CELLULOSE NANOCRYSTALS AS REINFORCEMENT OF POLY VINYL ALCOHOL NANOCOMPOSITES

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The development of micro/nanofibers has attracted significant interest in the last few decades due to the unique properties they endow, such as their very high surface area-to-volume ratio. This characteristic along with the remarkable suitability for surface functionalization and superior mechanical performance makes possible their use in a wide range of applications in medical, pharmaceutical, filtration, and catalysis fields, among others.1, 2 A versatile and inexpensive method for the production of micro and nanofibers is the electrospinning technique, based on the whipping of polymer solutions under electrostatic forces.3-5 Various polymers, including polyolefins, polyamides, polyesters, polyurethanes, polypeptides, and polysaccharides, have successfully been electrospun into micro- and nanofiber mats.5 Poly vinyl alcohol (PVA), a commonly used polymer obtained by controlled hydrolysis of poly vinyl acetate (PVAc), can be used to produce fibers via electrospinning.

PVA is water soluble, semicrystalline, fully biodegradable, nontoxic, and biocompatible, and therefore, it finds use in a broad spectrum of applications.6 PVA-based fibers have been considered as an attractive choice in tissue scaffolding, filtration materials, membranes, optics, protective clothing, enzyme immobilization and drug release, among others.7 However, the low mechanical strength and integrity of PVA fibers, demand the application of post-treatment, and cross-linking,8 as well as the use of reinforcing agents, for example, carbon nanotubes,9, 10 inorganic nanoparticles based on hydroxyapatite, gold, clay, silica, cellulose nanofibrils, and chitin whiskers.9,11-15

Currently, numerous efforts have been focused on the use of materials from renewable resources to reinforce nanocomposites. Cellulose, being known for its availability and excellent chemical, and strength properties, particularly in the form of nanocrystals, has received increased attention by the research communities. The incorporation of cellulose nanocrystals in a polymer matrix to form composites is an attractive option for replacing non-renewable materials in high-value, high-performance products. With their unique mechanical properties in addition to other features such as renewability, biodegradability, cellulose nanocrystals have been reported to effectively reinforce polymer matrices in electrospun composite mats consisting of poly(caprolactone) and polystyrene.16,17

In this study fiber nanocomposites of PVA reinforced with cellulose nanocrystals were successfully produced by the electrospinning technique (Figure 1). We used electron microscopy techniques (FE-SEM and TEM) to investigate the morphology of the fibers, and FTIR was used to chemically confirm the presence of the CNs inside the PVA nanofiber matrices. The enhancement of the thermo-mechanical properties of electrospun PVA nonwoven after adding CNs was demonstrated by thermal gravimetric analysis (TGA), differential scanning calorimetry (DSC), and dynamic mechanical analysis (DMA). Furthermore, the influence of CNs on the water uptake behavior on the fiber mats and their interaction with water molecules and/or the polymer matrix were also studied at different relative humidity.

Remarkable results were obtained from the studied systems. The nonwoven mats were very smooth with homogeneous nanofibers, showing enhanced thermomechanical properties as a result of the addition of cellulose nanocrystals to the PVA polymer matrix. Reinforcing cellulose nanocrystals induced a 3-fold increase of the storage modulus of PVA (Figure 2), which was ascribed to the efficient stress transfer between CN and PVA polymer in the electrospun fibers.
The addition of cellulose nanocrystals not only improved the thermo-mechanical properties of the composites but also stabilized the system at high moisture contents. For these nanocomposites to be used in filtration and membrane applications, their dimensional stability in presence of water needs to be improved. Therefore, current efforts are focused on esterification techniques to improve the integrity of the composite materials when in contact with water.

REFERENCES

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