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Typical interactions of composite additives with polyethylene and nanoclay

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Maleated polyolefins are commonly used to compatibilize wood fiber-reinforced composites, but can decrease tensile strength. Dicumyl peroxide may be a superior choice when natural fibers are not used.

Maleated polyolefins (MAPE) have been used industrially for decades in wood plastic composite (WPC) production because they are inexpensive and effective crosslinking agents.[1] Dicumyl peroxide (DCP) is another chemical used widely as an initiator and crosslinking agent for natural fibers in thermoplastics, particularly polyethylene (PE).[2] These plastic additives have been studied extensively in WPC, but there is very little in the literature on their effects on thermoplastics in the absence of fibers. Nanoclay is another additive used to reinforce plastic, and it enhances a broad variety of mechanical properties and water behavior of hybrid composites when used as reinforced filler.[3–7] In composites containing nanoclay only, it is uncommon to use coupling agents or initiators because people consider the nanoclay itself to perform some of the functions of a coupling agent. Such additives improve adhesion at the edges of natural fibers. But this can cause problems. Sometimes natural fiber aggregates during extrusion compounding, leading to the matrix blending with the additives and blocking the dies. This indicates improper feeding and compounding, as shown in Figure 1(a) and (b). Since poor compounding can sabotage material structures by forming white spots in the sheet, we should know what can go wrong and learn how to control the quality of composites when typical composite additives are used: see Figure 1(c). We conducted a series of studies on PE using just nanoclay, MAPE and DCP, excluding natural fibers. We are particularly interested in PE because of the potential reduction of PE's cost due to North America's abundant shale gas, a raw material from which PE can be made. And nanoclay is a very popular inorganic filler in the plastics industry.

PE can be flexible or rigid depending on the amount of filler. Generally when the fiber levels are over 30%, the resulting composites become rigid. The nature of the wood fiber will contribute to the material's rigidity. Fillers can also affect each other's distribution within

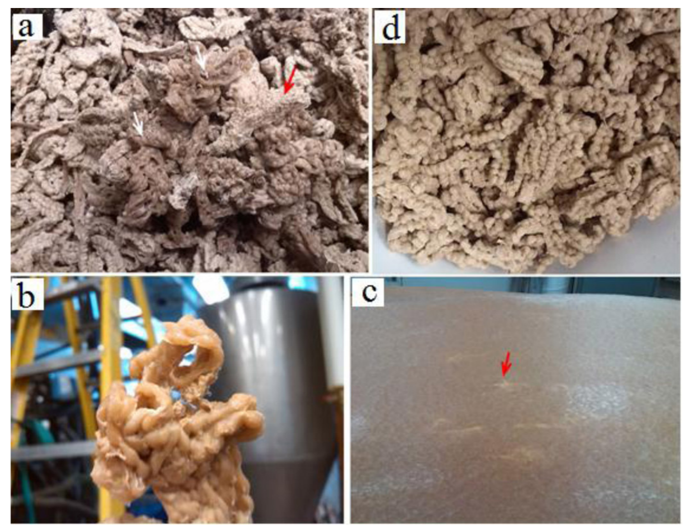

Figure 1. *Typical extrusion compounding and processing of wood-plastic composite (WPC). Improper extrusion compounding is shown in (a). The red arrow points to fiber aggregation, and the white arrows indicate segments with too high a concentration of polymer. (b) Detail of segments with too much polymer, (c) a non-uniform extruded sheet using improperly compounded pellets, and (d) normal composite material.*

the composite. For example, nanoclay particles distribute well with the help of wood fibers (see Figure 2). We used the ratio of fractural energy to yield energy to define the plasticity of the material. The addition of wood fiber decreased the composite's plasticity by a factor of thirteen when 30% fiber was introduced (see Figure 3). We also found that PE hybrid composites still have good plasticity with the addition of 3% nanoclay if no natural fiber is added.

We compounded PE, nanoclay and additives using a roll mill which can compound material more uniformly than an extruder. Though the adding sequence of composite components and additives influences the

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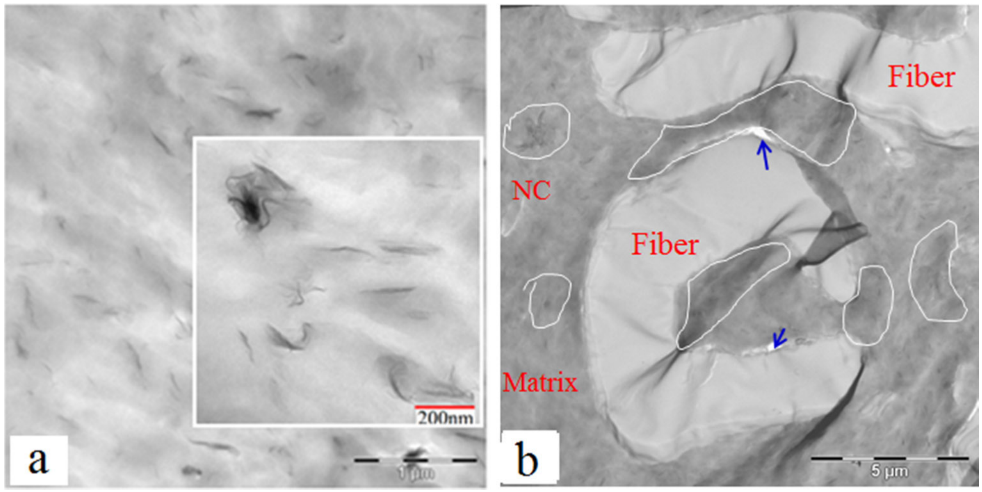

Figure 2. Tunneling electron microscope (TEM) images of the distribution of components in a polyethylene (PE) hybrid. (a) PE filled with nanoclay (NC) without additives and natural fibers, and (b) PE filled with additives and natural fibers in addition to NC.

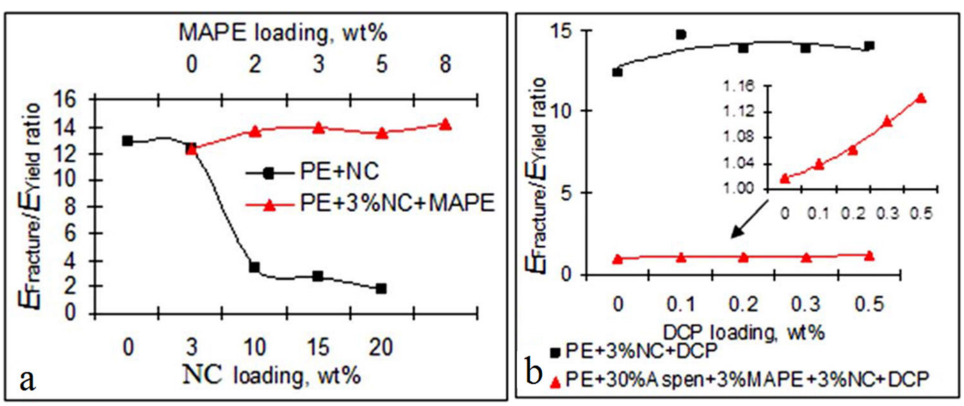

Figure 3. The plasticity of a PE hybrid upon the addition of maleated polyolefins (MAPE) and dicumyl peroxide (DCP), as expressed as the ratio of fractural energy to yield energy. (a) MAPE in PE nanocomposites, (b) DCP in a PE hybrid.

final properties, we obtained comparable results by using the same mixing method for each.[8] We added MAPE or DCP to investigate their effects on the mechanical properties of the nanocomposite when natural fiber was not present.

Analysis of the mechanical results and their fractural behaviors showed that MAPE and DCP both increased the plasticity of the resulting materials regardless of the presence of natural fiber (see Figure 3). However, MAPE slightly increased impact strength while decreasing tensile strength. Unlike MAPE, DCP enhanced impact strength without decreasing tensile strength, based on the results from PE nanocomposite without natural fiber. When natural fiber was introduced, the tensile strength of PE composites improved as the level of DCP increased, and we demonstrated that crosslinked structures were produced. Our results show that MAPE can give negative effects on the final products in the absence of natural fiber, while DCP will not hurt material properties. In the future, we will conduct pilot tests to validate our findings, and also probe polypropylene-based composites to see if the same results apply.

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