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Wood–polymer composites

Edited by Kristiina Oksman Niska
and Mohini Sain

CRC

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Wood–polymer composites

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Introduction

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In the past ten years wood–polymer composite (WPC) has become a state-of-the-art commercial product with a growing market potential in the area of building, construction, and furniture. The market share of WPC in the area of automotives is also increasing in Europe and Asia. Although WPC has a long history in Europe from the beginning of the twenty-first century, the main commercialization has happened only since the early 1990s. A major manufacturing initiative was undertaken by small and medium enterprises (SMEs) in North America in the mid-1990s that resulted in a fully commercialized decking product for the building industry. Since then, many other innovative products have been commercialized in the United States and Canada. A major market trend is now to expand the product range in construction with enhanced mechanical performance and durability. In recent years we have seen that WPC products are slowly penetrating the European market, in automotive applications, furniture, and in building products.

On the research and development front WPC has gained significant popularity as evidenced by a threefold to fourfold increase in international symposia and workshops in the past five years. Major growth in the technology is coming from equipment design, process formulation and product design.

The importance of promoting new and improved knowledge in the field of WPC has prompted us to develop this book, the content of which provides a comprehensive insight into the commercial development, technological innovation and market avenues of WPC materials and products. The book contains 15 chapters, relating to raw materials used, fundamental developments and future trends in technology and industrial products, technical challenges, standardization, and market opportunities for WPC.

Each chapter of this book has been written by authors who have a long experience of WPC and we believe that this book is an excellent handbook for industrial and academic readers to get the most recent insight on the state-of-the-art of used materials, technologies and products of WPCs. Both editors of this book are active in promoting WPCs in Europe and North America, and we think that this book will be a very useful textbook for classroom teaching.

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Raw materials for wood–polymer composites

C CLEMONS, USDA Forest Service, USA

1.1 Introduction

To understand wood–plastic composites (WPCs) adequately, we must first understand the two main constituents. Though both are polymer based, they are very different in origin, structure, and performance. Polymers are high molecular weight materials whose performance is largely determined by its molecular architecture. In WPCs, a polymer matrix forms the continuous phase surrounding the wood component. These matrix polymers are typically low-cost commodity polymers that flow easily when heated, allowing for considerable processing flexibility when wood is combined with them. These polymers tend to shrink and swell with temperature but absorb little moisture and can be effective barriers to moisture intrusion in a well-designed composite.

Wood itself contains polymers such as lignin, cellulose, and various hemicelluloses but has very different properties from the synthetic polymers with which it is most often combined. Wood is less expensive, stiffer, and stronger than these synthetic polymers, making it a useful filler or reinforcement. Though wood does not shrink and swell much with temperature, it readily absorbs moisture, which alters its properties and dimensions and can lead to biodegradation if not protected.

In this chapter, we explore the basic structure and properties of polymers and wood individually to lay a foundation for a greater understanding of the composites made from them. Basic concepts and properties are briefly summarized with emphasis on materials common to current commercial technology. Sources of further information are listed at the end of the chapter.

1.2 Polymers: structure and properties

Polymers are high molecular weight substances consisting of molecules that are, at least approximately, multiples of simple units (Carley, 1993). The word polymer comes from the Greek *poli*, which means many, and *meros*, which means parts (Osswald and Menges, 1996). Polymers can be natural (e.g. cellulose, collagen, keratin) or synthetic (e.g. polypropylene, polyethylene) in origin. A polymer is called a plastic when it has other materials such as stabilizers, plasticizers, or other additives in it.

Owing to the low thermal stability of wood flour, plastics that can be processed at temperatures lower than about 200 °C are usually used in WPCs. In North America, the great majority of WPCs use polyethylene as the matrix, though polypropylene, polyvinyl chloride, and others are also used (Morton *et al.*, 2003). The large use of polyethylene is due, in part, to that fact that much of the early WPCs were developed as an outlet for recycled film as well as the low cost and availability of recycled sources of polyethylene. Polypropylene is widely used in Europe.

1.2.1 Structure and organization

Molecular structure

Much of how a polymer performs is determined by its molecular structure. This structure is developed during the polymerization process where low molecular weight monomers are reacted to form long polymer chains. Table 1.1 shows the basic chemical structural units of several common polymers as well as their common abbreviations.

Table 1.1 Structural units for selected polymers with approximate glass transition (T_g) and melting (T_m) temperatures. Condensed from Osswald and Menges (1996)

Structural unit	Polymer	T_g (°C)	T_m (°C)
$-CH_2-CH_2-$	Polyethylene (PE)	−125	135
$-CH_2-CH(CH_3)-$	Polypropylene (PP)	−20	170
$-CH_2-CH(C_6H_5)-$	Polystyrene (PS)	100	—
$-CH_2-CH(Cl)-$	Polyvinyl chloride (PVC)	80	—
$-\overset{\overset{O}{\|}}{C}-C_6H_4-\overset{\overset{O}{\|}}{C}-O-CH_2-CH_2-O-$	Polyethylene-terephthalate (PET)	75	280