Optically transparent composites reinforced with plant fiber-based nanofibers

Shin-ichirou Iwamoto
Laboratory of Active bio-based materials, RISH, Kyoto University

The plant cell wall consists of nanofibers 4 nm in width and thickness, called cellulose microfibrils . Because the nanofibers are bundles of semi-crystalline extended cellulose chains, the Young's modulus and tensile strength are as high as those of aramid fibers (trade name: Kevlar), a well-known high strength fiber, and surprisingly the thermal expansion in the axial direction is as small as that of quartz.

Recently, we demonstrated that cellulose microfibril bundles of 50 nm width produced by bacteria, could reinforce transparent resins without losing transparency [1]. The nanocomposites exhibited low thermal expansion, as good as can be found with silicon crystal, high strength comparable to that of soft steel, and ease of bending similar to that of plastics. Our findings engendered a new interest in cellulose microfibrils, the most abundant biomass resource on Earth, as a promising nanofiber for use in materials of the future. This study is a first example of a successful fibrillation of wood pulp fibers into nanofiber bundles, which are thin enough to work as well as bacterial cellulose in maintaining the transparency of resin[2].

The plant fiber is a cellulose microfibril bundle of micro order diameter. To produce optically transparent composites reinforced with plant fibers, it is necessary to fibrillate these fibers into nanofibers. The fibrillation of pulp fiber was attempted by two methods, a high-pressure homogenizer treatment and a grinder treatment. High-pressure homogenizer treated pulp exhibited a wider distribution of fiber width, from some microns to 50 ~ 100 nm. Thus, homogenizer-treated pulp slurry was subjected to a grinder treatment. With the increase in the number of passes, the bundles of homogenizer-treated pulp were further fibrillated, and 10 repetitions of the grinder treatment resulted in uniform nanofibers 50 ~ 100 nm wide.

Figure 1 shows the results of light transmittance measurements versus wavelength for the fiber/acrylic resin composite sheets and an acrylic resin sheet. At a 600 nm wavelength, grinder treated pulp/acrylic resin composite transmits 70% of the light, including surface reflection (Fresnel's reflection), at a fiber content as high as 70 wt%. When we compared the light transmittance against that of pure acrylic resin, we found that the degradation in light transmission due to the fibrillated pulp fiber network is only 20%. On the other hand, the light transmittance of homogenizer-treated pulp/acrylic resin sheet is 30% and the degradation is around 60% at a fiber content of 62 wt %.

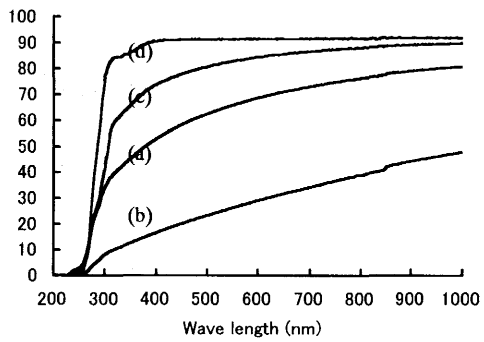

FIGURE 1 Regular light transmittance of (a) 45 μm-thick grinder-treated pulp/acrylic resin sheet, (b) 53 μm-thick high-pressure homogenizer-treated pulp/acrylic resin sheet, (c) 60 μm-thick bacteria cellulose/acrylic resin sheet, and (d) 40 μm-thick acrylic resin sheet

REFERENCES

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[2] S. Iwamoto, A. N. Nakagaito, M. Nogi, H. Yano: Appl. Phys. A, DOI: 10.1007/s00339-005-3316-z (2005)