Technical Data Sheet: Tunicate Cellulose Nanocrystals (TCNCs; Nature's Rebar™)

Product Overview & Value Proposition

Nature's Rebar™ is a commercially-available product of Tunicate Cellulose Nanocrystals (TCNCs). TCNCs are rod-like nanoparticles derived from the mantle of an abundant and invasive marine invertebrate known as tunicates.

Nature's Rebar™ has a unique ultra-high-aspect ratio, highly-crystalline structure, which imparts it with exceptional performance-enhancing properties in a variety of different application areas. Nature's Rebar™ delivers superior mechanical reinforcement, shear-thinning rheology control, and cracking/tearing prevention at ultra-low loading levels.

Physicochemical & Structural Specifications

A TEM image of Nature's Rebar™ is shown in Figure 1. Note the exceptional aspect ratio, narrow widths, and rigid structure of this product. Further specifications of TCNCs extracted via Tunistrong's process are shown in Table 1 below.

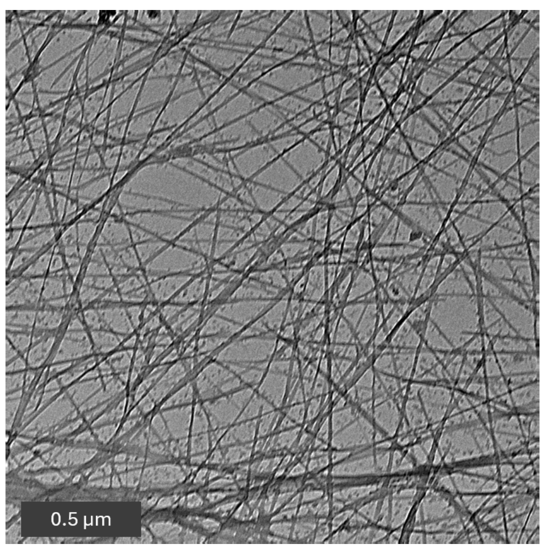

Figure 1: Representative TEM image of Tunistrong's TCNC product, Nature's Rebar™

Table 1: Properties of Tunistrong's TCNCs

Property	Value / Specification	Test / Analytical Method
Physical Appearance	Aqueous colloidal suspension	Visual inspection
Isolation Pathway	Acid & alkali protein removal, oxidation, homogenization	Pilot-scale processing
Average Aspect Ratio (L/D)	~65 (distribution spanning 20–130; peak at 60–80)	TEM & image analysis
Crystallite Width	~20 nm (associated with small bundles)	TEM analysis
Crystallite Appearance	Rigid, straight, unbranched	TEM
Crystallinity Index (XRD)	75%	Powder X-ray Diffraction
Crystallinity Index (Raman)	68% (380-Raman) / 96% (93-Raman)	FT-Raman spectroscopy
Crystal Allomorph	Pure Cellulose Iβ	XRD diffractometry & FTIR
Thermal Degradation Onset	225 °C (in oxidizing air atmosphere)	TGA (10 °C/min, RT to 700 °C)
Inflection Point (Tmax)	291 °C (in oxidizing air atmosphere)	Derivative Thermogravimetry
Char / Ash Content	<5% in air, <10% in Nitrogen	TGA residue at 600–700 °C
Specific BET Surface Area	91.9 ± 2.1 m^2/g (total pore volume: 0.2610 cm^3/g)	N2 adsorption at -196 °C
Surface Chemistry*	Predominantly hydroxyl and carboxyl groups	FTIR Spectroscopy
Carboxyl Content*	0.1 to 0.25 mmol/g	Conductometric Titration
Zeta Potential Range*	-15 to -25 mV (pH 2), -25 to -35 mV at pH 7, -35 to -40 mV (pH 10)	Dynamic Light Scattering

*Surface chemistry, carboxyl content, and Zeta Potential can be tailored upon request

Cracking Prevention & Tear Resistance

TCNCs provide exceptional performance for arresting crack propagation and improving tear resistance within a wide range of matrices, such as in **paints, coatings, films, polymer composites, spun fibres, and more**. The effects of TCNCs in these materials are more pronounced than those of traditional wood-derived CNCs, in part due to the significantly higher crystallinity, leading to higher tensile and flexural strength of individual crystallites. The nano-structured network of TCNCs are thought to delay cracking failure through three mechanisms:

- **Crack Bridging:** Due to their long lengths, TCNCs effectively bridge micro-cracks at the nanoscale, preventing them from coalescing into macro-scale failures.
- **Crack Deflection:** The presence of a rigid TCNC network forces advancing crack fronts to navigate a tortuous path around the rigid cellulose crystallites, dissipating significantly more energy during the fracture process.
- **Stress Redistribution:** The high-aspect-ratio network acts as a secondary load-bearing skeleton, redistributing localized stresses across a larger volume of the material.

These effects combine to make Nature's Rebar™ an exceptional additive for preventing cracking and tearing across applications such as paints, coatings, films, polymer composites, spun fibres, and many other materials.

Rheological Profile

The rheological behavior of TCNCs is governed by their high aspect ratio and surface charge density. In aqueous suspensions, TCNCs are strongly shear-thinning, and exhibit a complex phase behavior that transitions from isotropic to anisotropic as concentration increases. These effects can be particularly useful for applications in **paints, coatings, adhesives, fiber-spinning,** and some **optical applications**.

Application and Flow Control

- **Viscosity & Shear Thinning:** TCNC suspensions exhibit pronounced shear-thinning (pseudoplastic) behavior. This behavior enables **spraying, brushing, or syringe extrusion** of paints, coatings, and adhesives. The network locks back rapidly at rest to **minimize running or sagging**.
- **Storage Modulus (*G′*):** The resting gel state provides dominant elastic network integrity ($G' > G''$). This trait provides excellent **shape retention after deposition**.

Structural Alignment and Advanced Performance

- **Isotropic-to-Anisotropic Transition:** Spontaneous self-assembly into ordered liquid-crystalline domains occurs as evaporation proceeds or concentration rises. This alignment can provide benefits during **fibre spinning** and improved mechanical performance of spun fibres. This effect can also be exploited for **chiral optical applications**.

Material and Cost Efficiency

- **Percolation Threshold:** Due to their very high length-to-width ratio, the geometric percolation threshold in 3D networks is remarkably low, often occurring at volume fractions below 0.5 wt%. This allows TCNCs to achieve performance goals at **exceptionally low loadings**, helping to **reduce material costs**.

Composite Mechanical Reinforcement Performance

TCNCs enhance the mechanical properties of polymer matrices, including both traditional and bio-based matrices such as 3D printing resins, PLA, PVA, polyurethanes, and many others. These benefits can vary widely depending on the composition of the polymer matrix and the processing/integration methods used.

Processing and Compatibility

- TCNCs in their native form are hydrophilic, and have good compatibility with other hydrophilic polymer matrices, such as PVA and PEO.
- As with other nanocelluloses, TCNCs cannot be readily dried into a fully redispersible product format. Therefore, applications in composites are typically limited to aqueous

polymer processing, or to methods involving solvent exchange of the TCNCs into a polymer matrix-appropriate solvent for blending/integration.

Mechanical Performance

- **Low-Loading Geometric Percolation:** Due to high aspect ratios, TCNCs establish a continuous 3D reinforcing network at volume fractions as low as 0.5 - 1.5 vol%, compared to 3.5 - 7 vol% required for low-aspect-ratio wood CNCs.
- **Tensile Strength & Modulus Reinforcement:** TCNCs typically provide large (several-fold) **modulus gains**, particularly in the rubbery state.
- **Toughness, Ductility & Energy Absorption:** While rigid nanofillers commonly **embrittle** polymer composites, the high-aspect-ratio TCNCs can **improve the strength-to-toughness trade-off** at low loadings. In solution-cast thermoplastic systems like PLA, hybrid blends incorporating TCNCs at low loadings **enhance tensile toughness** (above that of neat resin and of composites containing wood-derived low-aspect CNCs).

Cold-Temperature Toughness

- In **low-temperature environments** where resin matrices undergo polymer chain immobilization and embrittlement, the percolated nanocellulose skeleton does not undergo a ductile-to-brittle transition; its continuous crack-bridging network **restrains thermal-contraction microcracking, limits matrix shrinkage, and preserves dynamic impact energy dissipation** below 0°C. This is of interest for Arctic, Antarctic, and space environments.

Processing & Handling Guidelines

To maintain the integrity and dispersibility of TCNCs, the following processing protocols are recommended:

- **Dispersion:** TCNCs are typically supplied as aqueous suspensions. These suspensions are readily dispersible in almost any aqueous systems using standard mixing practices.
- **pH Sensitivity:** Suspensions are most stable at neutral to slightly alkaline pH. Extreme acidity may promote further hydrolysis, while divalent cations can screen surface charges and induce flocculation.
- **Storage:** Store aqueous suspensions at 4°C to inhibit microbial growth. Do not freeze aqueous suspensions directly, as ice crystal growth can cause irreversible bundling of the TCNCs.
- **Solvent Exchange:** For use in non-polar organic solvents, TCNCs require a stepwise solvent exchange (e.g., Water → Ethanol → Acetone → Toluene) to prevent irreversible aggregation (hornification).
- **Safety:** While cellulose is generally regarded as safe, TCNCs should be handled with standard nanomaterial precautions. Use appropriate PPE, including gloves and respiratory protection when handling dry powders. See MSDS for further details.

References

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