



TUBALL™

graphene nanotubes

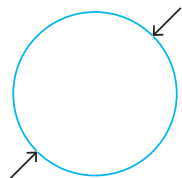


Wall thickness

1 atom

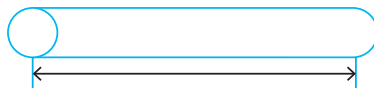
Specific surface area of 1 g

$\geq 300 \text{ m}^2$



Range
of outer diameters

$1.6 \pm 0.4 \text{ nm}$



Length $> 5 \mu\text{m}$

Thermal conductivity
compared with diamond

3 times more

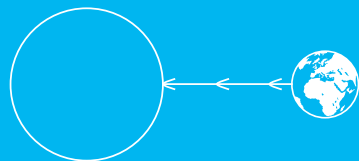


G/D
ratio

> 90

Amount
pcs in 1 g

10^{17}



1 g of TUBALL™ nanotubes
contains enough to stretch
from the earth to the sun

CARBON NANOTUBES

Human existence is shaped by the materials we use. More than 70% of all basic materials can be improved by introducing a universal additive – graphene nanotubes. These tiny tubes provide us with a rare opportunity to create nanoaugmented materials that have extraordinary properties.

Graphene nanotubes can be described as a one-atom-thick graphene sheet rolled in a tube more than $5 \mu\text{m}$ length. This material is also commonly called single wall carbon nanotubes (SWCNTs).

UNIQUE PROPERTIES OF GNTs

With these unique properties of graphene nanotubes, many characteristics of materials are improved.

The pre-eminence of these nanotubes is related to their exceptional properties, such as superior conductivity, high temperature resistance, ultra-low weight, record strength and high flexibility.

Excellent
conductor

**5 times
lighter than
copper**

Stronger
than steel

**up to
100 times**

Thermal
stability

**up to
1,600°C
in a vacuum**

Length
to diameter
ratio

**about
3,000 times**

GNTs — THE FIRST UNIVERSAL ADDITIVE FOR MATERIALS

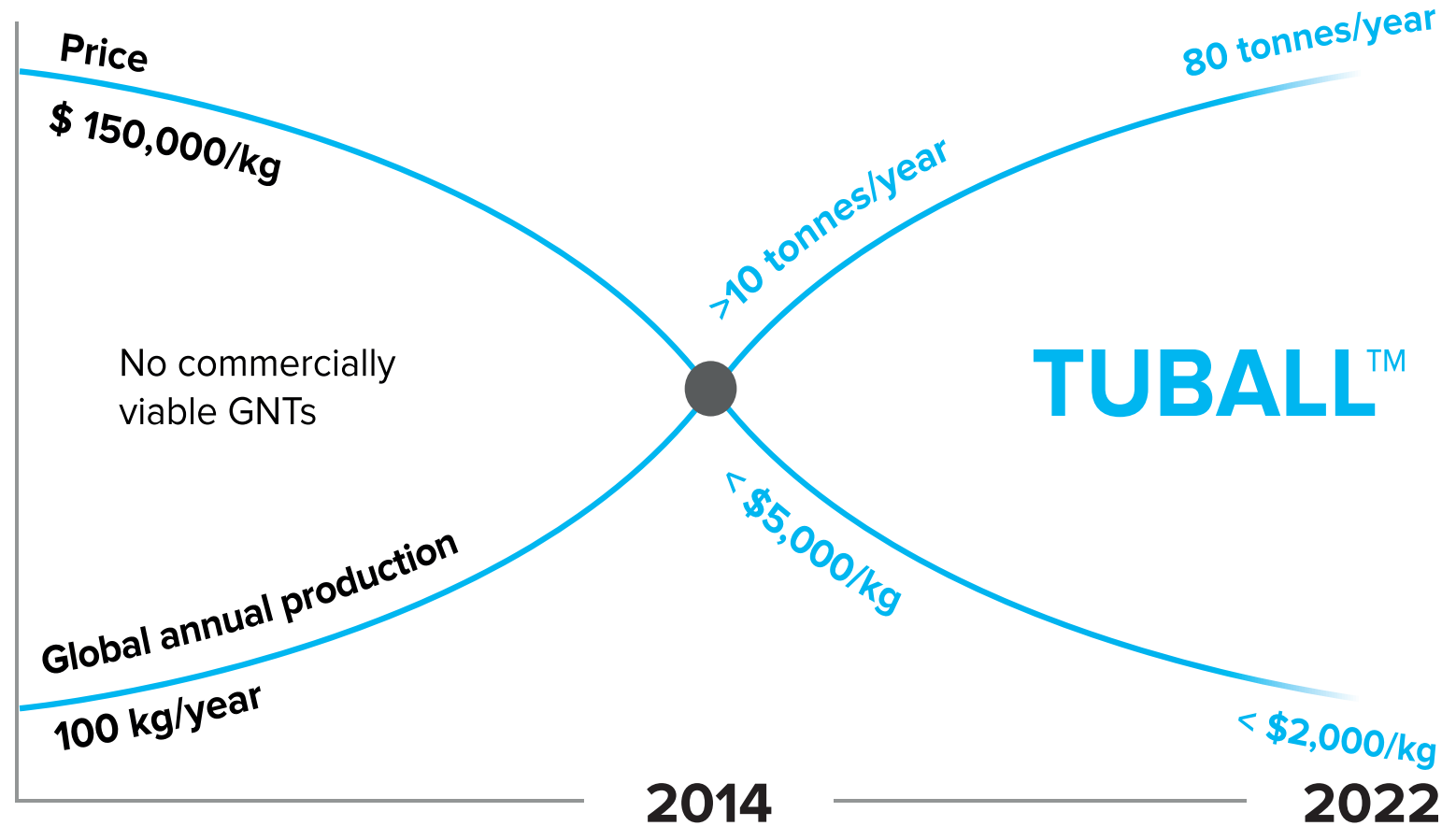
Owing to their extraordinary thermal conductivity and their mechanical and electrical properties, GNTs find applications as additives in an extremely wide range of structural materials.



WHY GNTs LEFT UNUSED

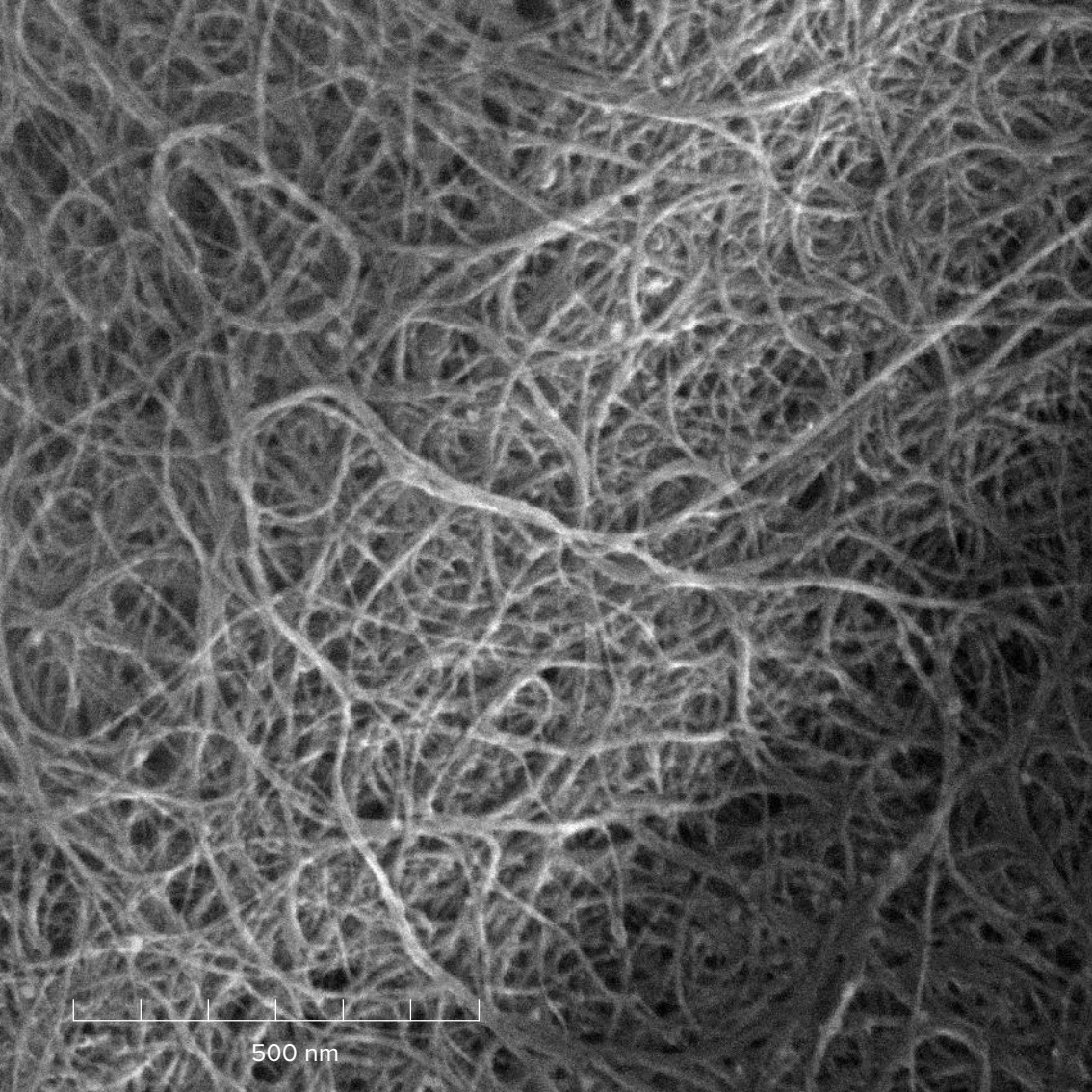
In 2014 GNTs became available to the mass industry

BY CIVILIZATION BEFORE?





FIRST MASS-PRODUCED GNTs



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 the absence of technology for their mass production, their high price and the 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 is low-cost mass-production technology has made the widespread use of nanotubes economically viable while still preserving their high quality.

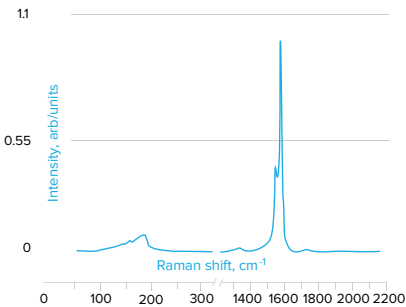
FEATURES

- High-quality nanotubes (G/D ratio > 90)
- Maintains color, elasticity, durability and other key properties of improved materials
- Gains traction starting from ultra-low concentrations
- Enhances mechanical properties
- Adds uniform, permanent and stable electrical conductivity
- Versatile for an extremely wide range of applications

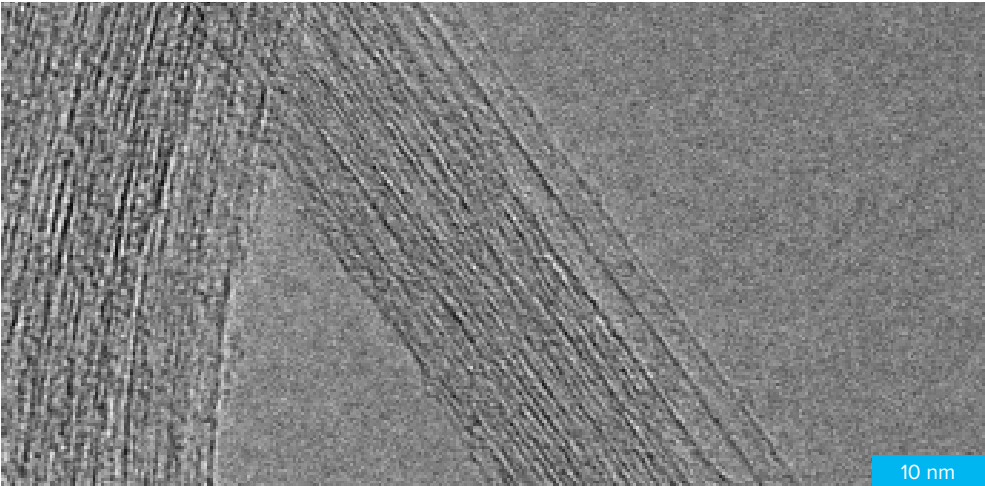
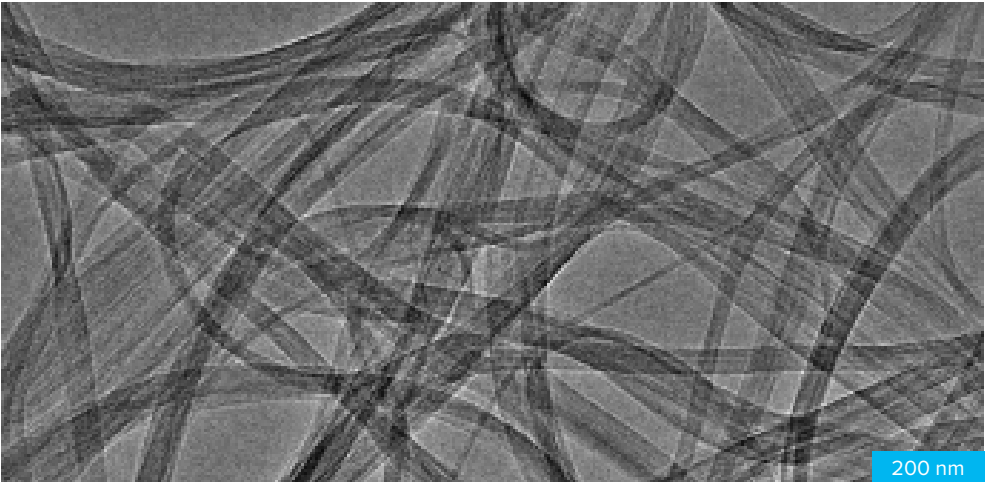
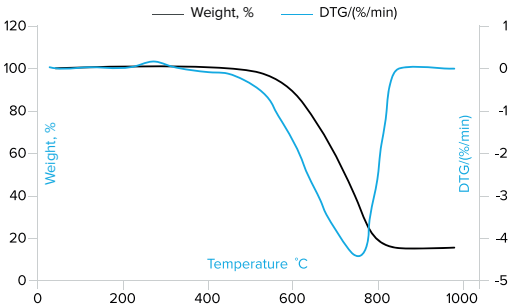
TECHNICAL INFO

	UNIT OF MEASURE	VALUE	METHOD OF EVALUATION
CNT content	wt.%	≥ 80	OCSiAl internal method: ash residue
Number of layers CNT	unit	1	TEM
Outer mean diameter CNT	nm	1.6 ± 0.4	Optical absorption: ISO/TS 10868:2017 (E)
Length of CNT	μm	> 5	AFM
Metal impurities	wt.%	≤ 15	OCSiAl internal method: ICP-AES
Moisture	wt.%	< 5	OCSiAl internal method: infrared thermogravimetry

RAMAN SPECTRUM



TGA CURVES





PRODUCTION



INDUSTRIAL PRODUCTION OF GNTs

OCSiAl is the only company with a scalable technology for industrial synthesis of graphene nanotubes.

On 14 November 2013, the company launched Graphetron 1.0 – the first industrial-scale facility for graphene nanotube synthesis. With a capacity of 1 tonne of TUBALL™ per year, it became the world's largest facility. In 2019 Graphetron 50 was commissioned.

The joint capacity of the two current synthesis facilities now amounted to 60 tonnes per year. It is planned to expand existing capacity and launch a new facility in Serbia in 2024 and Luxembourg in 2027.

FACILITIES

2013

● **GRAPHETRON 1.0**

2019

● **Graphetron 50**

2024

● **GRAPHETRON IN SERBIA**

2027

● **GRAPHETRON IN LUXEMBOURG**

IN 2021 OCSiAI HAD

97%

**OF THE WORLDWIDE
GNTs PRODUCTION
CAPACITY**

Source: estimates based on report and analysis provided by one of the leading management consulting firms



OCSiAl FACILITIES

OCSiAl is expanding and optimising its production globally by building new TUBALL™ synthesis facilities in various locations around the world. OCSiAl's annual production capacity as of 2022 is 60 tonnes per year.



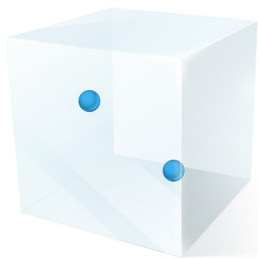
ISO certificates obtained from 2017 confirm the required high level of OCSiAl's quality control, environmental, health and safety management systems. Currently, OCSiAl is certified in accordance with ISO 9001, ISO 14001, ISO 45001: 2018 and BS OHSAS 18001. In 2019–2020, the OCSiAl production facility successfully passed an audit for compliance with German automotive industry standard VDA 6.3.

INDUSTRIAL APPLICATIONS

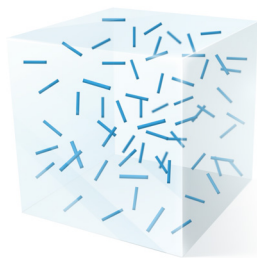


HOW IT WORKS

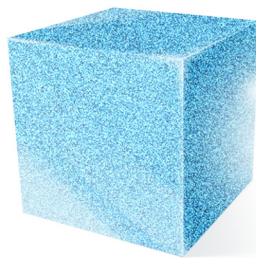
TUBALL™ provides significant improvements in material properties upon the addition of ultra-low loadings, starting from as little as 0.01%.



Microparticles



Nanofibers



GNTs

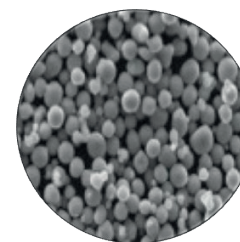
The same concentration of particles (~0.1%) in the same volume

Unlike conventional additives such as multi wall carbon nanotubes, carbon fibers and most types of carbon black, which all disperse unevenly throughout the material's matrix, GNTs create a uniform 3D reinforcing and conductive network.*

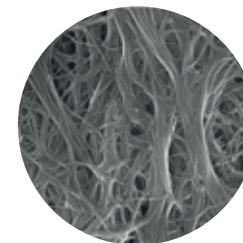
COMPARISON OF ADDITIVES THRESHOLD OF CHANGE



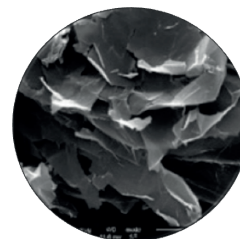
CARBON BLACK
20–40%



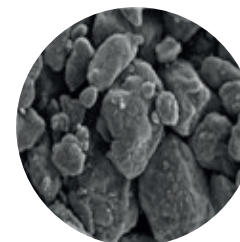
METAL FILLERS
15–35%



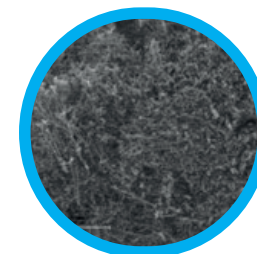
CARBON FIBERS
3–12%



ML GRAPHENE*
1–6%



MWCNTs
0.5–5%



GNTs
0.01–0.1%

* Graphene nanoplatelets, graphene oxide, reduced graphene oxide, etc.

TUBALLTM PROTOTYPING CENTER



analysis and quality
control of graphene
nanotubes



coatings



electrochemical power
sources



thermoplastics



elastomers



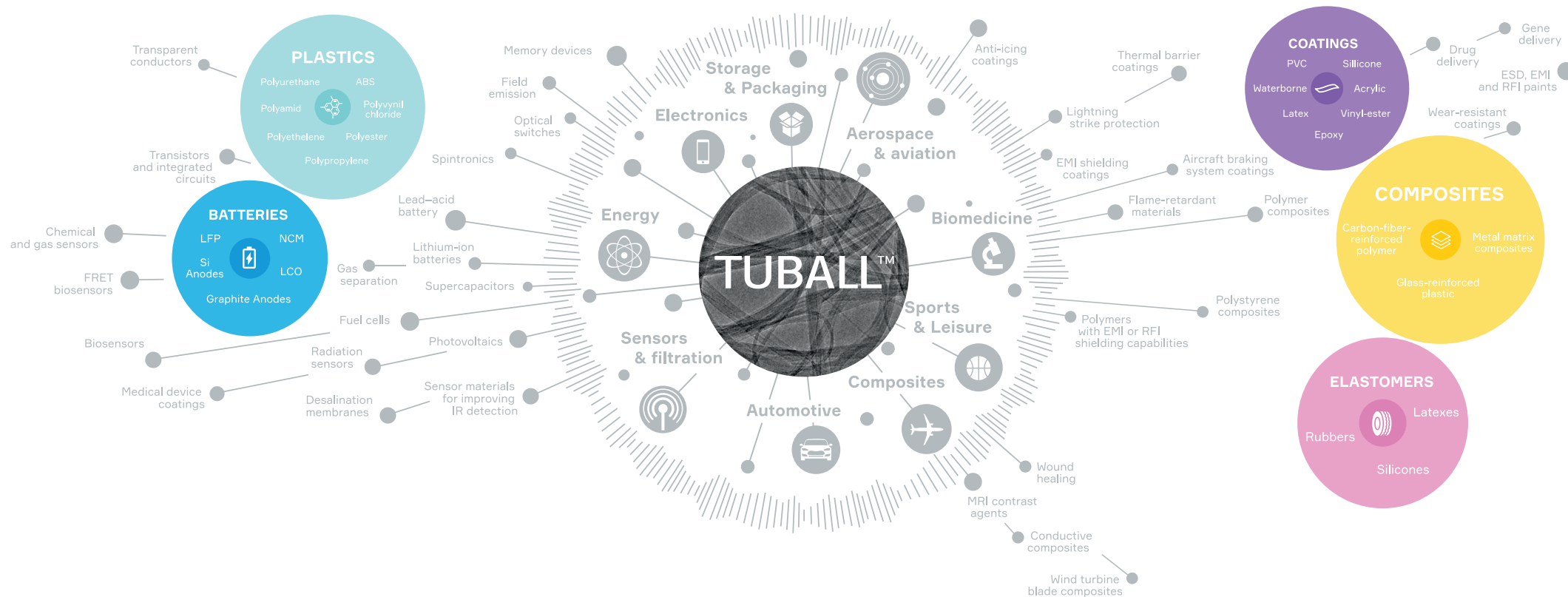
thermosets



... and others

TUBALL™ APPLICATIONS: ONE ADDITIVE FOR THOUSANDS OF MATERIALS

TUBALL™ nanotubes can dramatically improve the properties of the majority of materials used in industry. This wonder-material is just at the beginning of its journey. OCSIAl is taking the lead in the developing of numerous dispersion technologies that allow customers to integrate TUBALL™ into their products without changes in manufacturing technology or formulation.



TUBALL™ MATRIX CONCENTRATES



TUBALL™ MATRIX in a polymer

TUBALL™ MATRIX

OCSiAI has taken the lead in the creation of technologies for introducing nanotubes into material matrixes.

In 2016 OCSiAI presented TUBALL™ MATRIX – a line of graphene nanotube-based concentrates that provide materials with uniform and permanent electrical conductivity without compromising the original color or mechanical properties of the product. OCSiAI has now developed concentrates for most of the widely used industry-standard formulations.

BENEFITS



Ultra-low
concentration
from 0.1%



Retention of
wide range of
colors



Maintained or
even increased
mechanical
strength



Permanent
and uniform
conductivity
without
“hot spots”



Minimum
impact on
viscosity and
density



FOR NUMEROUS INDUSTRIAL APPLICATIONS

MATRIX
201

MATRIX
202

MATRIX
203

MATRIX
207

Epoxy, polyurethane

MATRIX
208

MATRIX
209

MATRIX
301

MATRIX
202

Phenolic

MATRIX
204

Polyester, vinylester,
acrylic, melamine

MATRIX
302

Acrylic

MATRIX
601

MATRIX
602

MATRIX
605

LSR, RTV and HCR silicones

MATRIX
603

MATRIX
610

MATRIX
620

Rubbers

MATRIX
808

MATRIX
814

Thermoplastics

...and many more to come

A scientist in a white lab coat is operating a large, complex industrial machine. The machine has a digital display on the front, which the scientist is touching. The machine is white and blue, with various pipes and components. The background shows a laboratory setting with other equipment and a clean, professional environment.

CERTIFICATION AND EHS



ENVIRONMENT, HEALTH & SAFETY

OCSiAl is the first company to be authorised to start large volume commercial shipments of SWCNTs to customers in Europe, North America and other key global markets.



REACH

Registration, Evaluation, Authorisation and Restriction of Chemicals

- First and only SWCNT completed (September 2016)
- TUBALL™ is registered under the number 01-2120130006-75-0000
- With the tonnage band upgrade, which is compliant with REACH Annex VIII, as of April 2020, its allowed commercialization volumes in Europe up to 100 tonnes of nanotubes annually



EPA

Environmental Protection Agency

- EPA consented
- PMN4 number P-17-0257
- On December 5, 2019, OCSiAl's regulatory status with EPA advanced with the publication of a significant new use rule ("SNUR") in the Federal Register covering OCSiAl's products with number § 40 CFR 721.11179. It removes restrictions on the sales and supply of TUBALL™ nanotubes in the United States

INDEPENDENT NANOSAFETY TESTINGS

OCSiAl invests in EHS-related research projects that are conducted by independent laboratories

For instance, VITO and INERIS, two of the leading European independent research centers, they supported OCSiAl in several studies and testing programs, including incineration and combustion tests, nano ecotoxicity, and various mechanical degrading studies to investigate and measure possible aerosol release to find out whether nano- and micro-sized particles were released from the different TUBALL™-containing composite materials that were tested.

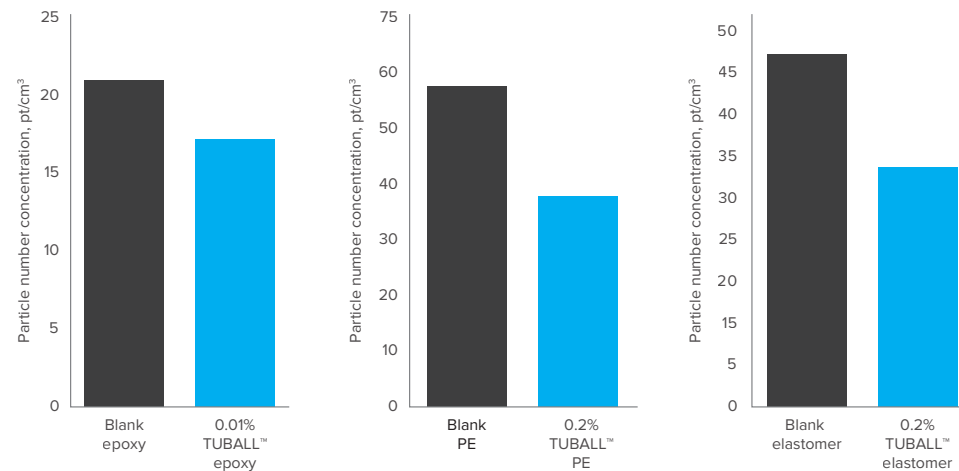
ECOTOXICITY TESTS RESULT

TUBALL™ itself has no eco-toxicity effect verified by:

- Daphnia magna, Acute Immobilization (eco-toxicity) test according OECD 202
- Freshwater Alga Growth inhibition (eco-toxicity) test according OECD 201

PARTICLES RELEASE

When TUBALL™ is used as a reinforcing material in polymer composites, it no longer displays nano-particle characteristics, and even in cases where such composite material is grinded, cut, or otherwise mechanically degraded, pure TUBALL™ typically does not become released, but is only release as part of highly aggregated, polymer-bound particles.



Graphics from original report from VITO

- No protruding nor free-standing CNTs or TUBALL™ were found
- As a result of the strength and cohesion improvement, nanotube-formulated materials release fewer nano-sized particles compared with the neat material

Exposure of TUBALL™ is extremely limited and not considered of posing any hazards to consumers, neither by inhalation, dermal or oral exposure.

OCSiAI ENABLES PEOPLE TO BENEFIT FROM ADVANCED TECHNOLOGIES WITHOUT DAMAGING THE PLANET

Materials – at all stages of their life cycle from extraction to recovery – contribute to one of the largest inputs of greenhouse gas emissions. And the production of materials to meet the needs of the increasing population will double in the next 40 years.

Additionally, materials and products are often used only partially to their full potential. Useful load of:



<40%

office building



15-30%

aircraft



20%

passenger car

To reduce global materials consumption, we need to make materials more energy efficient, stronger and more durable.

Graphene nanotubes can improve the properties of most materials existing on Earth. As a result, less materials can be used to achieve the same result. Enhanced products demonstrate higher energy efficiency and longer cycle life, decreasing the need for new products and thus the CO₂ emissions from their manufacturing.



Car body frames

TUBALL™ allows to reinforce thermoplastic compounds, improve durability and reduce weight, what potentially leads to higher energy efficiency of cars



Li-ion batteries

High-performance Li-ion batteries with TUBALL™ not only bring the mass adoption of EVs closer, they also enable a reduction in the number of battery cells to be sent for recycling



Tires

High-performance tires with TUBALL™ open the possibility to avoid required 600 g of carbon black per tire, potentially leading to a significant reduction in CO₂ emissions from the manufacturing of carbon black



Industrial coatings

TUBALL™ allows to enhance the properties of water-based coatings and allows them to overcome technological challenges, leading to reduced usage of solvent and other volatile organic compounds

... and many other ongoing projects with TUBALL™ show the potential for significant reductions in greenhouse gas emissions





OCSiAl is the world's largest manufacturer of graphene nanotubes, owning the only scalable technology capable of synthesizing them in industrial volumes.

A graphene nanotube, also known as a single wall carbon nanotube, is a rolled-up sheet of graphene possessing exceptional properties, such as high electrical and thermal conductivity, strength, and flexibility. These unique characteristics make graphene nanotubes a versatile additive with potential applications across up to 50% of global materials markets. When integrated into materials, they form a 3D reinforcing conductive network, providing a new set of properties to the final product. Advanced high-performance batteries, composites, plastics, coatings, and other materials additionally enable companies to contribute to reductions in CO₂ emissions at all stages of manufacturing and during usage of new products, stimulating global efforts to achieve carbon neutrality.

OCSiAl produces high-purity graphene nanotubes under the brand name TUBALL™ and accelerates the transformation process of nanotubes from the laboratory to being an industrial-scale material by simplifying their handling. The company has developed TUBALL™-formulated technologies for various applications.

TUBALL™ BATT, an ultrafine dispersion of graphene nanotubes in liquid carriers, is a ready-to-use solution designed for high-energy anodes and cathodes. OCSiAl nanotubes create long, robust electrical networks between active material particles, improving key battery characteristics, including cycle life, DCR (reduced resistance), C-rate performance, and cohesion between active battery material particles, making the battery electrodes more durable. Graphene nanotubes unlock new battery technologies, including high-silicon-content anodes, thick LFP cathodes, fast-charging graphite anodes, and more. They can be applied in both conventional and emerging battery tech, such as a dry battery electrode coating process, and in solid-state batteries.

The TUBALL™ MATRIX nanotube concentrate product line is specifically designed for various elastomers, thermosets, and thermoplastics. It is widely used as a conductive filler to impart anti-static and ESD properties. Depending on the specific requirements, the working dosage is in the range of 0.1–1 wt.% in the final compound. TUBALL™ MATRIX is also increasingly being used as a reinforcing additive in various types of materials, enabling the production of lightweight, strong, smart, conductive, and colored products.

The company's technical support centers are located in Luxembourg, China, and Serbia. They are designed to be capable of completing the full development chain: from initial research to the fine-tuning of the application of TUBALL™ in pilot industrial lines.

TUBALL™ graphene nanotubes are authorized for use across a wide range of industries. They comply with EU-REACH and US Environmental Protection Agency regulations, allowing the commercialization of up to 100 tonnes of single wall carbon nanotubes annually in Europe and an unlimited tonnage band in the US.

Headquartered in Luxembourg, OCSiAl is represented throughout Europe, the US, South Korea, China, Hong Kong, Canada, Mexico, Malaysia, Taiwan, Japan, and India. OCSiAl collaborates with more than 1,500 companies in over 50 countries worldwide and enjoys a network of 25 distributors.

200+ PEOPLE
30+ SCIENTISTS
1 DREAM



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