

TUBALL™ OVERVIEW

COMPOSITES APPLICATIONS

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WHAT IS SWCNT?*

The structure of a SWCNT can be conceptualized by wrapping a one-atom-thick layer of graphene into a seamless cylinder

DIAMETER

**1.6 ± 4
nm**

LENGTH

$>5 \mu\text{m}$

WALL THICKNESS

1 atom

* Parameters are given for TUBALL SWCNT

Graphene

Excellent Conductor

5 times
lighter
than copper

Stronger than steel

100 times

Thermal stability

up to
1000°C

The highest length to diameter ratio

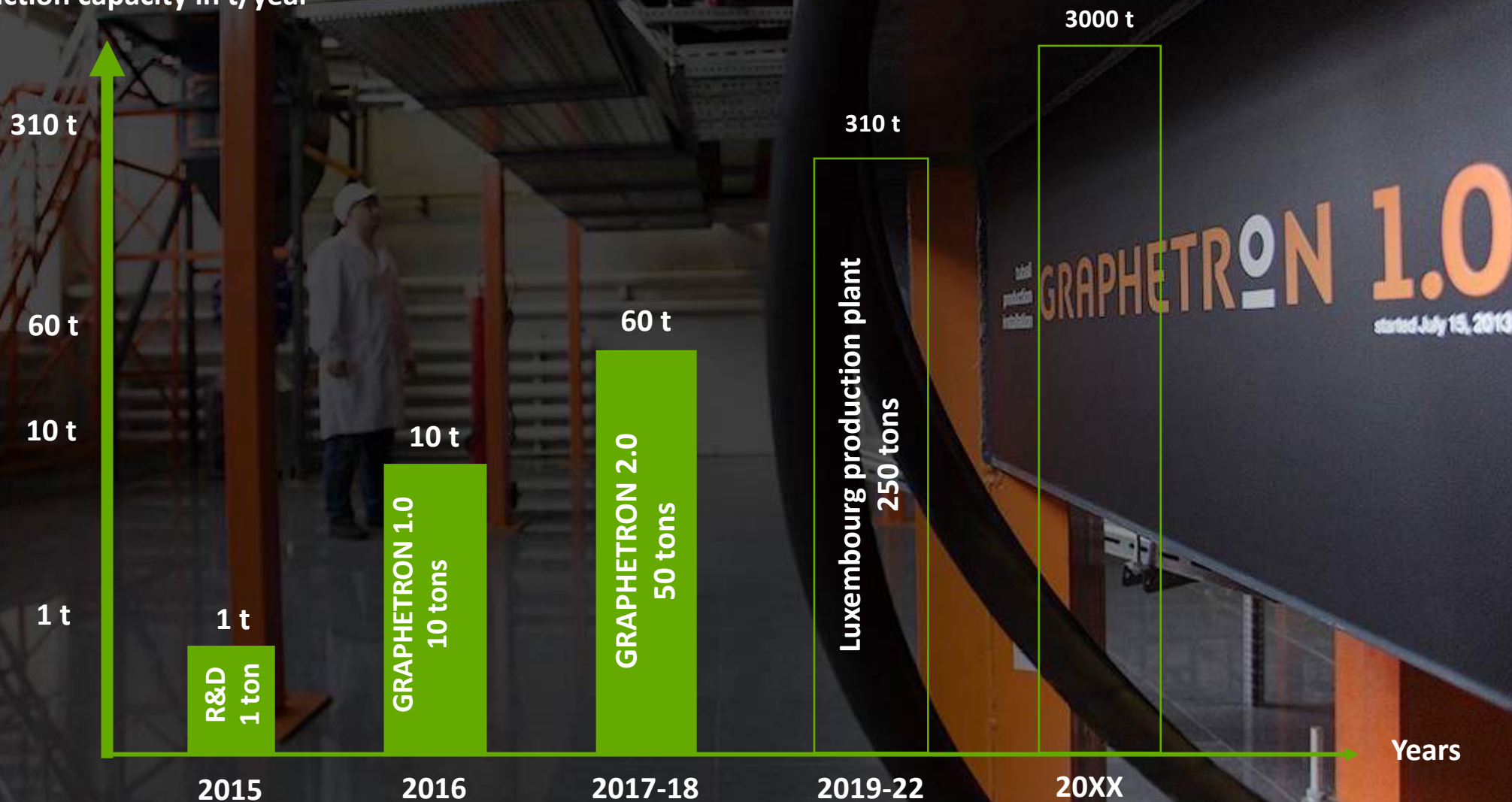
over
2 500 times

- Founded 2009, 400 employees, headquartered in Luxembourg
- World biggest SWCNT producer with 60t/year in 2018
- World first REACH-registered SWCNT producer since 2016
- World first high-quality & economically viable SWCNTs mass produced

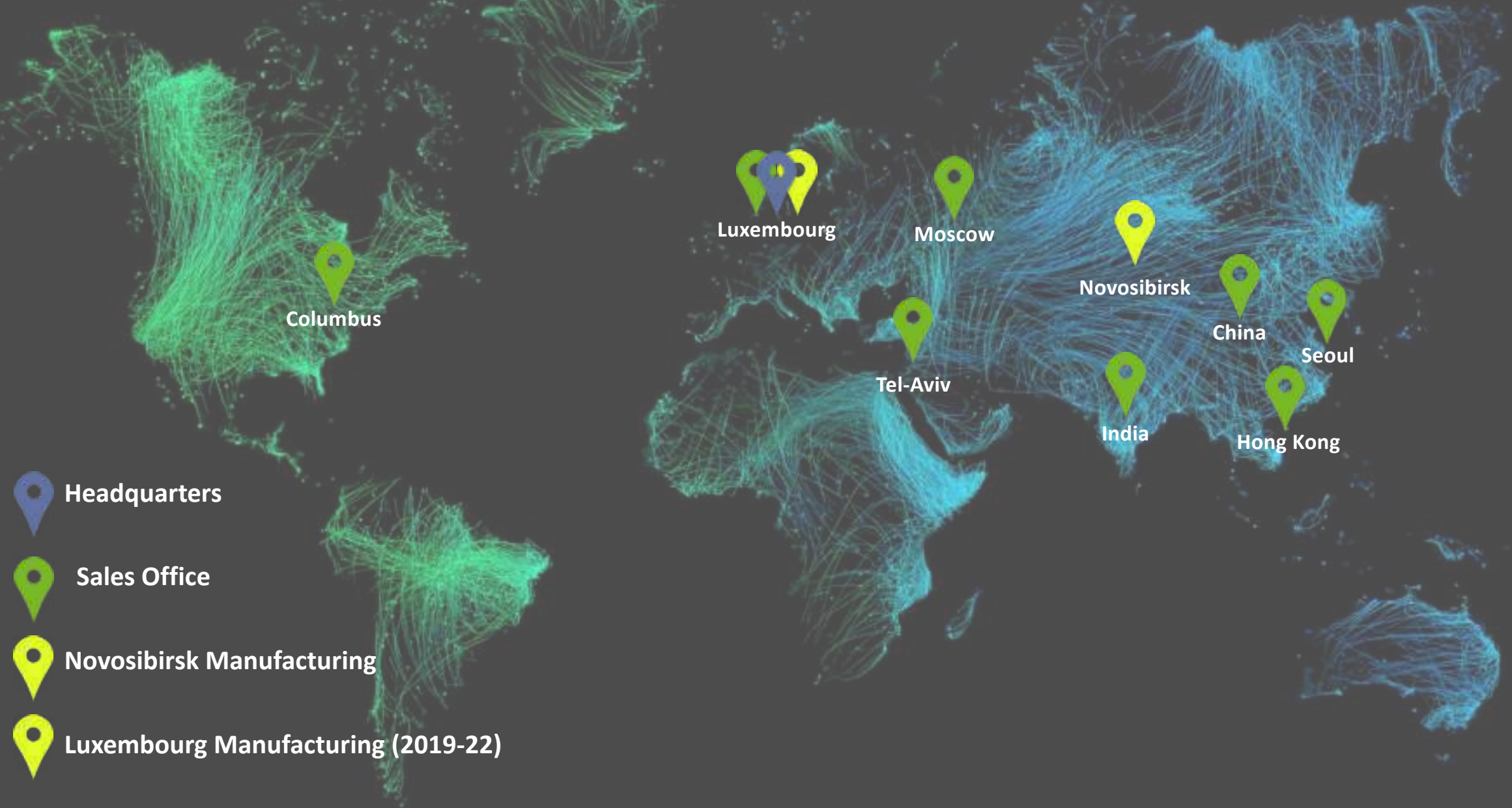


1 OCSiAl = Production capacity

TUBALL™
Production capacity in t/year



- 
- \$100m investment, engineering started in 2018
 - TUBALL™ + MATRIX productions and R&D center planned
 - More infos @ [Luxembourg Trade & Invest](#)



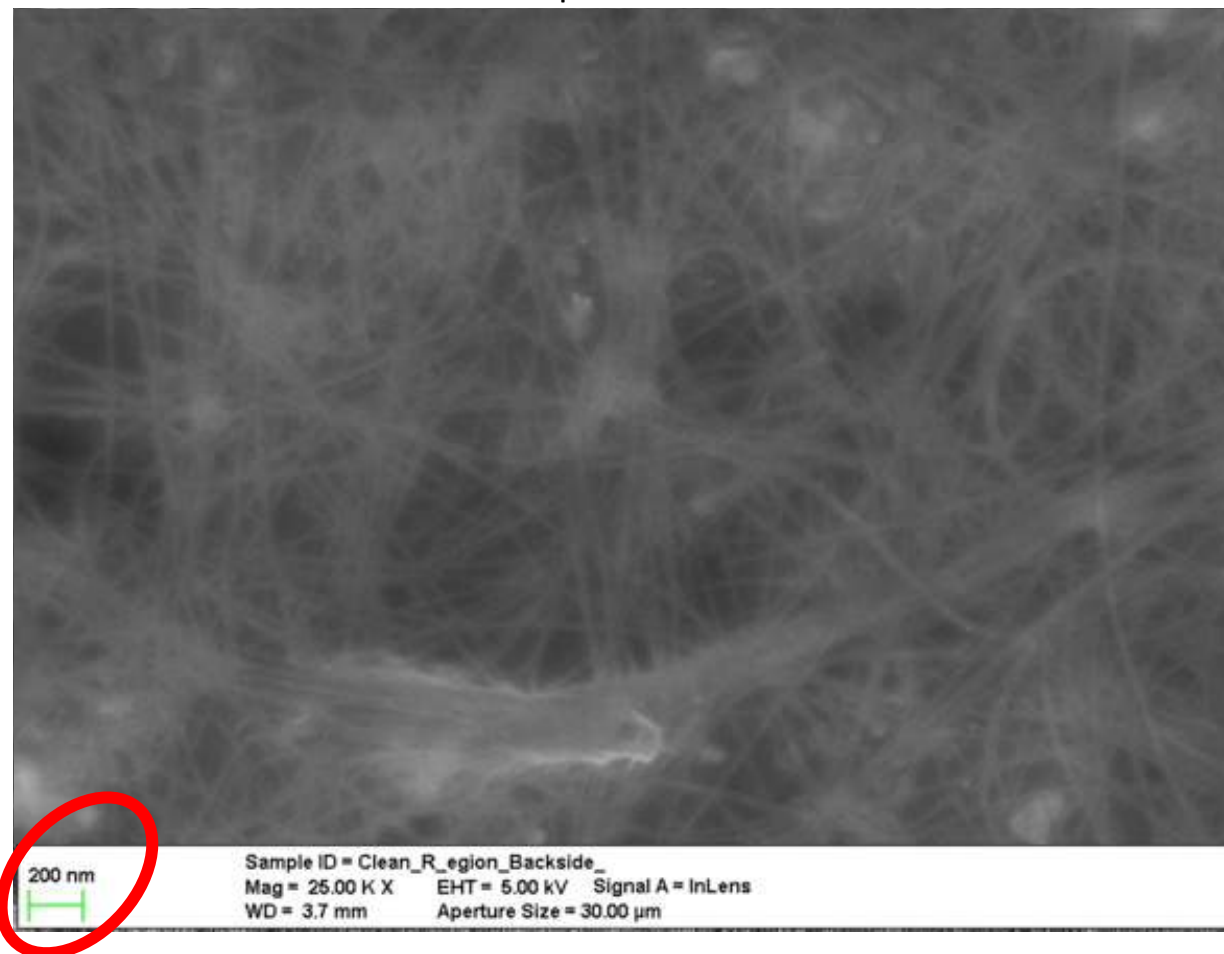
TUBALL™ purity grade ≥ 80%

TUBALL™ successful dispersion = 3D network formation

TUBALL™ in powder form



SEM & TEM images

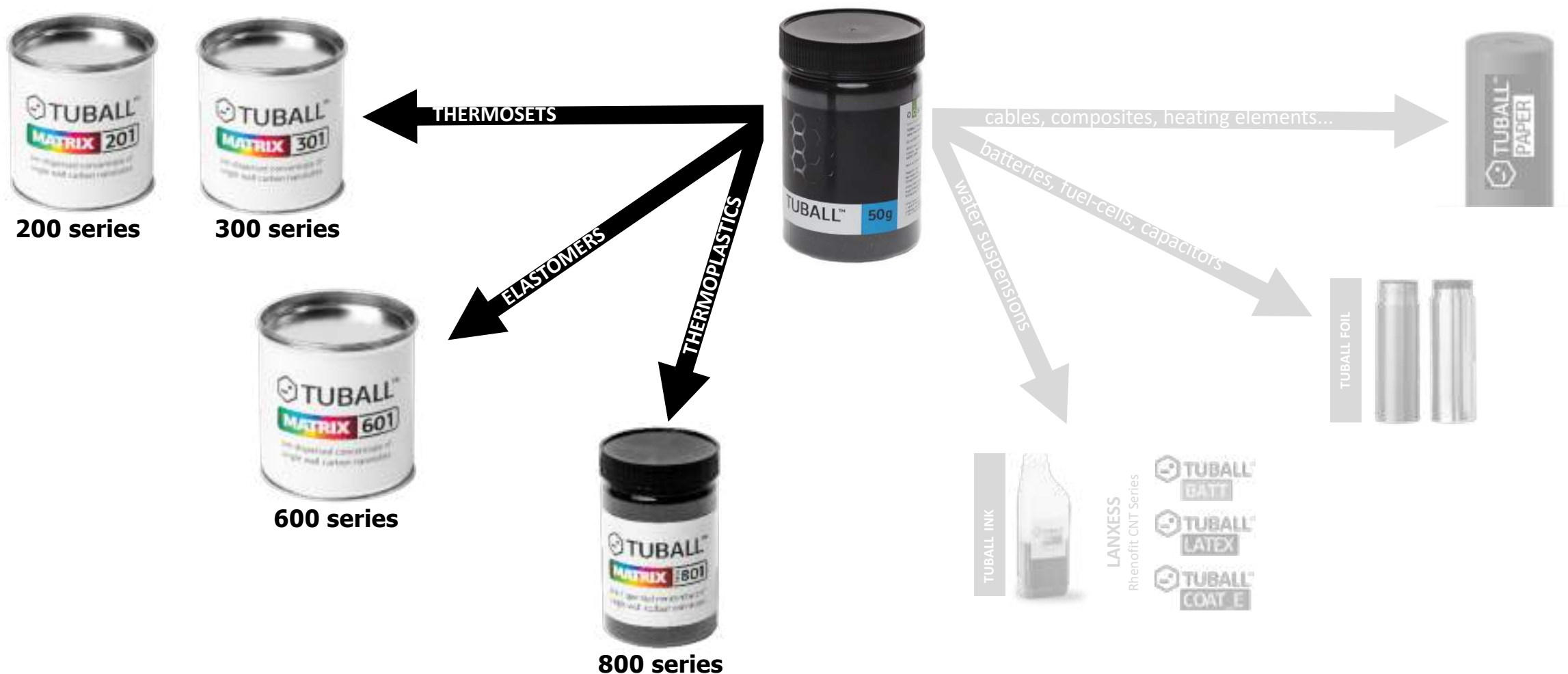


GRAPHENE NANO-TUBES

- TUBALL™ SWCNT (or TUBALL™) is made from one single graphene sheet
- Therefore TUBALL™ can be described as „Graphene Nano-Tubes“

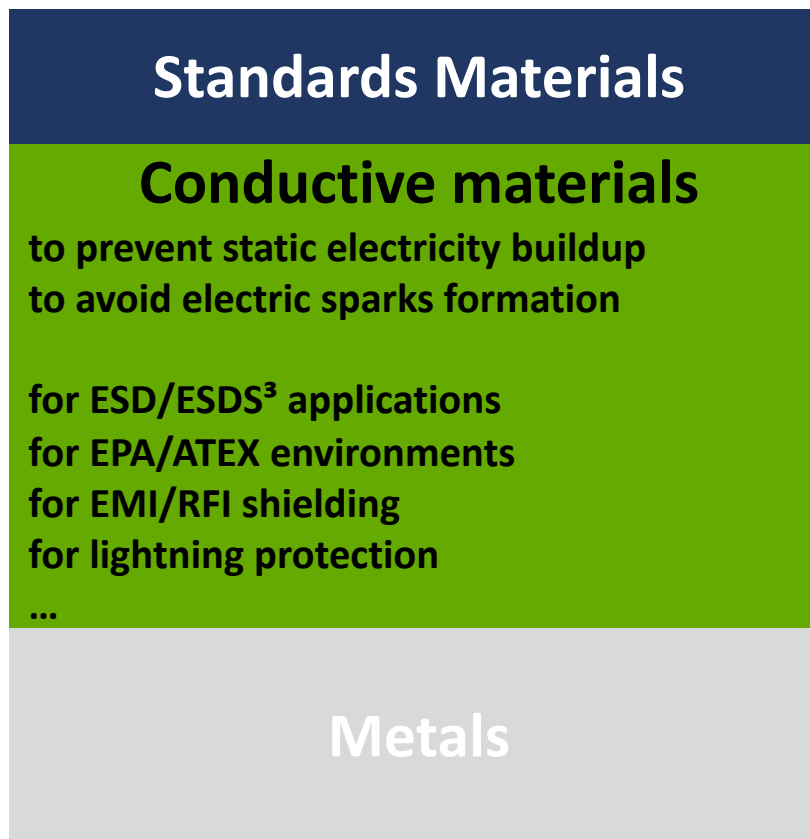
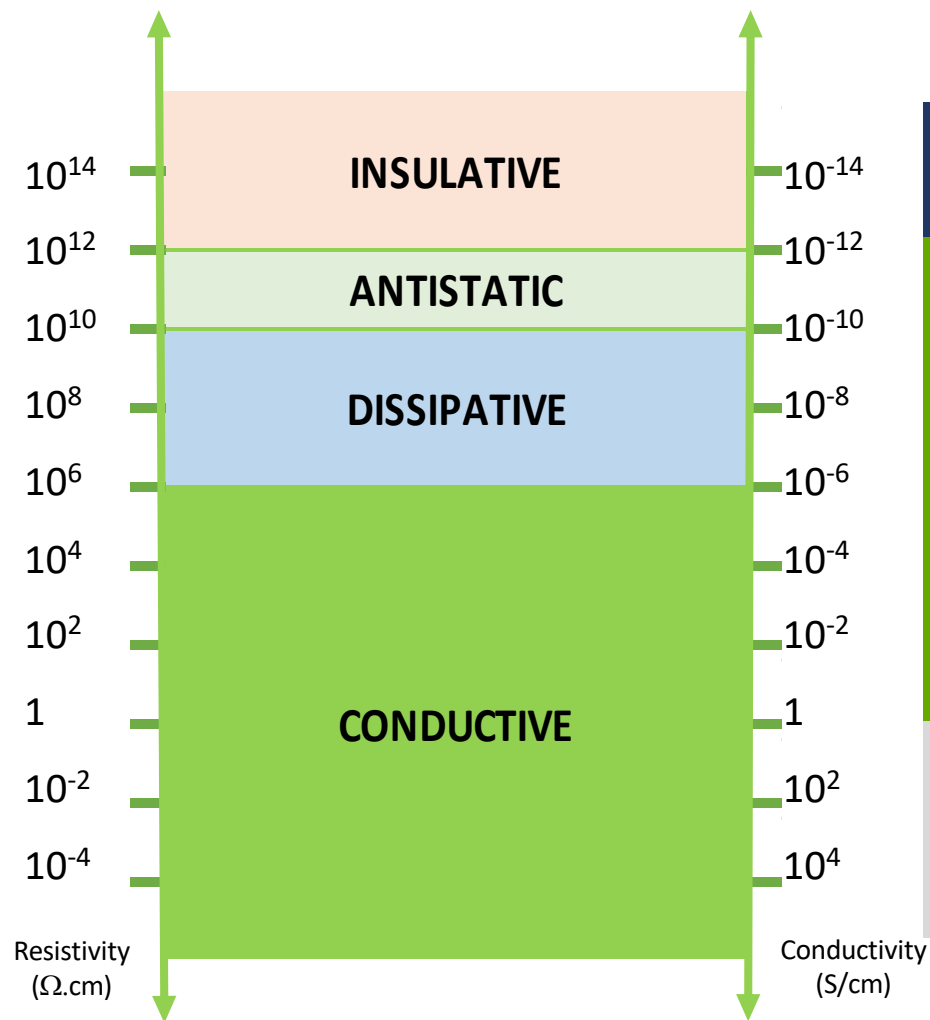
4

TUBALL™ MATRIX = Overview



TUBALL™ MATRIX (or MATRIX) are highly effective concentrates containing 10wt% TUBALL™

2 TUBALL™ SWCNT = Conductivity



0.01wt% - 1wt%²

² Typical range, TUBALL™ dosage to be adjusted for polymer type, client formulation, process conditions and application requirements

³ ESD: ElectroStatic Discharge / ESDS: ElectroStatic Discharge Sensitivity / EPA: ESD Protected Area / ATEX: Atmosphere Explosive / EMI: ElectroMagnetic Interference / RFI: Radio Frequency Interference

6 Composites properties² = Overview



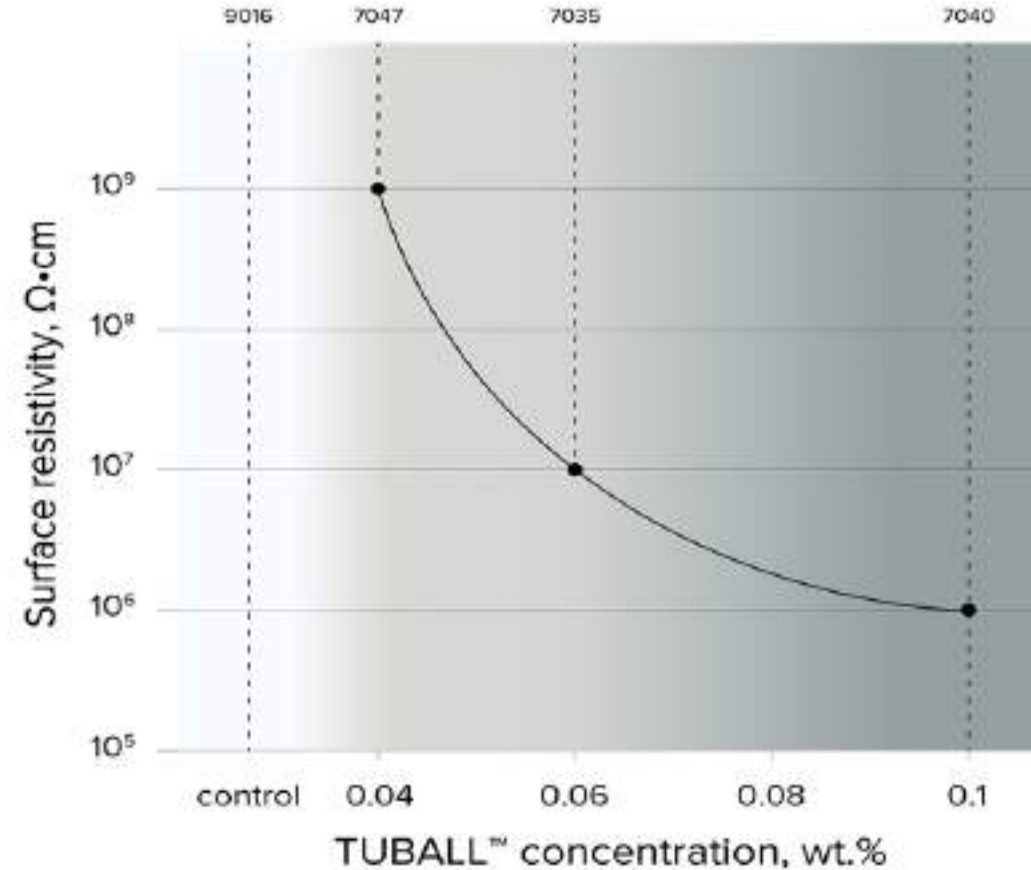
- ✓ Electrical colored³ conductivity
- ✓ Abrasion resistance
- ✓ Creep resistance
- ✓ Interlaminar shear strength
- ✓ Compression strength
- ✓ Electrical low-density conductivity
- ✓ Impact resistance
- ✓ Fatigue resistance
- ✓ Fracture toughness
- ✓ Tensile strength

² Main mechanical properties generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Depending of TUBALL™ loading level, the addition of a white agent (e.g. TiO₂) might be needed

6 Composites properties² = Electrical colored conductivity (ASTM D257)

OCSiAl LAB TEST³ – TUBALL™ SWCNT DISPERSED IN ACRYLIC PAINT (results for waterborne acrylic white paint Euro Power 7)



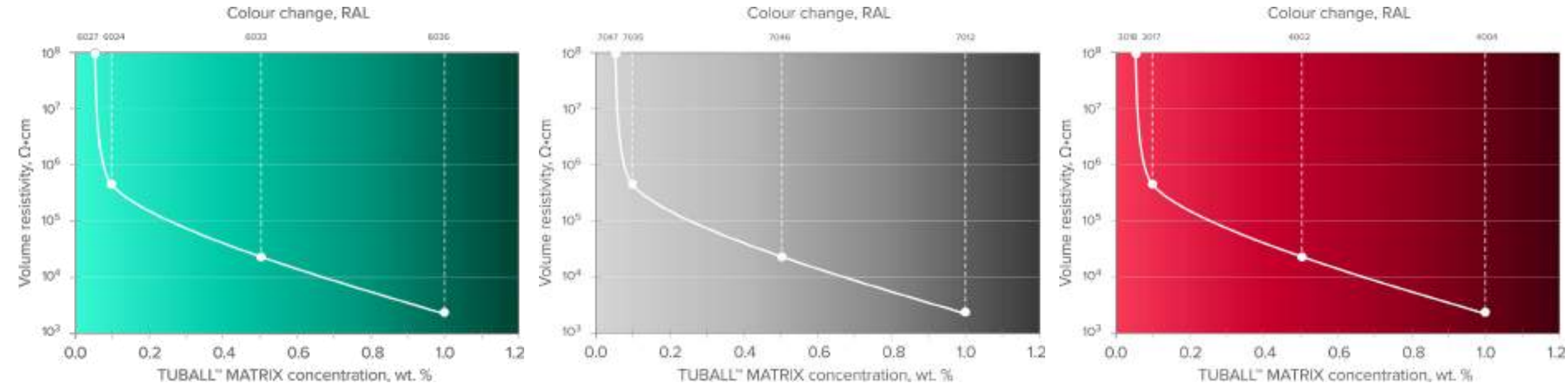
👉 Thanks TUBALL™ conductivity is not black anymore

² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test report available upon request

6 Composites properties² = Electrical colored conductivity (ASTM D257)

OCSiAI LAB TEST³ – MATRIX 201 + TiO₂ PROCESSED IN EP RESIN
(results for EP resin DER 351 including 5wt% TiO₂ as white agent)



👉 **MATRIX 201 mixed with TiO₂ enables colored conductivity at ultra-low loading levels**

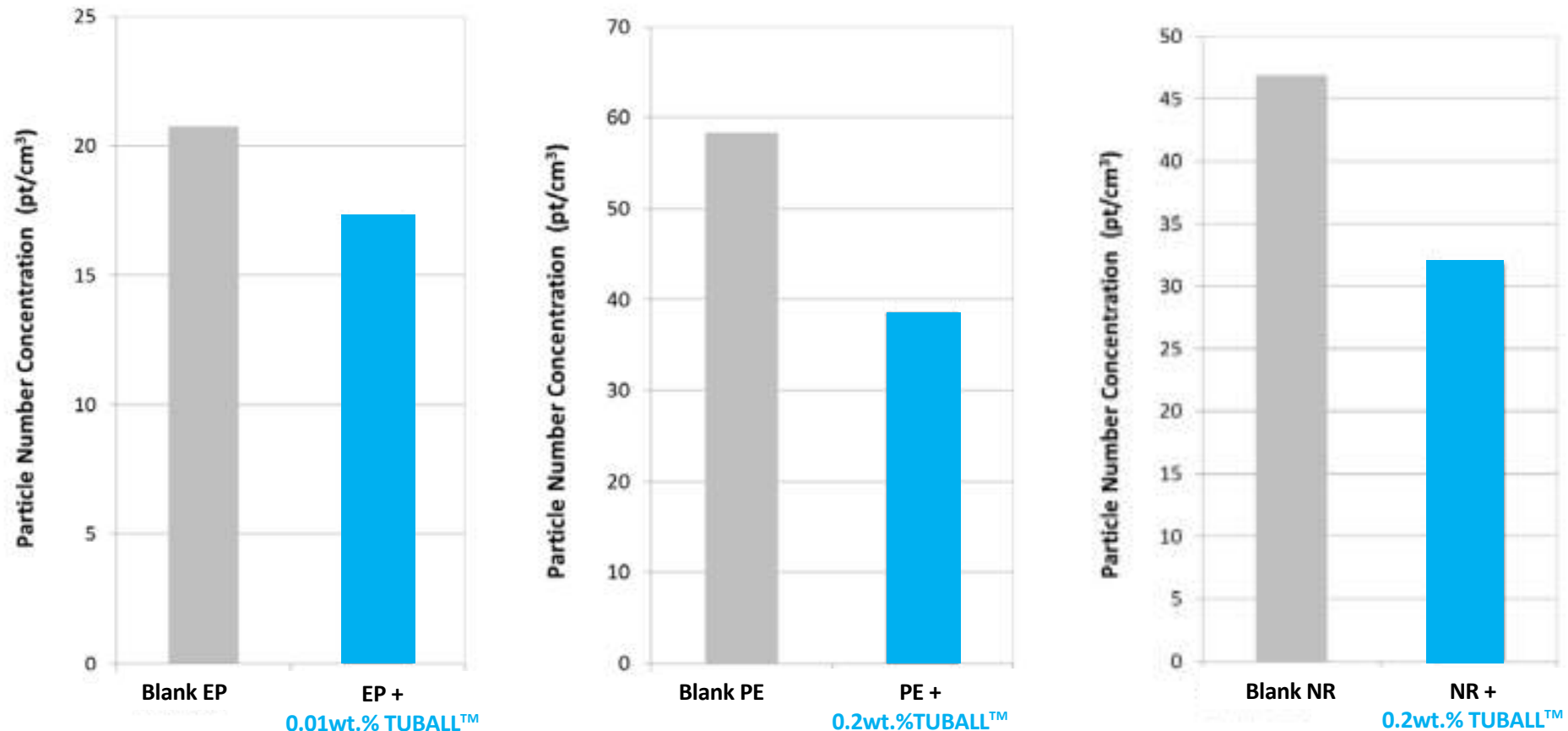
² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test report available upon request

6 Composites properties² = Abrasion resistance (ASTM D4060-07)



VITO LAB TEST³ - TABER ABRASION TEST



👉 **TUBALL™ containing EP, PE, NR⁴ releases less particles than the blank samples**

² Mechanical properties are generally maintained or improved, depending on the polymer/resin/elastomer type, client formulation, process conditions and application requirements.

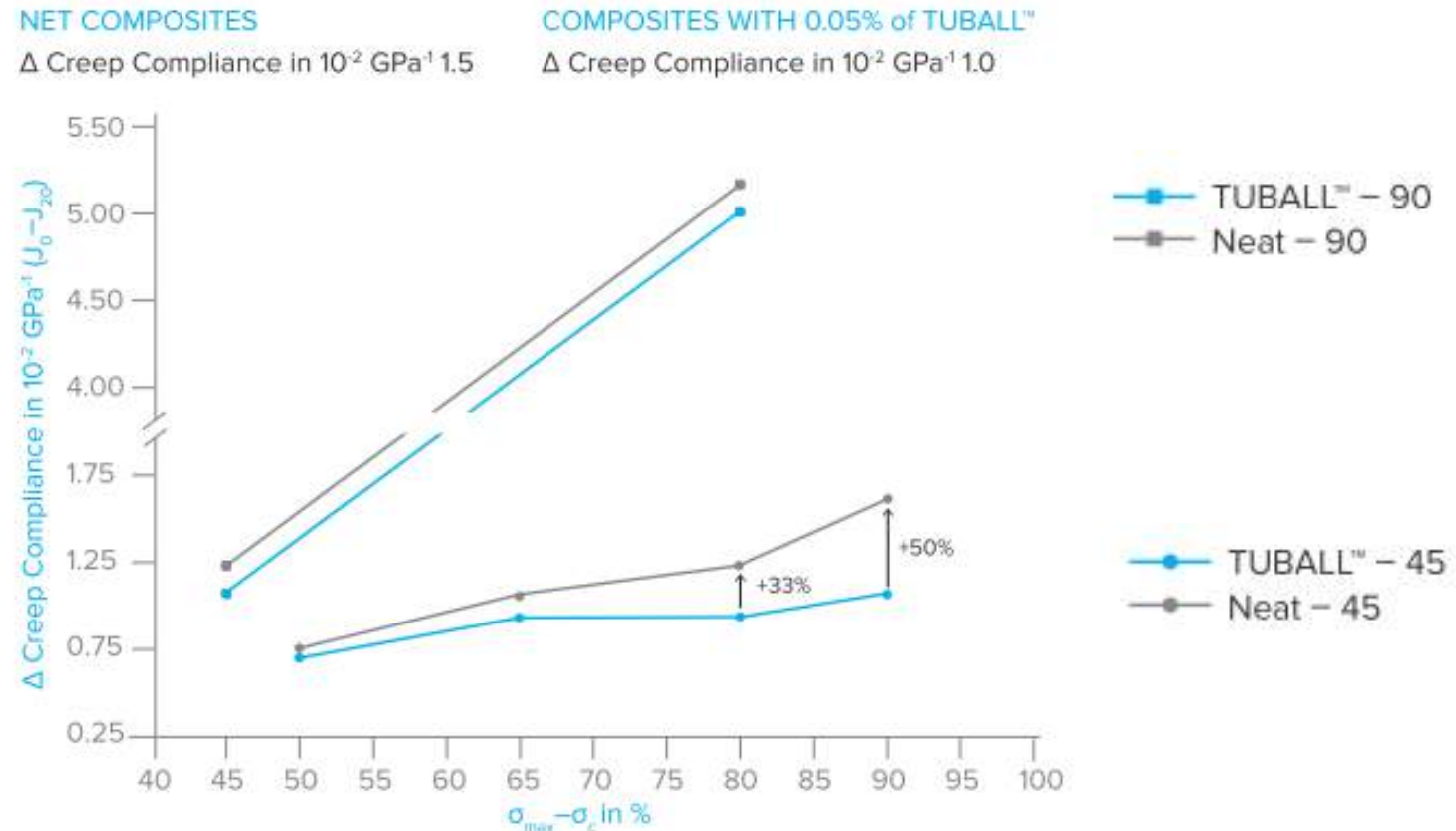
³ Complete abrasion test report iavailable upon request.

⁴ Whatever the polymer type, the formation of a SWCNT 3D-network is strengthening the intermolecular bondings which improves abrasion resistance

6 Composites properties² = Creep resistance (ISO 527-5)

TUHH TEST³ – TUBALL™ MODIFIED CFRP PREPREG – AUTOCLAVE

(Ludeko EP hotmelt system R481/H482, Mitsubishi Grafil 34-700 carbon fiber)



👉 **TUBALL™ improves creep resistance especially at high stress level in transverse direction**

² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test conducted by Prof. Bodo Fiedler (TUHH) and test report available upon request at jens.schneider@ocsial.com

7 Composites properties² = Impact resistance (ASTM D7136)

TUHH TEST³ – TUBALL™ MODIFIED CFRP PREPREG – HAND LAYUP + AUTOCLAVE
(Ludeko EP resin R480 & curing agent H481, Mitsubishi Grafil 34-700 carbon fiber)

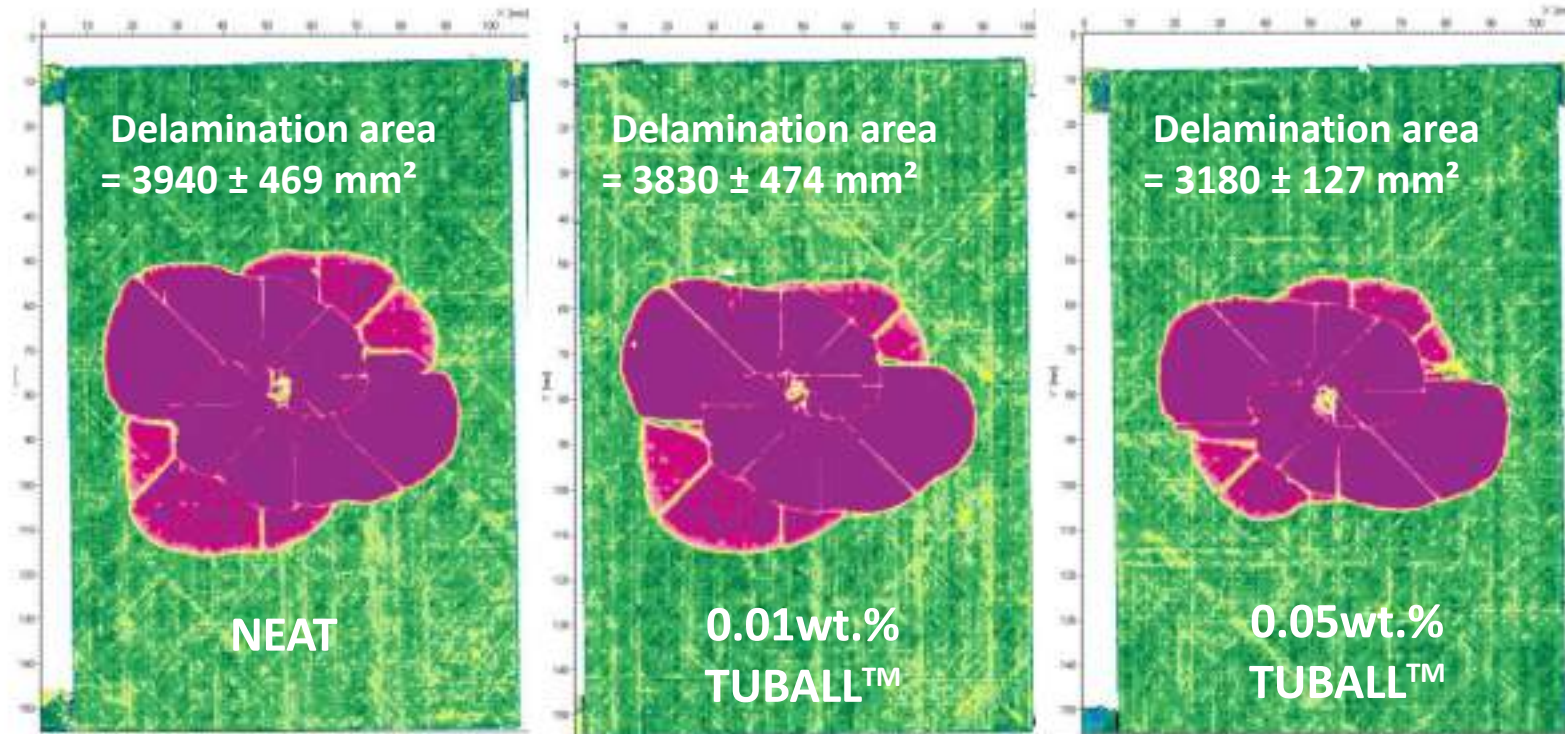


Figure 6: Ultrasonic C-scan (defect echo) of impacted specimens for delamination area determination: neat (left), 0.01 wt%. (mid) and 0.05 wt%. (right)

👉 **0.05wt% TUBALL™ containing CFRP reduces the delamination area by 20%**

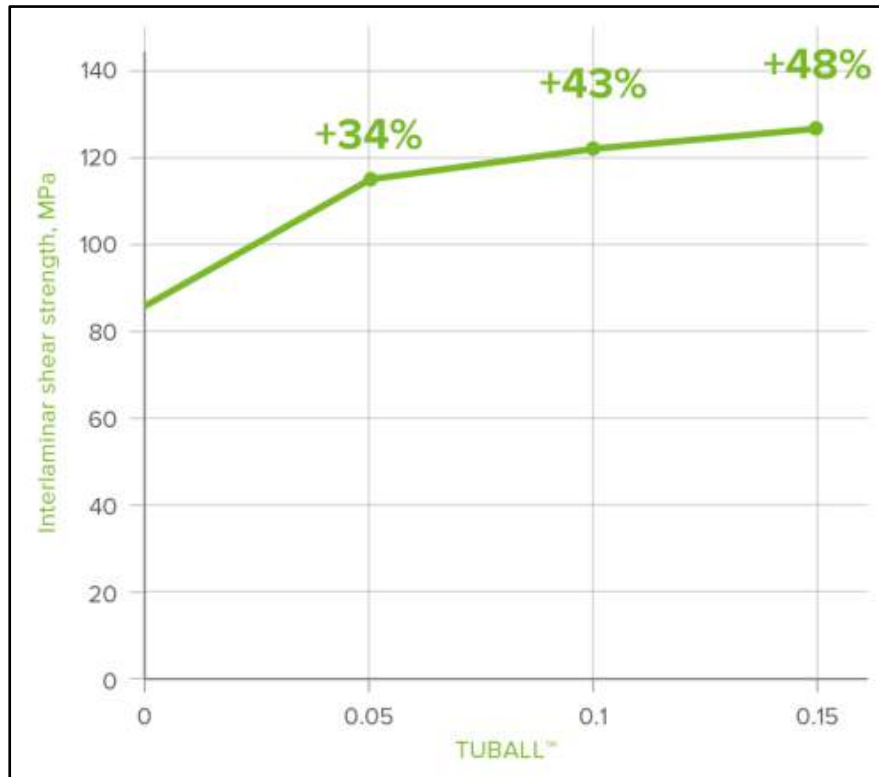
² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test conducted by Prof. Bodo Fiedler (TUHH) and test report available upon request at jens.schneider@ocsial.com

6 Composites properties² = Interlaminar shear strength (ASTM D2344)

OCSiA TEST³ – TUBALL™ MODIFIED GFRP – HAND LAYUP + COMPRESSION

(UP resin PN-609-21M, Steklonit fiberglass Armaton QX-1200 (0°/+45°/90°/-45°))



Testing machine:
Shimadzu AGS-20kN
Specimen size:
40×12×6 mm
Load speed: 1
mm/minute

<<< : position in the
testing machine

👉 **0.15wt% TUBALL™ containing GFRP
improves the interlaminar shear strength by 48%**

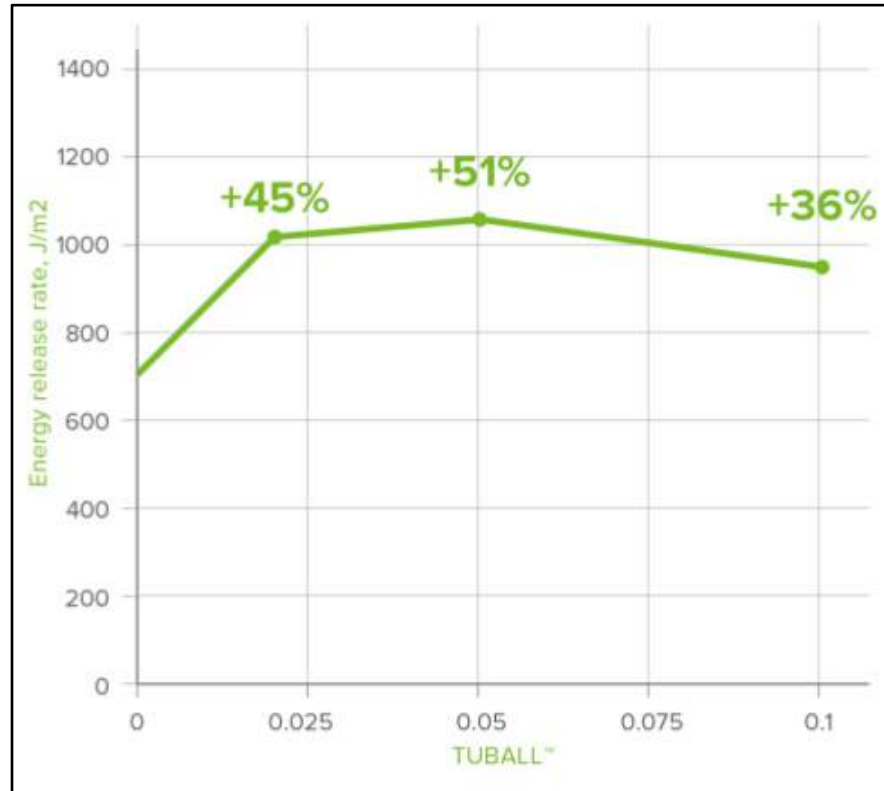
² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test report available upon request at jens.schneider@ocsial.com

6 Composites properties² = Fracture toughness (ASTM D5528-13)

OCSiAI TEST³ – TUBALL™ MODIFIED GFRP – HAND LAYUP + COMPRESSION

(UP resin PN-609-21M, Steklonit fiberglass Armaton QX-1200 (0°/+45°/90°/-45°))



Testing machine:
Shimadzu AGS-20kN
Specimen size:
40×12×6 mm
Load speed: 1
mm/minute

<<< : position in the
testing machine

👉 **0.05wt% TUBALL™ containing GFRP improves the fracture toughness by 51%**

² Mechanical properties are generally maintained or improved, depending on the thermoset resin type, client formulation, process conditions and application requirements

³ Test report available upon request at jens.schneider@ocsiai.com

COMPANY

XXXXXXX, Russia

APPLICATION

EP-based system processed with 0.5wt% MATRIX 201 instead of 4wt% premium carbon black and mixed with glass fibers

PRODUCT

GFRP pipes for oil transportation
Filament winding manufacturing process

KEY BENEFITS

- Provides volume resistivity of $10^4 \Omega \cdot \text{cm}$
- Permanent, stable & homogenous resistivity
- No “hot spots” & no influence of humidity
- Bright colours including white are possible
- Pipes hydrostatic pressure increased by 15%



COMPANY

XXXXX, Russia

APPLICATION

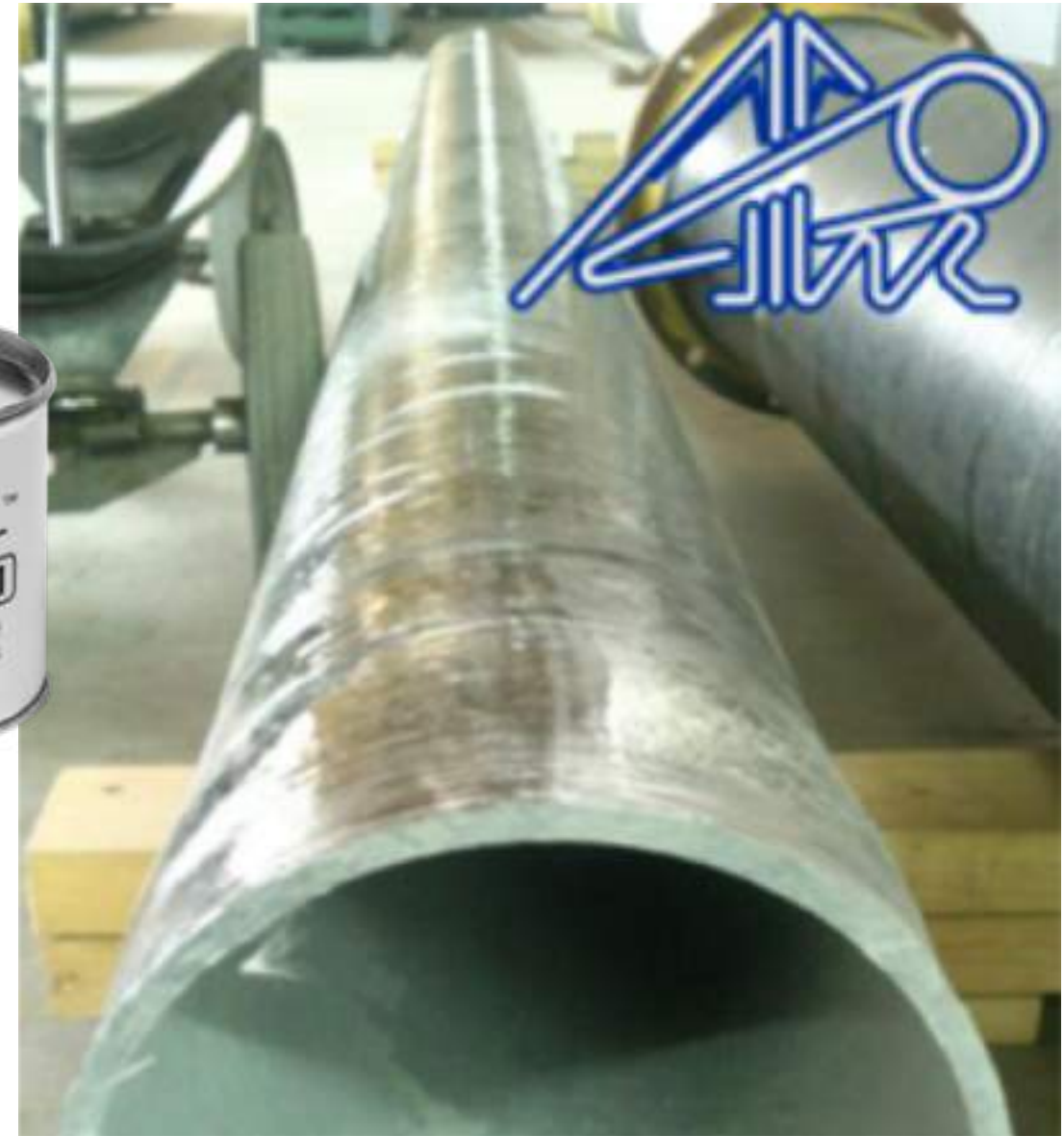
EP-based system processed with 0.2wt% MATRIX 201
and mixed with glass fibers

PRODUCT

GFRP pipes for flammables fluids transportation
Filament winding manufacturing process

KEY BENEFITS

- Provides volume resistivity of $10^6 \Omega \cdot \text{cm}$
- Permanent, stable & homogenous resistivity
- No “hot spots” & no influence of humidity



COMPANY

XXXXXX, India

APPLICATION

UP-based system processed with 0.07wt% MATRIX 204 instead of 6wt% premium carbon black and mixed with glass fibers

PRODUCT

Electric switchboards
SMC manufacturing process

KEY BENEFITS

- Provides surface resistivity of $10^8 \Omega/\text{sq}$
- Permanent, stable & homogenous resistivity
- No “hot spots” & no influence of humidity
- Bright colours including white are possible
- Original flame retardant property maintained



COMPANY

XXXXXXX, Russia

APPLICATION

EP-based system processed with 0.5wt% MATRIX 201
and mixed with glass fibres

PRODUCT

GFRP rebars for construction
Filament winding manufacturing process

KEY BENEFITS

- Mechanical properties improvements:

Properties	Blank rebars	Rebars + 0.5wt.% MATRIX 201	Improvement
Ultimate strength	1,100 MPa	1,456 MPa	+32%
Modulus of elasticity	51 GPa	54 GPa	+6%
Bending strength	615 MPa	795 MPa	+29%



COMPANY

XXXXXXX, USA

APPLICATION

PUR-based system processed with TUBALL™ SWCNT as a reinforcement additive without fibers

(loading rate not disclosed)

PRODUCT

CNTRP wind blades

KEY BENEFITS

- Lighter, more rigid, tougher than cb²
- Fatigue resistance improved by 8 times versus cb
- Delamination fracture test 8 times tougher versus cb
- Fracture growth rates significantly reduced versus cb



² cb: conventional blades made from EP or VE resin mixed with glass fibers

SINGLE WALL CARBON NANOTUBES

THE FIRST UNIVERSAL ADDITIVE FOR MATERIALS



Electrochemical
power sources



Ceramics



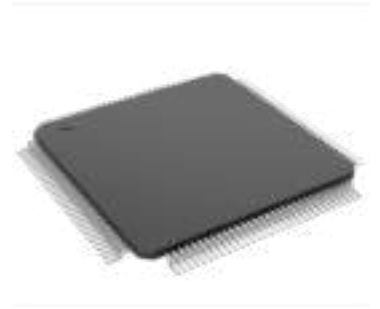
Concrete



Glass



Copper



Sensors
Semiconductors



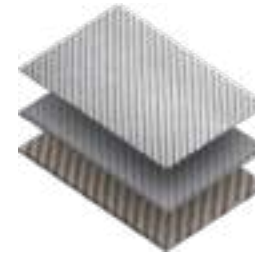
Rubber materials



Plastics



Aluminium



Composites



Paints



Adhesives

Owing to their extraordinary thermal conductivity and their mechanical, and electrical properties, carbon nanotubes find applications as additives to an extremely wide range of structural materials

8 Quality & EHS = ISO certifications



- TUBALL™ production is certified ISO 9001 : 2015
Certificate n°31100940 QM15 available since December 2017



- TUBALL™ production is certified ISO 14001 : 2015
Certificate n°31100940 UM15 available since December 2017



- TUBALL™ production is certified BS OHSAS 18001 : 2007
Certificate n°31100940 BSOH available since December 2017

QUALITY-RELATED ISSUES

Anastasiya Zagoruyko / Quality Assurance Manager / +7 913 956 10 10 / zagoruyko.aa@ocsial.com

8 Quality & EHS = REACH registration

10 tons



- TUBALL™ is REACH-registered for sales up to 10 tons
Registration n°01-2120130006-75-0000

100 tons



- TUBALL™ is REACH-registration for sales up to 100 tons started in 2017
Registration awaited in 2019



- TUBALL™ is RoHS certified

EHS-RELATED ISSUES

Gunther Van Kerckhove / H&S lead Manager / +352 661 183 429 / gunther.van.kerckhove@ocsial.com



- BAUA (Federal Institute for Occupational Safety & Health) will start in Q1/2018 a new R&D program to develop criteria for assessing the toxicological impact of carbon fibrous material
- OCSiAl will cooperate with the BAUA in the field of toxicological investigations and dustiness tests on TUBALL™



- TUBALL™ passed the mandatory nanomaterial register in France
France declaration for 2018: XS969-2018-10233409



- OCSiAl also cooperates with the Belgium authorities on a range of issues, including estimating types, quantities, applications of nanomaterials, as well as managing the risks associated with the substances
- Registered nanomaterials are given a single identification number that follows them all the way through the supply chain.



OCSiAl submitted the EPA a pre-manufacture notice (PMN) in Q1/2017:

- TUBALL™ is registered on the TSCA confidential list since December 2017
- TUBALL™ is EPA consented (PMN n°P-17-257)
- TUBALL™ can be sold in the USA up to 25t/year

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THANK YOU!

