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Reducing the filler content of electrically conductive composites

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Polypyrrole-coated peach palm fibers can be used within a polyurethane matrix to achieve a good level of electrical conductivity and high electromagnetic interference shielding effectiveness.

Electrically conductive composites are multiphase materials that are produced by adding electrically conductive fillers to insulating polymeric matrices.[1–4] The conductive fillers used in the composites can be substances such as intrinsically conducting polymers (ICPs) or carbonaceous fillers. The insulator–conductor transition (also known as the percolation threshold) is a characteristic of the final composite materials that occurs at a critical conductive filler content level.[5,6] Large amounts (i.e., more than 10wt%) of ICP particles, however, are usually required to achieve significant conductivity increases, which can lead to processing problems. The high ICP content can also cause a reduction in the mechanical properties of the polymer matrix in the composites.[4]

Several strategies have been used to prepare conductive composites with low percolation thresholds. For instance, we have previously reported that the incorporation of conductive fillers with higher aspect ratio (i.e., width-to-thickness) in polymer matrices allows higher electrical conductivity to be reached. This is because a lower filler content is required to ensure physical contact between the particles.[5–8] The polymerization of conducting polymers on the surface of different types of fibers (e.g., amorphous silica fibers,[5] insulating polymer fibers,[9] or textile fibers[10,11]) is an interesting approach for the preparation of conductive additives that are based on ICPs with high aspect ratios. In this context, the use of vegetal fibers is advantageous because such materials are obtained from renewable sources (or residues). These fibers can also be used to enhance the mechanical properties, and to reduce the weight and cost of the final composites.

In this work,[12] we have thus developed a new conductive additive—with high aspect ratio—that is made of polypyrrole-coated peach palm fibers. We can incorporate this conductive filler material into polymer matrices to improve the electrical conductivity of the composites. The high aspect ratio of the fibers means that we can ensure physical contact between the filler particles at a relatively low filler content. As such, we can achieve high electrical conductivity values at low percolation thresholds.

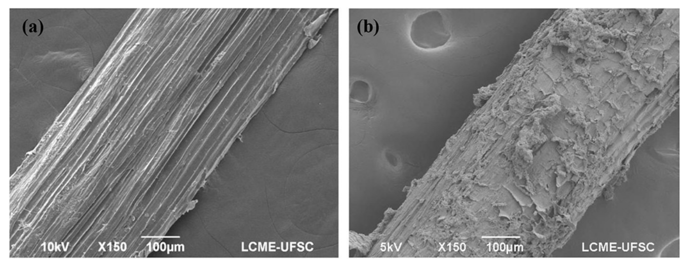

Figure 1. *Scanning electron micrographs of peach palm fibers (PPFs) that are (a) uncoated and (b) coated with polypyrrole (PPy).*[12]

To coat the peach palm fibers (PPFs) with polypyrrole (PPy), we used in situ oxidative polymerization. We find that the resultant PPF-PPy particles have a continuous and compact PPy layer that homogeneously coats the PPF surfaces (see Figure 1). It is this layer on the PPF surface that is responsible for the high electrical conductivity ($2.2\pm0.3 \times 10^{-1}$S cm^{-1}) of the fibers. This value is close to the conductivity of neat PPy, i.e., $1.5\pm0.1 \times 10^{-1}$S cm^{-1}. To produce our final conductive polymer composites, we incorporated the PPF-PPy particles into a polyurethane (PU) matrix that was derived from castor oil.

We have measured the electrical conductivity of our PU/PPF-PPy composites as well as those that contain neat PPy (PU/PPy). A comparison of the results (see Figure 2) shows that the electrical conductivity increases substantially with increasing PPy, in both sets of composites. This is caused by the formation of conducting pathways within the PU matrix. In addition, we find that the percolation threshold is 2.5 and 1.8wt% for composites containing neat PPy and PPF-PPy, respectively.

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We also note that the PU/PPF-PPy composites exhibit higher electrical conductivity—at lower PPy content—than the PU/PPy samples. We attribute this behavior to the geometry of the fillers, i.e., because the PPy-coated PPFs have higher aspect ratios than the neat PPy particles (spherical).

To evaluate the potential use of our conductive composites in shielding applications, we have performed a set of electromagnetic measurements on the PU/PPF-PPy samples. We conducted the tests, at a frequency of 8.2–12.4GHz, on composites with a range of conductive filler content. The electromagnetic interference shielding effectiveness (EMI SE) results are shown in Figure 3. These indicate that the EMI SE of the PU/PPF-PPy composites increases with increasing PPF-PPy filler content because of the formation of conducting pathways within the PU matrix. A composite that contains 25wt% PPF-PPy exhibits an electromagnetic attenuation of –12.0dB over all the frequency ranges that we studied, which corresponds to 93.2% attenuation.

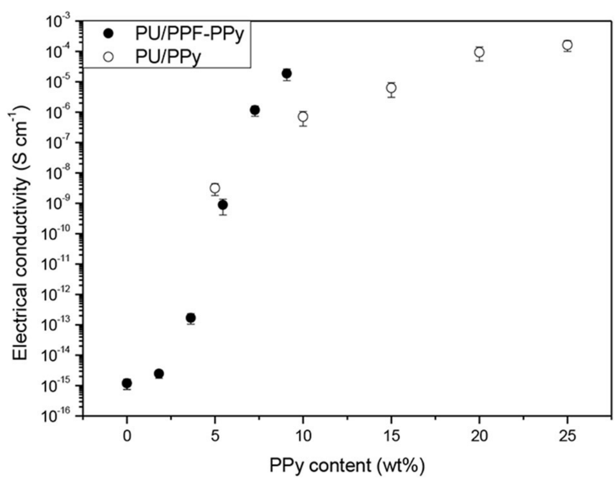

Figure 2. Electrical conductivity, shown as a function of PPy content, of polyurethane (PU) matrix composites that contain either PPF-PPy or neat PPy filler particles.[12]

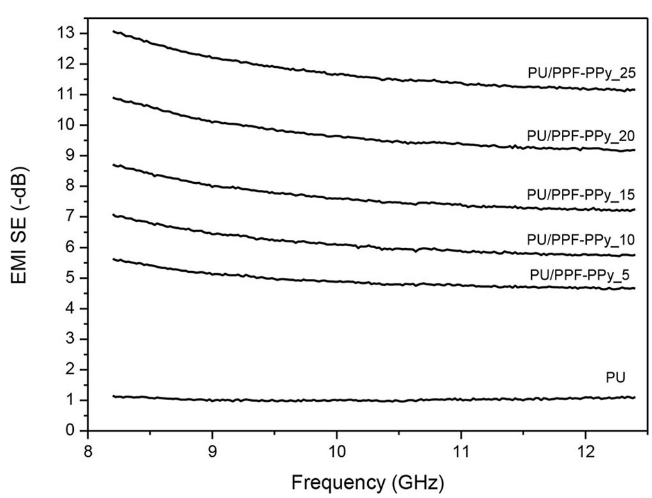

Figure 3. Electromagnetic interference shielding effectiveness (EMI SE) of PU/PPF-PPy composites that have 5, 10, 15, 20, and 25wt% conductive filler content.[12]

In summary, we have used polypyrrole-coated peach palm fibers as electrically conductive fillers in composites that have an (insulating) polyurethane matrix. We have also shown that our composites display a good level of electrical conductivity and electromagnetic interference shielding effectiveness. The high aspect ratio of PPF-PPy particles compared with neat (i.e., spherical) PPy means that it is necessary to incorporate less of the coated fillers into the PU matrix to reach high electrical conductivity. PPF-PPy fillers are therefore a viable alternative to neat PPy in the production of electrically conductive composites. In our future work we plan to develop conductive composites through the incorporation of PPF-PPy into other insulating matrices, particularly those that originate from vegetable sources. We also intend to coat the PPFs with alternative conductive polymers (e.g., polyaniline).

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Guilherme Barra obtained his PhD in materials science and engineering from the Federal University of São Carlos, Brazil. He has since been working on the development of intrinsically conducting polymers, nanocomposites, conducting polymer blends, and vegetal fiber-reinforced polymer materials.

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