PRODUCT CATALOG

NOVEMBER 2022

TABLE OF CONTENTS

GRAPHENE NANOTUBES

TUBALL™

Diameter

1.6±0.4 nm

Length

>5 μm

GRAPHENE NANOTUBES

Human existence is shaped by the materials we use. More than 50% of all materials can be improved by introducing a universal additive: single wall carbon nanotubes.* These tiny tubes provide us with a rare opportunity to create nanoaugmented materials that have extraordinary properties.

Single wall carbon nanotubes (SWCNTs) should be referred to as graphene nanotubes (GNTs) because each nanotube is an extremely thin rolled-up sheet of graphene. The superiority of graphene nanotubes is due to their exceptional properties, such as superior conductivity, high temperature resistance, strength and flexibility.

*Estimates based on report and analysis provided by one of the leading management consulting firms.

TUBALL™

While the huge potential of GNTs has been recognised for many years, until recently their wide application in industry was not possible because of an absence of technology for their mass production, their high price, and a lack of methods for introducing them into materials.

TUBALL™ nanotubes are the first GNTs to be available for commercial applications in a wide range of industries. OCSiAl's breakthrough yet low-cost mass-production technology has made the widespread use of nanotubes economically viable while still preserving their high quality.

FEATURES

• Best price-to-performance ratio compared with similar products
• Maintains color, elasticity, durability and other key properties
• Versatile for an extremely wide range of applications
• High-quality nanotubes (G/D ratio >90)
• Benefits start from ultra-low concentrations
• Adds uniform, permanent and stable electrical conductivity
• Enhances mechanical properties of materials

HOW IT WORKS

TUBALL™ provides significant improvements in material properties upon the addition of ultra-low loadings — starting from only 0.01%.

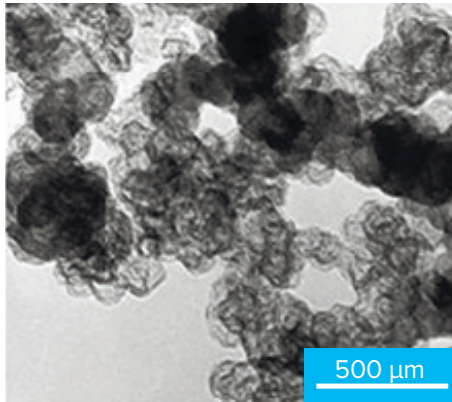Microparticles   Nanofibers   GNTs
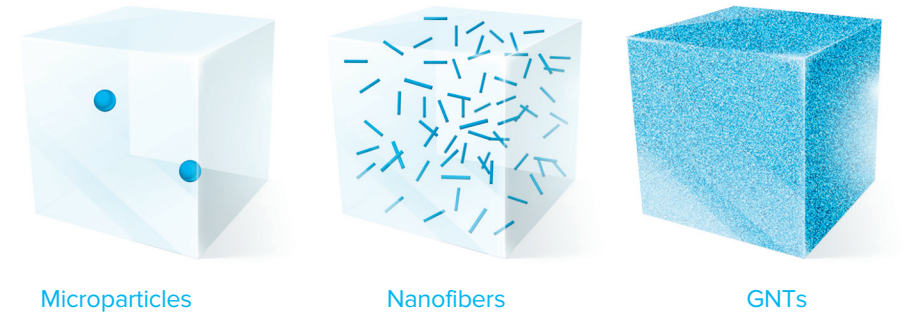
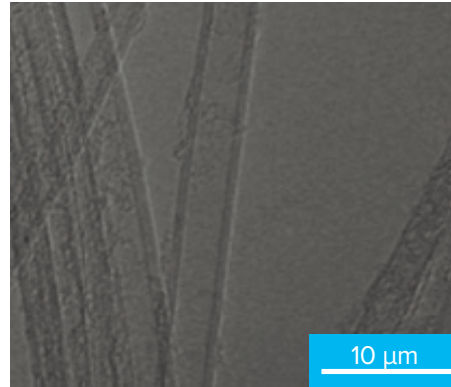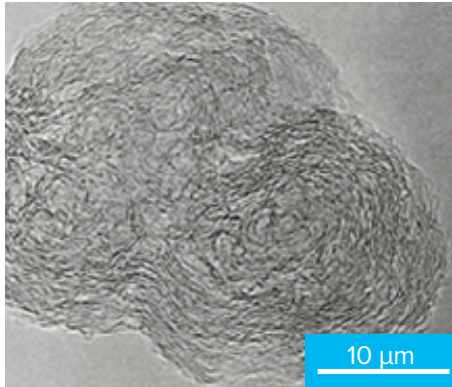The same concentration of particles (~0.1%) in the same volume.

Unlike conventional additives such as multi wall carbon nanotubes, carbon fibers, and most types of carbon black that unevenly disperse in a material's matrix, GNTs create a 3D uniform reinforced and conductive network.

NANOTUBES: THE ULTIMATE CARBON ADDITIVE

Conductive carbon black

TUBALL™ graphene nanotubes

500 µm

500 µm

10 µm

10 µm
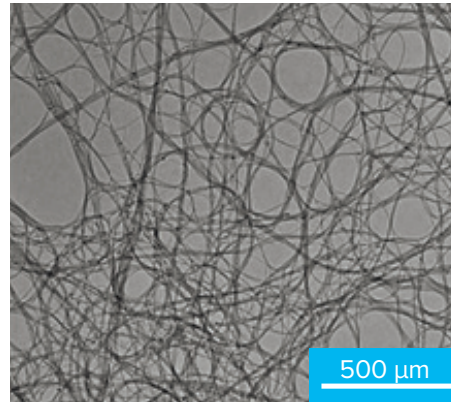
THERMOSETS WITH TUBALL™ SHOW A SIGNIFICANT INCREASE IN CONDUCTIVITY

Volume resistivity, Ω•cm

Anti-static compounds

ESD compounds and electrostatic paintings

Conductive compounds

Conductive filler, wt.%
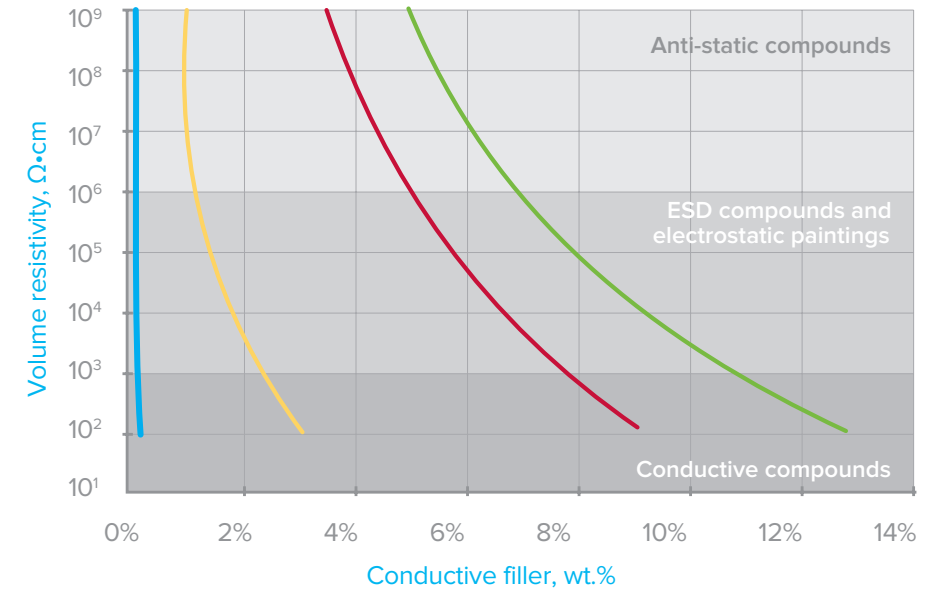
— TUBALL™ graphene nanotubes
— Multi wall CNT
— Premium carbon black
— Conductive carbon black

Results for unfilled polyester resin. ASTM D257.

TRULY UNIVERSAL ADDITIVE

To easily and properly incorporate TUBALL™ into materials, OCSiAl has developed and successfully brought to market a line of pre-dispersed concentrates, masterbatches and suspensions that are compatible with various industry-standard formulations.

For more information on TUBALL™ application in a specific matrix, refer to the product listing in the catalog or contact the nearest OCSiAl office for assistance in selecting the right solution.
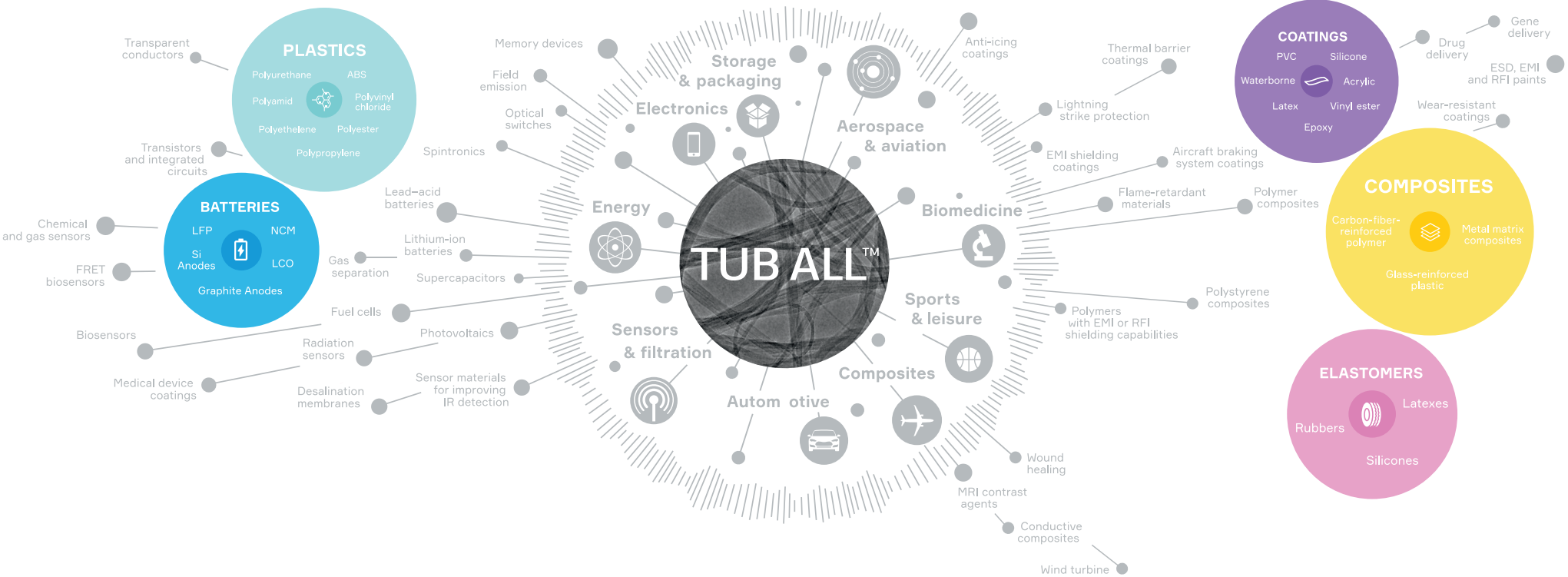

PLASTICS
Polyurethane · ABS · Polyamid · Polyvinyl chloride · Polyethelene · Polyester · Polypropylene

BATTERIES
LFP · NCM · Si Anodes · LCO · Graphite Anodes

COATINGS
PVC · Silicone · Waterborne · Acrylic · Latex · Vinyl ester · Epoxy

COMPOSITES
Carbon-fiber-reinforced polymer · Metal matrix composites · Glass-reinforced plastic

ELASTOMERS
Latexes · Rubbers · Silicones

TUBALL™

Transparent conductors · Memory devices · Anti-icing coatings · Thermal barrier coatings · Gene delivery · Drug delivery · ESD, EMI and RFI paints · Field emission · Optical switches · Lightning strike protection · Wear-resistant coatings · Transistors and integrated circuits · Spintronics · EMI shielding coatings · Aircraft braking system coatings · Chemical and gas sensors · Lead–acid batteries · Flame-retardant materials · Polymer composites · FRET biosensors · Lithium-ion batteries · Gas separation · Supercapacitors · Biosensors · Fuel cells · Polymers with EMI or RFI shielding capabilities · Polystyrene composites · Radiation sensors · Photovoltaics · Medical device coatings · Desalination membranes · Sensor materials for improving IR detection · Wound healing · MRI contrast agents · Conductive composites · Wind turbine

Storage & packaging · Electronics · Aerospace & aviation · Energy · Biomedicine · Sensors & filtration · Sports & leisure · Composites · Automotive

PRODUCTS FOR ENERGY STORAGE

TUBALL™ BATT

TUBALL™ BATT is a ready-to-use dispersion designed to easily incorporate TUBALL™ into electrode formulations during the battery manufacturing process.

TUBALL™ BATT provides a complete or partial substitute for carbon black in battery electrodes and can replace several percent of carbon black with 0.03–0.1% of TUBALL™.

TUBALL™ forms conductive 3D networks between active material particles at very low concentrations. The nanotubes reinforce the electrode structure and improve its mechanical stability during cycling. TUBALL™ improves adhesion by establishing strong ties between the particles, reducing the amount of binder required.

TUBALL™ BATT H₂O

Ultra-fine TUBALL™ dispersion in H₂O for high-energy Si-based anodes

CUSTOMER CASE

Customer: 3C battery maker
Product: Pouch cells for mobile phones
Why TUBALL™: Improving volumetric density of the battery is required
Dosage in recipe: 0.05%–0.1% of TUBALL™ in SiOx + graphite in anode slurry recipe
The result: 800 Wh/l volumetric density is achieved with a good cycle life performance

Nanotube dispersion in water creates a robust network inside the Si-anode and solves the problem of its degradation, allowing Li-ion battery makers to use record high quantities of silicon in the recipes of their cells for the first time and reach desired energy density targets, as well as unlocking fast-charging capabilities. The key element of Si-based anodes in the majority of silicon anode projects worldwide.

FEATURES

- Compatible with the majority of state-of-the-art SiO or Si/C anode recipes
- CMC or other binders available
- Low content of foreign impurities
- Ready, easy to use, efficient: proven by leading Li-ion battery makers

BENEFITS

Solves the Si-anode degradation problem
20% of SiO/C anodes with up to 600 mAh/g of capacity thanks to TUBALL™ BATT H₂O result in a battery cycle life acceptable to the modern EV industry

Record high energy density achievable
Boosts energy density up to 300 Wh/kg and 800 Wh/l due to Si-anode enabling

Fast-charging ability unlocked
Up to 4C charge-rate achievable due to high silicon content enabled by TUBALL™

Cycle life that meets the targets of the modern EV industry
Makes it possible to retain >80% capacity after 1,500 cycles

TUBALL™ BATT NMP

Ultra-fine TUBALL™ dispersion in NMP for high-energy cathodes

CUSTOMER CASE

Company: Manufacturer of cylindrical batteries for various applications
Product: Cylindrical battery 18650
Why TUBALL™: Solution of too much heat from high discharge rate mode as well as not enough power at lower temperatures problems
Dosage in recipe: 0.04%–0.08% of TUBALL™ in cathode slurry recipe
The result: DCR decreased significantly, improved continuous discharge rate at 0 ºC

Unmatched TUBALL™ conductivity for improved battery safety and energy density now comes in a more cost-efficient and optimized dispersion.

FEATURES

- Dispersion optimized specially for cathodes
- More than 80% solids achievable
- Low Fe content
- Choice of PVDF possible
- Ready and easy to use

BENEFITS

Boosted energy density
Thanks to 10–60 times lower loading of conductive additive. Up to 98.8% active material content possible in dry electrode

Higher discharge power
Increases >50% at high discharge rates

Higher safety
Increased safety due to twice lower battery resistance increase (DCR)

Improved adhesion
Twice higher thanks to the bond strength between cathode particles

ANODE

TUBALL™ graphene nanotubes cover the surface of the silicon particles and create highly conductive and durable connections between them. These connections are so dense, long, conductive and strong that, even when the silicon particles in the anode expand and the material starts to crack, the particles stay well connected to each other through the TUBALL™ graphene nanotubes. This prevents the anode from going out of service – the hugely improved cycle life is enough to meet even the most strict EV manufacturer requirements.

TUBALL™ UNLOCKS MASS PRODUCTION OF EV BATTERIES WITH SILICON ANODES

Bridging silicon anode particles and preventing their degradation during silicon volume expansion and cracking
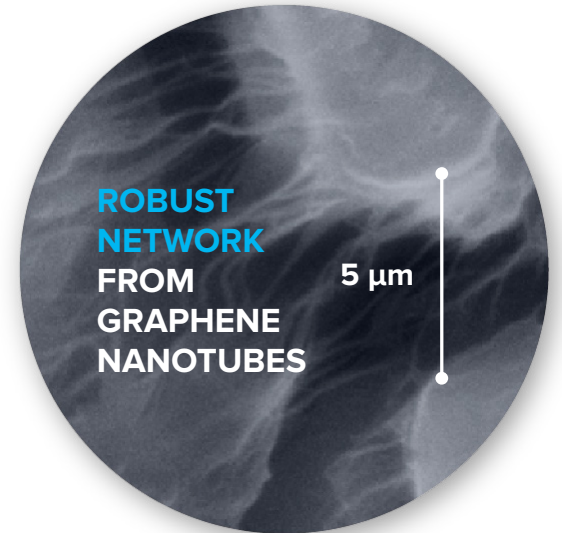
ROBUST NETWORK FROM GRAPHENE NANOTUBES

5 µm

TUBALL™ SOLVES THE SILICON ANODE PROBLEM – PREVENTING ITS DEGRADATION

23

TUBALL™ NETWORKS INCREASE SILICON-BASED ANODE CYCLE LIFE BY UP TO 4 TIMES

CAPACITY, %

0.06% TUBALL™

1% VGCF

NCM 523-SiOx, 18650
0.5 C/ 0.5 C

1% MWCNT

Threshold

CYCLES
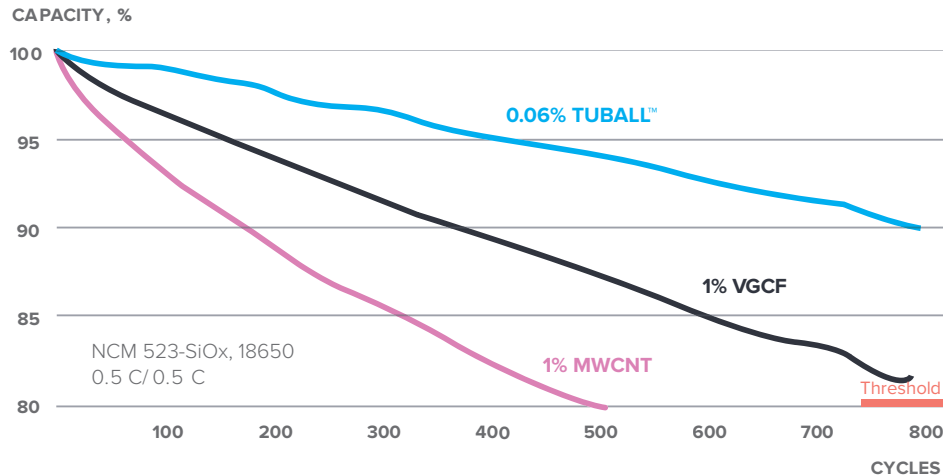
Leading Li-ion manufacturers have proven that TUBALL™ nanotubes make it possible today to create anodes containing 20% SiO and thus reach record-breaking battery energy densities – up to 300 Wh/kg and 800 Wh/l.

This enables fast-charging capabilities. Such battery cells can deliver up to +15% higher range than the best Li-ion battery cells on the market!

20%
SiO with TUBALL™ in Li-ion batteries is just the beginning

WE CAN GO FURTHER

90%
SiO is possible with TUBALL™

350
Wh/kg
energy density can be achieved

OCSiAl R&D team results show that it's possible to increase the SiO content in anodes to 90%, which will result in energy density of 350 Wh/kg.

CATHODE

Thanks to their unique intrinsic properties, graphene nanotubes outperform alternatives and offer substantial Li-ion battery performance improvements in terms of energy density, safety, discharge power, and adhesion. Such performance improvements for Li-ion battery cathodes cannot be demonstrated by any traditional conductive additives, such as carbon black or multi wall carbon nanotubes.

TUBALL™ IMPROVES KEY PARAMETERS

In comparison with MWCNT and carbon black cathode formulas:

SAFETY	ENERGY DENSITY	DISCHARGE POWER	ADHESION
higher due to	higher due to	higher	higher up to
2×	**10–60×**	**>50%**	**2×**
lower battery resistance increase (DCR) during high-temperature (HT) storage and cycling	lower loading	at high discharge rates >3C	nanotubes increase the bond strength between cathode material particles

Safety

Being the most conductive material that can be used in the formulation of Li-ion batteries, even a small amount of TUBALL™ graphene nanotubes is enough to reduce internal battery cell resistance (DCR). Stable TUBALL™ networks are maintained inside the cathode material even after multiple battery charge–discharge cycles and battery storage periods, enabling the DCR to be maintained at a low level as well — after high-temperature storage and cycling.

60%

lower resistance increase during high-temperature battery storage

The lower battery DCR results in lower temperature build-up, and thus a reduced risk of a battery fire. This is a crucial safety benefit, made possible by TUBALL™ graphene nanotubes.

TUBALL™ DECREASES DCR

134.34%
1.5% SP

85.38%
0.4% MWCNT

25.35%
0.08% TUBALL™
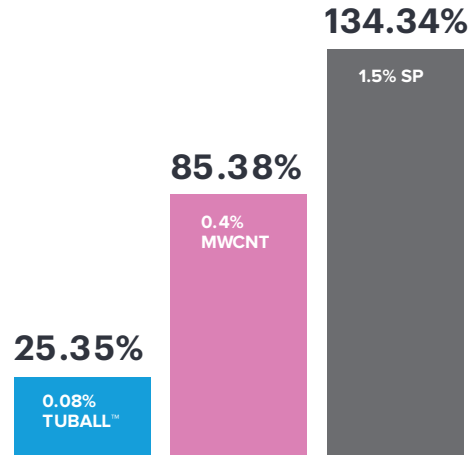
**HT STORAGE. 60 °C, 21 DAYS
NCM811-GRAPHITE 1.5 AH POUCH**

Energy density

Less than 0.1% of TUBALL™ provides higher energy density. This concentration is lower by 10–60 times than that needed when using multi wall carbon nanotubes or carbon black as a conductive additive. In a modern EV battery pack, 5 kg of conductive carbon black can be replaced by just 100 g of TUBALL™.

Discharge power

Thanks to the unmatched conductivity of graphene nanotubes compared with other conductive additives, using TUBALL™ in cathodes makes it possible to achieve fast discharging while also increasing the battery's capacity.

Cathode adhesion

Nanotube networks hold the cathode material particles together, increasing the bond strength between them.

90-DEGREE PEEL TEST

N/cm

TUBALL™

MWCNT

CNT (wt.%)
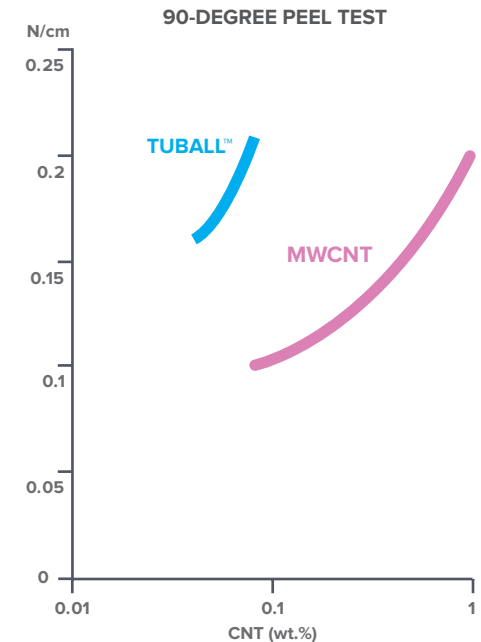
TUBALL™ BATT READY-TO-USE PRODUCTS FOR LIBs

	GNTs, %	DISPERSING AGENT, %	METAL IMPURITIES, PPM	DESCRIPTION
FOR CATHODES				
0.4% TUBALL™ BATT NMP	0.4%	PVDF 2%	<40	**ULTRA-FINE TUBALL™ DISPERSION IN NMP** for high-energy and high-power cathodes **Maximizes energy density** when used as a full or partial replacement of other conductive additives **Boosts C-rate, and reduces impedance** when used low dosage in combination with other additives
FOR Si/C ANODES				
0.4% TUBALL™ BATT H$_2$O	0.4%	CMC 0.6%	<40	**ULTRA-FINE TUBALL™ DISPERSION IN H$_2$O** for high-energy Si/C anodes **Improves cycle life of Si/C anodes,** enabling their industrial adoption in hi-energy cells **>240 Wh/kg – benefits start.** The more that high-energy-density anodes are used, the more essential is the application of TUBALL™ GNTs

PRODUCTS
FOR ELASTOMERS

APPLICATION EXAMPLES

Non-marking solid tires

Cables

Textile coatings

Conveyor belts and rollers

O-rings, hoses, jackets,
heat-resistant cords and plates

Pressure-sensitive adhesive film

Rubber seals

ESD gloves

TUBALL™ MATRIX FOR SILICONES

TUBALL™ MATRIX 601, 602 and 605 are nanotube concentrates specifically designed to provide superior electrical conductivity to silicone compounds (LSR – liquid silicone rubber, RTV – room temperature vulcanized rubber, and HCR – high consistency rubber) while retaining mechanical properties and minimally impacting the host matrix.

TUBALL™ MATRIX 601 / 602 / 605

PROPERTY — Electrical conductivity

TUBALL™ MATRIX 601

Carrier: polydimethylsiloxane oil

KEY APPLICATIONS

- LSR (liquid silicone rubber)
- RTV (room temperature vulcanised) silicones

TUBALL™ MATRIX 602

Carrier: vinyl-terminated polydimethylsiloxane

KEY APPLICATIONS

- LSR (liquid silicone rubber)
- HCR (high consistency rubber)

TUBALL™ MATRIX 605

Carrier: silicone gum

KEY APPLICATIONS

- HCR (high consistency rubber)

CONDUCTIVE SILICONES WITH TUBALL™ MATRIX

	Currently available	TUBALL™ MATRIX
Volume resistivity level	<100–10^8 Ω•cm	<100–10^8 Ω•cm
Concentration of conductive filler	30–70 wt.%	0.5–5 wt.%
Retain mechanical properties	No	Yes
Allow coloration	No	Yes

FULL RANGE OF RESISTIVITY

TUBALL™-BASED PRODUCTS		
CONDUCTIVE	DISSIPATIVE	

10^4 10^5 10^6 10^7 10^8 10^9

Ω
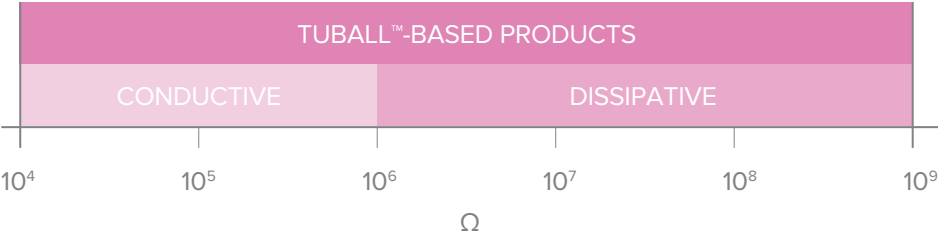
MECHANICAL PROPERTIES OF RTV WITH 3 wt.% TUBALL™ MATRIX 601 IN COMPARISON WITH CONDUCTIVE CARBON BLACK*

Volume resistivity 200 Ω•cm

M100, MPa — +40% +60% — RTV 0.5, 3 wt.% 0.7, 15 wt.% carbon black 0.8

M300, MPa — +4% — RTV 2.4, 3 wt.% 2.5, carbon black 0

Tensile strength, MPa — -20% -82% — RTV 5, 3 wt.% 4, carbon black 0.9

Elongation at break, % — -18% -80% — RTV 510, 3 wt.% 420, carbon black 100

■ RTV (base) ■ 3 wt.% TUBALL™ MATRIX ■ 15 wt.% carbon black
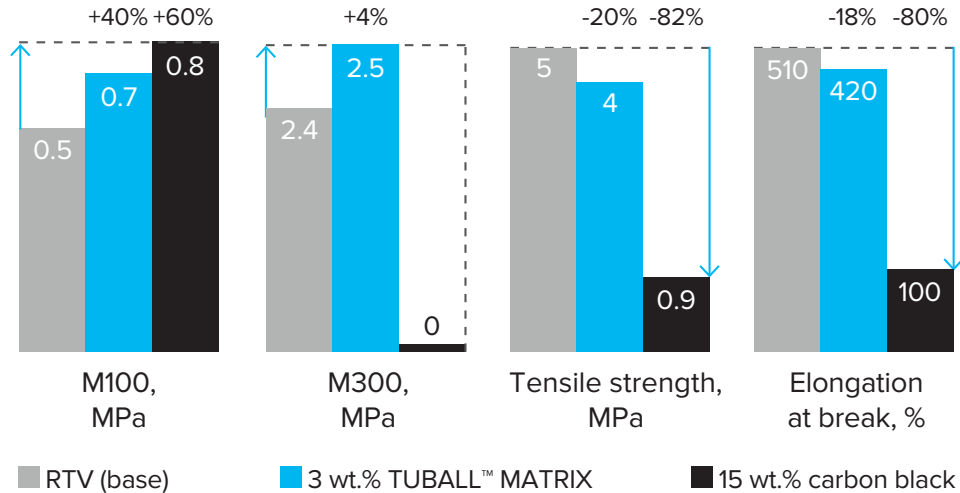
TUBALL™ MATRIX makes it possible to produce conductive compounds without impairing flexibility or mechanical properties

* Measurements conducted according to ASTM D412.
Study was conducted with conductive carbon black VULCAN® XC72R.

VOLUME RESISTIVITY OF LSR SILICONE WITH TUBALL™ MATRIX 601 IS IN THE RANGE 10–10^{16} Ω•cm*

Volume resistivity, Ω•cm vs TUBALL™ MATRIX 601 content, wt.%

* Tested in two-component LSR (Shore 40). Measurements conducted according to ASTM D991.
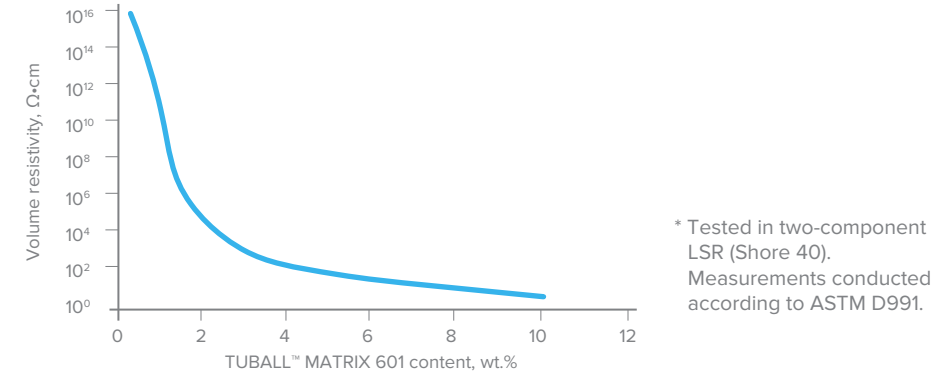
VOLUME RESISTIVITY OF HCR SILICONE WITH TUBALL™ MATRIX 605 IS IN THE RANGE <10–10^{11} Ω•cm*

Volume resistivity, Ω•cm vs TUBALL™ MATRIX 605 content, wt.%

* Tested in HCR (Shore 60). Measurements conducted according to ASTM D991.
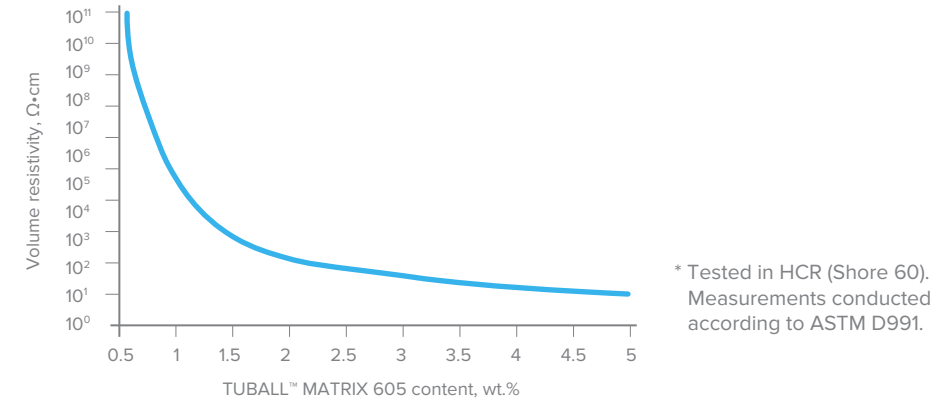
TUBALL™ MATRIX FOR RUBBERS

TUBALL™ MATRIX 600-x series are nanotube concentrates designed to impart required electrically conductive properties to rubbers and to significantly enhance their mechanical properties.

TUBALL™ MATRIX 610 / 620

PROPERTY — Electrical conductivity

FEATURES OF TUBALL™ MATRIX FOR RUBBERS:

• Suitable for anti-static, static dissipative, and conductive applications
• Extremely low loadings of nanotubes that preserve properties
• Retain mechanical properties including softness
• Maintain rheology and viscosity
• Standard processing and mixing equipment
• Allows for colored ESD compounds

Ensuring long service life and stable conductive properties to crucial products and processes, nanotube-modified rubbers are widely used in the electronics, automotive, and tire, oil & gas, and other industries.

OCSiAl has developed a variety of products based on TUBALL™ graphene nanotubes for EPDM, NBR, SBR, blends of NR/BR, FKM, and other types of rubbers.

TUBALL™ MATRIX 610

Carrier: Polymer, paraffinic mineral oil

KEY APPLICATIONS

• EPDM

TUBALL™ MATRIX 620

Carrier: Polymer, TDAE oil

KEY APPLICATIONS

• NR
• BR

IMPROVEMENT OF TEAR STRENGTH AND TENSILE PARAMETRS EVALUATION IN 3 VISCOSITY TYPES OF EPDM

LOW MOONEY

MEDIUM MOONEY

HIGH MOONEY

— 3–6 wt.% TUBALL™ MATRIX 610   — Reference compound
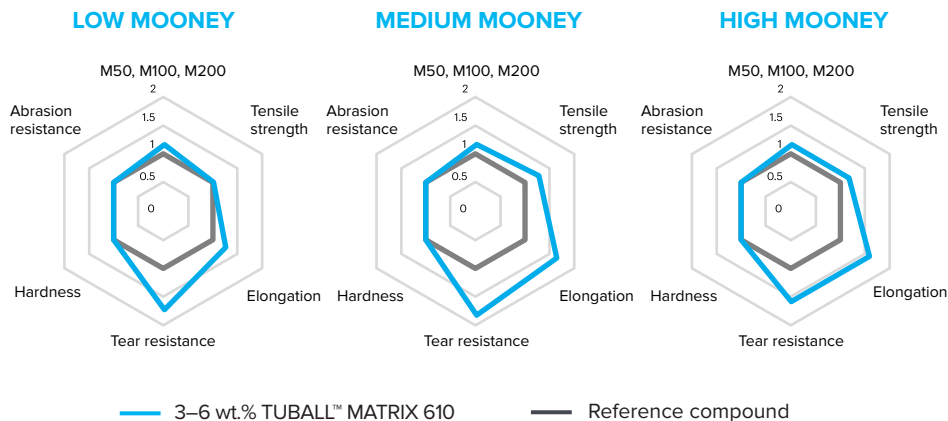
- M50, M100, M200 increased by 15–20%
- Tensile strength increased by 16–23%
- Tear resistance increased by 25–103%

- Abrasion resistance increased by 3–11%
- No drawback in elasticity
- Electrical restivity 10^6–10^9 Ω·cm

MECHANICAL PROPERTIES OF ANTI-STATIC NON-MARKING NR/BR SILICA BASED COMPOUND WITH TUBALL™ MATRIX 620

— Reference compound
— 4.4 wt.% TUBALL™ MATRIX 620
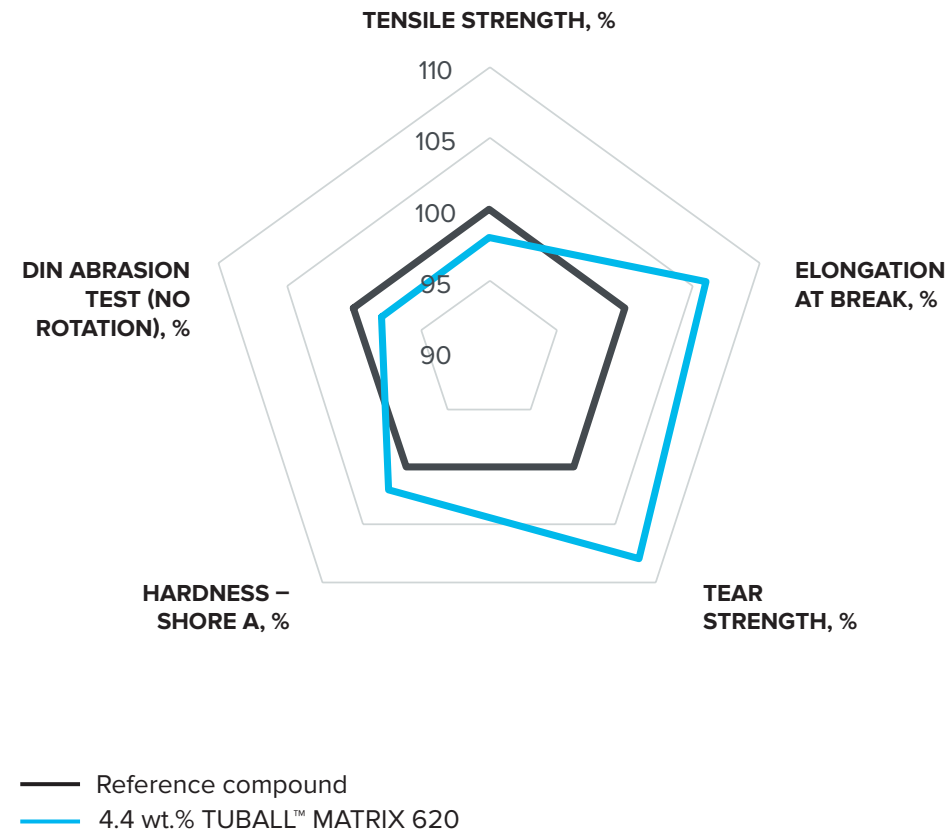
TUBALL™ LATEX

TUBALL™ LATEX is a water-based suspension for manufacturing latex gloves and latex products with anti-static properties, while retaining mechanical properties and minimally impacting the host matrix.

TUBALL™ LATEX makes it possible to attain permanent and humidity-independent conductivity that is fully compliant with the most demanding applications, including the new European standard EN 16350:2014 (EN 1149) for anti-static properties in safety wear.

TOUCHSCREEN OPERATION WITH INDUSTRIAL GLOVES

TUBALL™ graphene nanotubes provide an anti-static effect that allows smooth operation of touchscreens without gloves having to be removed and that ensures worker and product protection.

KEY BENEFITS

- Stable ESD properties according to international standards for protective wear
- Standard liners without conductive yarns
- No changes in formulation or dipping process
- Allows coloration

ANTI-STATIC NITRILE LATEX WITH TUBALL™

	Current solutions	Results with TUBALL™
Specific resistance level	10^7–10^{11} Ω	10^2–10^{11} Ω
Concentration of conductive filler	5–25 wt.%	0.03–0.075 wt.%
Negative impact on mechanical properties	Yes	No
Color retention	No	Yes
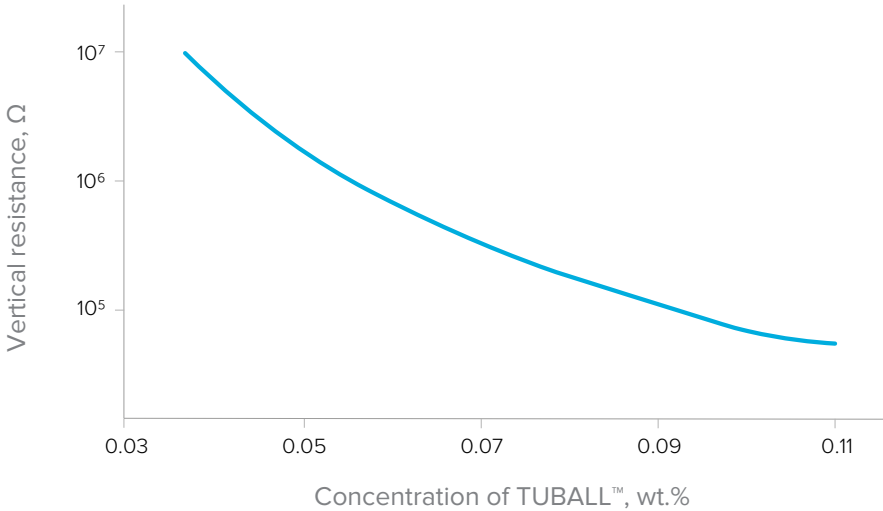
Measurement of electrical resistivity according to EN 16350:2014 carried out on teraohmmeter: TO-3 cable; electrode type - TE 50 for textile measurement (DIN 54345-1, DIN EN 1149-1 and DIN EN 1149-2)

ESD GLOVES WITH TUBALL™
PU & NITRILE LATEXES

LINER PU GLOVE
industrial
0.06 wt.%

NITRILE LATEX GLOVE
cleanroom
0.06 wt.%

LINER NITRILE GLOVE
industrial*
0.06-0.1 wt.%

ELECTRICAL RESISTANCE 10^7 Ω

*Gloves made by industrial partners with TUBALL™

HOW TO MAKE YOUR GLOVES CONDUCTIVE WITH TUBALL™

0.2% or 0.5%
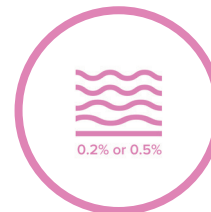
User-friendly water-based dispersion available in two concentrations of TUBALL™
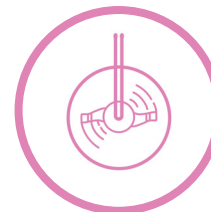
Standard compounding and dipping process
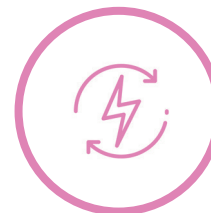
Touchscreen gloves compliant with international standards for protective wear

TUBALL™ GRAPHENE NANOTUBE SOLUTIONS FOR ELASTOMERS

PRODUCT	CARRIER MEDIUM	TARGET SYSTEMS						
		LSR silicone	RTV silicone	HCR silicone	EPDM	NR	BR, IR, SBR	NBR, PU, NR latex
SILICONES								
MATRIX 601	Polydimethylsiloxane	●	●					
MATRIX 602	Siloxanes and silicones vinyl group-terminated	●	●	●				
MATRIX 605	Siloxanes and silicones vinyl group-terminated			●				
LATEX								
LATEX H₂O	Water, anionic surfactant							●
RUBBERS								
MATRIX 610	Polymer, paraffinic mineral oil				●			
MATRIX 620	Polymer + plasticizer					●	●	

PRODUCTS FOR COMPOSITES & COATINGS

TUBALL™ MATRIX 200 / 300-X SERIES

TUBALL™ MATRIX 200 / 300-x series are nanotube concentrates designed to provide permanent, uniform electrical conductivity to various materials: epoxy, polyurethane, polyester, etc. TUBALL™ MATRIX is compatible with a variety of color shades while meeting ESD standards.
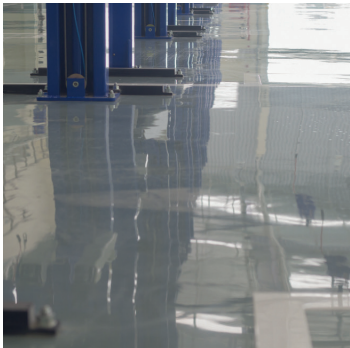
APPLICATION EXAMPLES

GFRP pipes

Equipment for mines, electronics, chemical plants and petrol stations

Epoxy and PU anti-static flooring

Gelcoats and moldcoats

Industrial rollers

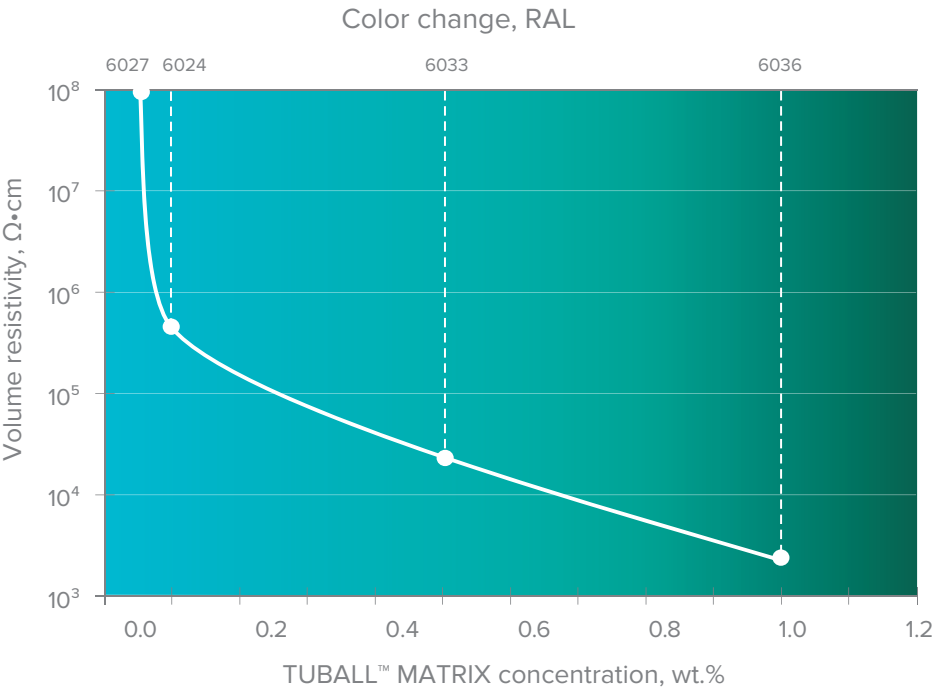Housing/packaging for sensitive electronics, and combustible powders or liquids

Lining coatings

Conductive primers for plastic components

TUBALL™ MATRIX CONDUCTIVITY AND COLOR

Color change, RAL
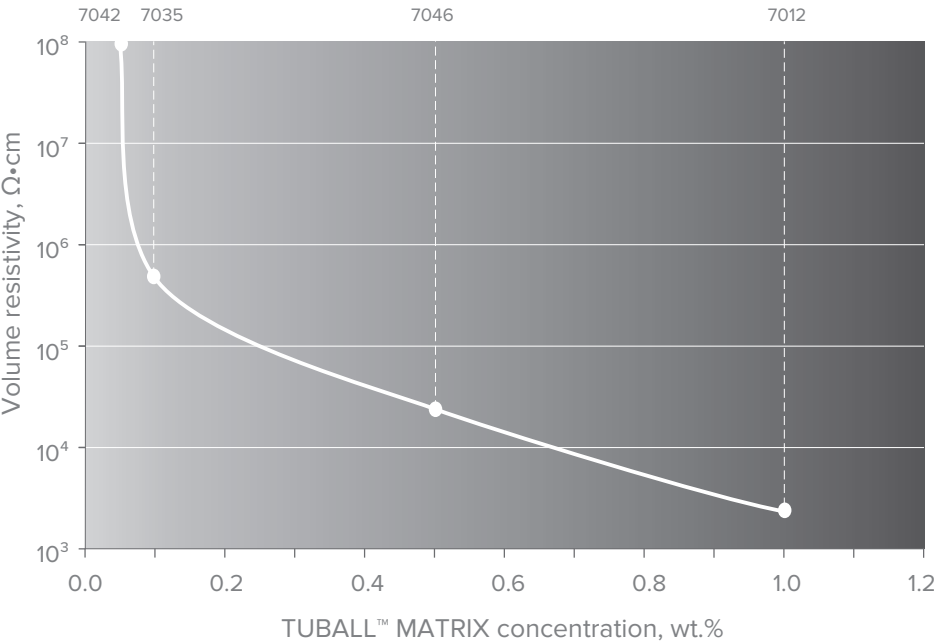
Note: all samples include 5 wt.% of TiO_2 as a whitening agent.
Results for epoxy resin D.E.R. 351. ASTM D257
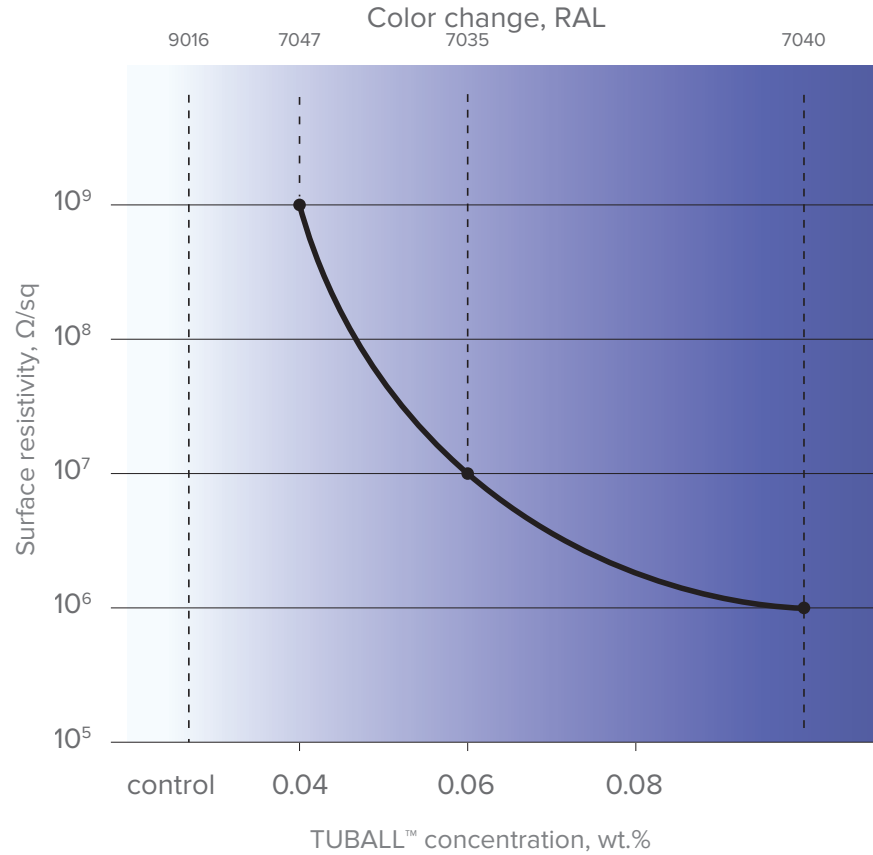
TUBALL™ COAT_E

TUBALL™ COAT_E is an easy-to-use single wall carbon nanotube suspension in water that provides permanent anti-static properties to waterborne paints and coatings with minimal impact on their color and mechanical properties.

TUBALL™ COAT_E is suitable for production of anti-static waterborne paints and coatings intended for the following applications:
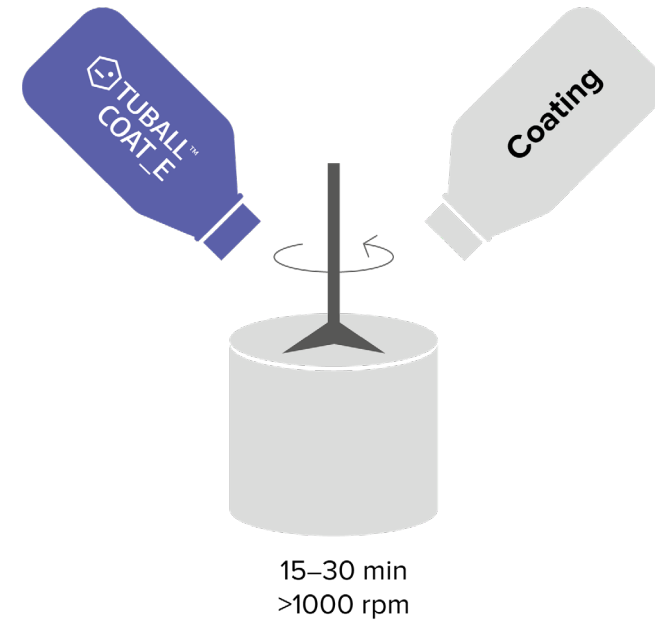
• UV coating
• Packaging for electronics

TUBALL™ COAT_E IS SUITABLE FOR COLORED AND TRANSPARENT SYSTEMS

Permanent electrostatic dissipative and conductive properties with color and/or transparency are achieved by simply mixing TUBALL™ COAT_E with the paint system.

- Easy to use
- Efficient ESD protection
- Permanent conductivity
- Suitable for colored and transparent systems

15–30 min
>1000 rpm

TUBALL™ GRAPHENE NANOTUBE SOLUTIONS
FOR COMPOSITES & COATINGS

PRODUCT	CARRIER	COMPOSITION	Target systems														
			Solvent-free				Solvent-based							Water-based			
			Epoxy	Polyester	Vinyl-ester	Polyurethane	Epoxy	Polyester	Vinyl-ester	Polyurethane	Melamine	Phenolic resoles	Acrylic	Epoxy	Polyurethane	Acrylic	Phenolic resoles
TUBALL™ MATRIX concentrates (Black flakes paste @ standard dosage 0.1%–1.0%)																	
MATRIX 201	Plasticizer	Fatty acid glycidyl ester (2,3-epoxypropyl neodecanoate, CAS-No. 26761-45-5)	●														
MATRIX 202	Plasticizer	Fatty carboxylic acid ester derivatives				●											
MATRIX 203	Plasticizer + stabilizing agent	Fatty acid glycidyl ester (2,3-epoxypropyl neodecanoate, CAS-No. 26761-45-5) + ammonium salt of polyolefins-based derivative					●			●							
MATRIX 204	Plasticizer + stabilizing agent	Triethylene glycol dimethacrylate (CAS No. 109-16-0) + ammonium salt of polyolefins-based derivative		●	●		●	●		●			●				
MATRIX 207	Plasticizer	Alkyl glycidyl ether (Oxirane, mono[(C12-14-alkyloxy)methyl] derivative, CAS No. 68609-97-2)	●														
MATRIX 208	Plasticizer + stabilizing agent	Alkyl glycidyl ether (Oxirane, mono[(C12-14-alkyloxy)methyl] derivative, CAS No. 68609-97-2) + ammonium salt of polyolefins-based derivatives					●			●							
MATRIX 209	Plasticizer	Fatty carboxylic acid ester derivatives				●											
MATRIX 301	Surfactant	Ethoxylated alcohol (C12-15-branched and linear, ethoxylated propoxylated, CAS No. 120313-48-6)	●			●											
MATRIX 302	Surfactant + stabilizing agent	Alkylene glycol derivative + stabilizing agent ((disodium 2,2'-([1,1'-biphenyl]-4,4'diyldivinylene) bis (benzenesulphonate, CAS No. 27344-41-8))										●			●	●	●
TUBALL™ suspensions COAT_E (Black liquid @ standard dosage 1.5%–6.4%)																	
COAT_E H₂O 0.4% (SDBS)	Water + anionic surfactant	Water + anionic surfactant (sodium dodecylbenzenesulfonate, CAS No. 25155-30-0)												●	●	●	
COAT_E H₂O (DBD) beta	Water + distyrylbiphenyl-derivative	Water + distyrylbiphenyl-derivative, (CAS No. 27344-41-8)												●	●	●	

PRODUCTS FOR THERMOPLASTICS

TUBALL™ MATRIX 800-X SERIES

TUBALL™ MATRIX 800-x series is a line of concentrates based on TUBALL™ graphene nanotubes that has been specifically designed to provide superior electrical conductivity to thermoplastic materials, while retaining mechanical properties and minimally impacting the host matrix.

TUBALL™ MATRIX 800 line is designed for the most demanding applications in the automotive, petrochemical, oil and gas, healthcare, pharmaceutical and electronics industries.

APPLICATION EXAMPLES

ESD containers

Ventilation ducting

Anti-static signal lamps

Conductive compounds for e-painting

Semiconductive shielding materials

Anti-static textiles

Treadmill belts

Filled polyamide injection-molded part

TUBALL™ FOR THERMOPLASTICS

PRODUCT	CARRIER	Target systems													
		Polyethylene	PE rotomolding	Polypropylene	EVA	PVC	Polystyrene	TPU	Filled PPS	ABS	PC	PC-ABS	PA	GF PA	Powder coatings
TUBALL™ MATRIX concentrates (Pellets or black flakes paste @ standard dosage 0.3%–3.0%)															
MATRIX 802 beta	Ethylene copolymer				●	●	●			●			●	●	
MATRIX 808	Polyol ester							●	●	●	●	●	●	●	
MATRIX 811 beta	Alkylolammonium salt		●												
MATRIX 814 *	Epoxidized fatty acid glyceride					●									
MATRIX 815 beta	Polyethylene wax	●	●	●											●
MATRIX 821 beta	Reaction mass of fatty acids, montan-wax, ethylene esters	●	●	●											●
MATRIX 822	Polyol ester			●				●	●	●	●	●	●	●	
TUBALL™ suspensions COAT_E (Black liquid @ standard dosage 1.5%–6.4%)															
COAT_E H₂O 0.2/0.4% (SDBS)	Water + anionic surfactant		●												

* PVC plastisol specific

TUBALL™ MATRIX 808 / 814 / 822

PROPERTY — Electrical conductivity

TUBALL™ MATRIX 808

Carrier: polyol ester

Materials: TPU, filled PPS, ABS, PC, PC-ABS, PA, GF PA

Working dosage: 0.5–5 wt.%

Shape: pellets

TUBALL™ MATRIX 814

Carrier: epoxidized soybean oil and polymeric stabilizing agent

Materials: PVC-plastisol

Working dosage: 0.25–2 wt.%

Shape: paste

TUBALL™ MATRIX 822

Carrier: polyol ester

Materials: PP, TPU, filled PPS, ABS, PC, PC-ABS, PA, GF PA

Working dosage: 0.2–2 wt.%

Shape: pellets

FEATURES OF TUBALL™ MATRIX FOR THERMOPLASTICS:

- Ultra-low dosage starting from just 0.05 wt.% of TUBALL™ graphene nanotubes*
- Maintains good balance of mechanical properties
- Provides thermoplastic compounders with opportunity for new conductive products development
- Permanent, stable and homogenous electrical resistivity without "hot spots"
- Surface resistivity of 10^3–10^9 Ω/sq*
- Volume resistivity of 10^3–10^9 Ω·cm*
- Stable performance reducing the number of out of spec parts
- Good processability
- Allows production of conductive parts that retain colors

*Dosages and values can vary depending on the formulation, processing and products. The shown values are mentioned as the typical reference

APPLICATION EXAMPLE: CONDUCTIVE PVC-PLASTISOL

TUBALL™ MATRIX is highly competitive conductive agent that enable a full set of properties.

FULL RANGE OF RESISTIVTY

- Ammonium salts
- TUBALL™ MATRIX 814
- Carbon black

STABLE AND PERMANENT ELECTRICAL RESISTIVITY

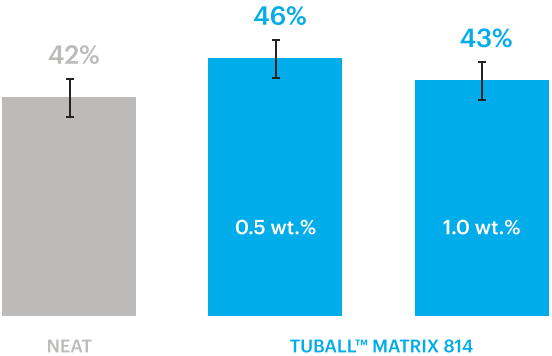LIMITED IMPACT ON RHEOLOGY

PRESERVED MECHANICAL PROPERTIES

MAINTAINED LIGHT COLORS

The diagram provides average trends compared with other additives, based on OCSiAl data.
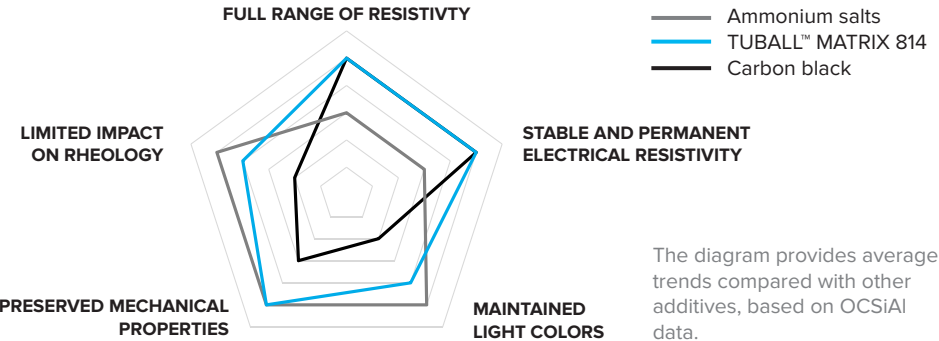
TUBALL™ MATRIX maintained abrasion resistance index.

42% — NEAT

46% — 0.5 wt.%

43% — 1.0 wt.%

TUBALL™ MATRIX 814

OCSiAl internal PVC plastisol formulation. ASTM D5963-04.

APPLICATION EXAMPLE: CONDUCTIVE GLASS FIBER-FILLED POLYAMIDE

TUBALL™ MATRIX provides a full range of electrical resistivity while maintaining mechanical properties.

TUBALL™ nanotubes, wt.%

- Surface resistivity, Ω/sq
- Volume resistivity, $\Omega \cdot$cm

NEAT   0.1 wt.% of TUBALL™ nanotubes

- Tensile modulus, MPa
- Flexural modulus, MPa

NEAT   0.1 wt.% of TUBALL™ nanotubes

- Tensile strength, MPa
- Flexural strength, MPa

NEAT   0.1 wt.% of TUBALL™ nanotubes

- Charpy impact strength unnotched, kJ/m^2
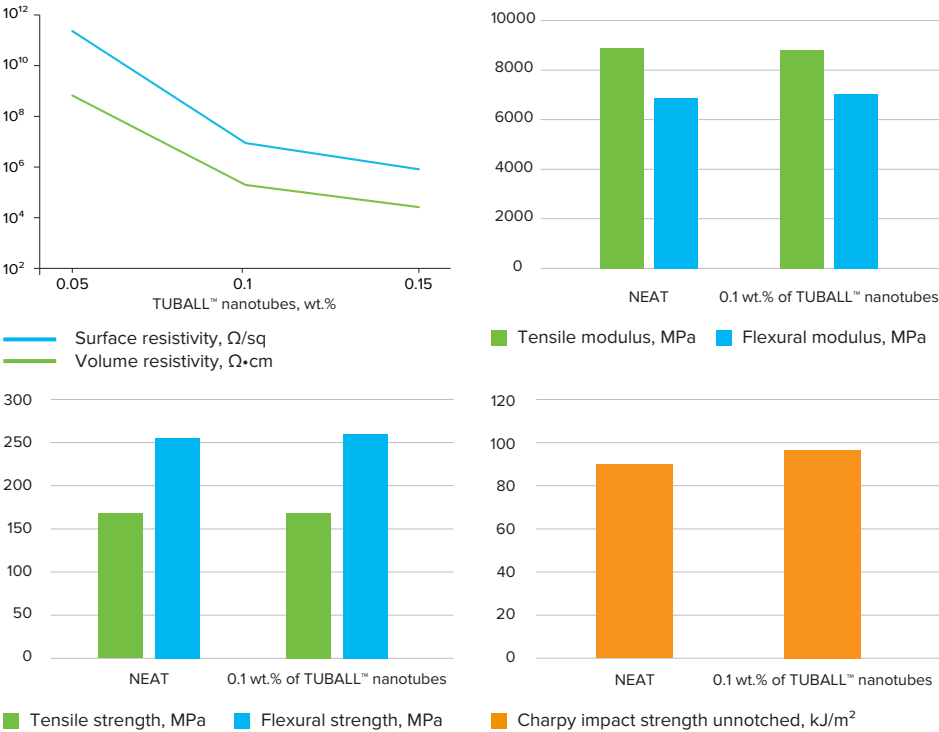
Injection molded samples. ISO 527, ISO 178, ISO 179.

SAFETY INFORMATION

OCSiAl produces nanotube dispersions and concentrates to enable a simple and easy integration process. TUBALL™ MATRIX products and TUBALL™ suspension products were developed to minimize handling requirements and provide all manufacturers access to the superior performance of single wall carbon nanotubes.

For handling and safety information please refer to the Safety Data Sheet and Safe Handling guide for the corresponding product.

More at **tuball.com**

WARRANTIES AND DISCLAIMER

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O C SiAl

OCSiAl is the world's largest manufacturer of graphene nanotubes and owns the only scalable technology that can synthesize them in industrial volumes.

A graphene nanotube (also known as a single wall carbon nanotube) is a rolled-up sheet of graphene. High electrical and thermal conductivity, strength, and flexibility – all together, these exceptional properties allow graphene nanotubes to improve the properties of most known materials. When embedded into a material, the nanotubes create a 3D reinforcing and conductive network. OCSiAl produces high-purity graphene nanotubes under the TUBALL™ brand name.

OCSiAl accelerates the transformation process of nanotubes from the laboratory to being an industrial-scale material by simplifying their handling. The TUBALL™ MATRIX nanotube concentrate product line allows nanotubes to be used directly in standard manufacturing technological processes. Often as little as 0.1% of the concentrate is enough to improve a material's properties significantly.

So far, OCSiAl has developed TUBALL™-formulated technologies for electrochemical power sources, elastomers, composites,

plastics, paints and coatings. To provide its customers with advanced technical support and to develop new nanotube technologies, the company has launched TUBALL Centers in Luxembourg, China and CIS.

For industrial-scale commercialization in global markets, OCSiAl has registered its TUBALL™ single wall carbon nanotubes with regulators of various countries, including EU-REACH (Registration, Evaluation, Authorsation and Restriction of Chemicals) and the US Environmental Protection Agency. OCSiAl is the only manufacturer authorized to commercialize up to 100 tonnes of single wall carbon nanotubes in Europe annually.

Luxembourg-based OCSiAl partners with more than 1,500 companies around the world in regions including Europe, US, South Korea, China, Hong Kong, Canada, Mexico, Brazil, South-East Asia, Taiwan, Japan, India. OCSiAl has over 450 employees, with over 70 of those being R&D experts.

CONTACT YOUR LOCAL DISTRIBUTOR TO ORDER A SAMPLE AND OBTAIN TECHNICAL/SAFETY DATA SHEETS

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