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Compatibilizer–photostabilizer interactions in coir fiber/polypropylene composites

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The use of photostabilizing additives may compromise the mechanical properties of coir fiber-reinforced polypropylene composites compatibilized with maleic anhydride-grafted polypropylene.

Sustainable, economically viable, lightweight, and recyclable materials have become a strategic issue for the materials industry in recent years. For this reason, the use of natural fibers for the fabrication of new materials (particularly as a component in polymeric composites) has become increasingly important. The use of coconut fiber (i.e., coir) as a natural reinforcement in polypropylene (PP) composites has attracted interest in recent years due to its useful properties (e.g., mechanical strength, and water and damage resistance). Generally, compatibilizers (such as maleic anhydride-grafted polypropylene, PPMAH) are used as additives in the fabrication of these materials to enhance processing, improve fiber dispersion in the polymer matrix, reduce water absorption, and increase tensile strength (i.e., due to improved mechanical-stress transfer from the polymer matrix to the fiber).[1,2]

To make these composites suitable for outdoor applications (e.g., in the automotive and construction industries), they must be made resistant to weathering (particularly from UV radiation) in the long term. To achieve this, hindered amine light stablizers (HALS), UV absorbers, and light screeners are generally added to the composite to prevent and/or to reduce the effects of photo-oxidative aging.[3–5] However, in the formulation of a material, it is common for researchers to be concerned with the isolated function of each additive. As such, the possible interactions or reactions among them (i.e., that may compromise the properties of the resultant composite) are often neglected in considerations.

In our work, we prepared a range of natural coir fiber-reinforced polypropylene composites. Among these samples, some were compatibilized with PPMAH and stabilized with a sterically hindered amine (Tinuvin®791) and a UV absorber (Hostavin®ARO 8). To fabricate our composites, we used a co-rotating twin-screw extruder. We then in-

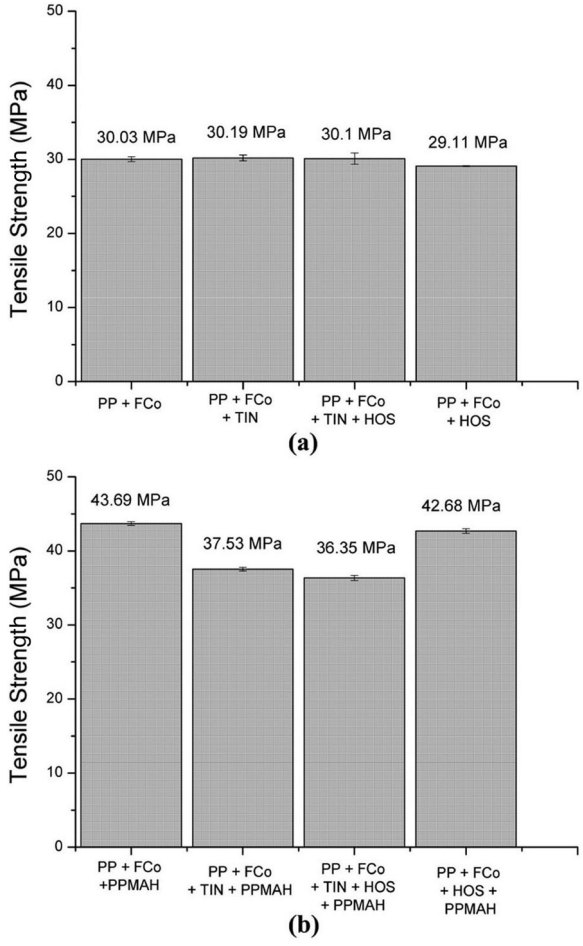

Figure 1. *Tensile strength (MPa) of our coir/polypropylene samples with various additives. (a) Uncompatibilized samples of polypropylene/coir-fiber (PP/FCo) composites, and those fabricated with a hindered amine light stablizer (Tinuvin® 791, TIN), and a UV absorber (Hostavin® Aro 8, HOS). (b) Composites compatibilized with maleic anhydride-grafted polypropylene (PPMAH).*

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Table 1. *Nominal composition, in mass, of our formulations.*

Nomenclature of compositions	PP (%)	FCo (%)	Irganox B214 (%)	PPMAH (%)	Tin (%)	Hos (%)
PP	99.8	–	0.2	–	–	–
PP/Tin	99.6	–	0.2	–	0.2	–
PP/Tin/Hos	99.4	–	0.2	–	0.2	0.2
PP/Hos	99.6	–	0.2	–	–	0.2
PP/FCo	69.8	30	0.2	–	–	–
PP/FCo/Tin	69.6	30	0.2	–	0.2	–
PP/FCo/Tin/Hos	69.4	30	0.2	–	0.2	0.2
PP/FCo/Hos	69.6	30	0.2	–	–	0.2
PP/FCo/PPMAH	66.8	30	0.2	3	–	–
PP/FCo/Tin/PPMAH	66.6	30	0.2	3	0.2	–
PP/FCo/Tin/Hos/PPMAH	66.4	30	0.2	3	0.2	0.2
PP/FCo/Hos/PPMAH	66.6	30	0.2	3	–	0.2

vestigated possible interactions and/or reactions between the compatibilizer and HALS.

The compositions of our coir fiber-reinforced polypropylene are shown in Table 1. All formulations were additionally stabilized with 0.2% Irganox B 215 (i.e., a 2:1 blend of Irgafos 168 and Irganox 1010) to provide thermal stability during processing. After fabrication, we performed tensile tests by using a universal testing machine (EMIC DL 10000), following the ASTM D638:2014 standard, at a speed of 5mm/min.

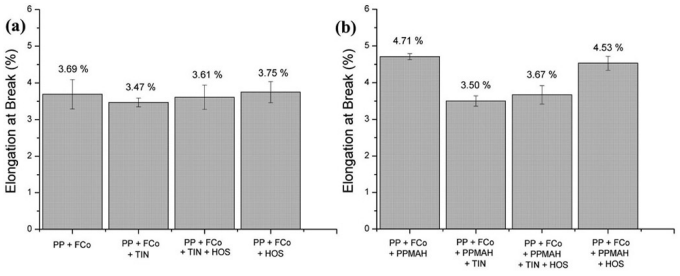

Figure 2. *Elongation at break (%) of the (a) uncompatibilized and (b) compatibilized composite samples.*

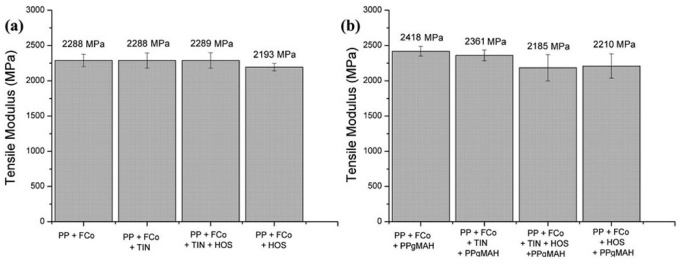

Figure 3. *Tensile modulus of the (a) uncompatibilized and (b) compatibilized samples.*

The results from our tests on the tensile strength, elongation at break, and tensile modulus of the samples are shown in Figure 1, 2, and 3, respectively. We found that the joint presence of Tinuvin® and PPMAH has a negative effect on both the tensile strength and the compatibility of the natural fiber with the polymer matrix. Based on these results and scanning electron micrographs obtained of the composites,[6] we believe that the compatibilizing effect of PPMAH is inefficient in the presence of HALS. This inefficiency may arise due to reactions occurring between the amine group of the stabilizer and the succinic anhydride/succinic acid of the compatibilizer at the high temperatures under which we prepared the composites. The reactions or interactions between such groups could reduce the efficacy of both additives, thus reducing adhesion (i.e., due to the reduction in the effective concentration of the compatibilizer and the efficiency of amine as a stabilizer to weathering).[6]

Our results for the compatibilized samples suggest that the addition of PPMAH to the PP/FCo composite increases the adhesion between the phases of PP and coir fibers and, consequently, increases the tensile strength. The compatibilizers increase the tensile strength by allowing an adequate transfer of mechanical stress between the phases (i.e., from the polymer matrix to the fiber). Since the fiber has greater mechanical strength, it reinforces the polymer.

Furthermore, the results shown in Figures 1–3 indicate that the addition of Tinuvin® 791 to a compatibilized composite (PP/FCo/PPMAH) resulted in a reduction in the tensile strength by ap-

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proximately 14% when HALS is the only stabilized additive, and by 17% when both HALS and a UV absorber are incorporated into the composite. With respect to the other properties, elongation at break is also reduced via the incorporation of the amines into the compatibilized composites, but tensile modulus is unchanged. We believe that this reduction in tensile strength of the composite occurs as a result of reactions and/or interactions between these additives.

In summary, our results show that the inclusion of photostabilizing additives, such as HALS, may compromise the mechanical properties of PP/FCo composites that are compatibilized with PPMAH. The compatibilized composites showed a lower tensile strength than those obtained without the incorporation of such additives. We have more recently conducted a systematic study on all of the formulations presented here to verify the effect of the additives on composite behavior against artificial weathering. In the next stage of our work, we will present results regarding the behavior of this natural composite and additivation system against UV-B and xenon arc artificial weathering tests.

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