flex-run (Össur) (c); sprinter (Otto Back) (d); sprint (Otto Back) (e), after [16], [9]

3. CONCLUSION

Biocomposite materials are composite medical materials in which the component phases are from biomaterials: metallic; ceramics; polymer; natural. Biomaterials can be bioresorbable or non-resorbable. Biocomposites are characterized by mechanical (elasticity), chemical / biological characteristics (biofunctionality and biocompatibility, behavior (tolerance) to deterioration (breakage), thermal behavior etc.

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