



# Interface and bonding mechanisms of plant fibre composites: An overview



Yonghui Zhou <sup>a, b</sup>, Mizi Fan <sup>a, b, \*</sup>, Lihui Chen <sup>a</sup>

<sup>a</sup> College of Material Engineering, Fujian Agriculture and Forestry University, Fuzhou, 350002, China

<sup>b</sup> College of Engineering, Design and Physical Sciences, Brunel University London, UB8 3PH, United Kingdom

## ARTICLE INFO

### Article history:

Received 12 April 2016

Received in revised form

27 May 2016

Accepted 11 June 2016

Available online 14 June 2016

### Keywords:

Plant fibre composite

Compatibility

Modification

Bonding mechanism

Interface structure

## ABSTRACT

The development of plant fibre composite is on the rise for a wide range of applications. Probably a single most important aspect with respect to the formulation of plant fibre composites with superior mechanical performance is the optimization of the interfacial bonding between the reinforcing plant fibre and polymer matrix. While the interface plays a pivotal role in determining the mechanical properties, e.g. transferring the stress and distributing the bond, it is among the least understood components of the composite. This paper presents an overview of the compatibility between the heterogeneous constituents of plant fibre composite, various modification approaches aiming at overcoming the incompatibility and refining the interfacial adhesion of the composite, interfacial bonding mechanisms, and the assessment of interface structure and bonding. It has been found that 1) the physical and chemical incompatibility between the fibre and matrix, leading to poor dispersion, weak interfacial adhesion and ultimately inferior composite quality, could be overcome through strategical modifications; 2) interdiffusion, electrostatic adhesion, chemical reactions and mechanical interlocking are in general responsible for the interfacial bonding and adhesion of plant fibre composites; and 3) a thorough knowledge of structure-property relationship of the composite could be established by conducting a set of direct and indirect interfacial assessments. This paper finishes with some critical suggestions and future perspectives, underscoring the roles of composite material researchers and engineers for the further in-depth studies and up-scale commercialization of plant fibre composite.

© 2016 Elsevier Ltd. All rights reserved.

## Contents

1. Introduction .....	32
2. Compatibility between constituents of plant fibre composites .....	32
2.1. Compatibility between plant fibre and synthetic polymer .....	32
2.2. Compatibility between plant fibre and bioplastic polymer .....	33
3. Modification of constituents of the composite .....	34
3.1. Physical treatments .....	34
3.2. Chemical treatments .....	35
3.2.1. Alkaline treatment or mercerization .....	35
3.2.2. Acetylation treatment .....	35
3.2.3. Benzoylation treatment .....	36
3.2.4. Peroxide treatment .....	36
3.2.5. Silane treatment .....	36
3.2.6. Maleated coupling agents .....	37
4. Bonding mechanisms .....	37
5. Interface structure .....	38

\* Corresponding author. College of Material Engineering, Fujian Agriculture and Forestry University, Fuzhou, 350002, China.

E-mail address: [fanfafu@gmail.com](mailto:fanfafu@gmail.com) (M. Fan).

5.1. Morphology .....	38
5.2. Interfacial bonding capacity .....	39
5.2.1. Micromechanical measurements of interface shear capacity .....	39
5.2.2. Nanomechanical measurements of interface bonding capacity .....	41
5.2.3. Spectroscopic measurements of interface bonding capacity .....	41
6. Conclusions and future trends .....	43
References .....	43

## 1. Introduction

Plant fibre composite, as a significant branch of composite materials, has experienced a rapid expansion over the last decade. This speedy growth is largely due to the advantageous features that plant fibres provide over inorganic fillers and/or reinforcements, i.e. abundance, environmental friendliness, biodegradability, non-toxicity, low cost and density, flexibility during processing, and high tensile and flexural modulus [1–8]. Compared with wood materials, the plant fibre composite possesses better flexural and impact strength, higher moisture resistance, less shrinkage and improved weatherability. However, regardless these benchmarking characteristics, the optimization of the interfacial bonding between plant fibres and polymer matrix is one of the most indispensable procedures with respect to the optimal formulation of plant fibre composite [8].

The fibre-matrix interface is a reaction or diffusion zone in which two phases or components are physically, mechanically and/or chemically combined. Interfacial adhesion between the fibre and matrix plays a fundamental role in terms of the factors govern the mechanical characteristics of the composite [9]. The factors affecting the interfacial bonding between the fibre and matrix are the mechanical interlocking, the molecular attractive forces and the chemical bonds. However, the naturally hydrophilic plant fibres are not inherently compatible with hydrophobic polymers. In addition to the pectin and waxy substances in plant fibre acting as a barrier to interlock with nonpolar polymer matrix, the presence of plenty hydroxyl groups hinders its operative reaction with the matrix [10–13]. Therefore, the modification of the surface characteristics of plant fibre and hydrophobic polymer matrix is in particular essential in order to formulate a reasonable composite with superior interfacial bonding and effective inherent stress transfer throughout the interface. Various approaches, including physical treatments (i.e. solvent extraction, heat treatment, corona and plasma treatments), physic-chemical treatments (i.e. laser,  $\gamma$ -ray and UV bombardment) [14] and chemical modifications, have been attempted for improving the compatibility and bonding between the lignocellulosic molecules and hydrocarbon-based polymers [15–17].

The increasing environmental awareness has brought substantial research and industrial invest in another class of plant fibre composites, in which the matrices including starch, cellulose, chitin and chitosan, collagen, lignin, natural rubber, polyhydroxyalkanoate, polylactic acid (PLA) and soy-based resins, are fully biodegradable and sustainable biopolymers. Unlike synthetic polymer based composites, the similar polarities of both reinforcements and matrices impart the biodegradable composites better compatibility and interfacial adhesion [18]. However, some surface treatments of the fibres are specifically needed for the benefits of lowering down moisture sensitivity which generally leads to the dimensional instability due to the fibre swelling and hence loss of interface integrity.

This work primarily focuses on the interface and bonding

mechanisms of plant fibre composites, which is organized into four main sections, i.e. the overview of the compatibility between the constituents of composites, the modifications aiming at improving the compatibility and interfacial bonding of the composites, the physical, mechanical and chemical bonding mechanisms, and the interface structure of the composites. The paper shall serve as a fundamental basis for further research and industrialization of plant fibre composites.

## 2. Compatibility between constituents of plant fibre composites

### 2.1. Compatibility between plant fibre and synthetic polymer

The main components of plant fibre include cellulose, hemicellulose, lignin, pectin, waxes and other low-molecule substances. Cellulose is the fundamental structural component found in the form of slender rod like crystalline microfibril, aligned along the length of fibre. It is a semicrystalline polysaccharide consisting of a linear chain of hundreds to thousands of  $\beta$ -(1-4)-glycosidic bonds linked D-glucopyranose with the presence of large amount of hydroxyl groups. Hemicellulose is a lower molecular weight polysaccharide that functions as a cementing matrix between cellulose microfibrils, presented along with cellulose in almost all plant cell walls. While cellulose is crystalline, strong, and resistant to hydrolysis, hemicellulose has a random, amorphous structure with little strength. Furthermore, it is hydrophilic and can be easily hydrolysed by dilute acids and bases. Lignin is a class of complex hydrocarbon polymers (cross-linked phenol polymers) that gives rigidity to plant. It is relatively hydrophobic and aromatic in nature. Pectin is a structural heteropolysaccharide contained in the primary cell walls of plants giving the plants flexibility. Wax and water soluble substances are used to protect fibre on fibre surface [19–22]. The unique chemical structure makes the plant fibre hydrophilic in nature.

Although there are many advantages associated with the use of plant fibre as reinforcement in polymer composites, the incorporation of plant fibre in hydrophobic and non-polar polymers leads to indecent systems due to the lack of moderate compatibility and adhesion between the fibre and matrix. These would also cause some problems in the composite processing and material performance, including poor moisture resistance, inferior fire resistance, limited processing temperatures, the formation of hydrogen bonds within fibre itself, the tendency of fibre agglomerating into bundles and uneven distribution in a polar matrix during compound processing and insufficient wetting of fibre by the matrix which results in weak interfacial adhesion [19,23–25].

By this token, various physical and chemical modifications have been attempted for decreasing the hydrophilicity of plant fibre, enhancing the wettability of the fibre by polymers and also promoting the interfacial adhesion. These modification approaches are of different efficiency and mechanism for optimising the interfacial characteristics of the composite. Physical treatments, such as

Download English Version:

<https://daneshyari.com/en/article/816757>

Download Persian Version:

<https://daneshyari.com/article/816757>

[Daneshyari.com](https://daneshyari.com)