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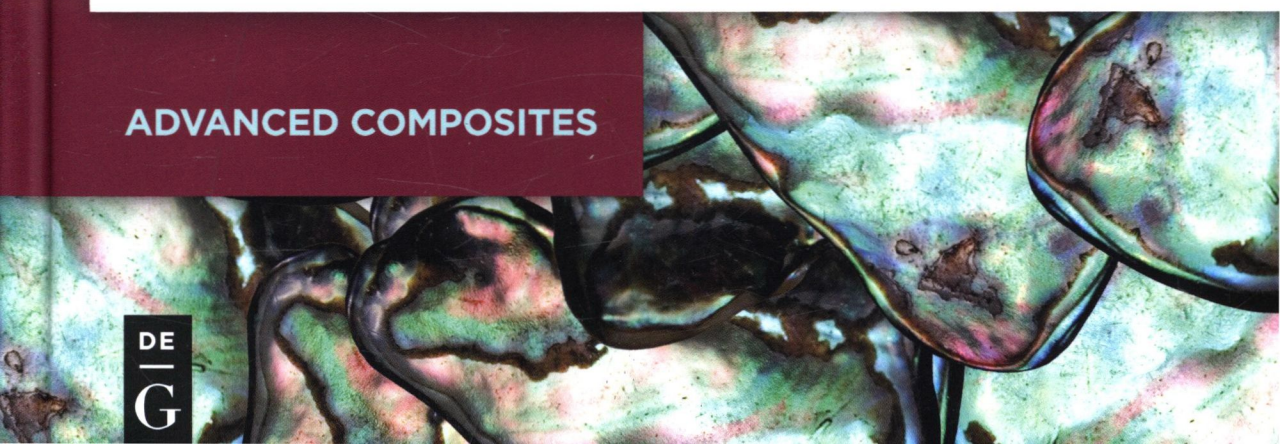

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Green composites discusses the latest results in academia and industry, since, biodegradable polymer based nanocomposites, materials from liquefied biomass, tribological aspects of natural fiber composites, thermal, mechanical and tribological behaviours of hybrid fibre reinforced friction composites, machining defects in green composites. Recent industrial efforts to minimize the environmental impact, e.g. biodegradable polymer matrix, renewable sources complete the approach.

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Green Composites

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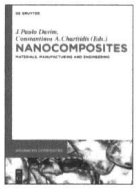

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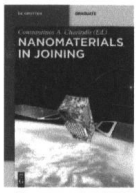

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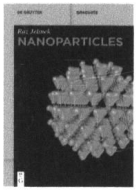

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Preface

Green composites (GCs) are "biocomposites where both matrix and reinforcement derive from renewable resources". GCs are a specific class of biocomposites, where a bio-based polymer matrix is reinforced by natural fibers. They combine plant fibers with natural resins to produce natural composite materials. Recently, GCs have undergone a great development, especially with the introduction of natural fibers from waste. In others words, in general, GCs combine natural fibers with biodegradable resins.

The current volume aims to provide recent information on green composites –materials, manufacturing and engineering – in five chapters. Chapter 1 is dedicated to green composite materials from liquefied biomass. Chapter 2 describes tribological aspects of natural fiber composites. Chapter 3 contains information on investigations on thermal, mechanical and tribological behaviors of hybrid fiber reinforced friction composites. Chapter 4 described machining defects in green composites. Finally, Chapter 5 is dedicated to GUSMRC – from concept to structural application.

The current volume can be used as a research book in a final-year undergraduate engineering course or as a topic on green composites at the postgraduate level. Also, this book can serve as a useful reference for academics, researchers, materials, mechanical and manufacturing engineers, professionals in green composites and related industries. The scientific interest of this book is evident for many important centers of research, laboratories and universities as well as industry. Therefore, it is hoped that this book will inspire and enthuse others to undertake research in this field of green composites.

The editor acknowledges De Gruyter for this opportunity and for their enthusiastic and professional support. Finally, I would like to thank all the chapter authors for their availability for this work.

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1 Green composite materials from liquefied biomass

1.1 Introduction

The energy and chemical needs of the world are continually rising on account of developing technology, industrialization and increasing population. Moreover, the reserves of fossil fuel sources are decreasing rapidly due to these facts and their regeneration cycle time being less than their usage ratio, which makes them nonrenewable resources. Thus, the usage of new and renewable resources as well as eco-friendly fuel and materials technologies have become a good alternative to solving the problems of fossil fuels and their products [1, 2].

Today, lignocellulosic biomass can be converted by thermal, biological or catalytic routes into a great variety of good quality value-added chemicals, biofuels and eco-friendly polymeric materials using a biorefinery system. A special facility called a biorefinery is equipped for the integration of biomass conversion and the production of polymeric materials. A biorefinery can be compared to a modern petroleum refinery in which multiple fuels and petroleum products are produced [3]. Biorefinery technology involves a variety of processes utilizing renewable resources such as grain, lignocellulosic or high moisture content biomass. The product or products are generated leaving no waste and by using every component for conversion in a value-added way supporting ecological sustainability [4].

Materials derived from biomass and particularly wood are among the most plentiful renewable resources on earth. Great effort has been dedicated in recent years to the exploration of techniques for transforming these materials into sustainable products for industrial and commercial usage via the biorefinery concept. One promising way of accomplishing this is through the process of liquefaction; one of the routes of thermochemical platforms of a biorefinery. In the liquefaction process, phenol or multifunctional alcohols are employed to convert wood or such lignocellulosic materials as agricultural and forest residues, waste paper, starch, and the like into low molecular mass liquid products for use in synthesizing polymers [5, 6].

Liquefaction is a promising technology among the thermochemical routes for converting biomass into liquid valuable products via complex chemical and physical reactions. The liquefied wood or wood residues has been considered as a possible bio-alternative raw material for polymer syntheses. In the liquefaction process, basically heating, various catalysts or pressure are used to separate macromolecular substances into small ones. Bio-oils, biocrudes or biopolyols obtained via liquefaction of biomass can be upgraded to gasoline- and diesel-like fuels and various polymeric materials. A significant majority of the main transportation fuels and polymeric biomaterials could

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be obtained from liquefied biomass, particularly biomass-based wastes, in the near future [7–9].

With the increasing impetus for a more extensive utilization of abundant and renewable biomass resources, liquefaction of wood and its application to green composite materials is a promising technique. Until now, liquefied biomass resins with good processability and reactivity have been successfully prepared by various methods. On the other hand, it has also been found that the liquefaction efficiency of wood, the thermoflow properties and reactivity of the resulting resins were remarkably dependent on the liquefaction conditions such as the kind of catalyst, temperature, etc. Therefore, for a more comprehensive understanding of liquefaction, and for the further development of its applications, more extensive studies on the fundamental phenomena of liquefaction should be accomplished. Thus, this chapter focuses on reviewing the studies about liquefaction of biomass for the production of engineered polymeric materials. Moreover, it explains the principles of the liquefaction methods, properties and synthesis of the liquefied biomass-based materials and pays attention to the importance of biomass-derived materials for the better understanding of the subject.

1.2 Liquefaction technique

In the liquefaction technique, biomass is dissolved in an organic solvent (e.g., phenol, ethylene glycol, glycerol, polyethylene glycol) in the presence of strong (e.g., H_2SO_4) or weak (e.g., $C_2H_2O_4$) acid or alkaline (e.g., NaOH) catalysts at moderate temperatures (80–180 °C) or at elevated temperatures (190–270 °C) without catalyst under atmospheric pressure [10–13].

Liquefaction process of biomass consists of two main steps: dissolution of raw material and filtration of resulting products for the separation of the liquefied part. Fig. 1.1 illustrates the steps of liquefaction and purification of the products. As shown in the figure, after liquefaction, the obtained black liquid is diluted with methanol and filtrated with a glass-fiber filter. The methanol-insoluble part, thus collected, is dried in an oven at 103 ± 2 °C for 24 h and weighed for the determination of the residual part and liquefaction yield. The methanol-soluble fraction is neutralized with MgO or NaOH and filtered with the glass-fiber to remove the salt produced during the neutralization. Subsequently, methanol and free phenol are removed from the methanol-soluble fraction by reduced pressure distillation at 50 °C and 180 °C, respectively. Finally, the liquefied wood resin is ground into powder as a starting material for the synthesis of several polymeric materials [14].

Biomass feedstock naturally comprise polymers such as cellulose, hemicellulose and lignin, which has plenty hydroxyl groups. These hydroxyl groups make it possible to convert liquefied biomass into biopolymers. Liquefaction is an effective way to

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