TUBALL

graphene 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 µm 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.
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.
In 2014 GNTs became available to the mass industry
FIRST MASS-PRODUCED GNTs
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**

<table>
<thead>
<tr>
<th>UNIT OF MEASURE</th>
<th>VALUE</th>
<th>METHOD OF EVALUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNT content</td>
<td>wt.%</td>
<td>≥ 80</td>
</tr>
<tr>
<td>Number of layers CNT</td>
<td>unit</td>
<td>1</td>
</tr>
<tr>
<td>Outer mean diameter CNT</td>
<td>nm</td>
<td>1.6 ± 0.4</td>
</tr>
<tr>
<td>Length of CNT</td>
<td>μm</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>Metal impurities</td>
<td>wt.%</td>
<td>≤ 15</td>
</tr>
<tr>
<td>Moisture</td>
<td>wt.%</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

**RAMAN SPECTRUM**

**TGA CURVES**
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 in Novosibirsk – 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 in Novosibirsk.

The joint capacity of the two Novosibirsk synthesis facilities now amounted to 90 tonnes per year. It is planned to expand existing capacity and launch a new facility in Luxembourg in 2025.

FACILITIES

| 2013 | Graphetron 1.0 |
| 2019 | Graphetron 50 |
| 2025 | Graphetron in Luxembourg |
IN 2020 OCSiAl HAD 97% OF THE WORLDWIDE GNTs PRODUCTION CAPACITY.
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 90 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 and confirmed compliance with IATF 16949, the international standard for automotive quality management systems.
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%.

Universe of particles in the same volume

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

<table>
<thead>
<tr>
<th>Additive Type</th>
<th>Threshold of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Fillers</td>
<td>15–35%</td>
</tr>
<tr>
<td>MWCNTs</td>
<td>0.5–5%</td>
</tr>
<tr>
<td>Carbon Black</td>
<td>20–40%</td>
</tr>
<tr>
<td>ML Graphene*</td>
<td>1–6%</td>
</tr>
<tr>
<td>GNTs</td>
<td>0.01–0.1%</td>
</tr>
<tr>
<td>Carbon Fibers</td>
<td>3–12%</td>
</tr>
</tbody>
</table>

* Graphene nanoplatelets, graphene oxide, reduced graphene oxide, etc.
TUBALL™ PROTOTYPING CENTER
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
OCSiAl has taken the lead in the creation of technologies for introducing nanotubes into material matrixes.

In 2016 OCSiAl 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. OCSiAl 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

- Epoxy, polyurethane
- Phenolic
- Polyester, vinylester, acrylic, melamine
- Acrylic
- LSR, RTV and HCR silicones
- Rubbers
- Thermoplastics

...and many more to come
CERTIFICATION AND EHS
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 allows 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:

- Daphina magna, Acure 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.

• 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
WARRANTIES AND DISCLAIMER

The information provided by OCSiAl in this Brochure is for general informational purposes only and under no circumstances does it constitute an offer to enter into a binding agreement with OCSiAl.

OCSiAl makes every reasonable effort to ensure that all information in this Brochure is correct. However, OCSiAl makes no representation or warranty of any kind, whether express or implied, regarding the accuracy, completeness, appropriateness, or suitability of the information contained therein.

OCSiAl will not be liable for damages of any kind arising from the use of any information contained in this Brochure, including, but not limited to direct, indirect, incidental, punitive or consequential damages, unless otherwise specified in writing.

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

ASIA

KOREA
208, Gaetbeol-ro 12, Yeonsu-gu, Incheon, 21999, Korea
+82 32 260 0407 asiapacific@ocsial.com

HONG KONG
Room 1102, 11/F, Lippo Sun Plaza, 28, Canton Road, Tsim Sha Tsui, Kowloon, Hong Kong
+852 3575 3946

CHINA
#2004, 20th floor, Tower B, Da Chong Business Centre, Yue Hai Street, Nanshan District, Shenzhen, Guangdong, China
+86 755 867 00059

Ground floor, Unit 4, Building 7, No.160, Basheng Road, Pudong district, Shanghai, China
+86 135 9012 5295
china@ocsial.com

JAPAN
Tokyo, Japan
070-1421-0331 japan@ocsial.com

INDIA
Vimal intertrade Pvt Ltd, Shivam centrum, Sahar road, Koldongri, Andheri East, Mumbai, 400 069, India
+91 22 6288 4200 india@ocsial.com

NORTH & SOUTH AMERICA

USA
500 S Front St, Suite 860, Columbus, OH 43215, USA
+1 415 906 5271 usa@ocsial.com

EUROPE

LUXEMBOURG
1 Rue de la Poudrière, L-3364, Leudelange, Grand-Duché de Luxembourg
+352 27990373 europe@ocsial.com