CHARACTERIZATION OF BIOCOMPOSITES

By Rasha M Sheltami

Introduction

Biocomposites are composite materials consist of one or more phase(s) derived from a renewable resource, commonly matrix material and natural reinforcements, to combine the different features and benefits of the components to produce a useful product having the requisite cost and performance properties for applications with eco-friendly features. Matrices might be natural or synthetic polymers such as starches, polylactic acid, polyethylene, polypropylene, polystyrene, polyvinyl chloride and unsaturated polyesters. The reinforcement could include plant fibers such as wood, kenaf, cotton, flax, hemp, sisal, and rice husk. Fibers from recycled waste papers and regenerated cellulose fibers are also included in this statement. The use of fiber-reinforced polymer composites began in early of the 1900s and the demand of the composites based on natural fibers rises with the increase of environmental concern as well as the increasing oil prices. The biocomposites are exploited in several applications such as automotive sectors, packaging, furniture and building components. Natural fibers are in general suitable to reinforce polymers owing to their relatively high strength and stiffness with low density. Moreover, the natural fibers possess excellent sound-absorbing efficiency and have excellent energy management characteristics (Bledzki and Gassan, 1999; Mohanty et al., 2005).To finalize the manufactured biocomposites for applications, the mechanical properties should be analyzed. The mechanical properties of a material are affected the mechanical strength and ability of material to be molded in suitable shape. In addition, other properties should be analyzed and investigated. In this article, the important characterizations of the biocomposites will be highlighted.

Characterization

Different characterizations can be applied to the biocomposites to evaluate their properties, including the mechanical, thermal and morphological properties as well as water uptake, acoustic emission, and the biodegradability studies. Figure 1 shows some of the instruments in the Institute of Tropical Forestry and Forest Products (INTROP) for investigation the biocomposites properties.

Figure 1: Some instruments in the Institute of Tropical Forestry and Forest Products (INTROP) for analyzing and testing the thermal

Mechanical properties are the properties in which the samples subject to forces (loads), the properties help to understand and measure how the biocomposites behave under the load. The common mechanical properties considered are strength, ductility, hardness, fracture toughness and impact resistance measured using tensile test and impact tests. The tests are carried out according to standard methods depends on the matrix type and size, e.g. the method used for tensile properties of plastics is ISO 527-1 (or ASTM D638) and a thin plastic sheet is ISO 527-3 (or ASTM D882).

Figure 2 shows the mechanical properties of several polymer composites, it displays the effect of different types of natural fibres on the mechanical properties of the polymer matrices. Generally, the use of natural fibres as reinforcement for polymeric composites improves the mechanical behaviour of polymers and usually the natural fibres reinforced polymer composites exhibit better mechanical properties than the polymer matrix. In previous studies, jute fibres improved the tensile strength of poly(lactic acid) (PLA) and the enhancement was about 75.8%.

In addition, the fibres enhanced all the mechanical properties of polyester composites. But, the tensile strength of PLA was decreased with the addition of flax fibres. Furthermore, kenaf, hemp, and cotton improved the tensile strength of polypropylene (PP) composite. The tensile strength of epoxy improved with the addition of jute fibres, meanwhile, the compressive strength was deteriorated (Shalwan and Yousif 2013, Plackett et al. 2003, Kim et al. 2008).

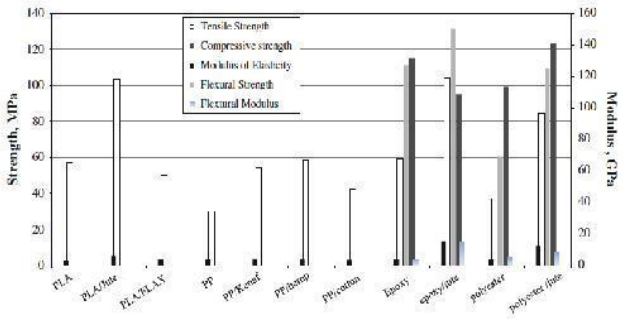

Figure 2: Some of the mechancial properties of natural fibre/polymer composites (Source: Shalwan and Yousif, 2013)

Thermal analysis is used to investigate the thermal parameters and properties of the biocomposites. Several instruments are applied, including differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical thermal analysis (DMTA) and thermomechanical analysis (TMA) for the thermal study. The thermal stability of the biocomposites is one of the important considerations; other parameters are important to be measured and understand inclusive thermal transitions and thermal expansion. That would be important for both the process of fabrication and the applications of the biocomposites which subject to heat. In general, the addition of natural fibres to polymer matrices leads to increase the thermal transitions, reduce the thermal expansion and might show different effect on the thermal stability. Figure 3 shows thermal degradation curves of kenaf fibers (KF) reinforced poly(vinyl chloride) (PVC)/thermoplastic polyurethane (TPU) poly-blend composites, it was studied by El-Shekeil et al. (2014). The degradation occurred in three stages and the effect of the fiber content was different during the degradation. The composites and the matrix had the similar stability at the first stage, the matrix showed a slightly better stability than the composites at the second stage. At the third stage, composites showed a better stability than the matrix.

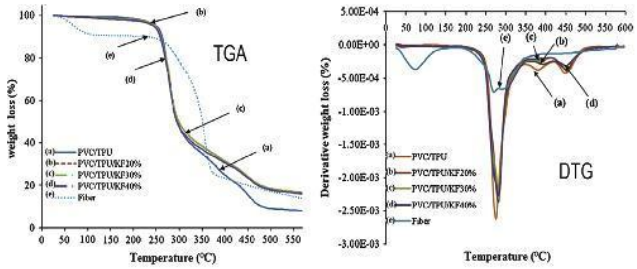

Figure 3: Effect of fiber content on thermal degradation of PVC/TPU/KF (Source: El-Shekeil et al., 2014)

The scanning electron microscope (SEM) is used to study the morphology of the biocomposite surfaces and to investigate the fibre-matrix interface. Figure 4 shows the SEM micrographs of fractured surfaces of low density polyethylene (LDPE)-based composites reinforced with cellulosic fibers for different magnifications to compare between the fibre-matrix interface before (Figure 4a) and after silane treatment with Methacryloxypropyltrimethoxysilane (MPS) (Figure 4b). It is clear that the interfacial adhesion between the fibre and matrix was improved after silane treatment as can be seen from the micrographs. For bio-nanocompostes, field emission scanning electron microscope (FESEM) and atomic force microscopy (AFM) are used to investigate the surface morphology. Furthermore, transmission electron microscopy (TEM) is used for the nanocomposites after preparing a thin film (~70 nm thickness) using cryo-ultramicrotomy. Figure 5 shows TEM images of unsaturated polyester (UPR) nanocomposites, they displays the distribution of cellulose nanocrystals (CNC) and silane treated nanocrystals (STCNC) into the UPR matrix.

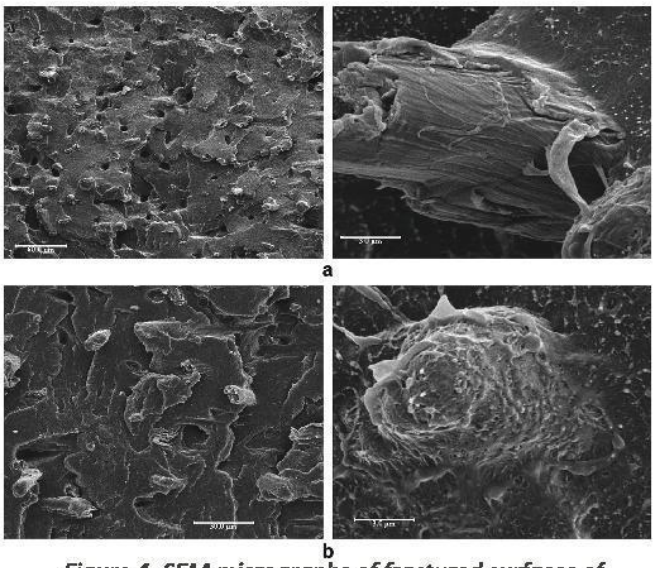

Figure 4: SEM micrographs of fractured surfaces of LDPE-based composites reinforced with cellulosic fibers (a) untreated and (b) MPS-treated fibers
(Source: Abdelmouleh et al., 2007)

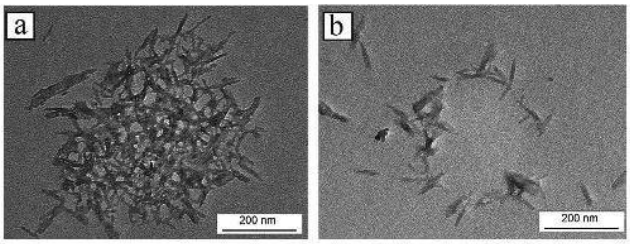

Figure 5: TEM images of (a) CNC-UPR nanocomposite, and (b) STCNC-UPR nanocomposite
(Source: Kargarzadeh et al., 2015)

Several standard test methods are used to study the behaviour of the biocomposites and the influence of moisture/weathering/environment on the properties of biocomposites, e.g. ISO 18249 (or ASTM E2076) is for acoustic emission test., ISO 62 (or ASTM D570) is used to measure the water absorption, ISO 15512 (or ASTM D789) is used to obtain moisture content, and ISO 14855 is a standard biodegradation test method to determine ultimate aerobic biodegradability. The importance of evaluation the biocomposite properties is to accomplish the manufactured biocomposites and reach the required properties for the applications. The characterization and testing should be chosen based on the fabrication and applications demands.

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Author:
Dr. Rasha M Sheltami
Post-doctoral Researcher
Laboratory of Biocomposite Technology
Institute of Tropical Forestry and Forest Products (INTROP)
Universiti Putra Malaysia
Email: rashasheltami@yahoo.com
rashasheltami@upm.edu.com