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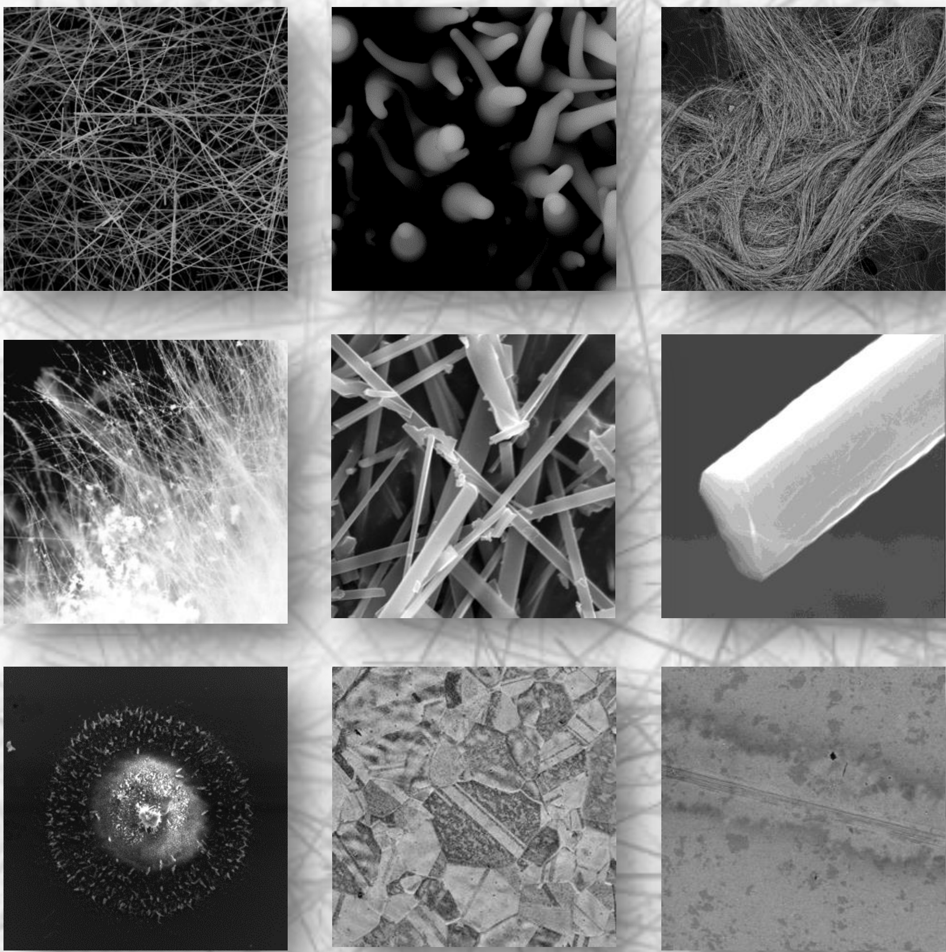
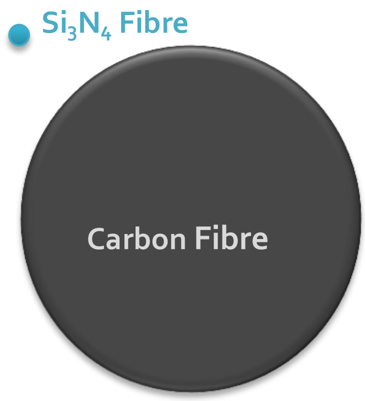
Polymer Composite Technology



www.nuenz.com

Nuenz is an advanced material company based in Lower Hutt, New Zealand. Nuenz was formed in 2011 from private-public research carried out between CRL Energy Ltd and Victoria University of Wellington.

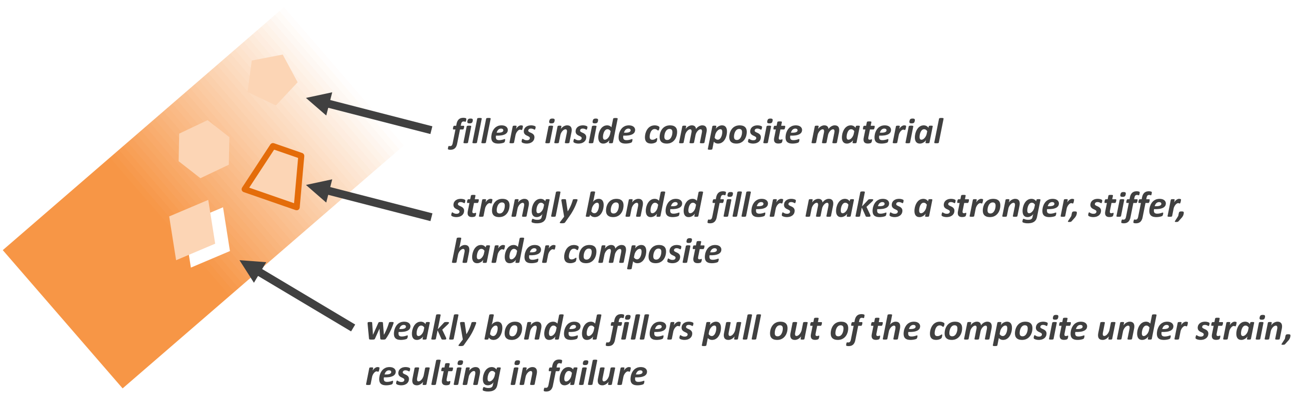


Nuenz is owned by NZCC which is one of the largest mining companies in New Zealand. Nuenz manufactures advanced additives for composite nanomaterials (100-500 nm), specialising in new materials from minerals. Our core competitive advantage is improving the dispersion of additives by understanding chemical interactions between those additives and the matrices with which they are being blended.

In late 2018 Nuenz launched our new polymer dispersion technology that allows us to rapidly disperse additives homogeneously in resins, ensuring that material property transfer occurs between the resin and the additive. Nuenz's rapid dispersion technology has now been tested across multiple case studies using silicon nitride, silicon carbide, natural New Zealand pounamu greenstone, and polymer microspheres. This versatile technology has had success in epoxy, toughened epoxy, polyurethane, vinyl ester and complex industrial adhesives such as shotcrete thin-spray liner adhesives. Nuenz is now looking to expand this technology by developing new applications with further industrial partners.

Key feature of the rapid dispersion technology:

- Homogenous mixing achieved rapidly
- Compatible with the substrate
- Test with wide variety of materials
- A service offered to predict, test and assess selected additives for compatibility and value to determine the optimum functionalisation agent for any substrate.



Case Studies

The case studies that we have developed show some examples of the dispersion technology. These have all been on resin plus additive systems. Nuenz is now moving to more complex systems which include FRP, SMC, sprayable and pultrusion model systems.

The table below shows the importance of high-quality dispersion technology. Here we added 0.1% Nuenz Si_3N_4 fibres to Derakane Vinyl Ester. Without a coating, the additive resulted in a 4% increase in the UTS – an insignificant increase. Four coatings resulted in an average 15% increase in the UTS which would be considered a significant improvement in the UTS for 0.1% additive addition. In this system, however, the ideal coating solution resulted in a 32% UTS improvement. Without a predictive method to identify Coating#7 as the ideal coating, it would be time-consuming and costly to identify this result. The reality is that many composite developments fail after identifying that the undispersed additive resulted in only a 4% UTS increase. Sometimes, undispersed additives can even result in a decrease in properties.

	UTS (MPa)	% Change
Pure vinyl ester	25	-
+Si_3N_4	26	4
+coating 1	26	4
+coating 2	28	12
+coating 3	29	16
+coating 4	29	16
+coating 5	29	16
+coating 6	32	28
+coating 7	33	32

The Nuenz Process

Nuenz's composite process is outlined below

Project Scoping

Identify desired improvements

Customer advises scope and success criteria

Cost requirements

Nuenz and the partner discuss the project and the product

Nuenz comes up with an additive proposal that meets the scope

Nuenz Testing

Samples sent to Nuenz

Nuenz produces test coupons and validates result

The partner sends resin and any other specified samples to Nuenz – typically 1kg is sufficient. Nuenz does not need to know any formulation or chemistry. The product family is sufficient. Nuenz will not reverse engineer your products.

Nuenz undertakes to meet the scope and success criteria. Typically 4-6 weeks. The timing can be longer if additional external testing is required.

Programme Review

Nuenz reports to partner

Technology transfer occurs

Nuenz prepares a report of the results based on the test results against the original scope and success criteria.

If the partner wishes to carry out further in-house testing, then Nuenz will assist with this.

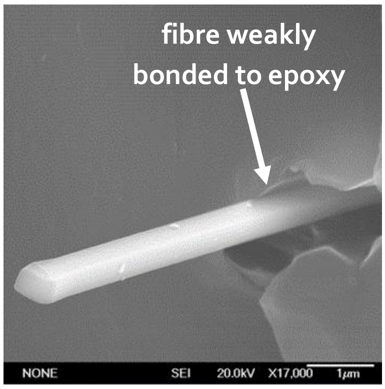
If the partner wishes to commercialise the technology, then Nuenz will facilitate this through technology transfer.

The following pages are of case studies. Please get in touch if there are any further questions about the technology at info@nuenz.co.nz

F80.FS1

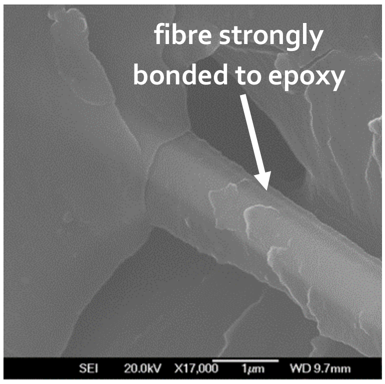
0.08% F80 Silicon Nitride Fibre in Epoxy Composite

Nuenz's Si_3N_4 was compounded with an industry standard epoxy resin. Electron micrographs showed that the fibres were poorly bonded to the resin with cavities around the fibres. These cavities would likely result in critical failure during use and could be a significant issue. Our process identified an additive to increase dispersion. The resulting product is reported as F80.FS1. The surface coating of the fibres facilitated strong fibre–epoxy bonding eliminating the cavities improved fibre dispersion and improved adhesion of epoxy to the fibres. The resulting composite material using F80.FS1 fibre demonstrated superior mechanical properties, such as hardness, tensile strength and toughness when compared to both standard epoxy and standard F80 silicon nitride fibre.

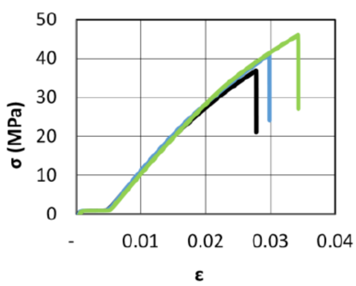


Standard F80 Silicon Nitride Fibre in epoxy resin

	Epoxy	+0.08% F80	**+0.08% F80.SF1**
Viscosity (cps)	1040	1000	**915**
Shore Hardness D ASTM D2240	80.4 ± 0.4	82.5 ± 0.3	**84.5 ± 0.3**
Tensile Strength (MPa)	37.5	39.5	**47.6**



F80.FS1 in epoxy resin showing improved fibre-resin adhesion

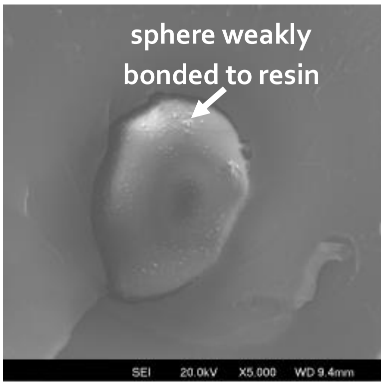


*Stress-strain curve for **Epoxy**, **Epoxy + 1% F80**, and **Epoxy + 1% F80.SF1***

Polymer Spheres

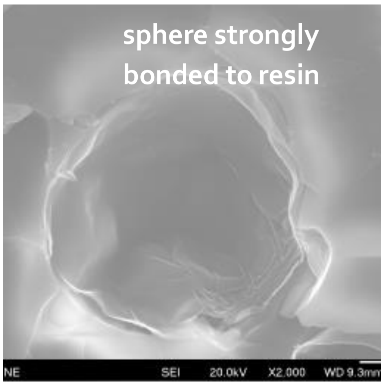
2% Polymer Spheres in Derakane Vinyl Ester

Polymer spheres from a third party were compounded with an industry standard vinyl ester. Different chemistry of resin and additive were chosen to demonstrate the versatility of our technology. Polymer spheres have a density much less than one and are used to lightweight materials. Electron micrographs showed that the spheres were poorly bonded to the resin with cavities around the spheres. The cavities were consistent with the previous case study and are a reasonably consistent phenomenon. Our process identified an additive to increase dispersion as before. The surface coating of the spheres facilitated strong sphere–resin bonding eliminating the cavities, improved sphere dispersion and improved adhesion of the resin to the spheres. The resulting composite material using polymer spheres demonstrated superior mechanical properties when compared to both standard vinyl ester, and standard polymer sphere reinforced resin.



Standard polymer sphere in vinyl ester resin

	Vinyl Ester	+2% PMS	**+2% coated PMS**
UTS (MPa)	**27 ±2**	**43 ±0.4**	**47 ±3**
Ductility (%)	**3.6 ±0.4**	**4.8 ±0.3**	**5.0 ± 0.4**
Density (g/cm^3)	**1.137**	**1.124**	**1.124**



Coated Sphere showing improved sphere-resin adhesion