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Processing of polymer nanocomposites using natural nanoparticles

A. Dufresne

The International School of Paper, Print Media and Biomaterials, Grenoble Institute of Technology, BP 65, 38402 Saint Martin d'Hères Cedex, France

Abstract – Aqueous suspensions of polysaccharide nanocrystals can be prepared by acid hydrolysis of the biomass. The main problem is related to the homogeneous dispersion of these nanoparticles within a polymeric matrix. Water is the preferred processing medium. Hydrosoluble polymers are well adapted for the processing of these nanocomposites. A second alternative consists in using non aqueous systems. It means that the nanoparticles should be dispersed in an adequate, with respect to the polymeric matrix, organic medium. A new and interesting way for the processing of polysaccharide nanoparticles-based nanocomposites is their transformation into a co-continuous material through long chain surface chemical modification.

Over the last two decades a good deal of work has been dedicated to the use of lignocellulosic fibers as reinforcing elements in polymeric matrix and for the possibility of replacing conventional fibers such as glass. This considerable interest is due to a variety of well-known specific properties of natural fibers. Among others, a main drawback of lignocellulosic fibers is the big variation of properties inherent to the natural products. The properties are related to climatic conditions, maturity, and type of soil. Disturbances during plant growth also affect the plant structure and are responsible for the enormous scatter of mechanical plant fiber properties. One of the basic idea to achieve further improved fiber and composite is to eliminate the macroscopic flaws by disintegrating the natural grown fibers, and separating the almost defect free highly crystalline fibrils.

Aqueous suspensions of cellulose nanocrystals can be prepared by acid hydrolysis of the biomass [1-2]. The object of this treatment is to dissolve away regions of low lateral order so that the water-insoluble, highly crystalline residue may be converted into a stable suspensoid by subsequent vigorous mechanical shearing action. The resulting nanocrystals occur as rod-like particles or whiskers, which dimensions depend on the nature of the substrate, but range in the nanometer scale. Then, the main problem is related to the homogeneous dispersion of these nanoparticles within a polymeric matrix. Because of the high stability of aqueous suspensions of cellulose whiskers, water is the preferred processing medium. Hydrosoluble polymers are therefore well adapted for the processing of cellulose whiskers reinforced nanocomposites. Solid nanocomposite films can be obtained by mixing, casting and evaporating the aqueous polymer solution and the aqueous suspension. A first alternative consists in using an aqueous dispersed polymer, i.e. latex. After mixing and casting the two aqueous suspensions, a solid nanocomposite film can be obtained by water evaporation and particles coalescence. A second alternative consists in using non aqueous systems. It means that the nanoparticles should be dispersed in an adequate, with respect to the polymeric matrix, organic medium. For instance it is possible to coat the surface of nanoparticles with a surfactant. The chemical modification of nanoparticles surface is another way to disperse them in organic solvents. It generally involves reactive hydroxyl groups from the surface. Recently, it was shown that cellulose whiskers could be dispersed in dimethylformamide, dimethyl sulfoxide or N-methyl pyrrolidine without additives or any surface modifications. A solvent exchange procedure can also be used. Other possible processing techniques of nanocomposites are filtration of the suspension to obtain a film and then immersion in a polymer solution, or melt extrusion.

A new and interesting way for the processing of cellulose whiskers-based nanocomposites is their transformation into a co-continuous material through long chain surface chemical modification [3]. It involves the surface chemical modification of the nanoparticles based on the use of grafting agents bearing a reactive end group and a long compatibilizing tail. Two grafting approaches can be used, i.e. "Grafting onto" or "Grafting from" methods.

References

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