

**Transparent Nanofiber Paper - 21st century paper-**

**(Laboratory of Active Bio-based Materials, RISH, Kyoto University)**

Masaya Nogi, Antonio Norio Nakagaito, and Hiroyuki Yano

We cannot see through ordinary paper because it's constituent micrometer sized cellulose fibers and large cavities scatter light, which makes paper opaque (Fig. 1. left). Now, we have developed transparent paper (Fig. 1. right) [1, 2]. Using cellulose—as in normal paper—and downsizing the fibers using a simple processing technique, we produced 'transparent paper' which, unlike many transparent plastics, does not expand significantly on heating. This paper is ideal as an alternative substrate for electronics, which could even be used in roll-to-roll processing.

The transparent paper was made using wood flour, in which cellulose nanofibers are usually bundled together to make larger, 30  $\mu\text{m}$ -wide fibers. We started by swelling the bundled cellulose fibers in water and then mechanically grinding them just once. This broke them down into single nanofibers.

To form optically transparent sheets of paper, the fibers must be squashed together to prevent large gaps forming between them—large spaces would scatter light and render the material opaque. We filtered the suspension to bring the fibers together and then sandwiched the resulting layers between wire mesh and filter paper and dried it for three days. Once the fibers are compacted together in this way, hydrogen bonds hold them in this configuration even after the pressure is removed.

After polishing the surfaces, the sheet became transparent with 71.6% light transmittance at 600nm (Fig.2). The sheets were foldable like normal paper and had high strength and a thermal expansion coefficient comparable to that of glass. This flexibility makes it perfect for roll-to-roll processing, which will be vital for making future bendable electronic devices.

**References**

- [1] M. Nogi, S. Iwamoto, A. N. Nakagaito, and H. Yano, "Optically Transparent Nanofiber Paper", *Advanced Materials*, vol. 21, no. 6, pp1595-1598, 2009.
- [2] D. Pile, "Materials: Transparent Nanofibre Paper", *Nature Photonics*, vol. 3, no. 6, pp314, 2009.

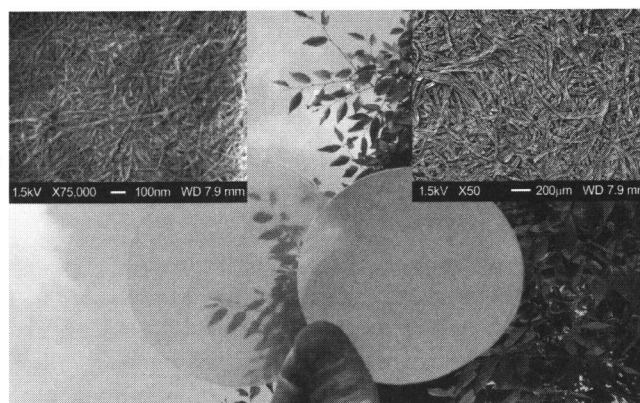


Figure 1. Optically transparent nanofiber paper (left) composed of 15nm cellulose nanofibers (upper left, scale bar in inset: 100 nm) and conventional cellulose paper (right) composed of 30  $\mu\text{m}$  pulp fibers (upper right, scale bar in inset: 200 $\mu\text{m}$ ).

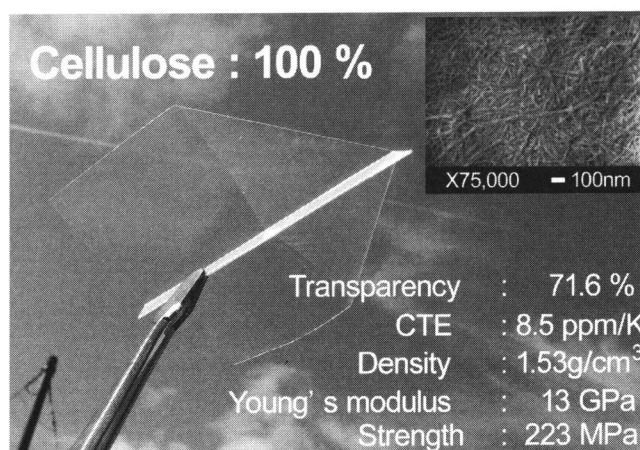


Figure 2. Paper airplane; The transparent nanofiber sheet folds like traditional paper.