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Fabrication of sisal fibers/epoxy composites with liquid crystals polymer grafted on sisal fibers

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Abstract. In this word, microcrystalline cellulose fibers (MCFs), extracted from sisal fibers, were treated with function end-group hyperbranched liquid crystals (HLP). This work brought some insights into the successful surface modification in epoxy composite with HLP. The HLP-MCFs/epoxy composites are studied systematically. The HLP - MCFs/epoxy composites were studied by Fourier transform infrared spectroscopy (FT-IR), polarizing microscope (POM), X-ray photoelectron spectroscopy (XPS) and mechanical properties analysis. The results reveal that the reinforcement of EP composites was carried out by adding HLP-MCFs. In particular, with 1.0 wt% filler loading, the flexural strength, tensile strength, impact strength and flexural modulus of the HLP-MCFs/EP composites were increased by 60 %, 69%, 130 %, and 192 %, respectively. It anticipates that our current work exploits more efficient methods to overcome the few nature fiber/polymer (NPC) adhesion in the interface region and provides implications for the engineering applications of the development of NPC.

1. Introduction

The tendency of natural fibers as a sustainable materials have attracted many researchers because dwindled fossil resources.[1] It is particularly desirable that composites modified by natural fibers for the development of environmentally sustainable materials, because natural fibers offer more advantages than synthetic fibers such as its low cost, biodegradability, and renewability.[2] However, the main drawback are the little compatibility and poor interfacial adhesion between natural fibers with the polymer matrix. Accordingly, the affection of composites with natural fibers is unsatisfactory, and its modifications by specific treatments are certainly necessary. To date, several method of modified the surface of natural fibers are proposed, such as alkalization, acetylation, and cyanoethylation. Additionally, hyperbranched polymer is another efficient way to improve the interfacial bonding with matrix and graphene.[3,4] The end-groups of hyperbranched polymer with three-dimensional space structures interact with functional groups of epoxy resins(EP), which can effectively improve the compatibility between fillers and EP, and enhance the toughness of the EP.[5]

In the present work, the MCFs, extracted from sisal fibers, were modified by HLP to improve the compatibility and interfacial adhesion with epoxy matrix. Because HLP has dendritic architecture and abundant functional groups which can react to epoxy matrix via covalently incorporation, furthermore, it contain liquid crystal characters. The introducing of HLP is hoped to improve MCFs/EP composites with excellent mechanical properties. Furthermore, the MCFs derived from the eco-friendly and

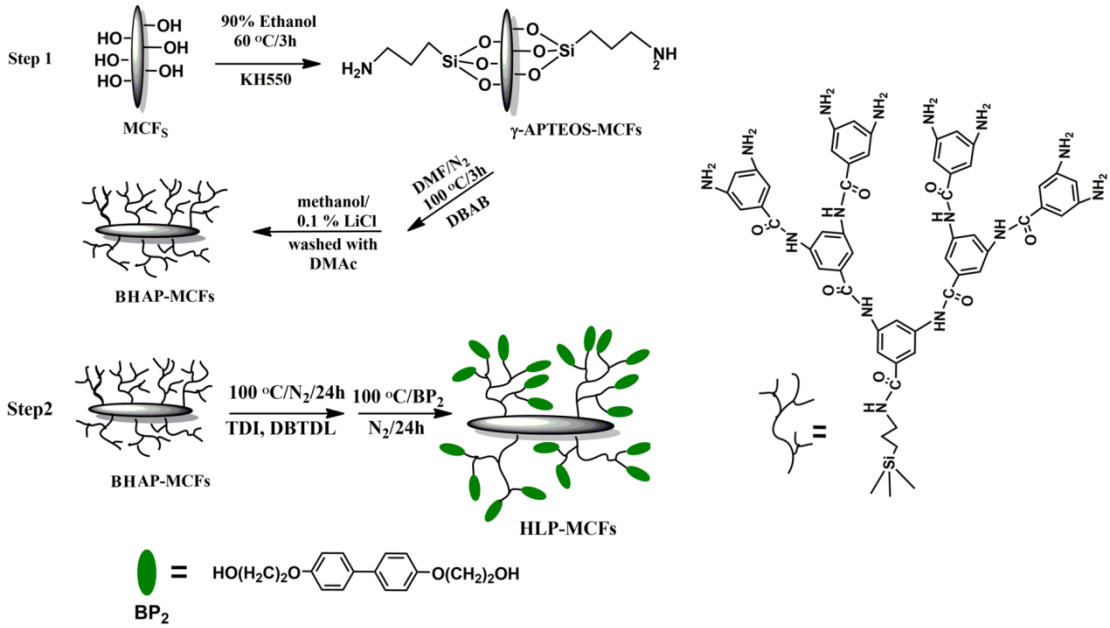
renewable of sisal fibers, would replace synthetic fibers to apply in polymer composite reinforcement and endow the NPC with some unexpected performances.

2. Materials

MCFs, as a reinforcement, were extracted from Sisal fibers. Yueyang Chemical Plant, China afford epoxy resin (DGEBA, E-44, epoxy value ¼ 0.44) to complete the research. triphenylphosphine (TPP) use as catalyst in this study. g-Aminopropyl-triethoxysilane (g-APTEOS) was coupling agent in this study. We also purchased drugs from Aladdin Chemistry Co., Ltd, such as The hardener (4,4-Diaminodiphenylsulfone), 3,5-diaminobenzoic acid (DABA). 4,4-Biphenol was obtained from Tokyo Chemical Industry Co., Ltd. N,N-dimethylacetamide (DMAc), acetone, Piperidine, N,N-dimethylformamide (DMF), N-methyl-2-pyrrolidone (NMP), used as a solvent, were obtained from Sinopharm Chemical Reagent Co., Ltd., China. furthermore, Sinopharm Chemical Reagent Co., Ltd., China also furnished necessary laboratory reagents to complete the study. such as, methanol, Lithium chloride (LiCl). The rest of the sample were provided by Guang Zhou Jin hua du Chemical Reagent Co., Ltd. in China. Such as xylene (Xyle), NaOH, 36%HCl, disodium tetraborate decahydrate, 30%H_2O_2, 65–68% HNO_3, 99.5% CH3COOH.

3. Experimental details

As shown in scheme1, the HLP-MCFs were synthesized as follows. Firstly, the MCFs were modified by KH550. Then the hyperbranched aromatic polyamides modified MCFs (BHAP-MCFs) were obtained. The last, the liquid crystal BP_2 were grafted on the surface of the BHAP-MCFs, so the hyperbranched liquid crystals modified MCFs (HLP-MCFs) were obtained. Afterward, HLP-MCFs were used to modified epoxy resin.



Scheme 1. Preparation process of HLP-MCFs

4. Results and discussion

As shown in Fig.1, FTIR of MCFs shows the peaks at 3343 cm^{-1}(due to -OH stretching) and 2920 cm^{-1}(arised from alkane C-H stretching) which show the composition of MCFs. The bands present at 1731 cm^{-1} and 1638 cm^{-1} pointed out that the cellulose is hygroscopic and forms strong hydrogen bonds. FTIR of BHAP-MCFs exhibits bands at 1548 cm^{-1}, 1344 cm^{-1} owing to -NHCO- and amine stretching, respectively. 1604 cm^{-1} and 1434 cm^{-1} caused by benzene ring, which indicates the reaction between BHAP and MCFs. Furthermore, in the spectrum of HLP-MCFs, the peak at 1605 cm^{-1}, 1498

cm^{-1}, 1249 cm^{-1} is the characteristic of the amine N-H deformation, aromatic hydrocarbon C=C stretching and the -NHCOO-, respectively. The absorptions at 1093 cm^{-1}, 1054 cm^{-1} are arising from the amine C-N stretching. These changes in the characteristic peaks prove that BP_2 have successfully grafted on the surface of BHAP-MCFs.

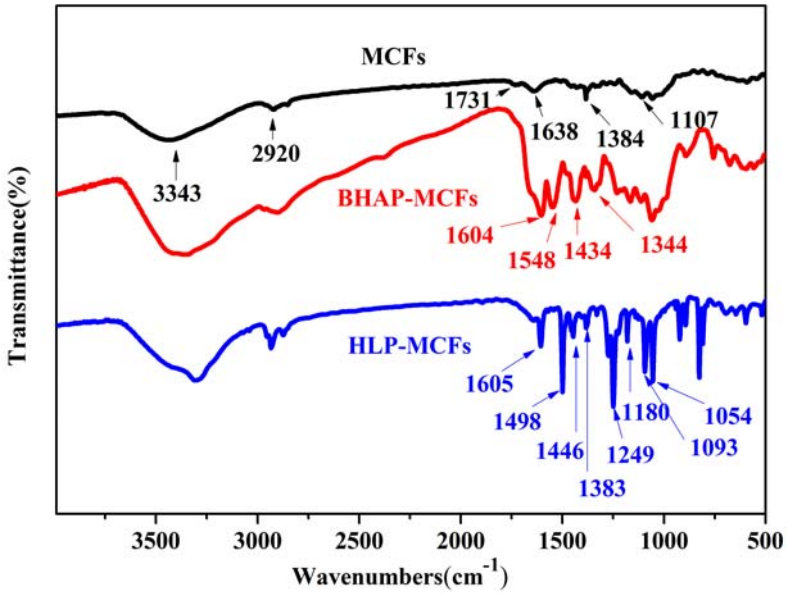


Figure 1. FTIR spectrum of the untreated and treated MCFs

The surface compositional analysis of HLP-MCFs have been performed by the X-rays photoelectron spectroscopy (XPS) in Figure 2. The detected elements were carbon (C), oxygen (O), nitrogen (N), and silicon (Si) which also indicates the HLP grafted on the surface of MCFs successfully.

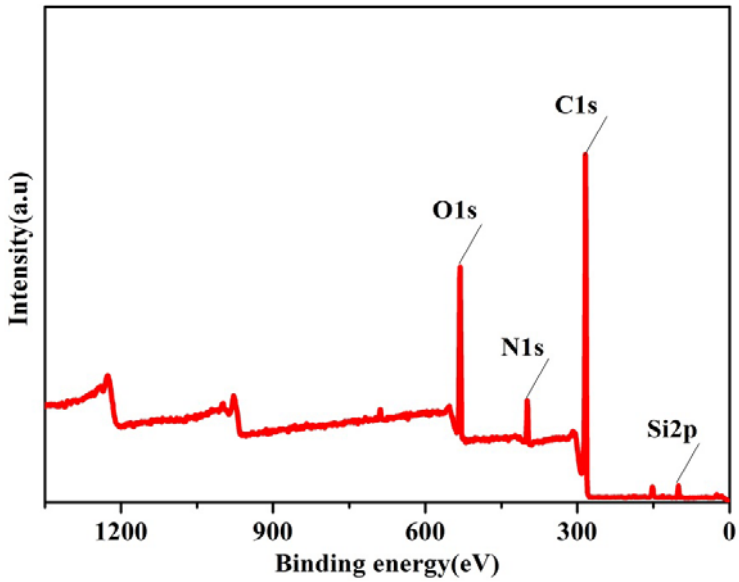


Figure 2. XPS analysis of HLP-MCFs

As shown in Fig. 3, the stress-strain curves of the pure epoxy and HLP-MCFs/epoxy composites were carried out. Compared with the pure epoxy, it was found that the HLP-MCFs/epoxy composites exhibit a higher elongation at break and higher stress, because of the higher cross-linking densities of the HLP-MCFs/epoxy composites and the more efficient interfacial interactions between the

HLP-MCFs and epoxy.[6] With the increment of HLP-MCFs, the stress of these composites was gradually improved. When HLP-MCFs content is 1.0 wt%, reached its highest value. Additionally, there is a maximum elongation at break for HLP-MCFs/EP composites with 0.5 wt% HLP-MCFs.

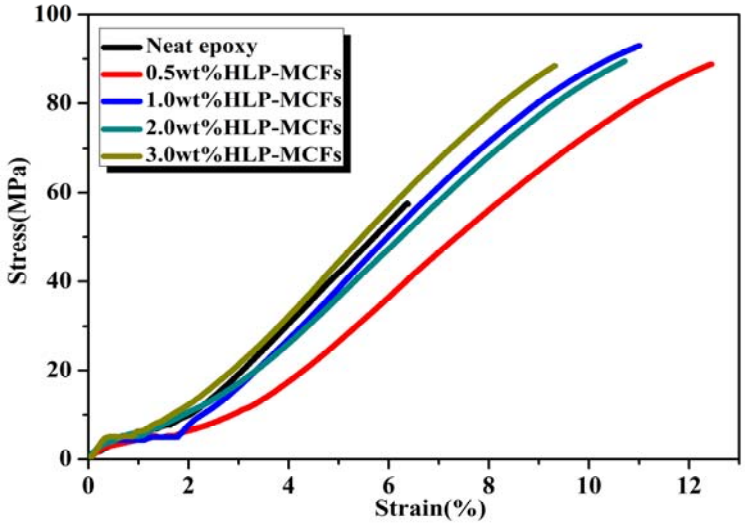


Figure 3. Tensile test of pure epoxy and HLP-MCFs/epoxy composites

As shown in Fig.4 and Fig.5, the mechanical property of the HLP-MCFs/epoxy composites such as flexural, impact, tensile strength and flexural modulus have increased significantly, and then decrease slightly with the increment of HLP-MCFs contents, because of the cross-linking densities of HLP-MCFs/EP composites. The higher cross-linking densities of the HLP-MCFs/EP composites lead to the more efficient interfacial interactions between the HLP-MCFs and EP matrix and stronger network structure of HLP-MCFs/EP composites, which can dramatically improve the mechanical properties of HLP-MCFs/EP composites.[7] Also, the improvement of various strength are attributed to the rigid benzene ring structure of HLP-MCFs[8] and the orientation of the mesogenic units, which hindered the development of the silver pattern. Therefore, a small amount of HLP-MCFs (1.0 wt%), as a filler, can dramatically affect the mechanical properties of HLP-MCFs/EP composites.[7] In short, a small amount of HLP-MCFs can significantly improve the strength and toughness of the EP.

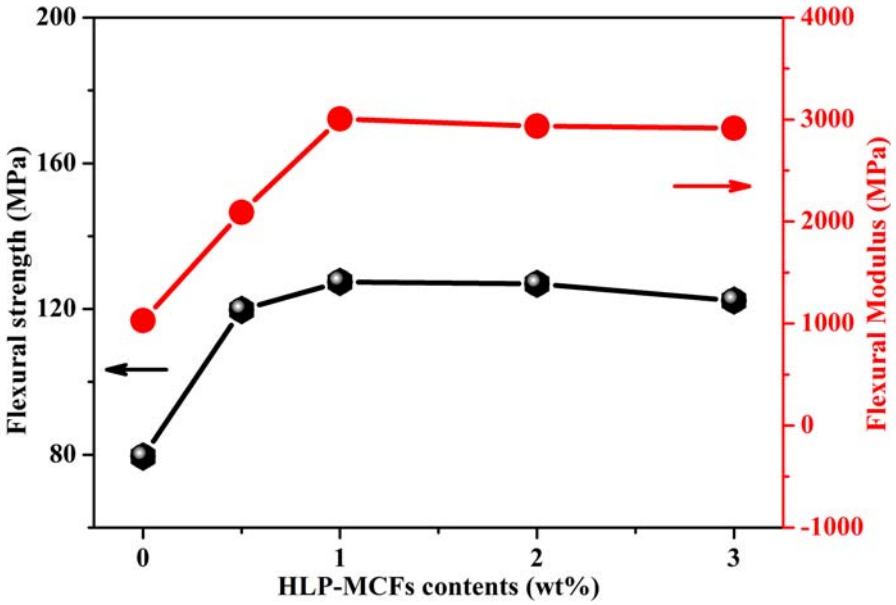


Figure 4. Flexural strength and modulus of pure epoxy and HLP-MCFs/epoxy composites

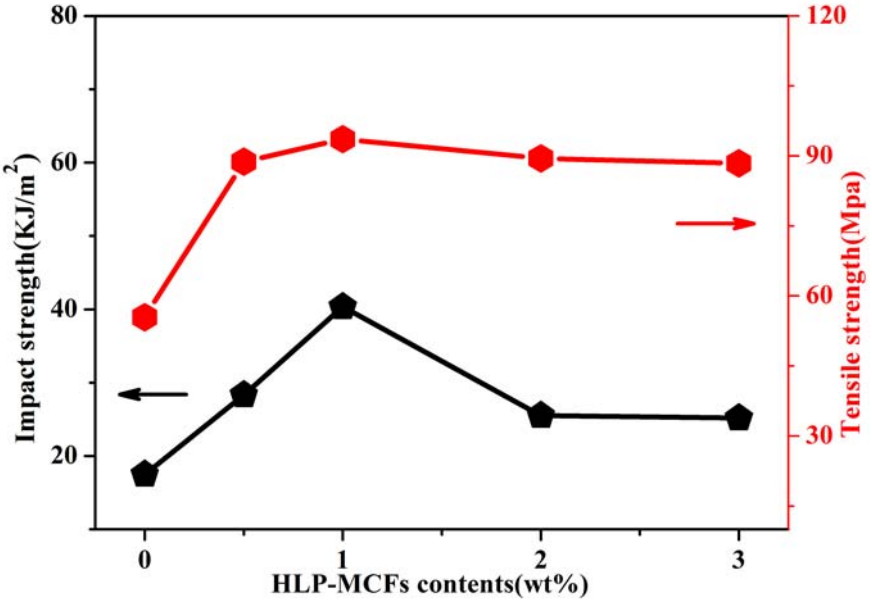


Figure 5. Impact, tensile strength of pure epoxy and HLP-MCFs/epoxy composites

5. Conclusion

This work brought some insights into the successful surface modification in epoxy composite with HLP. The HLP-MCFs/epoxy composites are studied systematically. The results reveal that the reinforcement of EP composites was carried out by adding HLP-MCFs. For instance, with 1.0 wt% filler loading, the flexural strength, tensile strength, impact strength and flexural modulus of the HLP-MCFs/EP composites were increased by 60 %, 69%, 130 %, and 192 %, respectively.

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