Optically Transparent Composites Reinforced with Networks of Bacterial Nanofibers

(Laboratory of Active bio-based materials, RISH, Kyoto University)

Hiroyuki Yano

Mechanical reinforcement of optically functional materials is of significant interest to various industries, due to the rapid expansion of related devices, e.g. displays. Nanocomposite materials with components less than one-tenth of the wavelength in size are free from scattering, making them acceptable for a variety of optical applications. Acetobacter (*Acetobacter xylinum*) cellulose fiber is an extracellular product excreted into the culture medium in the form of pellicles. Its fiber content is structured in a web-like network, composed of continuous nanofibers of about ten nm in thickness and 50 nm in width (Fig.1). Each nanofiber is a bundle of cellulose microfibrils, each of which is about 4 nm thick and 4 nm wide. Since the cellulose microfibrils are aggregates of semi-crystalline extended cellulose chains, their thermal expansion is as small as quartz glass. The density, Young's modulus, and tensile strength of the cellulose microfibrils are almost equal to those of aramid fibers, a well known high strength fiber. Thus, we undertook the development of a transparent polymeric nanocomposite, with the web-like bacterial nanofiber network as the mechanical reinforcing agent.

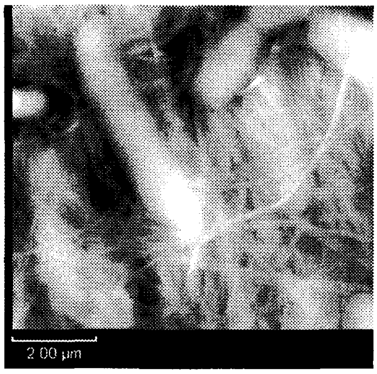

Fig. 1. AFM image of bacterial cellulose pellicle (bar: 2μm)

We used bacterial cellulose (BC) pellicles as the starting material and created composites by filling the cavities of the BC sheets with transparent thermosetting resins such as epoxy and acrylic by impregnation under vacuum. Surprisingly, the composite is optically transparent at a fiber content as high as 70% as well as flexible as shown in Fig. 2, with low thermal expansion coefficient (similar to that of silicon crystal), and mechanical strength five times that of engineered plastics.

Fig. 2 Flexibility of 65-μm-thick bacterial cellulose sheet with acrylic resin, 60% fibre content sheet.

These significant improvements in thermal and mechanical characteristics of the BC composite make it an excellent candidate for transparent substrate of organic EL (OLED) flexible display, since one of the greatest barriers to realize OLED flexible display is that the metal wiring, transparent conductive film, and gas barrier film configured on the traditional substrates made of polymer materials could be broken or damaged by the temperatures involved in the assembly and mounting processes because of the difference of their thermal expansion coefficients from that of the substrate material.

This optically transparent composites material was created by the fusion of all of the information required among the Research Institute for Sustainable Humanosphere with deep knowledge of cellulose microfibrils, Mitsubishi Chemical Corporation and Nippon Telegraph and Telephone Corporation, the material manufacturer, with the knowledge of transparent polymer materials and composite materials.

Part of these results was published in *Advanced Materials*, 2005, 17(2), 153-155.