Chapter

Functionality Based Design of Sustainable Bio-Composite

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Abstract

Bio-composites have diverse functional demands for many structural, electrical, electronic, and medical applications. An expansion of the composite functionality is achieved by manipulating the material and design scheme. Smart selection of matrix-reinforcement combinations will lead to applications that have never even been considered. Research holds a huge potential to create a wide variety of usable materials by mixing different fillers and modifying the parameters. Apart from selecting the polymer and the filler, the engineer will have to understand the compatibility of the polymer and the filler, dispersion, and bonding behavior making the design of polymer nanocomposite a rather complex system. In this chapter, we have tried to display different functional materials development pursuit.

Keywords: bio-composite, functional design, conductive polymer, nanotube encapsulation, bioactive, biodegradable, food packaging, medical applications

1. Introduction

Biocomposite materials derived from biodegradable, renewable sources have perceived substantial attention in current times, in particular due to the amplified consciousness towards more environmentally sustainable technologies. In most of the cases bio-composites offer weight reduction, supplemented capabilities (e.g., structural, electrical, electronic, and medical) and occupational health benefits. These bio-composites have great potential for their use in electronic, automobile, packaging, insulations and construction industries with a potential to disassociate material costs from the fluctuating price of oil and energy.

2. Design with functionality approach

Addition of reinforcements to a bio-composite matrix does more than just enhance on the properties of the composite but also imparts some other "unexpected" properties that can satisfy these requirements. For example, bio-composites with conductive polymer matrices impart unique functional properties which makes them useful for medical applications. On the other hand, use of clay nanotubes as reinforcement materials not only enhances mechanical properties but also opens the way for surface topology enhancements resulting more unique applications. Moreover, smart choice of matrix-reinforcement combinations and understanding their surface interactions can result in applications never even thought about. Such as, keeping both the in-situ surface interactions and interactions with

the environment in the mind, choice of appropriate matrix-reinforcement combination can reward us with bio-degradable food packaging materials. This creates a situation where the excellent design of bio-composites provides an extension of the composite functionality. By combining the filler and manipulating the parameter space, bio-composite research holds a vast possibility to produce a wide range of functional materials with controllable properties. To illustrate functionality-based designs, a few of the bio-composites that have been formulated with functional properties are presented here.

2.1 Conductive polymer bio-composites

There is an emerging attention in the field of natural fiber fortified conductive polymer combinations in numerous aspects of technical functions. Such attention ascends from the fact that the natural fiber supported polymer matrix composites show conjoined possessions of useful insulation and elevated degree of anticipated mechanical strength that allows it to be magnificent structural provision for conductors. Such exclusive characteristics allow these composite structures to be exploited in broadened regions for instance terminals, connectors, switches, insulators, printed circuit boards, industrial and house hold plugs, panels and so on [1, 2]. Moreover, the dielectric features of materials greatly control the transformation of the electromagnetic energy toward heat [3]. At present, several textile fibers and fabrics such as cotton, nylon, lycra, polyester, viscose rayon, and wool, are being employed with technical polymers for diverse functions e.g. conductive textiles, heating appliances, electro-magnetic interference, super-capacitor, shielding and antimicrobial cloths and so on [4–6]. Nonetheless, conducting polymers with receptive to electrical stimulation are competent to bio- functions such as tissue scaffolds for the restoration or replacement of damaged or malfunctioning tissues [7]. A graphic demonstration showing the significance of designing biomimetic conducting polymer-based materials is exhibited in **Figure 1**. A continuing push to foster more bio-conforming and intrinsically ecological conductive polymer types with various functionalization techniques are evolved for different possible applications. Optimization of various properties (e.g., conductivity, roughness, porosity, hydrophobicity and degradability) in combination with the attachment of biological molecules have made the conductive polymers as a promising candidate

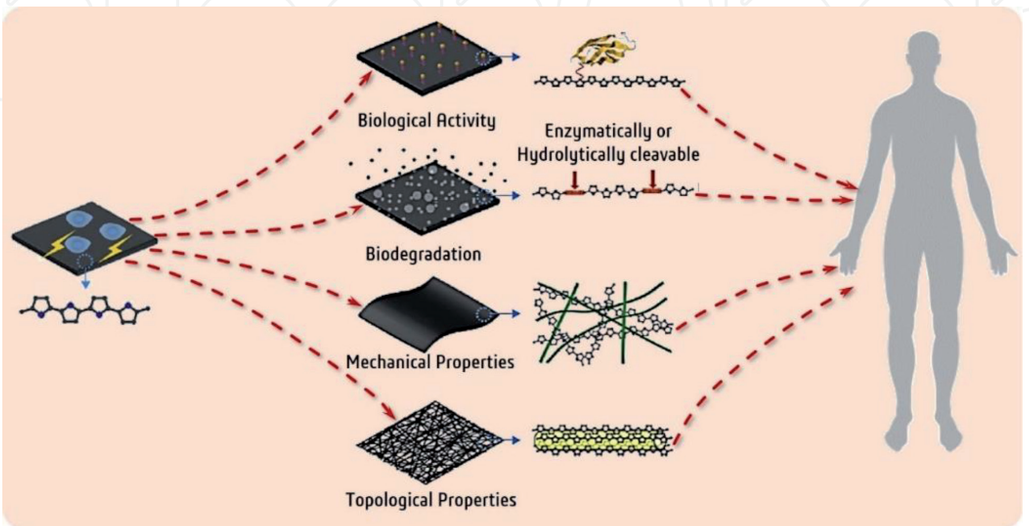

Figure 1.
Schematic illustration of the critical considered aspects for designing biomimetic conducting polymer-based materials. Redrawn from [7].

for biomedical applications. This binding of organic molecules can be conducted via four key synthetic ways [8] (**Figure 2**). First process is adsorption where a solution of functionalizing chemical is put together with the synthesized polymer. The organic molecules are attached to the polymer structure due to the stable contacts with ionic interaction [9]. Secondly, engrossing the functional molecules within the polymer matrix. The entrapment is usually carried out by combining the matrix monomer and functionalizing chemical agent with the polymerization reaction afterwards [10]. Thirdly, by cementing the biomolecules to the polymer matrix with covalent bonding. In this case, functionalization of the polymer is more stable and long-lasting [8]. Lastly by doping practice with a wide variety of charged molecules for inducing the polymers to conductive character [8, 11]. The obvious benefit of conductive polymers is their immense flexibility in terms of dopant selection for proper functionalization to suit a particular usage [12]. Therefore, the fundamental understanding of these dielectric properties is essential for various industrial applications.

Conductive polymers have more extensive favorable circumstances over other electro-active biomaterials (for example electrets, piezoelectric and photovoltaic materials) according to electrical perspective [13]. They have astounding authority over electrical stimulus, have a high conductivity to weight ratio, can have generally excellent electrical just as optical properties, and can likewise add to making biodegradable, permeable, and biocompatible items [14–17]. Their physical, synthetic, and electrical properties can be custom fitted for providing explicit necessities of their applications and viewed as one of their exceptional focal points. This can be possible by fusing antibodies, proteins and other organic moieties [14, 16, 18]. In addition, such helpful properties of conductive polymers can be controlled, and changed even after combination through incitement (for example using various methods like electricity, light, pH and so forth.) [19–21].

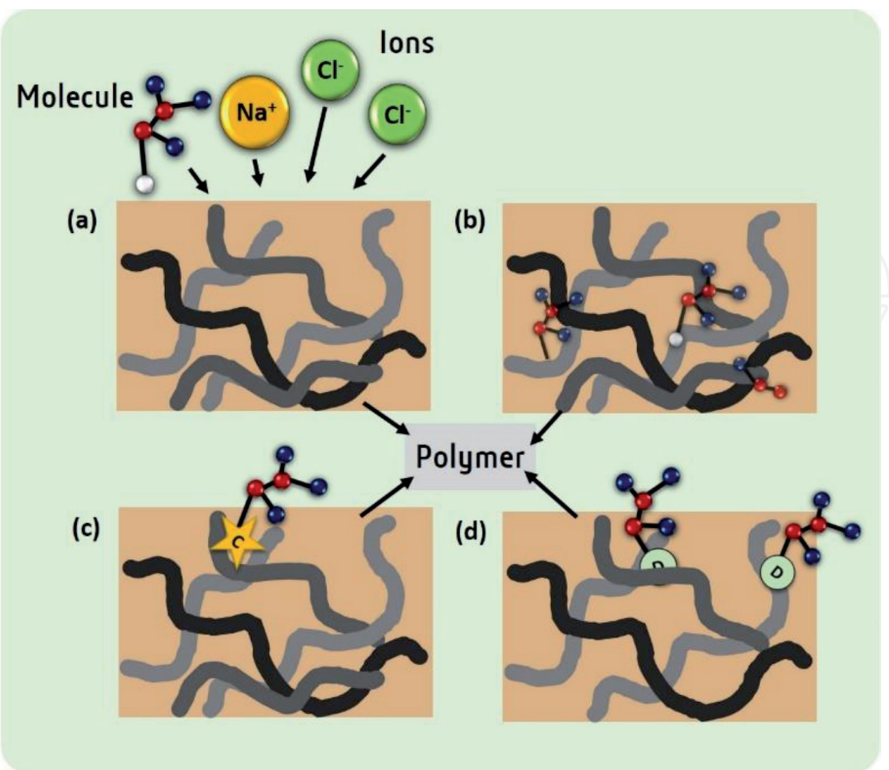

Figure 2.
Methods of functionalizing conductive polymers: (a) physical absorption, (b) entrapping, (c) covalent bonding and (d) exploiting the doping mechanism.

Recently, their unexpected applications in functional papers just as packaging industries have drawn exceptional consideration. A few investigations affirmed critical need of utilizing such conductive polymers in electrical applications. Coated paper with conducting properties can be utilized to produce anti-static and electromagnetic shielding papers, anti-bacterial papers, novel wall coverings and electrical resistive heating papers [22–24]. Johnston's group designed conducing paper using natural strands and conductive polymers, where unbleached bagasse as well as rice straw filaments were injected into polyaniline (PANi). Results demonstrated that increased conductivity was achieved with the increase of PANi in the composite [22]. Youssef et al. also architectured a composite system based on unbleached cellulosic bagasse or rice straw fibers and PANi as conducting polymer by means of emulsion polymerization. In this context, PANi was formulated with in situ polymerization via oxidative reaction with help of ammonium persulfate accompanied with a specific quantity of emulsifier n-dodecylbenzenesulfonic acid (DBSA) and dopant HCl. DBSA was used as emulsifier to catalyze the polymerization reaction of aniline via cation-radical mechanism in the presence of unbleached pulp fibers and also to increase the electrical conductivity of the formed PANi/pulp fiber composites.

In addition, Pramila Devi's group have studied the cure characteristics, thermal and microwave properties, DC conductivity, and mechanical properties of both natural rubber (NR)/polypyrrole and natural rubber/polypyrrole/polypyrrole-coated short nylon fiber composite. The composites were designed by a two-step process: in situ polymerization in NR latex followed by compounding in a two-roll mill. It was noted that the natural rubber/polypyrrole composite's DC conductivity was only improved at very high polypyrrole load and a maximum conductivity of 8.3×10^{-4} S/cm was reached at loading time of 100 phr [25].

In addition to this, Jabbour's group developed conductive papers of graphite particles (GPs)/ carbon fibers (CFs)/cellulose fibers (FBs) composites with low cost of production, good mechanical properties, and tunable electrical conductivity. Flexible GP/FB, CF/FB and GP/CF/FB composite papers with tunable conductivity and good mechanical properties were obtained by means of a papermaking production process. It was perceived that ultraviolet absorbance in UV–vis spectroscopy amplified with adding Carboxymethyl cellulose [26].

In addition, effective current carrying passages were established across agglomerates or scattered nano-fillers [27]. It was also determined that resistivity varied drastically with the distribution of carbon nanofiber into polycarbonate regulated by sonication facilities.

In addition, conductive polymer with silk fiber bunch was effectively used in the manufacturing of thread-fashioned electrodes. In this case, conductive polyelectrolyte, poly(3,4-ethylenedioxythiophene) -poly(styrene sulfonate) (PEDOT-PSS) and silk bundle were amalgamated electrochemically to produce the electrodes. It has been shown that the polymer composite has conductivity of 0.00117 S/cm. Adding glycerol to the PEDOT-PSS silk thread has allowed the conductivity to increase to 0.102 S/cm. It has also been stated that such biocompatible electrodes can be implemented in both the biomedical and health promotion sectors [28].

Different research groups investigated the dielectric properties of composites made from natural fibers with various polymers including the conductive ones. Chicken feather fiber (CFF)/Epoxy composites' electrical resistivity was found to be two to four orders of magnitudes higher than that of E-glass fiber composites. Composites with hybrid (CFF-E-glass/Epoxy) fibers were also found to typically have a low dielectric constant value [29].

On the other hand, Xia and Lu fabricated highly conductive polymers with composite silk fibroin fibers through in-situ polymerization. Polypyrrole/silk

fibroin, polyaniline/silk fibroin, and poly3,4-ethylene-dioxythiophene/silk fibroin composite fibroins were reported to exhibit differed conductivity in the range of $3.8-4.2\times10^{-1}$, $0.9-1.2\times10^{-2}$ and $4.9-5.2\times10^{-3}$ Scm^{-1}, respectively. It has also been exhibited that these composites confirmed better electrical and thermal characteristics showing possibility of uses in textile and biological areas as novel functional materials [30].

Gelfuso's group also studied the electrical resistivity of composites based on composites made from polypropylene/coconut fibers. They aimed to investigate the electrical properties of low-cost and composites that are environmentally friendly in order to enhance their implementation in industrial applications [31].

Moreover, W. Jia's group researched and analyzed the electrical conductivity of composites based on epoxy resin with polyaniline-dodecylbenzenesulfonic acid (DBSA) fillers. They used both conductive filler PANI-DBSA in powder and paste forming the composite with matrix polymer bisphenol, hydride hardener, and epoxy resin as well as accelerator. Results showed a conductivity of the order 10^{-3} at high filler content [32].

In addition, Wang's group had introduced the theory of percolation and its principles by conducting experiments to study the effect of absorption of moisture on electrical conductivity in natural plastic composites. It was confirmed that there is no observable electrical conductivity in the dry natural fiber-reinforced polymer composite. But electrical conductivity for the natural fiber composite was achieved successfully after water submersion [33].

Moreover, there was investigation of the dielectric properties of date palm fiber/epoxy composite where three relaxation processes were found. These processes were primarily relaxation in the α mode, relaxation due to diffusion of carrier charges for high temperatures above glass transition and low frequencies, and relaxation in the interfaces or Maxwell -Wagner-Sillars relaxation [34–36].

Similarly, as a biodegradable material, conductive nanocomposite using polypyrrole/dextrin was synthesized. The conductivity of the nanocomposites was investigated using four probe methods and analyzed with 2,2-diphenyl-1-picryl-hydrazyl assay (DPPH) for antioxidant activity. It was shown that by increasing the polypyrrole in the matrix, both the conductivity and antioxidant activity have improved. The nanocomposites were indicated to be considerably effective against all such bacteria studied. It was also stated that composites in the range of 30.18–74.52% degradation is biodegradable in the natural environment [37].

In addition, Pavlović's group studied the effects of electrical conductivity of electrodeposited copper powder material filled into the lignocellulose matrix. The conductivity measurements were shown to have S-shaped dependence with a percolation transition from non-conductive to conductive region. The concentration percolation threshold was reached at a copper fraction of 14.4% (v/v) volume [38].

2.2 Clay nanotube encapsulation for functional bio-composites

Halloysite clay is a natural medium of tubules formed by rolled kaolin sheets. Halloysite is alumosilicate and is chemically identical to kaolin although in some position of aluminum usually, contains a small amount of metal ions replacing it. Usually, 10–15 layers of alumosilicate roll into the cylinder and its wall packing can be monitored with 0.72 nm X-ray reflection (001) for dry halloysite [39–42]. Halloysite tube surface is silica, and its innermost surface is alumina, having a good negative zeta-potential of ca. -30 mV on the surface of the tube and + 25 mV on the innermost tube in aqueous dispersions at standard pH. The diameter of the halloysite tubes is 40-70 nm with an inner lumen diameter of 10-15 nm and a length

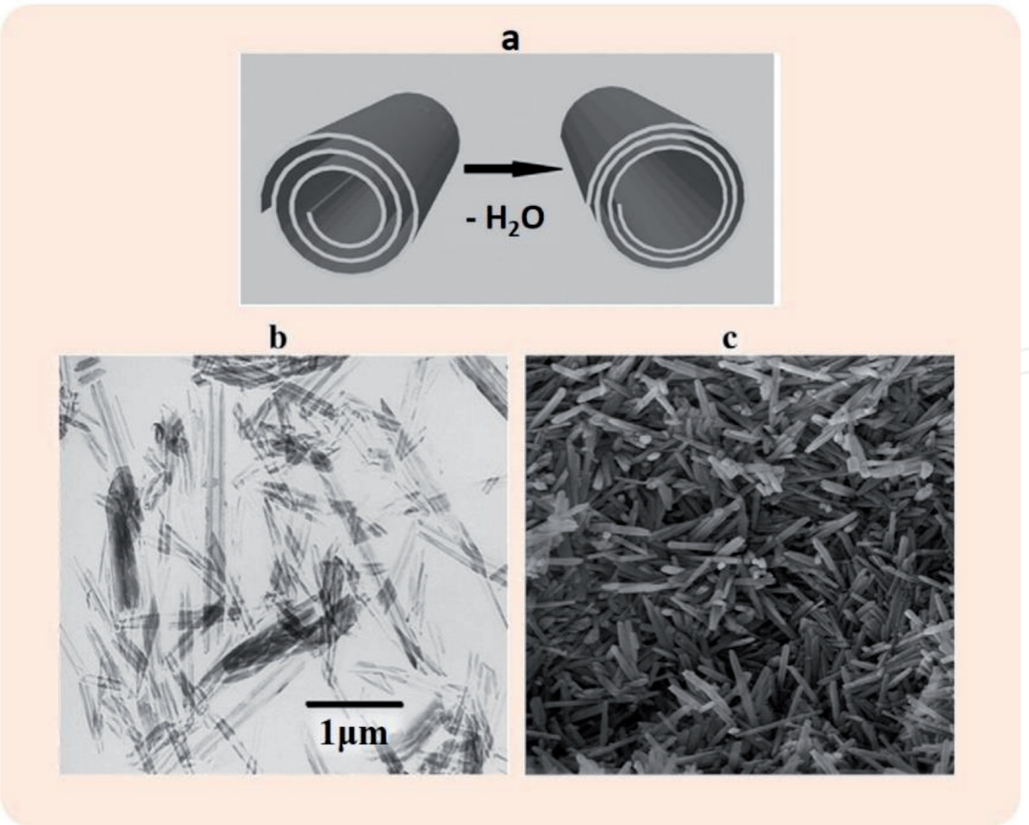

Figure 3.
Scheme of tightening halloysite tube walls during heating dehydration (a). Aqueous dispersion TEM and dry powder SEM images of halloysite from Dragon Mine, Utah, Applied Minerals Inc. (b–c). Redrawn from [43].

of 1500 ± 500 nm (**Figure 3**) [42, 44, 45]. It is interesting that sonication leads to the formation of halloysite-like tubes over a long time of kaolin aqueous dispersion, although the concentration of the substance is very low and the tube shape is rather poor [46].

In contrast with platy clays such as montmorillonite, kaolin and laponite packed in larger crystallites, halloysite has an important advantage that these nanotubes do not need exfoliation and can easily be dispersed in water or polar polymers. Halloysite-water dispersion is stable for a few hours and can be re-dispersed with quick shaking or brief sonication. It was proven that nano clay-tubes have a solid interfacial characteristic with biopolymers (e.g., polysaccharides, polyamides) and also with polar polymers (e.g., polyacrylates, epoxy, polyvinylchloride, polyethylene). Most importantly, these nanotubes can be incorporated into polymer matrix with proper dispersion. These clay-based nanotubes develop a sort of "structural framework" in bulk polymers which enhances the strength the composite. In addition, these "skeleton bones" can be filled with bioactive substances, such as loading real bones with a marrow offering additional functionality. Halloysite is biocompatible "green" material and its simple processing combined with low cost makes it a prospect for polymeric composites in nano-architecture.

The straightforward application of clay nanotubes is their use in the modification of biological devices' surface topography, such as microfluidic devices, to distinguish the circulating tumor cells from non-malignant. Halloysite nanotubes functionalized with human selectin protein have been successfully used to isolate myeloid leukemia from colon cancer cells [47]. The system was based on internal-coated 300 µm glass tubes with P or E-selectin molecules and alternated with negatively charged halloysite nanotubes with poly-L -lysine. Microscopic experiments showed that halloysite nanotubes adapted to the glass surface greatly decreased the

speed of rolling and increased the number of cells captured. Improving cell separation is caused by the increase in the total surface area following the immobilization of clay nanotubes and the resulting increase in the amount of selectin molecules responsible for the cell capture. In some other situations, the same method can be used where we can pick a suitable molecular agent (i.e., antibodies, receptors, and aptamers), and then exclusively remove the cells accordingly.

In addition, it was found that the nano clay tubes could be functionalized with sensory stimulus molecules and could be stuffed with gradually liberating molecules, enhancing the coating functionality. It was also established that enriched human dermal fibroblast addition on halloysite nanotube coatings which spread, proliferate and sustain the cellular phenotype [48].

An emerging application of halloysite nanotubes in biomaterials is their use in tissue and dental engineering scaffolds. Bottino's group investigated the manufacture of three-dimensional endodontic regenerative scaffolds based on electro spun polymers doped with halloysite nanotubes. Nanotubes were found predominantly inside the polydioxanone fibers and allowed an increase in the diameter of the fiber. Halloysite addition also impacted the mechanical properties of scaffolds. It has been shown that fibroblast cells derived from human dental pulp exhibited the usual proliferation rate, indicating high biocompatibility of polymer scaffolds doped with electro spun halloysite [49].

Liu's group have used the idea of using halloysite nanotubes as dopants in the fabrication of chitosan-based tissue engineering scaffolds. Nanocomposite halloysite-doped scaffolds demonstrated the enhanced mechanical and thermal properties of compressive power, compressive assembly, and temperature stability compared to pure chitosan scaffolds. Human fibroblasts had effectively colonized these scaffolds [50].

Another fascinating field of research is the tailoring of nanomaterials to cell surfaces that enables living microbial cells to make new functionalities. Max Planck Institute's team led by Helmuth Möhwald proposed layer-by-layer (LbL) encapsulation of biological cells and it was first demonstrated for surface modification of *Escherichia coli* bacteria and erythrocytes (red blood cells) [51, 52]. These so-called "cyborg cells" have recently become a common and promising biomaterial for composites [53–58]. For example, living cells can be anchored with surface-attached magnetic nanoparticles by means of micro-capsules that enable in vitro manipulation through a magnetic field. Halloysite nanotubes were also immobilized on microbial cell walls by LbL deposition with opposite charged polymers [54, 58].

Halloysite-coated cells can be used as adaptable patterns for the manufacture of hollow inorganic microcapsules by calcination.; On the other hand, the fascinating uses are anticipated from live cells carrying a vehicle of halloysite nanotubes packed with different ingredients in advance of the confinement process. These "nanocarrier" cells could be considered as an active composite structure that provides a load of nutrients, defensive antibodies or biocides, DNA, and enzymes for the cells. For example, the extended release of glucose loaded into halloysite nanotubes immobilized on yeast cells has been demonstrated as a proof of principle [57].

2.3 Functional bio-composites for food packaging

Packaging must ensure its fundamental function as container and food damage against physical damage, by displaying adequate mechanical properties, but also by regulating the properties of mass transfer to restrict food degradation reactions. It has been shown that lignocellulosic fibers frequently act as defects that affect both mechanical and permeability properties, degrading the former and increasing the latter. Increasing material permeability by choosing the right formulation seems to

be a valuable approach, especially for the packaging of respiring products such as fruit and vegetables.

Mechanical properties for multiple combinations of bioplastics and lignocellulose fibers were widely explored and published. Despite the value of the properties of mass transit, however, the state of information on this subject remains very weak. Clearly, a need for fundamental research turned towards full-bio-composites emerges from this context, by developing understanding and modeling methods capable of considering the entire intricacy of the systems. The present blockages are the deficiency of proper know-how on the underlying characteristics of vegetable yarns in mass transfer and the function of the interphase between the fiber and matrix. Because of the high complexity of vegetable fibers and their vulnerability to ecological surroundings (e.g., humidity, temperature), the assessment of numerical physical factors that could be additionally exploited in standards continues a challenge. Lastly, owing to the great variety, heterogeneity, and sophistication of raw constituents, we are presented with a multitude of systems and composite structures. Thus, the overall performance of complete bio-composites is very system-dependent, which makes the design of packaging materials with a reverse engineering approach difficult. To overcome this bottleneck, a few main parameters showing key effects of overall functional properties required to be established.

The key parameters evoked for regulating water vapor permeability (WVP) include fiber content and size, fiber/matrix adhesion, and matrix crystallinity and plasticization [59, 60]. In principle, assuming fibers are impermeable and well distributed in the matrix, WVP is likely to decrease due to tortuosity effect. In fact, lignocellulosic fibers are not impermeable. Thus, in most cases the composite WVP increased with the addition of fiber. Thus, the hygroscopic fiber character should be added to the list of the key parameters that govern WVP. Owing to aggregation and percolation phenomena WVP will increase. For small fibers and/or weak fiber/matrix adhesion the first one may occur. Weak adhesion of the fiber/matrix would also create voids in the polymers which could allow the transport of water molecules across these regions [61].

Shortly afterwards agglomeration, percolation will appear for higher fiber content and also, more likely, for higher fiber size. WVP will also increase due to a reduction in the crystallinity of the matrix and/or plasticization of the matrix caused by the addition of fiber.

Sonia and Dasan examined cellulose microfibers (CMF)/poly (ethylene-co-vinyl acetate) (EVA) with the amount of up to 13 wt.% of fiber. The introduction of low fiber content (up to 5 wt.%) resulted in an improvement in the barrier properties, while over this limit value, the 200 mm fibers induced an increase in oxygen permeability through the materials [62].

Valdés García's group studied a composite in a poly (b-caprolactone) matrix, based on almond skin residues. Since composites produced 10, 20, and 30 wt.% of 50 mm fibers, no information is given on low fiber content, and the oxygen transfer rate (OTR) showed the same evolution as Sonia and Dasan observed for highest fiber loads. In all cases, the introduction of fiber increased OTR, with a 5-times rise in the fiber content at 30 wt.%. On the contrary, Valdés García's group, measuring 10, 20, and 30 wt.% of almond skin residue content in PCL, observed a steady increase in WVP, although no major differences were noticed for smooth PCL and 10% composite PCL ($p > 0.05$). Such findings were due solely to fiber agglomeration that caused reduction in the homogeneity and cohesion of the matrix [62, 63].

Ludueña's group also reported a rise in WVP with content of cotton-based fibers (0,.5, and 15 wt.%) in PCL, but also assessed the effect of size of fibers. There is a competitive influence between the size of fibers and their water-related affinity, thus with the matrix. The smallest type of fiber (0.20 mm), being the most

hydrophilic form, increases WVP composites almost to the same degree as the longest fibers (59 mm), while the medium size fiber (9.1 mm), the most hydrophobic, retains WVP composite at the same level as pure PCL [60].

2.4 Functional bio-composites for medical application

The bio-composites nowadays emanate with superior biocompatibility which perform in contemporaneous manner with the body. The architecture of these biocomposite materials is designed in such a manner that some exceptional characteristics are evolved eventually.

A combination of hydroxy apatite (HA) layer with high-density polyethylene (HDPE) as a substitution material for bone has been designed and commercialized as HAPEXTM [64–70]. In these cases, the span of HA was selected between 20 to 40 volume%. Recently, bone graft consisted of demineralized bone powder between two collagen layers was fostered and exhibited cell migration both in Vitro and in vivo investigation [71]. In another development, hydroxyapatite and a PEG/PBT (polyethylene glycol and poly-butylene terephthalate) block copolymer composites were designed with enhanced chemical linkages by using hexamethylene diisocyanate as a coupling agent. They showed that the HA particles in conjunction with polymeric matrix with covalent bonding helps in achieving bone replacement [72].

A complicated bilayer coating of graphene oxide (GO) and Poly (ε-caprolactone) (PCL)/Gelatin-forsterite nanofibers on 316 L stainless steel (SS) were developed and ultimately it showed increased suitability as orthopedic implant with improved corrosion resistance of SS [73]. However, toxicity of metallic materials is still remained as a major concern for health safety. In this connection, the biocompatibility of the scaffolds was enhanced by designing new nanocomposite system with the activation of functionalized multi-walled carbon nanotubes, kappa-carrageenan, and chitosan in hydroxyapatite (MHAp) [74].

The pursuit for targeted and coordinated drug release achieved a new dimension with the manipulation of composite structure. Nanocomposites of N-isopropyl acrylamide (NIPAAm) hydrogel with magnetic nano iron oxide particles was formulated for the pulsatile drug delivery system. By alternating the high frequency magnetic field, the heat generation in nanocomposites was controlled to regulate the swelling transition of the hydrogel [75, 76]. For another instance, nanocomposites of paclitaxel were organized using poly- (D,L-lactide-co-glycolide)/montmorillonite (PLGA/MMT) nanoparticles decorated by human epidermal growth factor receptor-2 (HER2) antibody were designed for targeted chemotherapy treatment. The NP formulation exhibited a biphasic drug release with a moderate initial burst followed by a sustained release profile. The surface decoration speeded the drug release. PLGA-MMT demonstrated increased cellular uptake by CaCo-2 and HT-29 cells [77].

With the development of biocomposite technology, there are various types of dressings for different wounds were studied for better wound healing. Consequently, many therapeutic dressings with different architecture with diverse activity have materialized and employed medically, such as natural dressings, synthetic dressings, medical dressings, and tissue engineering dressing. A promising bio-nanocomposite from nanocellulose (NC), poly(vinyl pyrrolidone) (PVP), and chitosan was fabricated by solution casting method for in vitro wound dressings [78]. The solution blended PVP and chitosan mixer formed a biocompatible combination with nanocellulose particles via hydrogen bonding. The nanocomposite showed enhanced swelling, blood compatibility and antibacterial activity. Recently, Kamel's group have fabricated distinctive biocomposite membranes from banana

peel nano powder (BPnP) reinforcement in chitosan matrix. In this structure, glycerol was added as plasticizer and crosslinker to the membranes. It was found that the swelling properties of chitosan were reduced with the incorporation of BPnP. Furthermore, the results also showed that chitosan/BPnP membranes have a collaborative action with the highest activity at 10 wt% of BPnP loading [79].

3. Conclusions

In this chapter we have tried to show the usefulness of functional design concepts through variety of biocomposites design ideas and processes found in the literature. To devise a biocomposite with the expected functionality, it is indispensable to comprehend the meticulous effect of size, shape, volume fraction, orientation, distribution of filler and its compatibility with matrix. Additionally, grasping the interaction among these aspects is vital for fruitful design of biocomposites. Also cost, environmental requirements, weight, complexity and processing are the key drivers that should influence the design of biocomposites. Often, the priority of the design drivers will determine the optimum design. Consequently, this chapter has illuminated the development attained by scientists in engineering biocomposites with different functionality.

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Conflict of interest

The authors declare no conflict of interest.

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