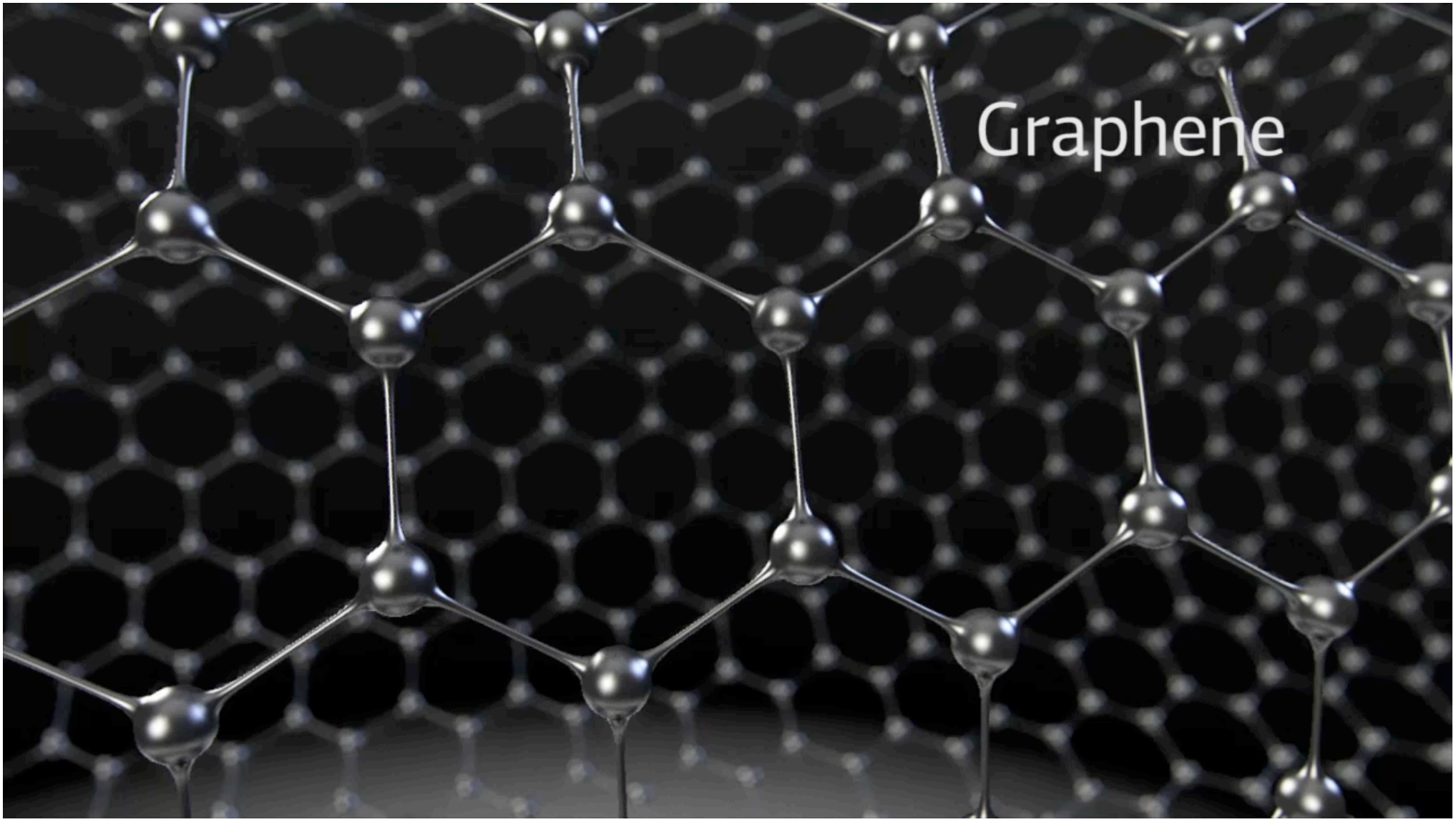
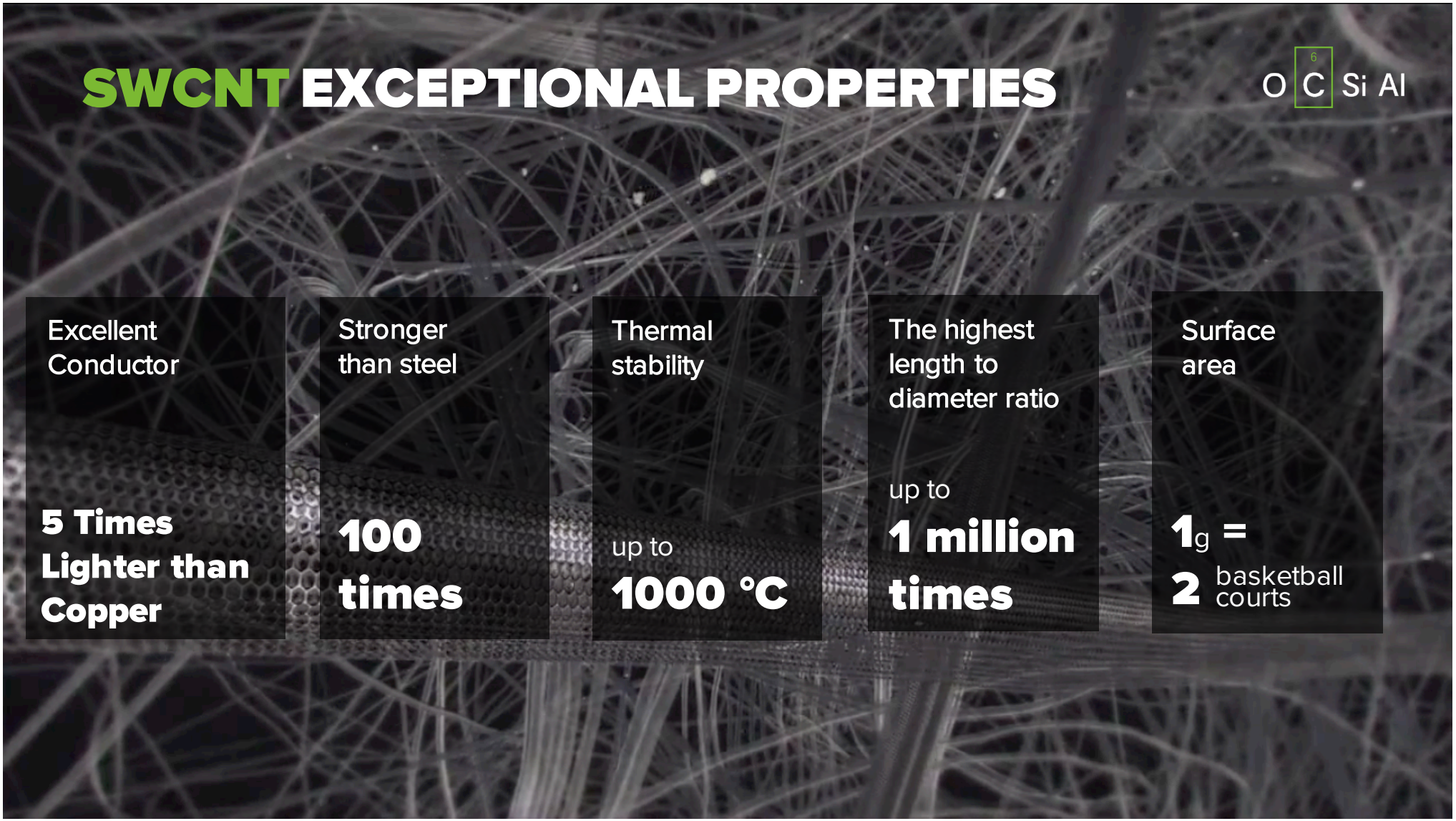
O C Si Al

carbon nanomaterials for the global industry

REDEFINING MATERIALS
REINVENTING TECHNOLOGIES

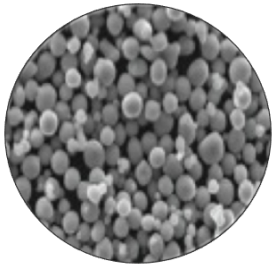

Graphene


SWCNT EXCEPTIONAL PROPERTIES
O C Si Al
Excellent Conductor
5 Times Lighter than Copper
Stronger than steel
100 times
Thermal stability
up to
1000 °C
The highest length to diameter ratio
up to
1 million times
Surface area
1g =
2 basketball courts

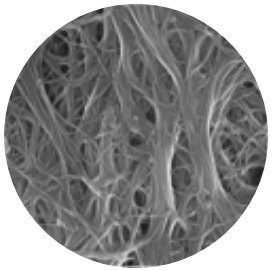
MATERIAL'S PROPERTIES

DOSAGE LEVEL REQUIRED FOR CHANGE

CARBON BLACK
20 - 40%

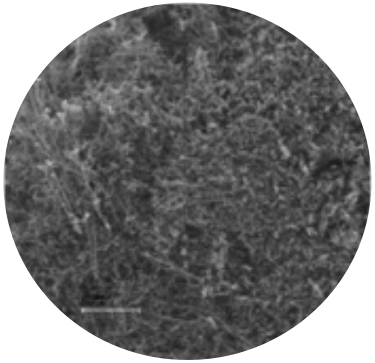


METAL FILLERS
15 - 35%



CARBON FIBERS
3 - 12%

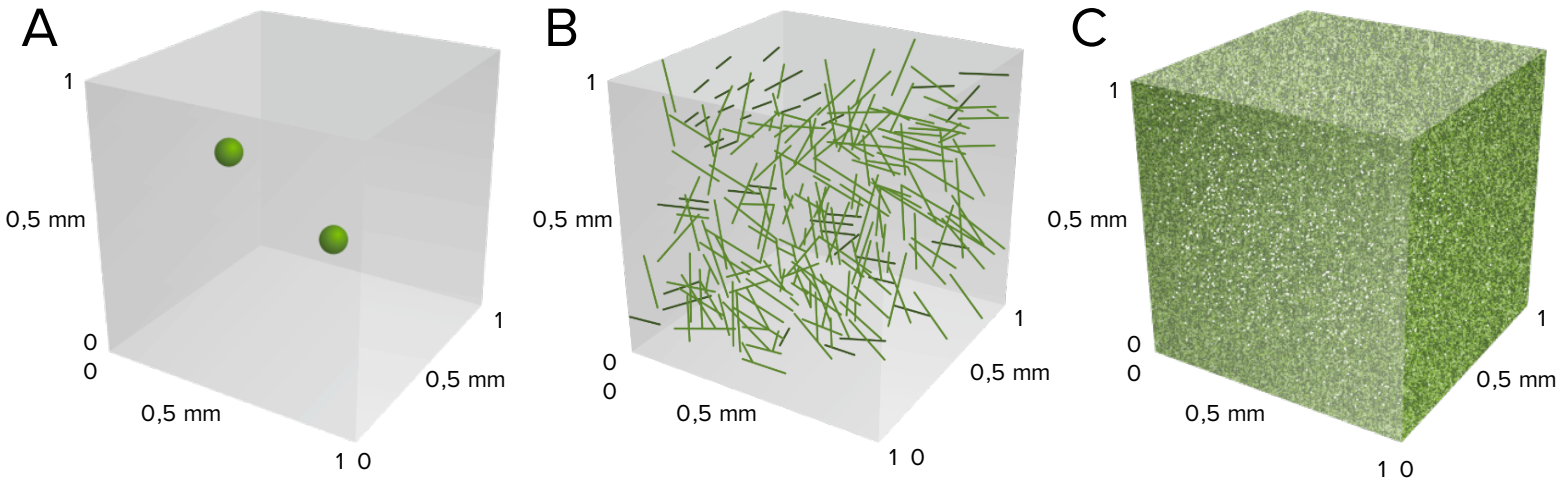
MWCNT
1 - 6%



SWCNT
0.001 – 0.03%

DISPERSION IN MATRIX

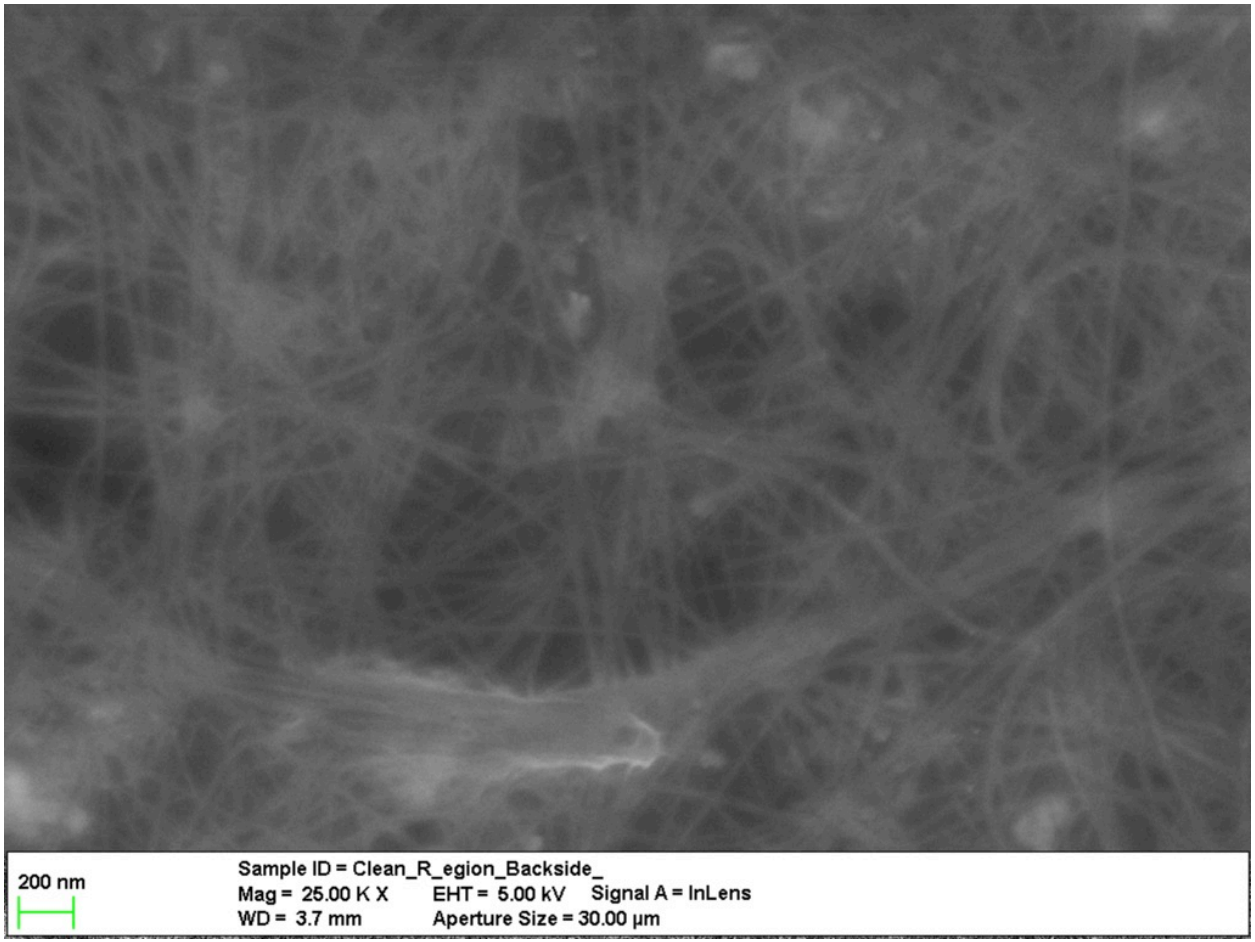
Concentration of particles ~0,1%



MICROPARTICLES CARBON NANOFIBERS SWCNT

SWCNT FORMS ITS OWN CONDUCTIVE 3D NETWORK AT ULTRA LOW CONCENTRATIONS

SEM IMAGES OF DISPERSED NANOTUBES



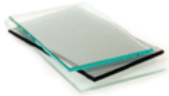
SWCNT: THE FIRST UNIVERSAL ADDITIVE

6 C

Plastics

Paints

Concrete



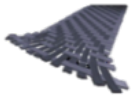
Glass

Copper

Sensors
Semiconductors

Rubber materials

Electrochemical
Power sources



Composites

Aluminium

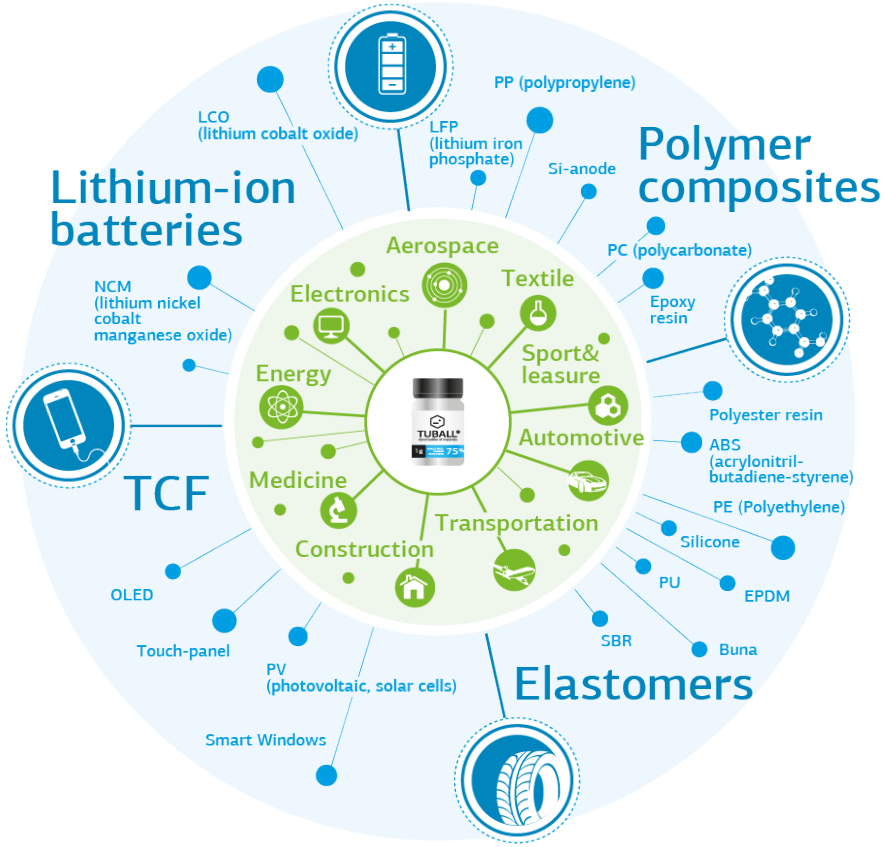
Ceramics

Adhesives


TUBALL™
First Mass Produced SWCNT
90% of Global Production
GRAPHETRON 1.0
O C Si Al
TUBALL
100g
>75%


GRAPHETRON 1.0
CAPACITY
10 TONS/YEAR
50 TONS/YEAR
IN 2016
ENOUGH TO SUPPORT
NUMEROUS GLOBAL
INDUSTRIAL PRODUCTS
O C Si Al

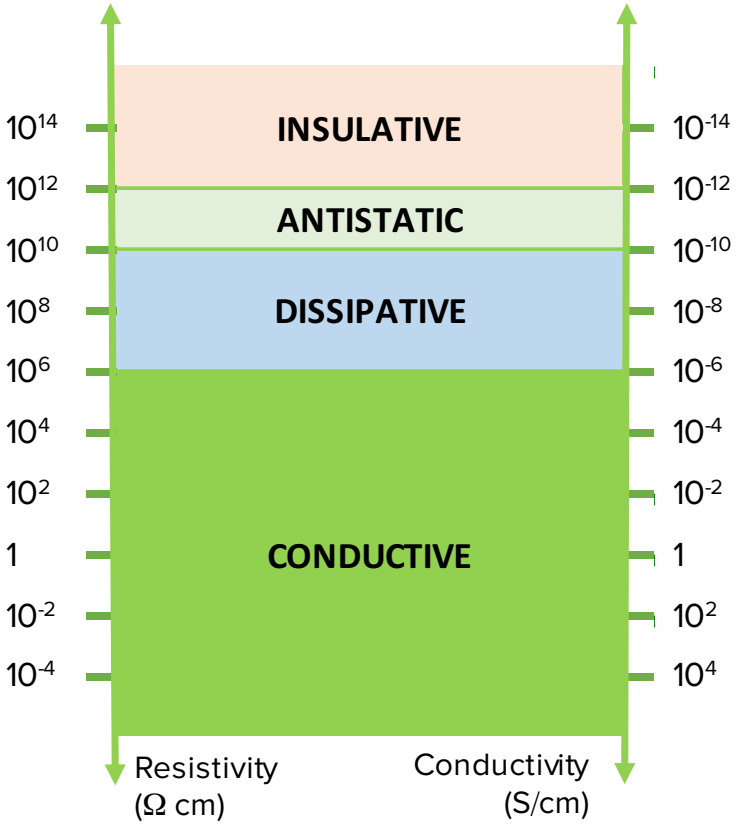
TUBALL™ INDUSTRIAL APPLICATIONS

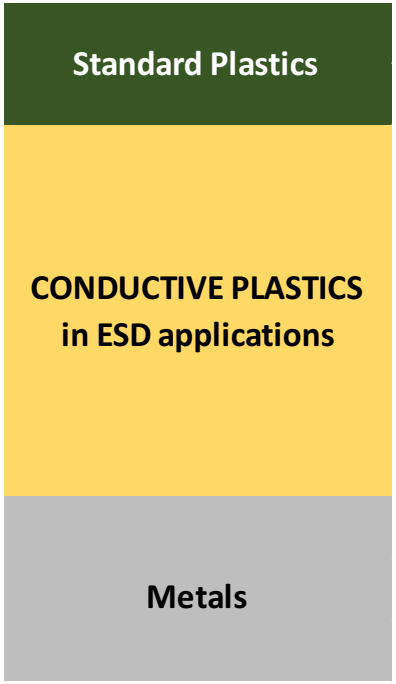


Electrical conductivity in POLYMERS

WHY CNT FOR THERMOPLASTICS?

TYPICAL CONDUCTIVITY RANGES





*0.1 - 1% **

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

WHY CNT FOR THERMOPLASTICS?

ANTI–STATIC ADDITIVES ARE USED IN:

Floors, mats, linoleum, textile carpets, floor finishes and coatings

Shoes, grounders. Casters and wheels of moving articles

Clothing

Workstations and work surfaces

Gloves and finger cots

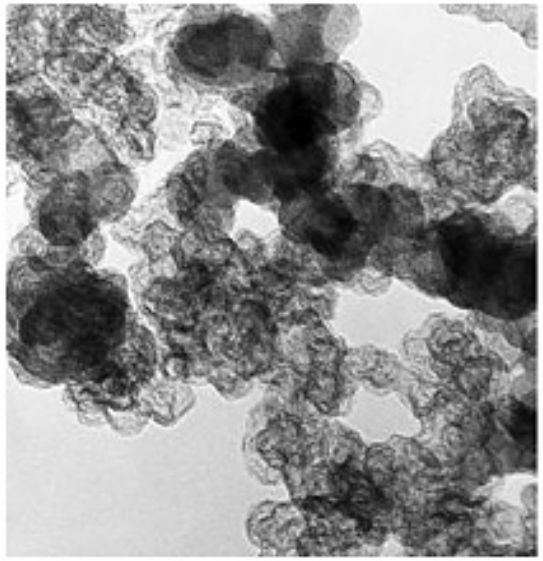
Packaging: carrier trays, holders, tubes, boxes, bags

Fuel tanks and hoses

Wire and Cable

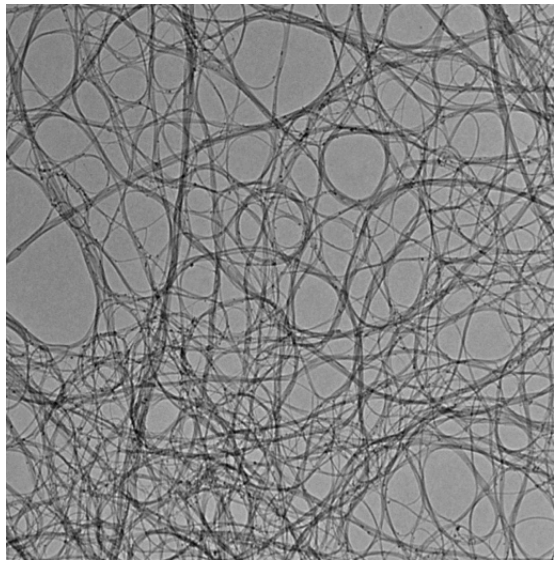
Other

WHY CNT FOR THERMOPLASTICS?



CONDUCTIVE BLACK

vs

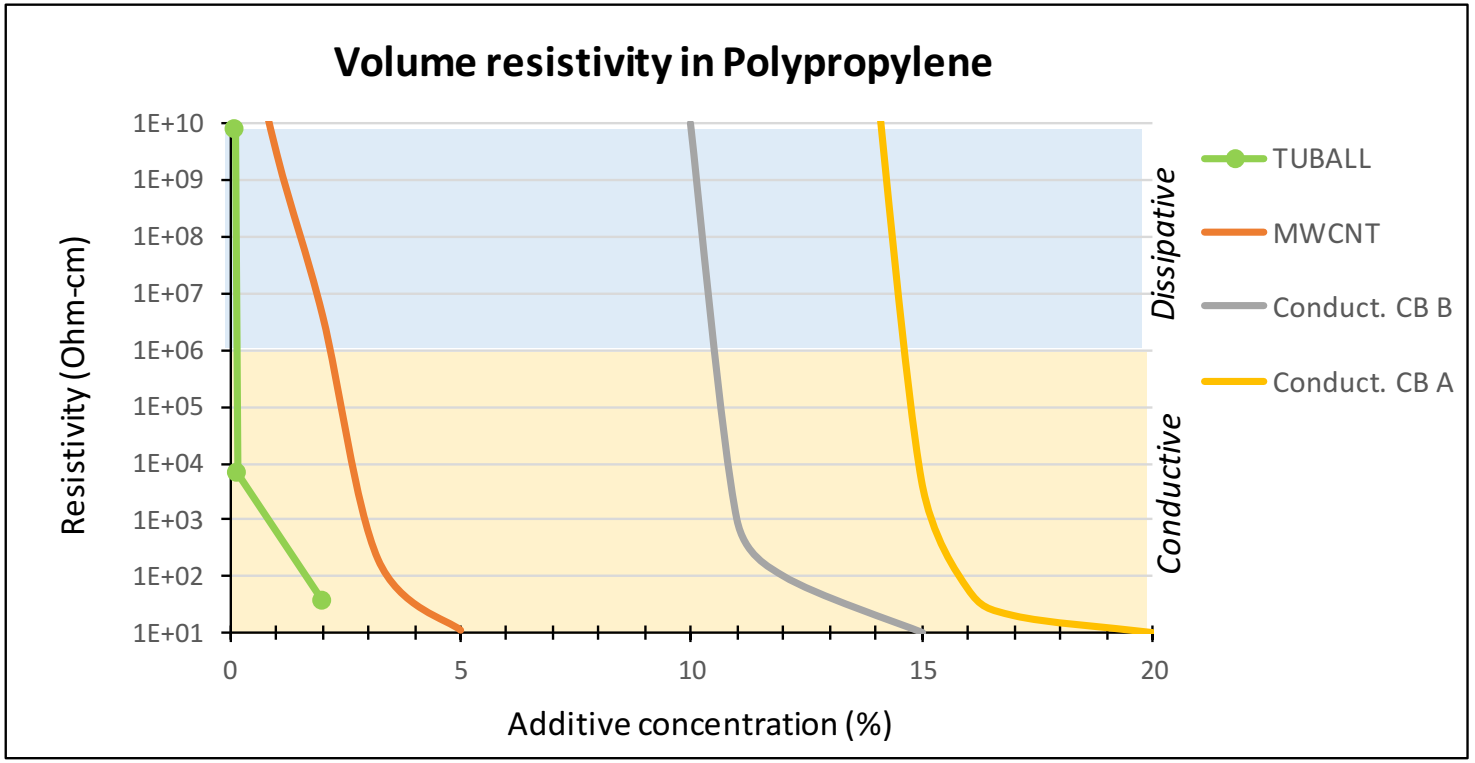


TUBALL™

SWCNT's additive can impart electrical conductivity in plastics. High aspect ratio results in electrical conductivity at lower loadings than for conventional additives like carbon black, carbon fiber or metallic fiber.

PERFORMANCE IN POLYPROPYLENE

TUBALL™ unique characteristics enables conductive plastics production with ultralow percolation threshold



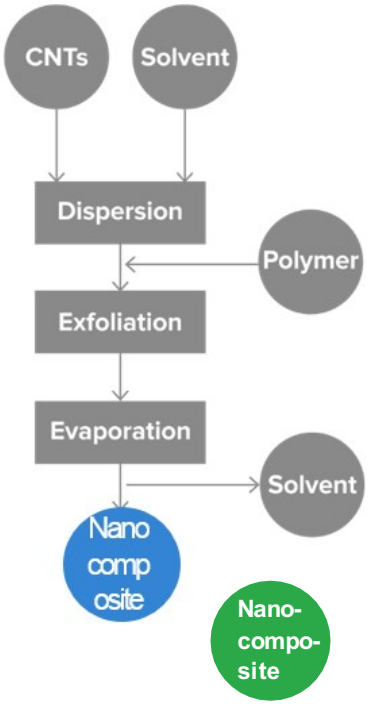
PERFORMANCE IN POLYPROPYLENE

THE NEW GENERATION OF CONDUCTIVITY

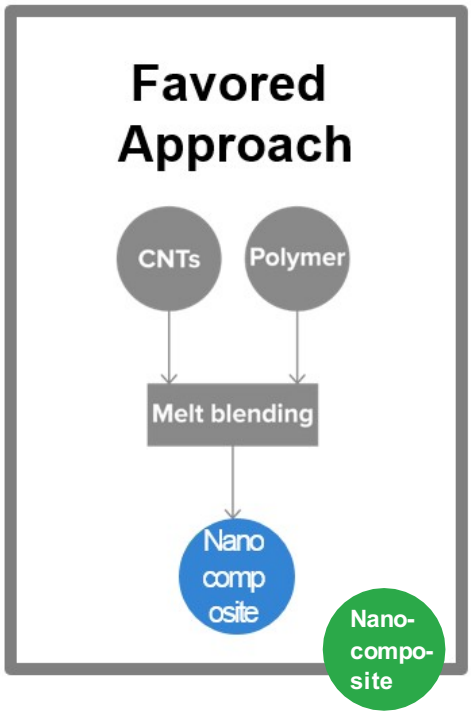
- TUBALL single wall carbon nanotubes enable ultralow loading starting with 0.1-0.2%;
- Allow for production of conductive parts that retain colors;
- Ensure permanent and uniform electrical conductivity without hot spots;
- Maintain or can improve mechanical strength;
- Without significant increase of viscosity of the host material.

TUBALL™ INCORPORATION METHODS

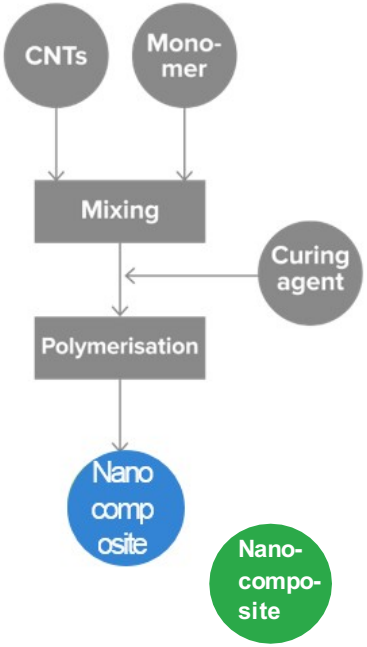
Ultralow percolation & tendency to the agglomeration



Solution Mixing



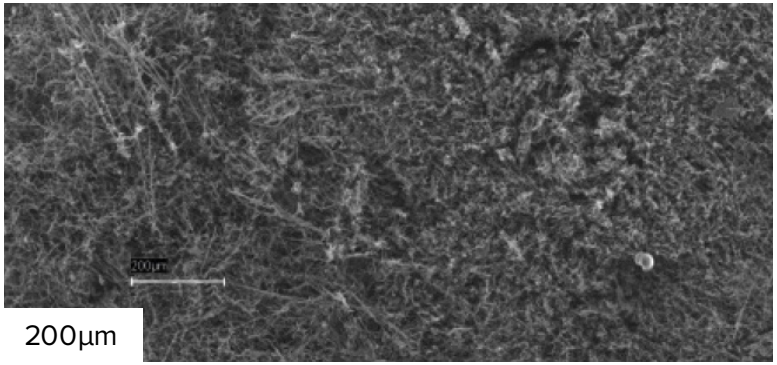
Melt Mixing



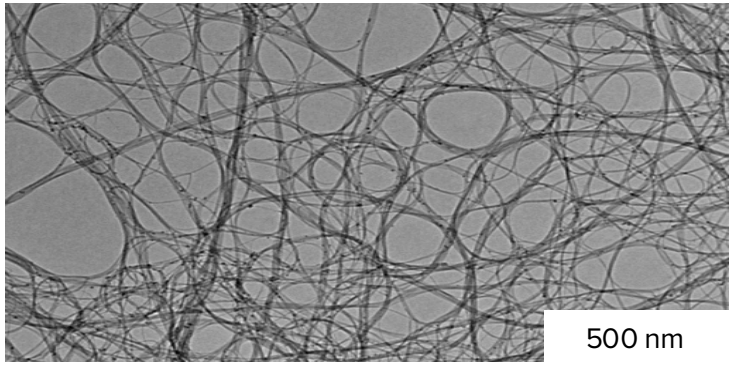
In Situ Polymerization

CNT COMPOUNDING IN THERMOPLASTICS

WHAT ARE THE CHALLENGES IN MIXING?



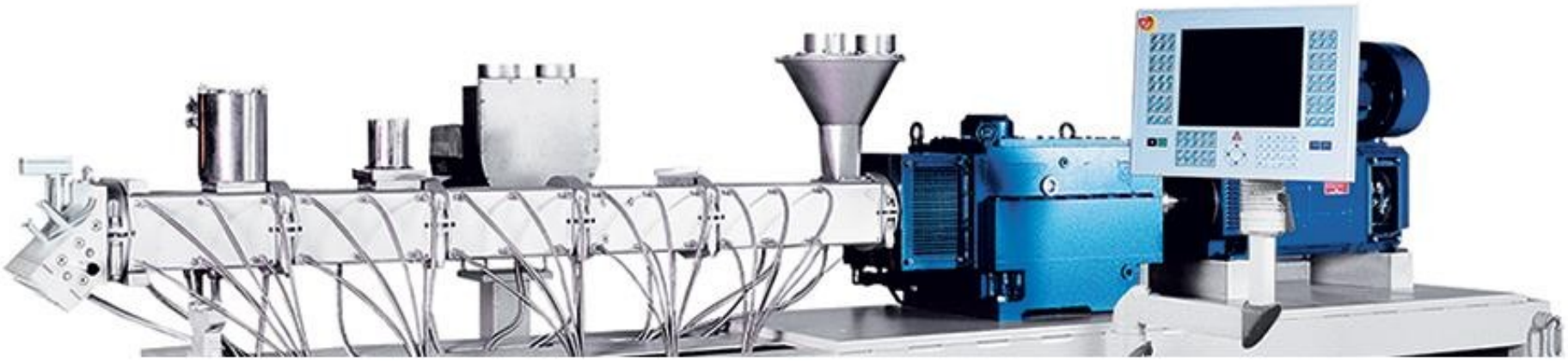
MIXING



Potential challenges to overcome:

- Good dispersion of the CNT's in polymeric matrices
- Homogenous distribution of the CNT's in the bulk of polymer
- Good interfacial interaction between CNT's and the polymer matrices

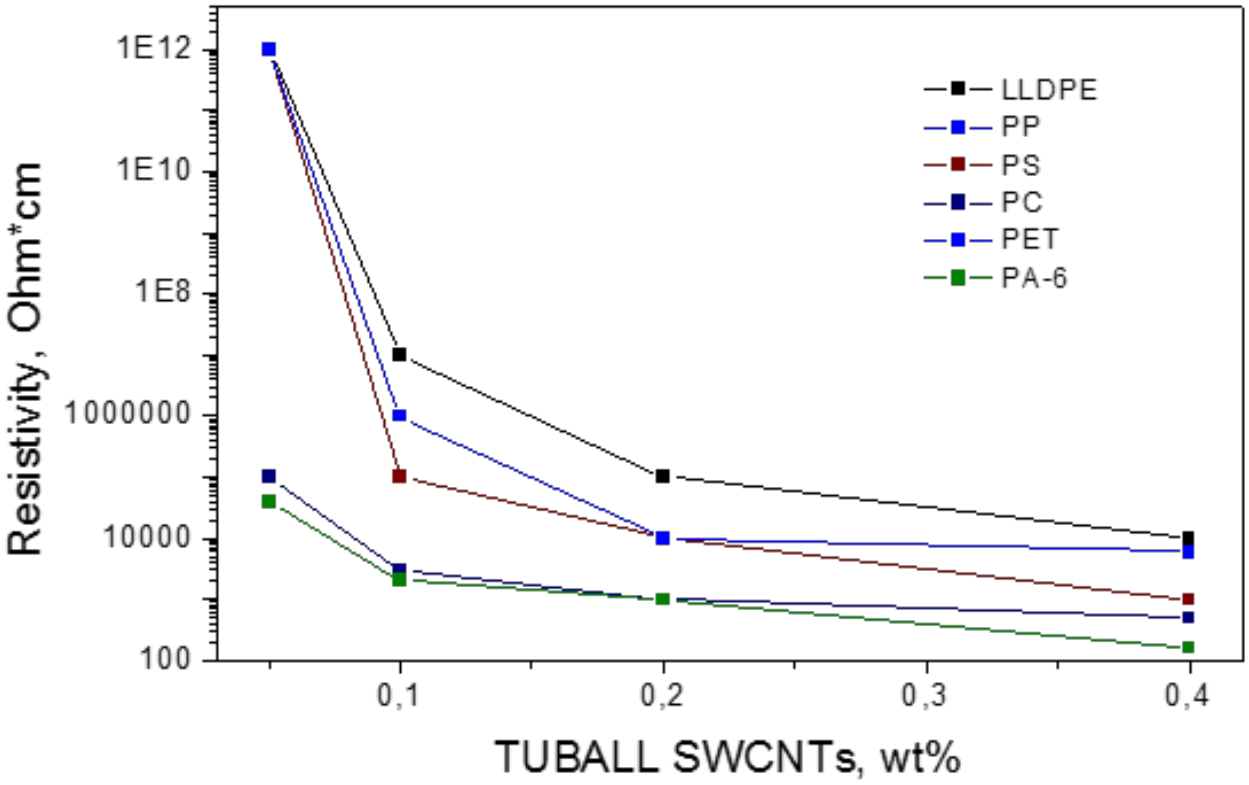
TUBALL™ MELT MIXING APPROACH
POLYOLEFINS AND ENGINEERING PLASTICS



DISPERSION THROUGH 2 STEPS PROCESS

1. Preparation of a MB at 2% TUBALL™
2. Masterbatch dilution on twin screw for compounds preparation

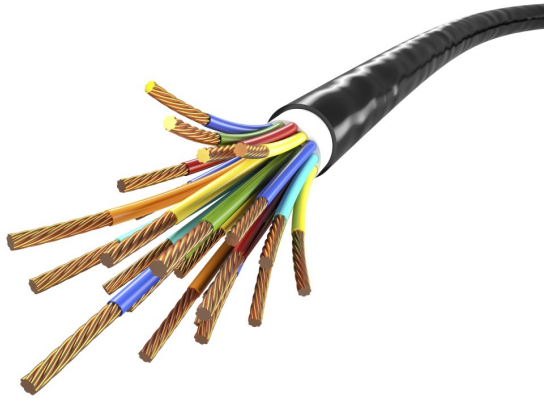
ANTISTATIC & DISSIPATIVE VARIOUS THERMOPLASTICS



Percolation is observed at ultralow SWCNTs concentration for poliolefins and engineering plastics

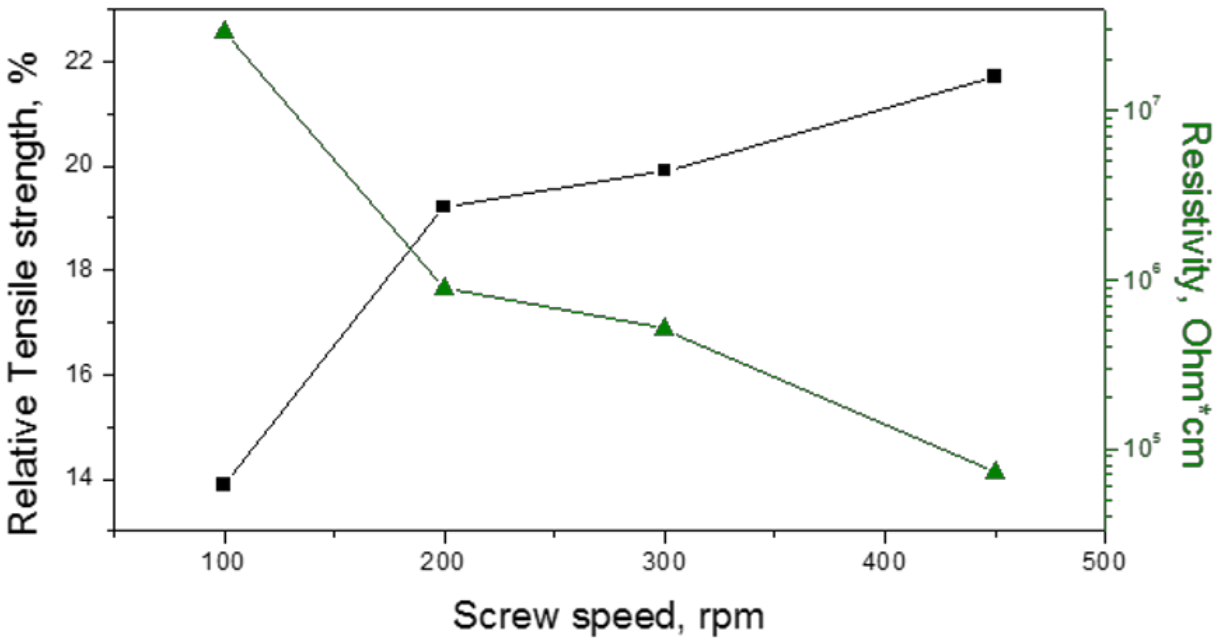
ANTISTATIC & DISSIPATIVE POLYETHYLENE

1. Polyethylene – more than 1500 grades: LDPE, LLDPE HDPE etc.
2. Wide range of MFI between 0 and > 100 g/10min at 190 °C and 2.16 kg



ANTISTATIC & DISSIPATIVE POLYETHYLENE

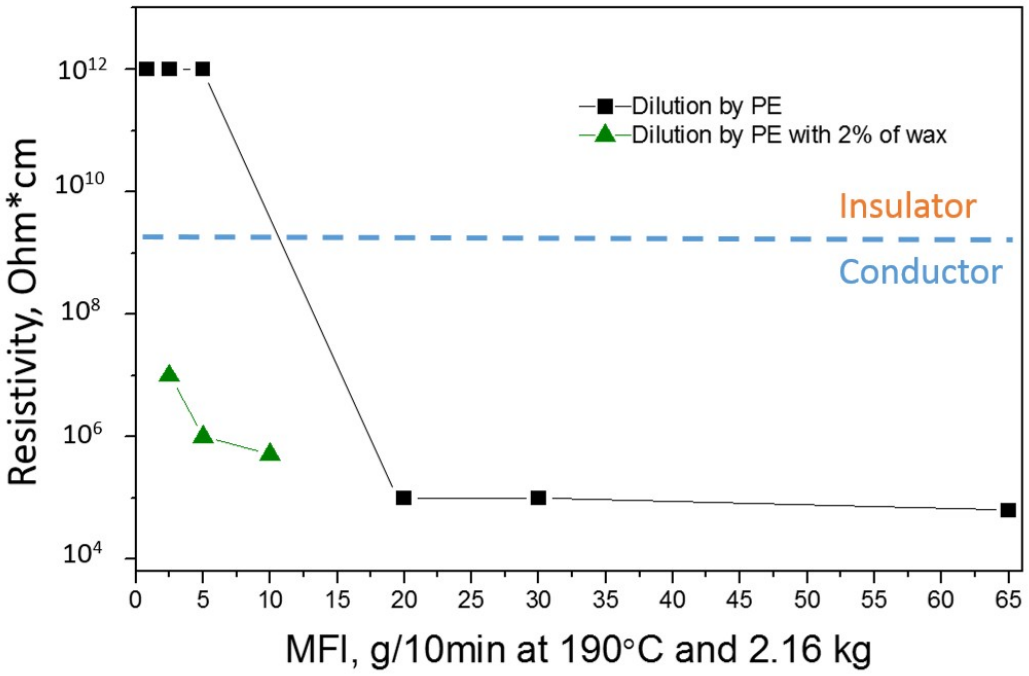
Extrusion parameters should be adopted for reaching good SWCNTs dispersion quality: **high fluidity polyethylene**



Application of higher rpm leads increasing SWCNTs dispersion quality

ANTISTATIC & DISSIPATIVE POLYETHYLENE

Polymer fluidity can be increased thanks to the plasticizers:
high vs. low fluidity polyethylene

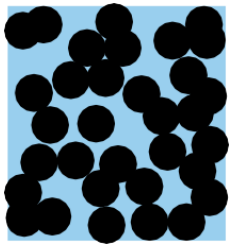


- Right extrusion parameters
- Ingredients which increase polymer fluidity

- High quality of SWCNTs dispersion i.e conductive network

CONDUCTIVE PROPERTIES
CABLE APPLICATIONS

Hybrid system: Carbon black and SWCNTs



*

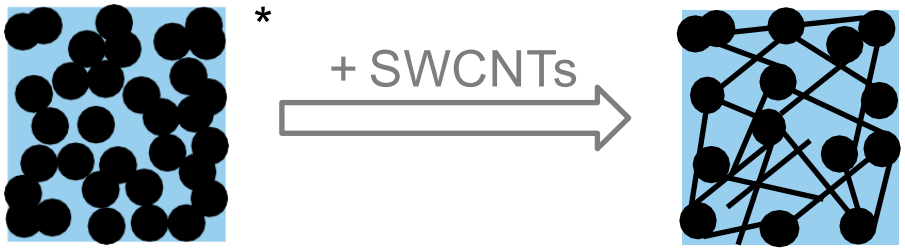
Carbon black conductive network in polymer

*up to 40 wt% of carbon black

Protecting screen
($R_{vol} \leq 100$ Ohm*cm)

CONDUCTIVE PROPERTIES CABLE APPLICATIONS

Hybrid system: Carbon black and SWCNTs



Carbon black conductive network in polymer

Carbon black & SWCNTs hybrid system

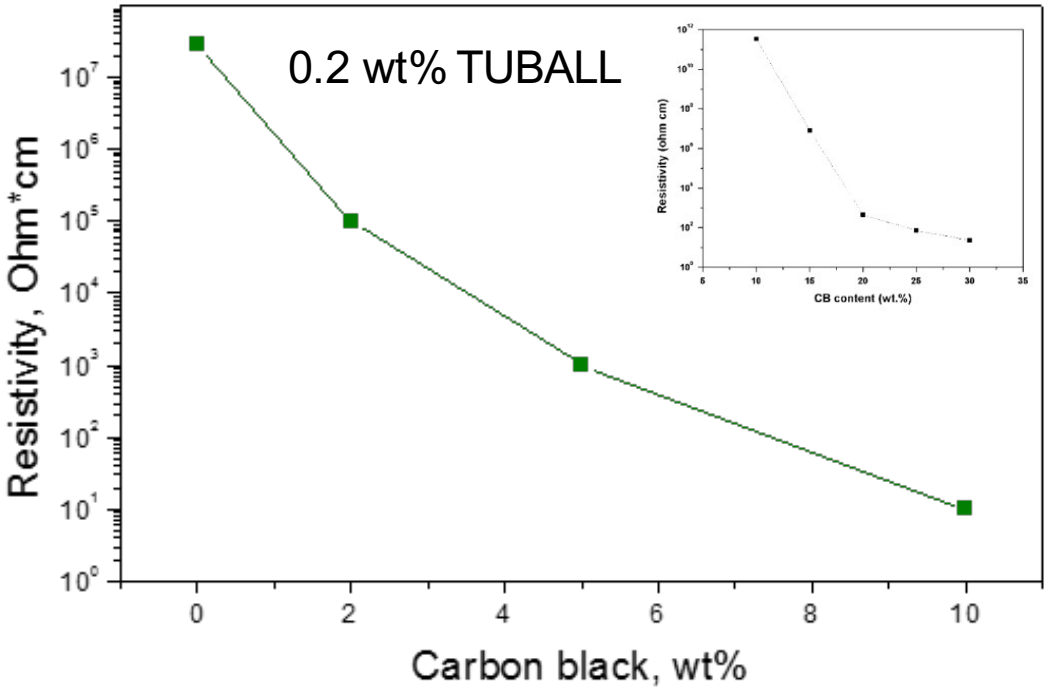
*up to 40% wt. of carbon black

Protecting screen
(R_{vol} ≤ 100 Ohm*cm)

- Decrease Carbon black content adding SWCNTs as a linkers
- Keep conductive network decreasing carbon black content

CONDUCTIVE PROPERTIES CABLE APPLICATIONS

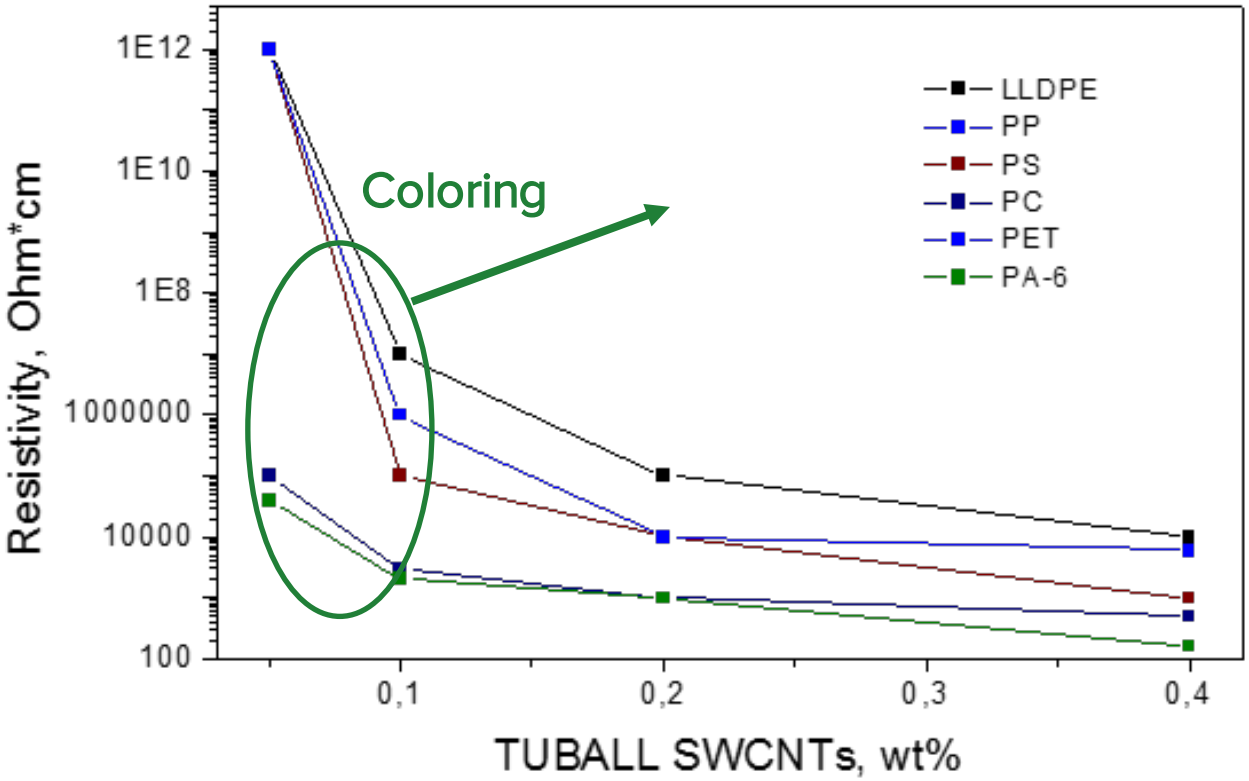
Hybrid system: Carbon black and SWCNTs

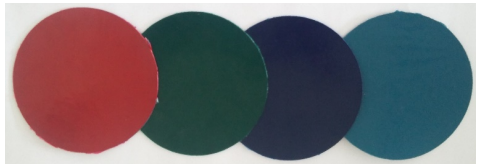


- Decrease Carbon black content
- Keep the same conductivity level
- Improve physico-mechanical properties
- High voltage cables: protecting screens **(vol.resistivity of compound should be ≤100 Ohm*cm**

© 2009 Jeevananda at al; Polym Int.

ANTISTATIC IN DIFFERENT POLYMERS





Resistivity as a function of TUBALL SWCNTs wt%

Polyolefins and engineering plastics

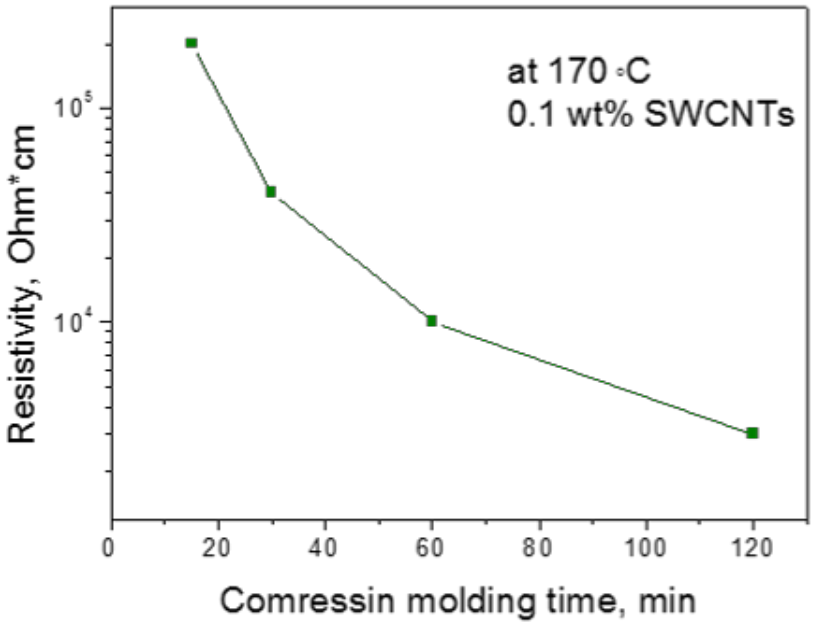
Compression molding

MOLDING

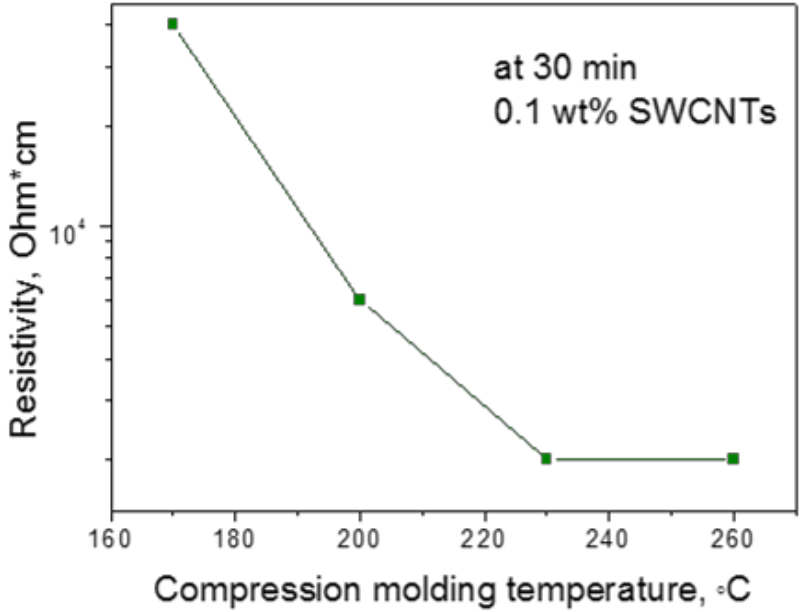
- Compression molding
- Rotation molding
- Injection molding
- Extrusion

COMPRESSION MOLDING

vs. **Compressing Time**

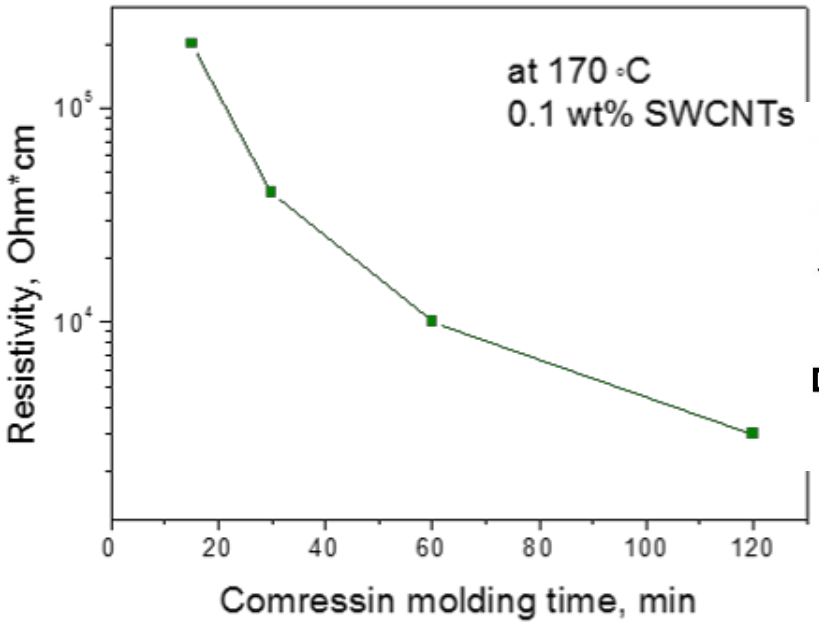


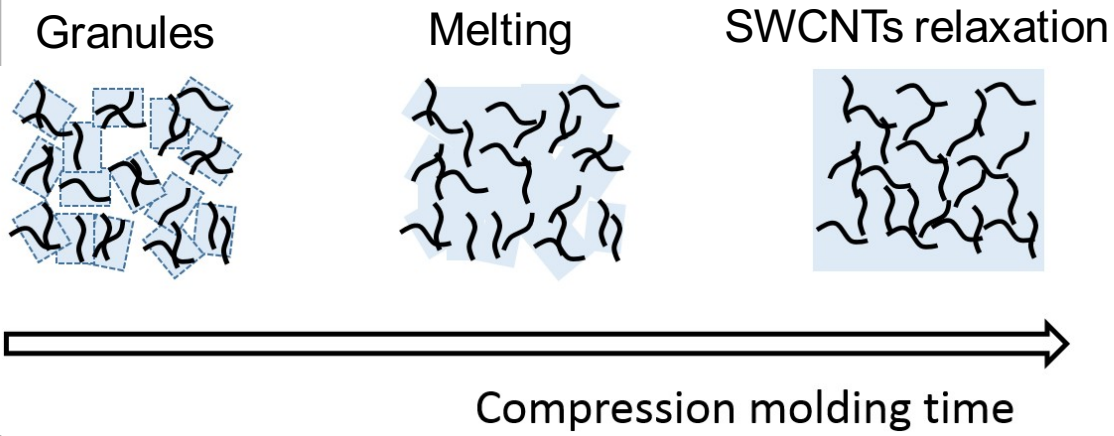
vs. **Compressing Temperature**



COMPRESSION MOLDING

vs. **Compressing Time**

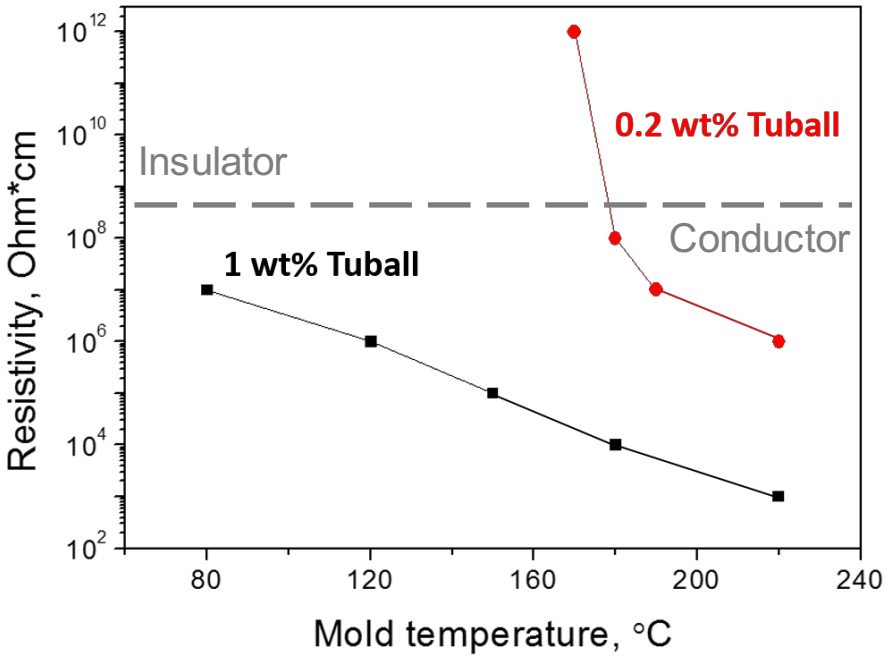




✓ Compression molding time and temperature can be increased for obtaining higher conductivity

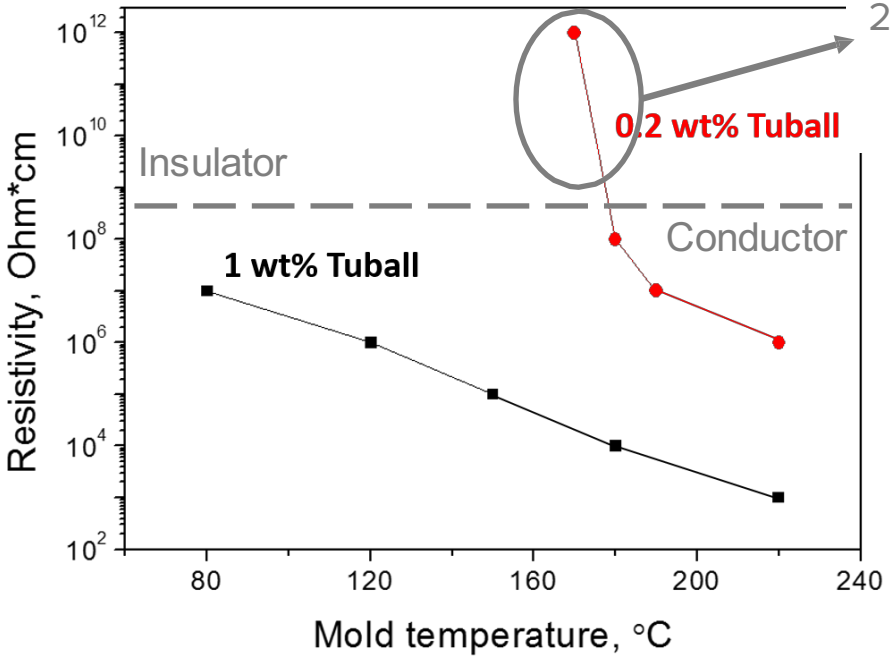
INJECTION MOLDING

Common usable method in plastic industry

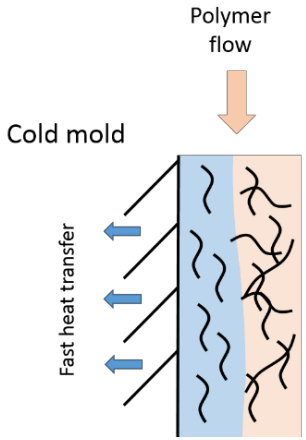


INJECTION MOLDING

Common usable method in plastic industry

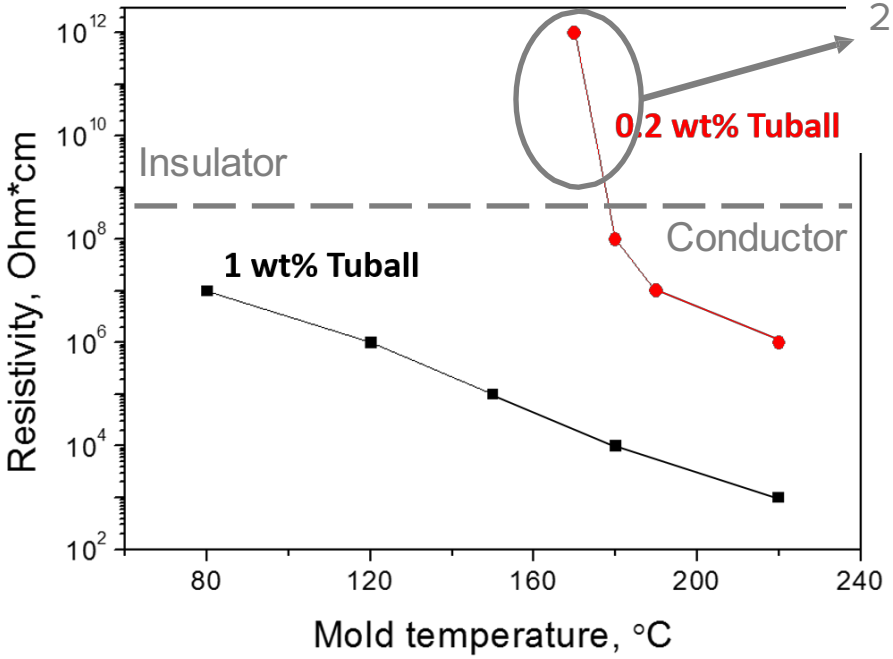


1. CNTs orientation by the polymer flow
2. CNTs migration from the surface due to polymer crystalization process

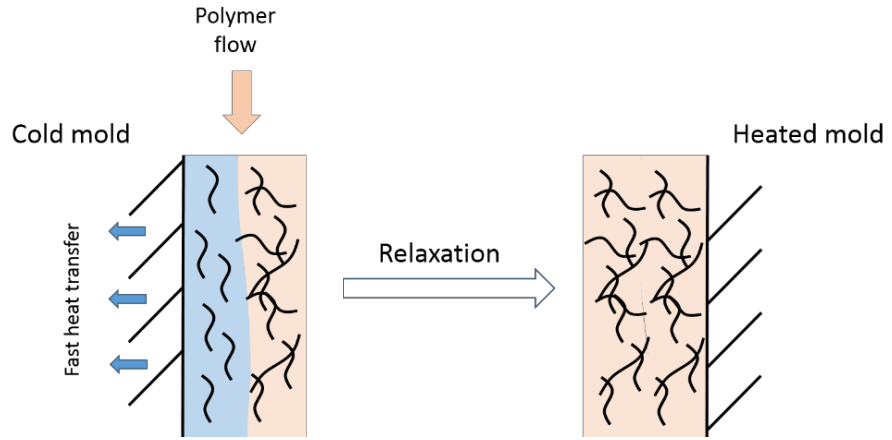


INJECTION MOLDING

Common usable method in plastic industry



1. CNTs orientation by the polymer flow
2. CNTs migration from the surface due to polymer crystalization process



Mold should be heated up to polymer melting temperature

INJECTION MOLDING

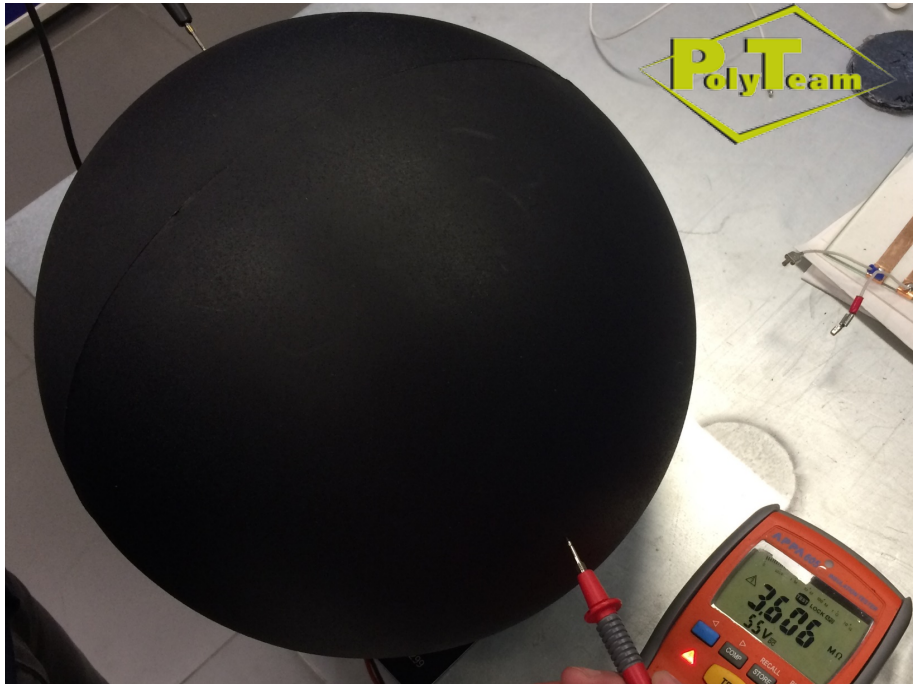
Antistatic reservoirs etc. based on ABS-plastic

RESISTIVITY:
10^6 Ω×cm

0.3 wt% TUBALL™

ROTATION MOLDING

Antistatic reservoirs etc. based on polyethylene



RESISTIVITY:
10^6 Ω×cm

0.2 wt% TUBALL™

801

CONCLUSION

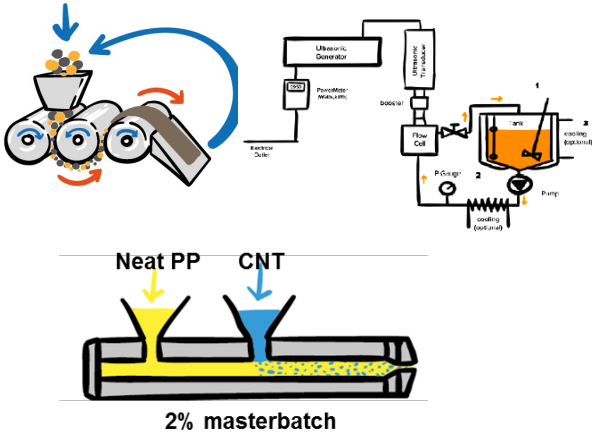
1. TUBALL can be incorporated into thermoplastics through the melt mixing approach.
2. Conductive networks can be created in a various polymer matrices at **ultra**low TUBALL dosage without compromising properties.
3. Thermoplastic polymers can be colored keeping antistatic properties
4. Hybrid TUBALL – Carbon black system can be applied for achieving conductive compounds
5. Molding parameters play a critical role for final properties of the part

OCSiAl : BUSINESS MODEL

OCSiAl

TUBALL production
TESTING support

PARTNERS

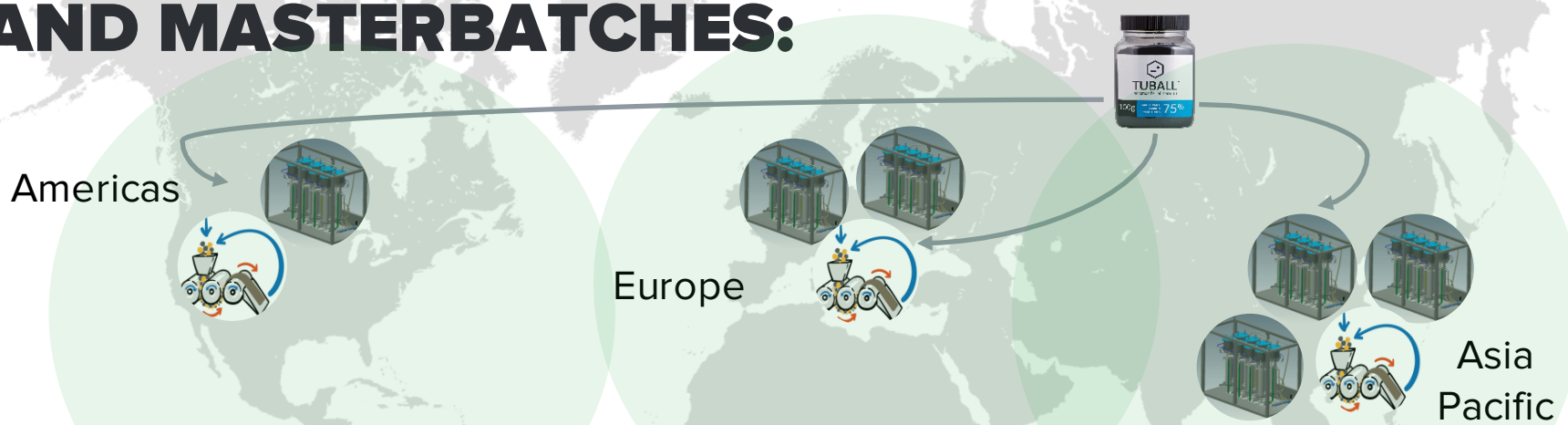


PRODUCTION & SALES

CUSTOMERS

TESTING AND PURCHASE

SWCNT DISPERSIONS AND MASTERBATCHES:



We deliver our technology to partners and create local manufacturing centers

OCSiAl WORLDWIDE

FOR ENQUIRIES

OCSiAl

Indianoffice@ocsial.com

O 6 C Si Al

REDEFINING MATERIALS
REINVENTING TECHNOLOGIES