Advanced **Ma**terials **De**sign & **Ma**nufacturing Ltd
Ayiou Dimitriou 92, 1027 Nicosia
T: +357 22262280 **W:** www.amdmcomposites.com

NanoWeld® Technical Description & Specifications

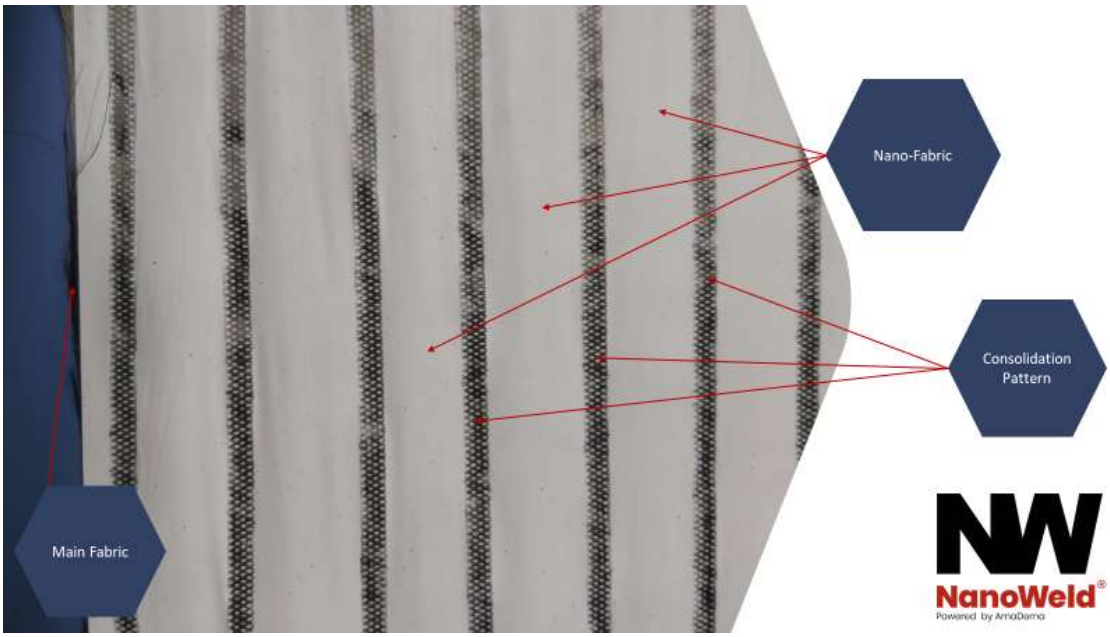


Figure 1

NanoWeld® enhances existing technical fabrics as well as prepregs offering superior mechanical performance to the resulting Carbon Fiber Reinforced Polymer Composites

NanoWeld® Technology consists of three distinct phases:

NanoCreation → NanoInsertion → NanoConsolidation

NanoCreation

The result of NanoCreation is the electrospun nanofabric. The Nanofabric (Figure 1, 2 and 3) has the following characteristics:

Material: Nanofabric material precursor is PA6. Different thermoplastic polymers have been optimized and can be used, such as PVDF or PAN or other depending on the mechanical performance requirements of the end composite application.

The nanofabric contains nanoparticles. These nanoparticles vary in terms of type and quantity again depending on the end composite application. Different nanoparticles have been optimized and can be used, such as Carbon-MWNTs, Graphene nanoplatelets, etc.

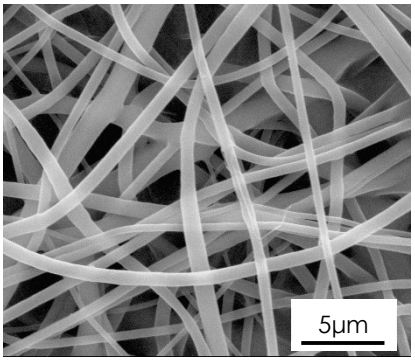


Figure 2: SEM image of nanofabric

Specifications: The nonwoven nanofabric for composite applications has been optimized at:

- Nanofabric Areal density: 0.5 up to 5 grams per m^2
- Nanofabric Thickness: 7 to 20 micrometers
- Nanofiber Average Diameter: 40 to 180 nanometers

NanoInsertion

The nanofabric is placed either on one surface or both the top and the bottom surfaces of the base-technical fabric to be enhanced. Again this depends on the requirements of the end composite application

- The base-technical fabric can be carbon or glass or aramid or other
- The base-technical fabric can have a grammage from 60 gsm up to 600 gsm.
- The base-technical fabric can be of any knitting such as unidirectional, woven, biaxial or other.
- The base- technical fabric which is enhanced in Figure 1 and 3 (given as an example) is a non-crimp carbon fiber unidirectional fabric.

NanoConsolidation

During NanoConsolidation the base-technical fabric is consolidated with nanofabrics either on one or both surfaces.

The NanoConsolidation is achieved through ultrasonic welding or thermocompression.

The pattern used for consolidation in Figure 1 and 3 is a stripped pattern with welding lines at a desired distance from each other. The pattern depends on the end composite application and in certain cases can include the entire surface of the sandwiched lamina.

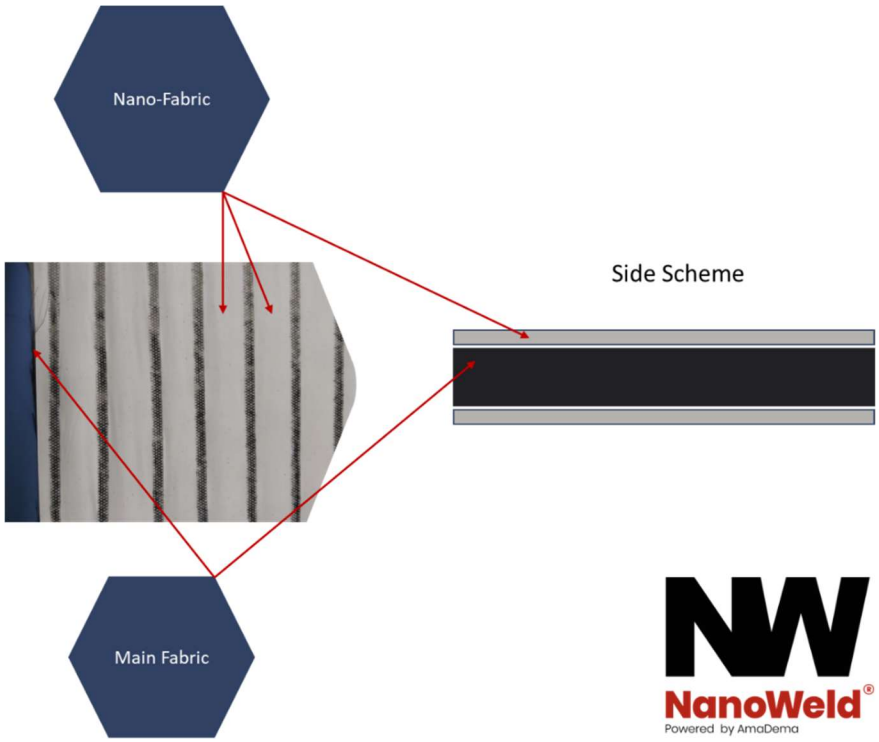
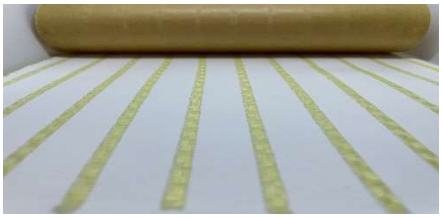


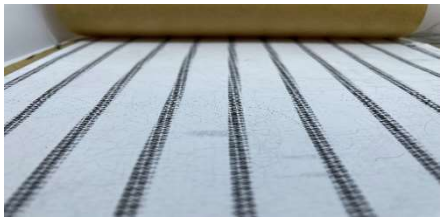
Figure 3: Schematic of the cross section of a NW® enhanced fabric/lamina

The technology of NW is applicable to any technical textile.

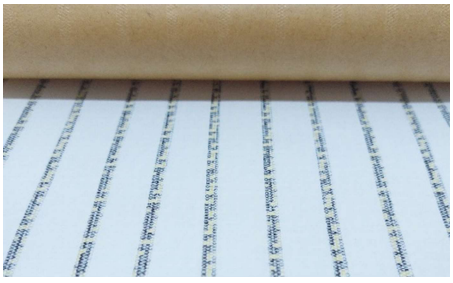
Aramid NW®



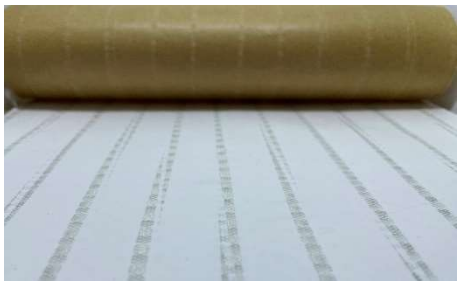
Carbon NW®



Hybrid Carbon/Aramid NW®



Glass NW®



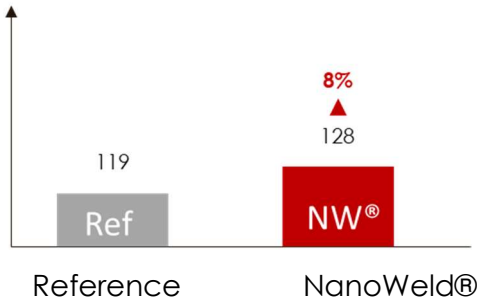
Mechanical Performance Review

This last section presents a summary of NanoWeld® Technology applications, as tested either by independent testing laboratories or by our customers following standard mechanical testing procedures. More information on materials & testing can be provided upon request.

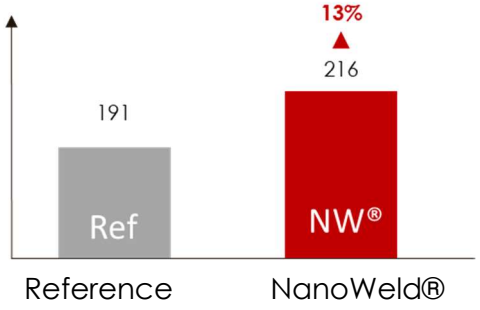
NanoWeld CFRP – 1 (Tested at APPLUS laboratory for Customer)

Base fabric: Unidirectional Non-Crimp Zoltek PX35 Carbon fiber – 200 gsm
Resin System: L20 + Hardener EPH 161 (https://www.r-g.de/en/art/112123)
Processing: Vacuum assisted hand lay-up and Autoclaving

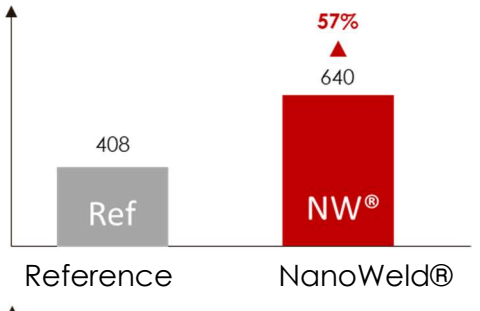
Tensile Modulus (GPa)
Lamination: $[0]_{10}$
FVF: Normalised to 60%
Testing Standard: ISO 527-4



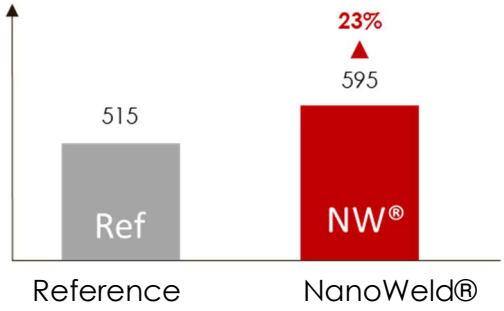
Compression After Impact Strength (MPa)
Lamination: $[45/0/135/90]_{3s}$
FVF: Normalised to 60%
Testing Standard:
ASTM D7136-D7136M-15, ASTM D7137-D7137M-17



Fracture Mode I - CC (J/m²)
Lamination: $[0]_{30}$
FVF: 56% for all plates produced
Testing Standard: ASTM D5528-13



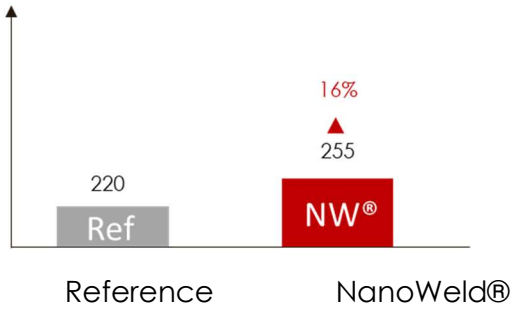
Fracture Mode II – GIIC Max (J/m²)
Lamination: $[0]_{30}$
FVF: 56% for all plates produced
Testing Standard: DIN EN6034:2015



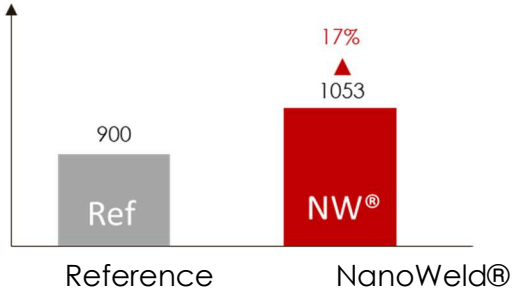
NanoWeld CFRP – 2 A & B (Tested at APPLUS laboratory for European Space Agency)

Base fabric: Unidirectional Non-Crimp Dialead K63712 Carbon fiber – 250 gsm
Resin System: Polyamide 12 (in powder form)
Processing: Thermoplastic prepreg processing and Autoclaving

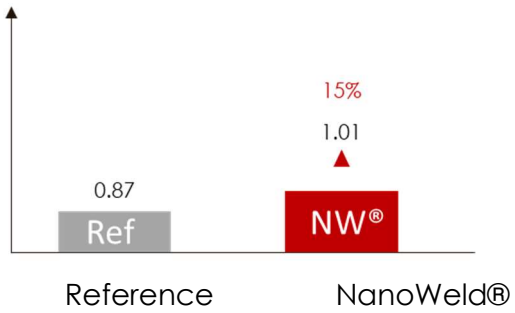
Tensile Modulus (GPa)
Lamination: $[0]_{10}$
FVF: 53% for all plates produced
Testing Standard: ASTM D3039



Tensile Strength (MPa)
Lamination: $[0]_{10}$
FVF: 53% for all plates produced
Testing Standard: ASTM D3039

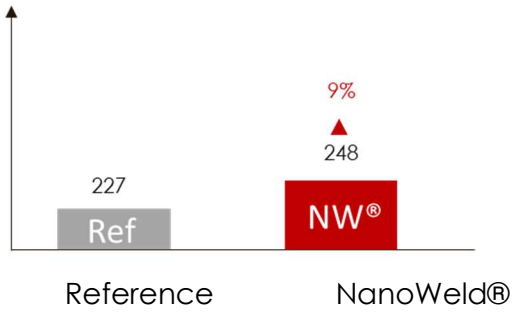


Damping Ratio (%)
Lamination: $[0]_{30}$
FVF: 51% for all plates produced
Testing Standard: ASTM E756



Base fabric: Unidirectional Non-Crimp Dialead K63712 Carbon fiber – 250 gsm
Resin System: Araldite 1556 (4 component system)
Processing: Prepreg processing and Autoclaving

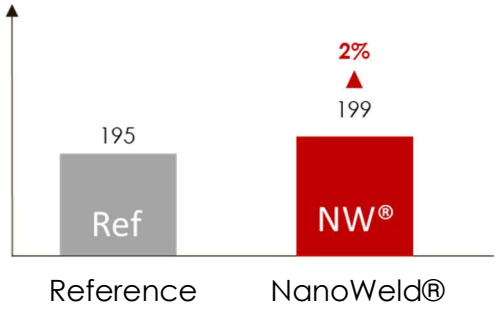
Tensile Modulus (GPa)
Lamination: $[0]_{10}$
FVF:60% for all plates produced
Testing Standard: ASTM D3039



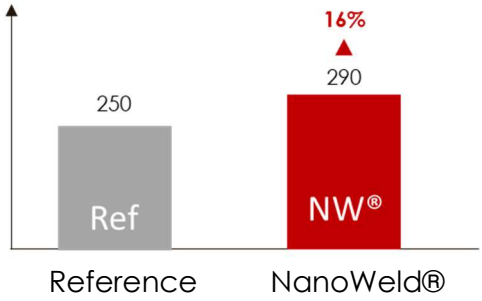
NanoWeld GFRP – 3 (Tested at Customer's laboratory for Customer)

Base fabric: Unidirectional Glass Fiber – 600 gsm
Resin System: Epoxy System (Customer proprietary)
Processing: Sheet Molding Compound at 90 °C

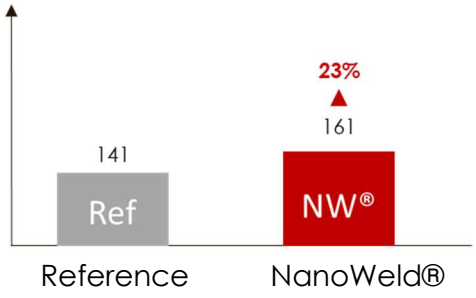
Tensile Modulus (GPa)
Lamination: $[0]_{10}$
FVF: Normalised to 60%
Testing Standard: ASTM D3039



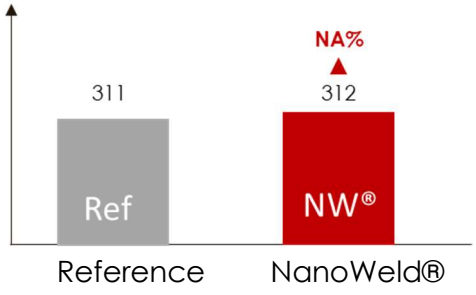
Tensile Strength (MPa)
Lamination: $[0]_{10}$
FVF: Normalised to 60%
Testing Standard: ASTM D3039



Flexural Modulus (GPa)
Lamination: $[0]_{10}$
FVF: Normalised to 60%
Testing Standard: ASTM D7246_D7246M



Flexural Strength (MPa)
Lamination: $[0]_{10}$
FVF: Normalised to 60%
Testing Standard: ASTM D7246_D7246M



**Internal testing in certain base-baric cases has exhibited even higher level of mechanical performance improvement*