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論　文　内　容　要　旨

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学位論文題目	Effect of Alkali Treatment on the Microstructure and Tensile Properties of Abaca Fiber (マニラ麻繊維の微視構造と引張特性に及ぼすアルカリ処理の影響)		

内容要旨

Natural fibers are increasingly being used in fiber-reinforced composites (FRCs) due to their high tensile strengths, light weight, low cost and non-toxicity. Abaca, also known as Manila hemp, is a native plant of the Philippines where it is grown as a commercial crop. Abaca fiber has a high cellulose content and very good mechanical properties, including a high tensile strength and high Young's modulus. Chemically modified abaca fibers demonstrate enormous potential as natural reinforcing agents in composite materials, though little work to date has been reported on the effect of different chemical treatments on abaca fiber structure, composition and mechanical strength, motivating a detailed investigation.

This thesis systematically explored the effects of alkali concentration and treatment time on the microstructure and tensile properties of abaca fibers. Further, the interfacial bonding mechanism in abaca fiber-reinforced epoxy was also studied. Scanning electron microscopy (SEM), X-ray diffraction (XRD), Fourier transform-infrared spectroscopy (FT-IR), fiber tensile tests and fiber composite pull-out tests were used to obtain a detailed picture of different alkali treatments on abaca fiber properties and composite performance.

The effect of NaOH concentration and treatment time on the mechanical properties of abaca fibers was first investigated. Abaca fibers were immersed in 3, 5, 7, 9, 11, 13 and 15 wt. % aqueous NaOH solutions for 5 min, and 5, 10 and 15 wt.% aqueous NaOH solutions for 5, 10, 15, 20, 25 and 30 min. The mechanical properties of the fibers increased after each alkali treatment. The highest Young's modulus and tensile strength was achieved after 7 wt.% NaOH treatment for 5 min. The effect of treatment time on fiber properties was modest compared to the effect of alkali concentration.

The effect of NaOH concentration (5, 10 and 15 wt. %) and treatment time on abaca fiber microstructure and chemical composition was subsequently studied.

The abaca fibers were immersed in different NaOH solutions for specific times, rinsed with water and dried. The morphology of the treated abaca fibers were then characterized in detail. After alkali treatment, it was found by SEM that the lumen (the hollow core in the center of the elementary abaca fibers) had completely disappeared due to the swelling of surrounding cell walls. The abaca fiber bundles also became twisted after 10 and 15 wt. % NaOH treatments. The XRD measurements revealed that cellulose I in the abaca fibers was partially transformed to cellulose II after 15 wt. % NaOH treatments. Meanwhile, FT-IR analysis revealed that the alkali treatments caused gradual removal of the binding materials, such as hemicelluloses and lignin from the abaca fibers, resulting in the separation of abaca fiber bundles into individual elementary fibers. The Young's modulus of the abaca fibers treated with 5 wt. % NaOH for 30 minutes increased by 30-40% compared to the native fibers, whereas the Young's modulus of fibers treated with 10 and 15 wt. % NaOH decreased by 20-25% and 25-30%, respectively, compared to the native fibers. A non-linear behavior was observed in the stress-strain curves of the abaca fibers after 10 and 15 wt. % alkali treatments, which is explained by alkali-treated fiber twisting.

The effect of NaOH treatment on the abaca fiber-epoxy interface was then studied. The crystallinity index, microstructure, surface morphology, chemical composition, and mechanical characteristics of the untreated and alkali-treated abaca fibers were evaluated, along with the interfacial adhesion with epoxy and interfacial shear strength (IFSS). Results showed that the degree of crystallinity in the abaca fibers increased by 12% following 5 wt. % NaOH treatment for 2 hours. This treatment also increased the tensile strength and the Young's modulus (increased by 37.8%) of the fibers. However, the Young's modulus of abaca fibers decreased by 34% and 49% after 10 and 15 wt. % NaOH treatments for 2 hours, respectively, indicating that strong alkali treatments negatively impacted fiber stiffness and suitability for use in composite applications. The 5 wt. % NaOH treatment improved the interfacial shear strength (IFSS) of abaca fiber-reinforced epoxy by 32 %. It can be concluded that pre-treatment of raw abaca fibers with 5 wt. % NaOH is highly beneficial for the fabrication of abaca fiber-reinforced composites.

Results guide the development of improved abaca fiber-reinforced composites for automotive and other high-value applications.