C10G-E087

SHIMADZU
Excellence in Science

Solutions for Utilizing New Environmentally Friendly Materials

Analytical and Measuring Instruments for Cellulose Nanofibers





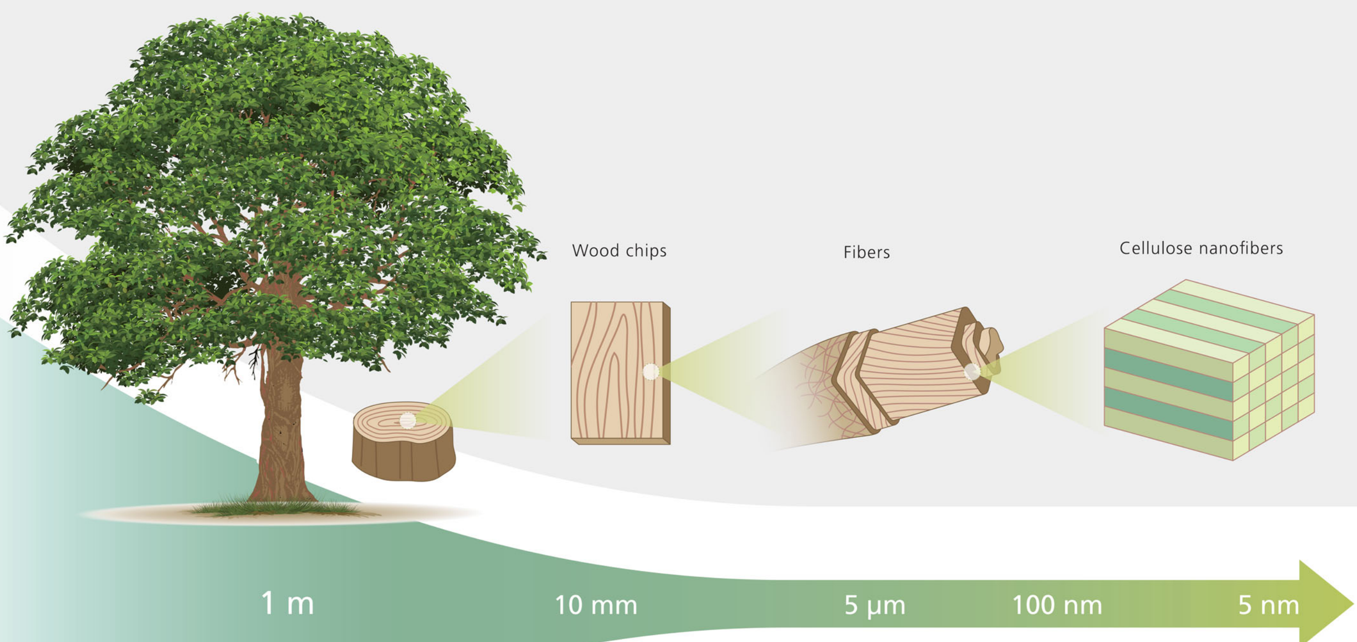
A Future World Built with Cellulose Nanofibers

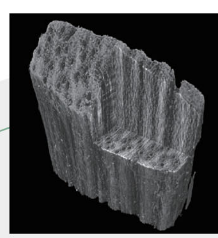
Since the second industrial revolution, humans have used petrochemical fuels to increase industrial efficiency to high levels. Industrial development during the second half of the twentieth century resulted in affluent lifestyles in much of the world. While there are many positives from this era, we must now confront various consequences from that development, such as global warming and other potential environmental problems.

Given that cellulose nanofibers (CNFs) offer attractive physical characteristics, such as light weight, strength, and hardness, they not only enable materials with advanced functionality, but are expected to be used as a reinforcing material that can reduce the weight of composite materials. In contrast to advanced nanomaterials made from petrochemical fuels and inorganic substances, CNFs are made from plant biomass. In addition to being environmentally friendly and safer, they have been confirmed to offer superior performance.

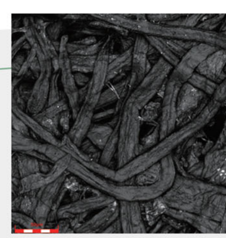
Mixing CNFs into the pulp used to make speaker diaphragms, for example, enabled higher quality sound reproduction by improving the Young's modulus of the diaphragm and broadening the range of high-frequency sounds they can produce. Adding CNFs to the midsole of running shoes achieved a lighter shoe and superior cushioning performance. Thus, CNFs have started being used in many everyday products, such as rip-resistant disposable wipes, ballpoint pen ink, cosmetics that provide a young appearance without feeling sticky, and waterproof cosmetic face masks.

Applications for CNFs are expected to continue expanding; examples include lighter and stronger CNF polymer composite materials used as structural materials in aircraft and transparent CNF panels enhanced with functionality for conductivity.





X-Ray CT Scan of Eucalyptus Wood Chip Used to Produce Pulp



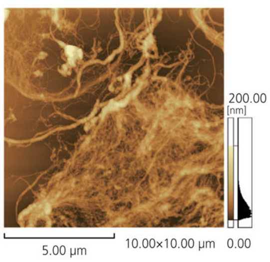
Laser Microscope Image of Pulp Fiber, a Raw Material in CNFs

Photograph of Cellulose Nanofibers

Main Types and Characteristics of Cellulose Nanofibers

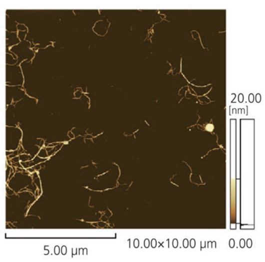
There are two basic methods for manufacturing CNFs. The break-down method creates fine fibers by breaking down (defibrating) plant-based fiber used as a raw material, whereas the bottom-up method uses sugar as a raw material to create fine fibers as metabolites of microorganisms. The break-down method involves either using an external force to physically break apart the fibers or using a catalytic chemical reaction to break the fibers apart chemically.

The shape and properties of CNF nanofibers can vary widely depending on the methods used to manufacture them. Mechanical defibration often involves using a grinding stone or millstone. Given that it uses shearing forces to break apart pulp fibers several millimeters long into nanofibers, controlling the fiber length and thickness is difficult, but mechanical defibration is well suited to mass production. In contrast, the aqueous counter-collision (ACC) method breaks the fibers apart in water due to a pressure differential generated by microcavitation. The cushioning effect of the water results in transferring the external forces necessary for breaking the fibers apart more uniformly, which produces nanofibers with a narrower range of thicknesses. The most typical chemical defibration method is TEMPO oxidation. This method involves using a TEMPO oxidation catalyst to add carboxyl groups to the cellulose microfibrils to produce CNFs with high dispersibility in water, due to repulsion between the molecular chains. In the case of nanocellulose from fermentation, acetic acid bacteria produce CNFs as a metabolite of glucose, which results in fibers with uniform diameters and extremely high aspect ratios.

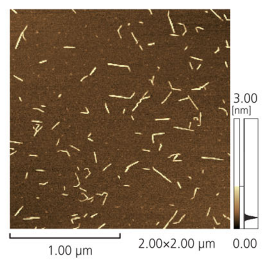


Mechanical Defibration Method

Source: Paper Industry Innovation Center of Ehime University

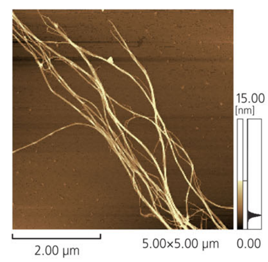


Water Jet Method



Chemical Defibration
(TEMPO oxidation catalyst)

Source: Professor Isogai, The University of Tokyo



Nano-fibrillated Bacterial Cellulose: NFBC

Source: Associate Professor Tajima, Hokkaido University

Measurement Matrix for Evaluating Cellulose Nanofibers

CNF Evaluation

Evaluation Parameter	Measuring Instrument	Product/System Name
Dispersibility	UV-VIS spectrophotometer	UV-2600i
Functional Group Type	Fourier transform infrared spectrophotometer	IRSpirit™
		OLS5000
Fiber Diameter and Length	Scanning probe microscope	SPM-9700HT
Crystal Structure	X-ray diffractometer	XRD-7000
Heat Resistance	TG/DTA simultaneous measuring instrument	DTG-60
Constituent Sugars	Ultra high performance liquid chromatograph	Nexera™ reducing sugar analysis system
Cohesiveness	Nanoparticle size analyzer	SALD-7500nano high-sensitivity model
Monodispersity	Single nanoparticle size analyzer	IG-1000 Plus
Solids Content	Moisture analyzer	MOC63u
Metals Concentration	Energy dispersive X-ray fluorescence spectrometer	EDX-8000
Metals Concentration	Simultaneous ICP atomic emission spectrometer	ICPE-9800 series

CNF Composite Material Evaluation

Evaluation Parameter	Measuring Instrument	Product/System Name
Non-Destructive Observation of Interior	Microfocus X-ray CT system	inspeXio SMX-100CT Plus
Thermal Properties	Differential scanning calorimeter	DSC-60 Plus
Material Strength	Tabletop precision universal testing machine	Autograph AGX™-V series
		Autograph AGS-X series
	High speed impact testing machine	HITS-X series

Note: System configurations may vary depending on the given measurement conditions. For more details, contact a Shimadzu representative.

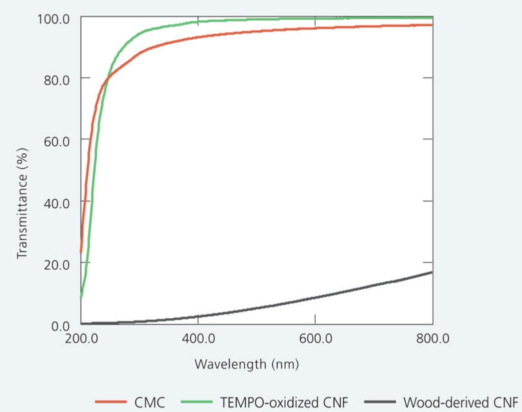
Evaluation of the Dispersibility of CNF Water | UV-2600 | Application News A610

CNF water dispersion varies depending on the fiber diameter and shape. Monodisperse CNFs with small fiber diameters are dispersed in water without aggregation by surface treatment, such as a functional group modification, and become transparent. Networked CNFs with large fiber diameters contain various sizes and shapes, and easily flocculate in water due to a hydrogen bond, etc. and become cloudy. The dispersibility of CNFs can be evaluated by measuring the transmittance of the CNF water dispersion using an UV-VIS spectrophotometer.

UV-VIS spectrophotometer

UV-2600i

- •Equipped with a low-noise, low stray light diffraction grating with a wide wavelength range
- •Wavelength range of 220 to 1,400 nm can be measured with ISR -2600 Plus integrating sphere attachment
- •Automated data processing with standard software



The transmission spectra of 3 different kinds of CNF-related materials measured at 0.1 wt% water dispersion is shown above. The transmittance of a TEMPO oxidized CNF and a carboxymethyl cellulose (CMC) were high in the visible region. On the other hand, the transmittance of a wood-derived CNF, which is the networked type, was low. From this, it is understood that the TEMPO oxidized CNF and the CMC have high dispersibility.

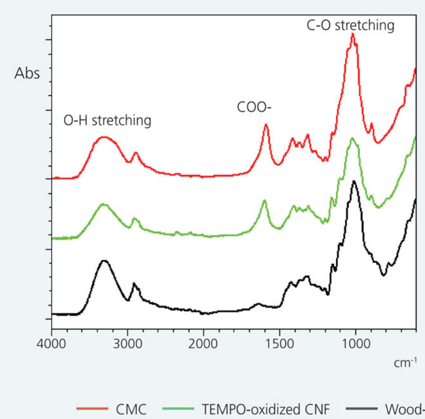
Evaluation of Modification Functional Groups in CNFs | IRSpirit-T | Application News A611

CNFs are expected to be applied to automotive, electronic, and packaging materials, because they can give various properties such as transparency and dispersibility by modifying functional groups on the surface. The modification functional groups in CNFs can be easily evaluated using a Fourier transform infrared spectrophotometer.

Fourier transform infrared spectrophotometer

IRSpirit™ (Equipped with an ATR accessory QATR-S)

- •Space-efficient system with high expandability, this compact FTIR travels where it's needed.
- •For sites with only a narrow space available, samples can be measured with the unit positioned horizontally or vertically.
- •With the widest sample compartment in its class, it easily accommodates Shimadzu and third-party accessories.



The above figure shows the infrared spectra of three types of cellulose film samples measured by the ATR method. A peak originating from the antisymmetric stretching vibration of COO- of carboxylate can be seen around 1,600 cm^{-1} in a TEMPO-oxidized CNF and a CMC. The results reveal that the modification functional groups are different in the TEMPO-oxidized CNF, the CMC, and a wood-derived CNF.

Borregaard

Borregaard produces advanced and environmentally friendly biochemicals that replace oil-based products. Borregaard is also a leading producer of cellulose fibrils, including Exilva Cellulose Nano Fibrils, and has launched the world's first commercial plant for producing this product.

Industrialization and practical use of Exilva

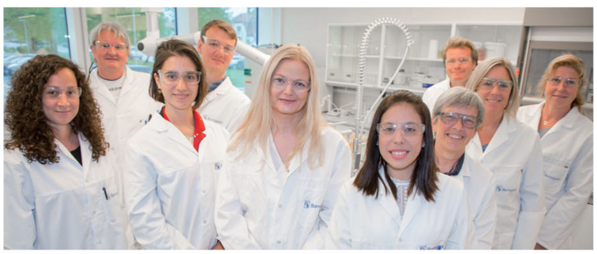
Exilva microfibrillated cellulose gives functionalities relating to rheology, stability and film forming. It can build yield stress, combined with a sharp and defined yield point. This provides a very efficient additive for stability. Exilva is used for stabilizing materials such as coatings, adhesives, and agricultural chemicals. The shear thinning behavior makes it very suitable for controlling spray behavior and stability in chemical formulations. Consequently, Exilva can offer benefits like anti-settling, anti-sag, improved spraying, and film forming.

Outlook for the future of CNF

Some sources are expecting the market for cellulose fibrils to surpass USD 1 billion by 2024. The interest in this product is very high from industry and the sustainability profile this product delivers is fitting well with the increased demand for bio-based additives.

Expectation for analysis and measurement (for Shimadzu products).

We encourage further development of measurement methods to determine individual fibril size and distribution as well as the aspect ratio of dispersed CNF. Other properties such as morphology and surface charge and potential are also of high interest. Continuous measurement of coalescence behavior would be very helpful for the development of applications for CNF. Furthermore, it will be highly beneficial to relate advanced and time-consuming measurements to less complex in-line or lab measurements to facilitate faster CNF market growth.



Dr. Hans Henrik Øvrebø

Chief Technology Officer

Borregaard Group

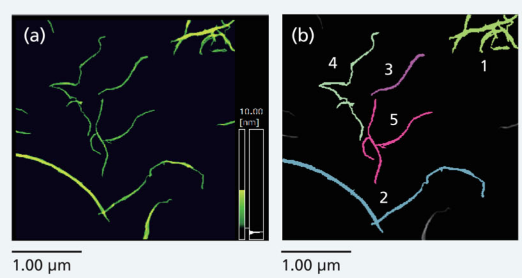
Nanoscale Observation of CNFs and Analysis of Fiber Length and Width | SPM-9700HT | Application News S030

One of the current issues is that evaluation methods for basic physical properties of CNFs have not yet been established. For example, as the fiber length and width of the CNFs are thought to influence the mechanical strength of CNF composites, establishment of a method for measuring the fiber length and width is demanded. A Scanning Probe Microscope (SPM), a type of Atomic Force Microscope (AFM), and a transmission electron microscope are generally used for observation of CNFs.

Scanning Probe Microscope

SPM-9700HT

- 3D observation and measurement on a nanometer scale
- Insulators can be observed as they are.
- Enables observation in air, solution, atmosphere and vacuum.
- Various physical properties such as electromagnetism and viscoelasticity can be measured.



These are the measured results of water-dispersed CNFs using SPM. The shape image (a) clearly shows the fiber shape.
(Observation range: 2.5 μm × 2.5 μm)

No.	Fiber Length [μm]	Fiber Width [μm]
1	2.3	10
2	3.3	10
3	0.8	6
4	2.2	6
5	2.2	6
Average	2.2	8

By using particle analysis software for the shape image (a), individual fibers can be extracted and the fiber length and width can be easily measured. (Refer to the shape image (b)) As a result, the fiber length was 1 to 3 μm and the fiber width was 6 to 10 nm.

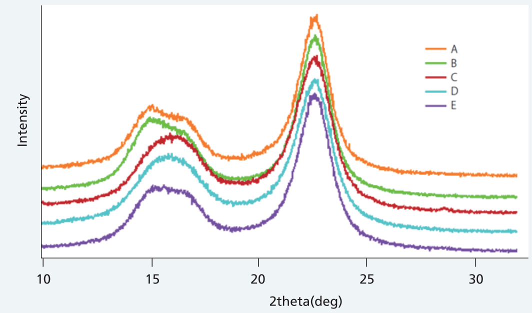
Measurement of Crystallinity of CNFs | XRD-7000 | Application News X269

Cellulose is known to be composed of various sugars. Sugars are broadly divided into two types: crystalline, represented by glucose, and amorphous, represented by xylose. Crystallinity is a factor that affects the chemical and physical properties of cellulose. The Segal method (1959) is widely used to calculate the crystallinity of cellulose.

X-ray Diffractometer

MAXima_X XRD-7000

- Equipped with a high-precision horizontal goniometer
- Automatic stress mapping of samples up to 350 nm in diameter is possible.
- Various analyses such as particle system, crystallinity, and precise X-ray structure analysis can be performed with the angle spread and profile of a peak.



Sample	Crystallinity (%)
A	84
B	86
C	76
D	77
E	82

The above figure shows the waveform measured by an X-ray diffractometer with a sheet made by removing water from five types of CNF water dispersions with different fiber lengths. Also, the crystallinity results obtained from the Segal equation are tabulated. Differences in crystallinity are observed among the samples. As a quality control of CNFs, it is possible to evaluate crystallinity by an X-ray diffractometer.

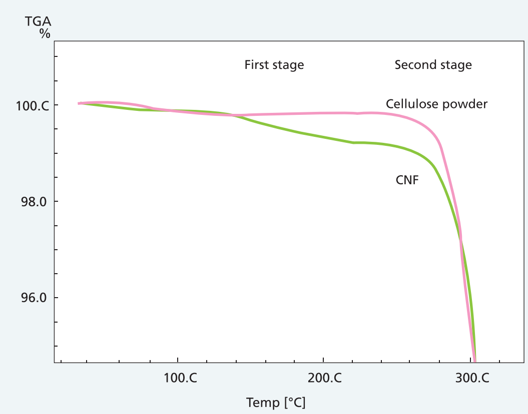
Thermal Stability Evaluation of CNFs by Thermogravimetry | DTG-60 | Application News T155

Thermogravimetry is a technique used to measure the change in weight of a sample when it is heated at a constant rate. It can be applied to measuring weight changes such as evaporation and decomposition, and thermal stability can be evaluated. The properties of CNFs vary greatly depending on crystallinity and degree of polymerization (fiber length), and there is also a difference in decomposition starting temperatures, which are indexes of heat resistance, with respect to thermal stability. It is thought that CNFs with high-purity cellulose show the same weight change as cellulose powder whereas CNFs with low purity cellulose show weight change at a lower temperature than cellulose powder.

TG/DTA Simultaneous Measuring Instrument

DTG-60

- An analytical balance mechanism (Roberval mechanism) offers high-sensitivity and high-accuracy measurement
- Easy-to-maintain plug-in detectors
- Direct reaction gas to a sample



Shown above are results from an analysis of a wood-derived CNF and cellulose powder (Purity: 97% or more), which were dried after heat treating at 80 °C for 10 hours. Weight reduction (decomposition) of the CNF occurred in two stages: around 140 °C and 260 °C. The temperature for weight reduction in the second stage was similar to the temperature for weight reduction of the cellulose powder, suggesting that the first-stage weight reduction was caused by a substance other than cellulose.

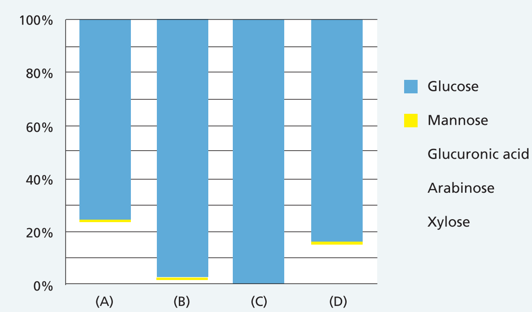
Analysis of Constituent Sugars in CNFs

Reducing Sugar Analysis System

Cellulose is a main component of cell walls in plant cells and plant fibers, and bundles of cellulose fibers constitute CNFs. In addition to cellulose, plants consist of hemicellulose, lignin, and other substances, but the ratio of those substances varies depending on the types, parts, and habitats of the plants. The purity of CNFs can be determined by an analysis of constituent sugars in cellulose. The constituent sugars can be analyzed by hydrolyzing the CNFs into monosaccharides. The figure on the right shows the results of analysis of hydrolyzed samples by an HPLC sugar analysis system.

Nexera™ Reducing Sugar Analysis System

- This system is used to detect saccharides with high sensitivity and selectivity by thermal reaction with a reaction solution containing arginine to form a fluorescent derivative after separation on a column.



The ratio of glucose derived from cellulose to xylose derived from hemicellulose is different between a hardwood pulp (A) and a softwood pulp (B), indicating that the purity of CNFs varies depending on the types of plants. Nano-fibrillated Bacterial Cellulose: NFBC (C), which is produced from acetobacter using glucose as a raw material, is composed entirely of glucose. TEMPO oxidized cellulose nanofibrils (D) contain glucuronic acid. It is found that the glucose on the surface of microfibrils was ionized by a TEMPO catalyst because of the defibration process, and detected as glucuronic acid with a negative charge.

Analytical Instruments Are Essential for Utilizing CNFs

CNFs are generally produced from pulp by a top-down approach, using a variety of methods, such as TEMPO oxidation, grinding, aqueous counter collision, and acidic or enzymatic hydrolysis methods. At the same time, CNFs (NFBCs) can also be produced from sugars or other small biomass molecules based on a bottom-up approach, by cultivating the fibers in an aerated culture with a suitable dispersing agent added to cellulose-producing bacteria (acetic acid bacteria). Due to the variety of methods available for producing CNFs, the CNFs produced by each method can have a wide range of structural and compositional characteristics.

Currently, there are active efforts around the world to develop CNF applications that take advantage of the specific properties and structural characteristics of the different CNFs. However, in order for CNFs to be used on a commercial scale, as a raw material with a given quality level, it is extremely important to measure a wide variety of characteristics, such as dispersibility, shape, fiber length, crystallization level, heat resistance, molecular composition, cohesiveness, concentration of solids, and mechanical properties, so that standards can be established.

With current efforts to establish standards being spearheaded around the world and in Japan, such as at the National Institute of Advanced Industrial Science and Technology and at other relevant companies, there is a need for measuring devices that are not only accurate, but also quick and easy to operate. In Japan, CNFs with unique characteristics are being created in respective regions of the country, with academic institutions engaged in basic research and companies developing commercial applications in each of those regions. Consequently, we anticipate the use of CNFs in a wide range of fields.

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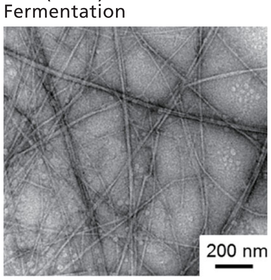
田島健次

CNF (NFBC) from Microbial Fermentation

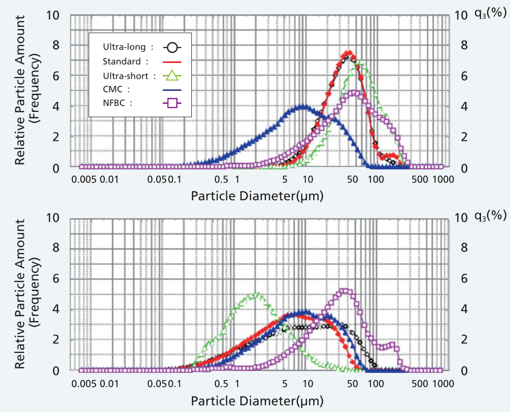


Evaluation of Fiber Length and Dispersibility of Water-Dispersed CNFs | SALD-7500nano | Application News Q121

Fiber length and fiber diameter are known to be related to the physical properties of CNFs, which are mainly observed with a microscope. However, since they are observed in a dry condition, the properties may be different from those before drying. Therefore, there is a need for a quick and simple method for evaluating the fiber length of CNFs in the water-dispersed state.
This section introduces examples of evaluating the fiber length and dispersibility of various CNFs using the SALD-7500nano nano particle analyzer (special specification).

Nano Particle Size Analyzer
SALD-7500nano (highly sensitive model)

•A particle size analyzer measuring wide-ranging particle sizes from 7 nm to 800 µm with high sensitivity. Everything from primary particles to aggregates and contamination can be measured in a single unit.



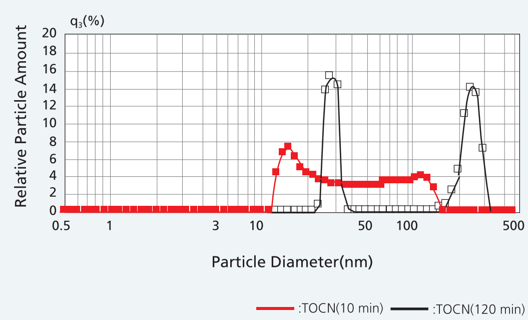
Shown above are results of pulp-derived CNFs (Ultra-long, Standard, Ultra-short), carboxymethyl cellulose (CMC), and nano-fibrillated bacterial cellulose (NFBC) before and after dispersion treatment using an internal sonicator. For all pulp-derived CNFs and NFBC, there is no correlation between fiber length and particle size because fibers aggregate before the dispersion treatment, but there is correlation with fiber length after the dispersion treatment. With CMC, there is no clear difference in the particle size before and after the dispersion treatment. This is thought to be because the dispersion is stable in water.

Evaluation of Fiber Length and Dispersibility of Monodisperse CNFs | IG-1000 Plus | Application News S31

In addition to needing a method for evaluating the fiber length of CNFs in the water-dispersed state, a simple method to evaluate the fiber length and dispersion in a liquid is also required.
This section introduces an evaluation example of fiber length and dispersibility of TEMPO oxidized CNFs (TOCN), monodisperse CNFs, using the IG-1000 Plus single nano particle size analyzer.

Single Nano Particle Size Analyzer
IG-1000 Plus

•Shimadzu original particle size analyzer can measure particles with a minimal size of 0.5 nm. High-sensitivity analysis of single nanoparticles, which are difficult to measure with ordinary scattered light, is possible.



The above figure shows the results of two TOCN measurements at different defibrating times. Peaks of 30 nm and 250 nm were detected at a 10-minute processing time and a wide peak range between 10 and 150 nm was detected at 120 minutes. This indicates that the longer the machine processing time, the smaller the particle size. However, it is conceivable that the IG-1000 Plus not only detects the fiber length as the particle size, but also the information obtained by averaging the fiber length and the fiber width as the particle size.

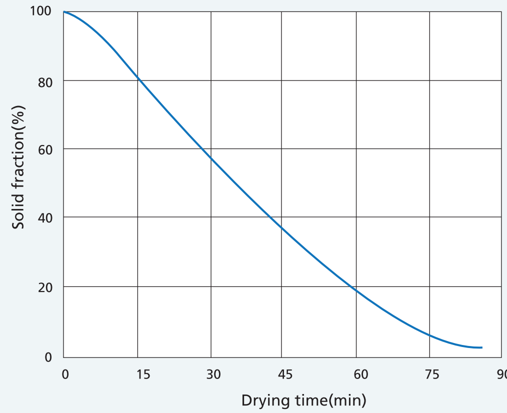
Evaluation of Solid Fraction in CNF Water Dispersion — MOC63u

CNFs are mainly produced in water dispersion. To understand the quality of CNFs, it is necessary to know solid compounds in the water dispersion. By using an electronic moisture analyzer, it is possible to easily and quickly measure the amount of CNFs contained in the water dispersion during the manufacturing process. Accurate measurements typically require multiple steps in an oven, which can take several hours, but the electronic moisture analyzer reduces the number of steps, enabling quick measurement of the solid compounds.

Electronic Moisture Analyzer

MOC63u

- Equipped with a UniBloc achieving accurate moisture measurement.
- Loaded with a halogen heater which can heat up to 200 degrees at high speed.
- Maximum weight capacity: 60 g / Minimum readability: 1mg



The above figure shows an example of measuring the solid fraction of a networked CNF in a water dispersion. The electronic moisture analyzer was set to sample the mass every 5 seconds, and raise the temperature from normal temperature to 120 degrees for 5 minutes and heat at 120 degrees. In addition, the heating was set to stop when the mass fluctuation rate was 0.05% or less compared to the latest mass. As a result of drying approximately 10 g of CNF water dispersion, the solid fraction was 2.4%. The drying time was less than 90 minutes.

Analysis of Metal Species Contained in CNFs — EDX-8000, ICPE-9820

Energy Dispersive X-Ray Fluorescence Spectrometer

EDX-8000

Metal ion concentrations contained in the CNF water dispersion can be measured easily without any special pretreatment. It is suitable for high-throughput measurements for monitoring and screening purposes. It can also be used for qualitative analysis and helps identify unknown samples.

Simultaneous ICP Atomic Emission Spectrometer

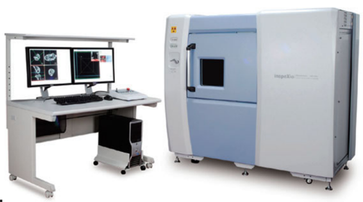
ICPE-9820

Mainly metal element concentrations contained in CNFs can be measured with high sensitivity and high accuracy. For example, it is important to accurately quantify metal ions, such as Na, which are necessary for surface modification to enhance dispersibility, and small amounts of Ag and Cu ions, which are included in CNFs to provide antibacterial and deodorant properties, in order to control quality to a certain level.

Evaluation of Internal Structures of CNF-containing Foamed Plastics

inspeXio SMX-100CT Plus | Application News N134

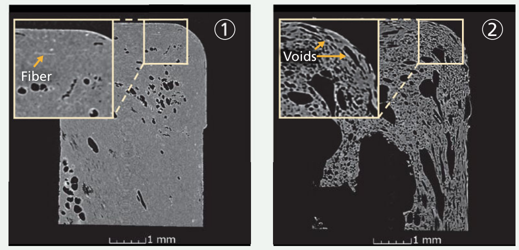
Porous-structured foamed plastics are lightweight and have excellent heat insulation, but offer less strength than non-foamed plastics. To increase strength while imparting light weight and heat insulation, fibers are added to foamed plastics as a reinforcing material. CNFs have attracted attention as a new reinforcing material due to their light weight and high strength, and are being studied for practical use. In this research, X-ray CT systems are useful for observing the internal structure of plastics and fiber dispersion.



Micro Focus X-Ray CT System

inspeXio SMX-100CT Plus

- High-magnification 3D observation of light materials such as resins and chemicals
- Ultra-fast computing system enabling high-speed creation of large amounts of data
- Full of functions such as automated CT scanning to support novice CT users



These are cross-sectional images of foamed plastics. Image 1 contains CNFs but image 2 does not. Higher density parts are shown in white and lower density parts in black. Image 1 shows that voids are more independent, smaller, and fewer than in image 2. This suggests that the size and number of voids can be controlled by adding CNFs to the plastics and foaming them. White linear inclusions, which are considered to be cellulose fibers of several tens of micrometers or more that are not defibrated when CNFs are produced, are also observed.

Thermal Properties of CNF Resin Composites

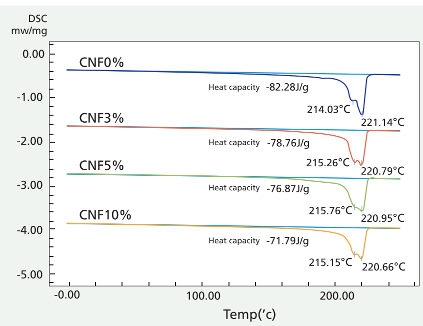
DSC-60 Plus

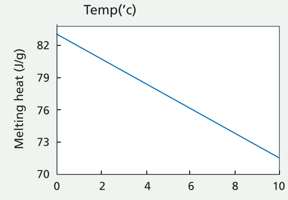
A differential scanning calorimeter (DSC) can detect changes in heat flow due to endothermic or exothermic reaction of a sample, and observe melting of polymer materials. This DSC is used to measure the melting heat of thermoplastic composites reinforced with CNFs (CNF reinforced resins). Since thermoplastic resins are recyclable, the CNF content of recycled products can be estimated by measuring the melting heat of the CNF reinforced resins.

Differential Scanning Calorimeter

DSC-60 Plus

- Achieves a stable baseline from low to high temperatures
- Standard-equipped refrigerant tank for liquid nitrogen
- Automatic analysis using a template method





The amount of melting heat was determined from DSC curves when PA6 containing 0%, 3%, 5%, and 10% of CNFs was heated from 0 °C to 250 °C, cooled to 0 °C, and heated again. As the CNF contents increased, the melting heat decreased, and a linear relationship was obtained between the CNF contents and the melting heat.

Three-Point Flexural Tests of CNF Resin Composites

AGS-X | Application News i265

CNFs are theoretically 1/5 as light as steel but five times as strong with a high specific strength. By using them as composite materials with resins and rubbers, CNFs can obtain better properties than conventional materials, and are attracting attention as a new material following carbon fiber.

A high-density polyethylene (HDPE) with 5 wt% CNFs and a HDPE without CNFs were subjected to a three-point flexural test to compare the flexural strength with and without CNFs.

Precision Universal Testing Machines

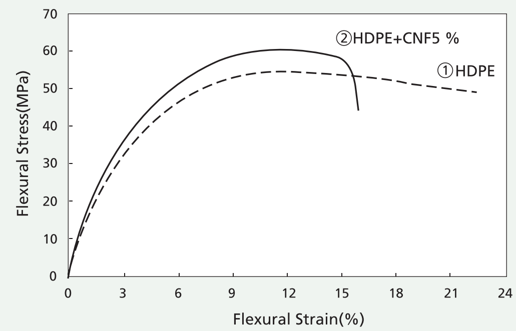
Autograph AGS-X

Performance comparable to high-performance machines

- Guaranteed test force add a space after range:±0.5 % of indicated values (1/1~1/500 of load cell rated values)
- High-speed sampling (1 sec)
- Return speed :1500 mm/min
- Testing speed :0.001 mm/min~1000 mm/min

Software equipped with macro function

- Pursuing ease of use TRAPEZIUM X
- Simple software enhancing efficiency TRAPEZIUM LITE X



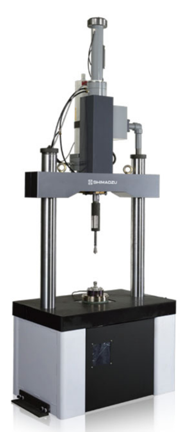
	Flexural Modulus of Elasticity(GPa)	Flexural Strength(MPa)
① HDPE	1.29	55.2
② HDPE+CNF5 %	1.56	61.8

The HDPE with CNFs showed brittle fracture with a sharp decrease in the test force after achieving the maximum strength, while the non-CNF HDPE showed ductile behavior as the test force slowly decreased and did not fail. When the maximum flexural stress of the graph was calculated from the flexural strength and the slope of the graph, the HDPE with CNFs showed high values in both the flexural modulus of elasticity and flexural strength, and both values could be increased by adding CNFs to the HDPE.

High-Speed Tensile Tests of CNF Resin Composites

HITS-TX | Application News i275

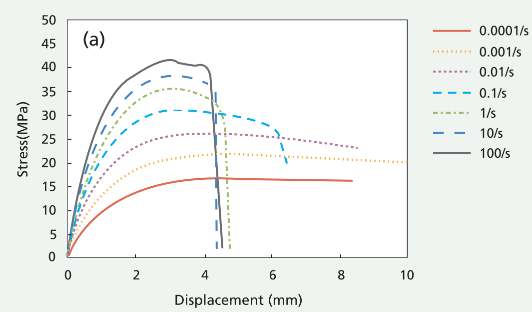
Tensile strength of a high-density polyethylene (HDPE) and a HDPE reinforced with 10% CNF (CNF10% HDPE) at various testing speeds (strain rate: 0.0001~100/s) was evaluated using an AGS-X and a HITS-TX. The figures to the right show examples of the stress-displacement curves of the HDPE and the CNF10% HDPE at various strain rates. Both materials exhibited lower tensile strength as the test speed decreased and higher tensile strength at higher test speeds.

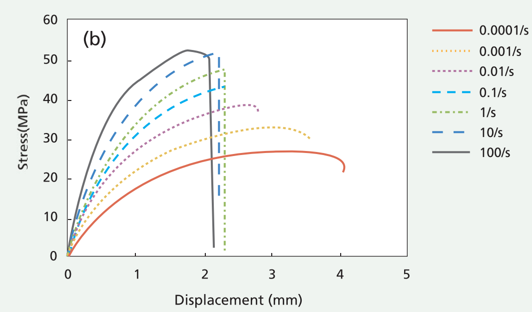


High-speed Impact Testing Machine

HITS-TX

- Maximum speed :72 km/h
- Thoroughly designed to minimize the impact
- Specialized approach jigs are used
- State-of-the-art software
- Environmentally friendly energy-saving design
- Comprehensive safety features





Stress-displacement curves
(a) HDPE (b) CNF10 %/HDPE

Shimadzu's Material Analysis and Evaluation Technology

Shimadzu provides analytical and evaluation solutions for all materials.

Test Evaluation Parameter	Material Characteristics	Measuring Instrument/Product Name
Observation/ Analysis Evaluation	Observation	Scanning Probe Microscope/SPM-9700HT, SPM-8100FM
	Non-Destructive Internal Observation	Fluoroscopic Apparatus/SMX Fluoroscopy System, SMX-CT System
	Elemental Analysis	Energy Dispersive X-ray Fluorescence Spectrometer /EDX Series
		Wavelength Dispersive X-ray Fluorescence Analyzer/XRF-1800
	Observation·Elemental Analysis	Electron Probe Micro Analyzer/EPMA Series
	Observation·Component Analysis	Imaging Mass Microscope/iMScope QT
	Elemental Analysis·Chemical State Analysis	X-ray Photoelectron Spectrometer (XPS)/KRATOS ULTRA2
Material Evaluation (Research and Development, Quality Control)	Analysis of Synthetic Reactions	Probe Electrospray Ionization Mass Spectrometer/DPiMS™-2020, DPiMS-8060
		Fourier Transform Infrared Spectrophotometer/IRTracer™-100, IRAffinity-1S, IRSpirit
		Photoreaction Evaluation System/Lightway
	High Separation and Purification	Preparative Liquid Chromatograph/Preparative LC System, Nexera Prep
		Supercritical Fluid Chromatograph/Nexera UC
		Recycle Preparative System Recycle-Assist
	Molecular Weight Distribution,	Ultra High Performance Liquid Chromatograph/Nexera Series, Prominence™-i GPC System
	Molecular Weight Measurement	MALDI-TOF Mass Spectrometer/AXIMA™ Series, MALDI-7090, MALDI-8020, MALDImini™-1
	Material Determination	Fourier Transform Infrared Spectrophotometer/IRTracer-100, IRAffinity-1S, IRSpirit
	Crystallinity	X-ray Diffractometer/XRD-6100/7000 OneSight™
	Color Measurement, Optical Characteristic	UV-Vis-NIR Spectrophotometer/UV Series, SolidSpec™-3700i
Evaluation of Additives and Hazardous Substances	Odor and Gas generated	Gas Chromatograph Mass Spectrometer/Thermal Desorption System
	Heavy Metals and Trace Elements	Inductively Coupled Plasma Mass Spectrometer/ICPMS-2030
		Inductivity Coupled Plasma Optical Emission Spectrometer/ICP Series
		Atomic Absorption Spectrophotometer/AA-7000
		Ion Chromatograph/HIC-ESP
	Identification and Quantification of Additives	Ultra High Performance Liquid Chromatograph/Nexera Series, i -Series Plus
		Ultra High Performance Liquid Chromatograph Mass Spectrometer/LCMS-8060NX, LCMS-IT-TOF™
		Gas Chromatograph Mass Spectrometer/Pyrolysis GC/MS Analysis System
	Residual Solvent	Gas Chromatograph Mass Spectrometer/GCMS Headspace Analysis System
Thermal Characterization	Endothermic and Exothermic Reactions, and Reaction Rate	Differential Scanning Calorimeter/DSC-60 Plus, TG/DTA Simultaneous Measuring Instrument/DTG-60
	Specific Heat Capacity	TG/DTA Simultaneous Measuring Instrument/DTG-60
	Evaporation/Decomposition, Gas Adsorption, Moisture Content, Heat Resistance	Differential Scanning Calorimeter/DSC-60 Plus
	Thermal Expansion and Shrinkage Rate, Softening Point	Thermomechanical Analyzer/TMA-60
Physical Characterization	Particle Size Distribution	Particle Size Analyzer/SALD Series
		Dynamic Particle Image Analysis System/iSpect DIA-10
Mechanical Performance Evaluation	Tension, Compression, Bending	Precision Universal Testing Machine/Autograph AGX-V, AGS-X
		Micro Strength Evaluation Testing Machine/Micro Autograph MST-I
	Hardness	Micro Hardness Tester/HMV-G Series, Dynamic Ultra Micro Hardness Tester/DUH-211 Series
	Friction Force (Tribology)	Scanning Probe Microscope/SPM-9700HT, SPM-8100FM
	Fatigue Strain Test	Fatigue/Endurance Testing Machines/Servopulser
		Electromagnetic Force Micro Material Tester/Micro-Servo
	High Speed Tension/High Speed Punching	High Speed Impact Testing Machine/HITS-X Series
	Particle Strength	Micro Compression Tester/MCT Series
Rheological Characterization	Viscosity Property	Capillary Rheometer Flowtester/CFT-500EX/100EX
	Viscoelastic Evaluation	Mooney Viscometer/SMV-301/301RT
Mass Evaluation	Specific Gravity	Specific Gravity Measurement Kit/AP/AU/AT-R/UP/UW/UX Series
	Mass	Analytical Balance, Precision Balance, Platform Scale
	Moisture	Moisture Analyzer/MOC63u

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