Tensile Characteristics and Measurement of Micro/Nano Fibers

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Performing accurate tensile measurements on a large range of specimens has identified a need for a nanoTensile test instrument. The Hysitron nanoTensile™ 5000 integrates proven techniques allowing for the application of mechanical loads up to 10N and providing high-resolution elongation measurements.

Recently, much work has been done on the development of tensile testers for single fibers. These instruments, however, show some limitations in the application of very small loads. One critical issue that can cause errors in micro/nanoscale tensile testing is alignment. Figure 1 shows a typical offset angle along the loading direction. It was found that longitudinal stress decreases with increasing offset angles.

Within the nanoTensile instrument, an alignment control system has been developed to assure accurate longitudinal load and elongation measurement. Figure 2 shows the alignment detector from the software interface. The system senses X-Y lateral force/displacement and automatically moves the X-Y stage to adjust the offset angle. As illustrated in Figure 2, the movement from position A to B indicates that the offset angle is adjusted to zero.

The nanoTensile instrument can be used to study the tensile properties of single micro/nano fibers such as polymeric fiber, optical fiber, wool and cotton fibers, as well as biological samples, as seen in Figure 3. One interesting example is the determination of the tensile properties of human hair. The tensile strength can be measured using the nanoTensile instrument to determine the effects of hair treatments and chemical processes.

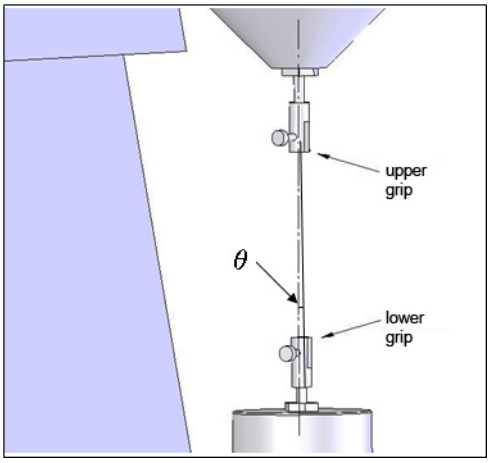

Figure 1. Alignment of the fiber at an offset angle.

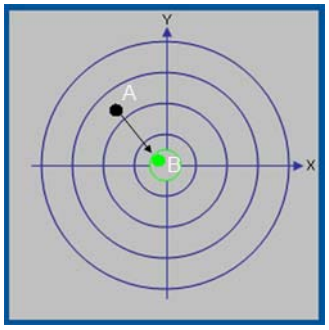

Figure 2. Schematic of the alignment detector.

Depending on the type of fibers, a number of gripping methods can be considered. In general, one approach is to attach two metal tabs to either side of the sample support and then mount the fiber to the tabs with an adhesive (Figure 4). Mounting the specimen is simplified through the use of

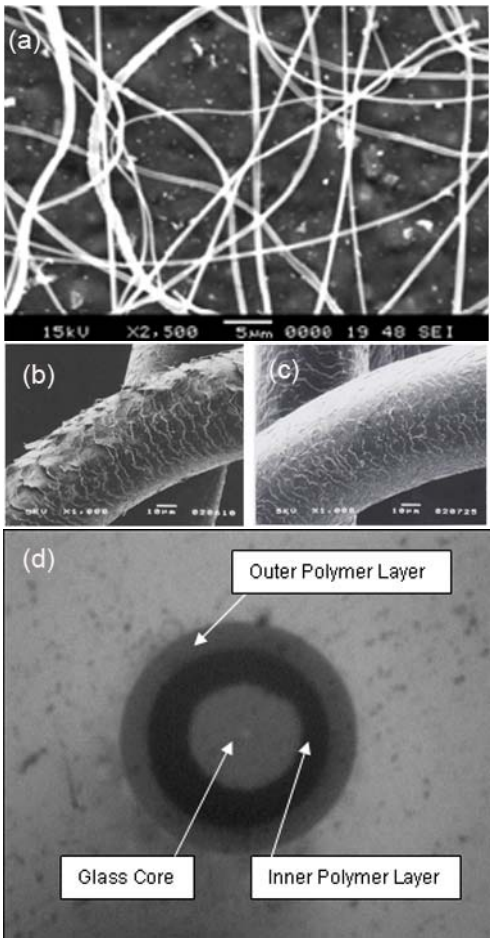

Figure 3. Typical micro/nano fiber samples. (a) electrospun PCL fibers[1]; (b) damaged hair fiber [2]; (c) LIPIDURE treated hair fiber[2]; and (d) a cross-sectioned optical fiber sample[3], image size: 528×436μm.

grips custom designed for this application. The tab fits into a groove and is then secured with a small screw. Before starting the test, the vertical edges of the support frame will be cut so that the tensile load is applied to the fiber specimen.

When both the displacement and the force are measured in the tensile test, Young's modulus (E), yield stress (σ_y) and strain (ε), and ultimate tensile strength (σ_u) can be determined. Figure 5 shows a typical diagram of stress vs. strain behavior of some fiber/hair samples.

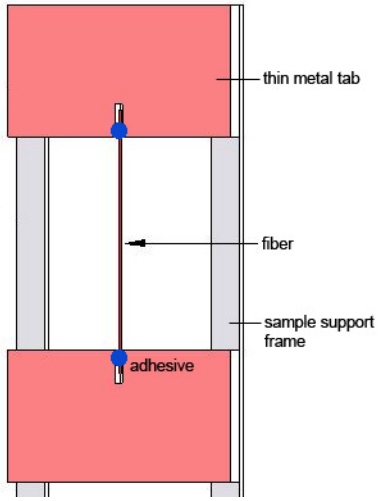

Figure 4. Schematic diagram of specimen mounting method.

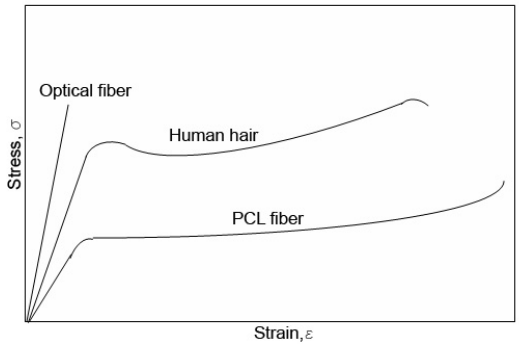

Figure 5. Typical stress-strain curves for optical fiber, PCL fiber and human hair.

Reference:

[1].K.P. Kladi, etc. "Fibrous Scaffolds by Electrospinning of poly-(ε-caprolactone)/Layered Silicate Nano composites", ISNM 2005.
[2].http://www.nof.co.jp/business/life/lipidure/english/lipidure/02.html
[3].Jeff Turek, Dehua Yang, http://www.hysitron.com/Applications/Indentation%20optical%20fiber.htm.

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