



# Talga Resources

Supply and tuning of graphene  
for industrial coating applications

Dr. Siva Bohm

Graphene Week 2018, San Sebastian

13 September 2018



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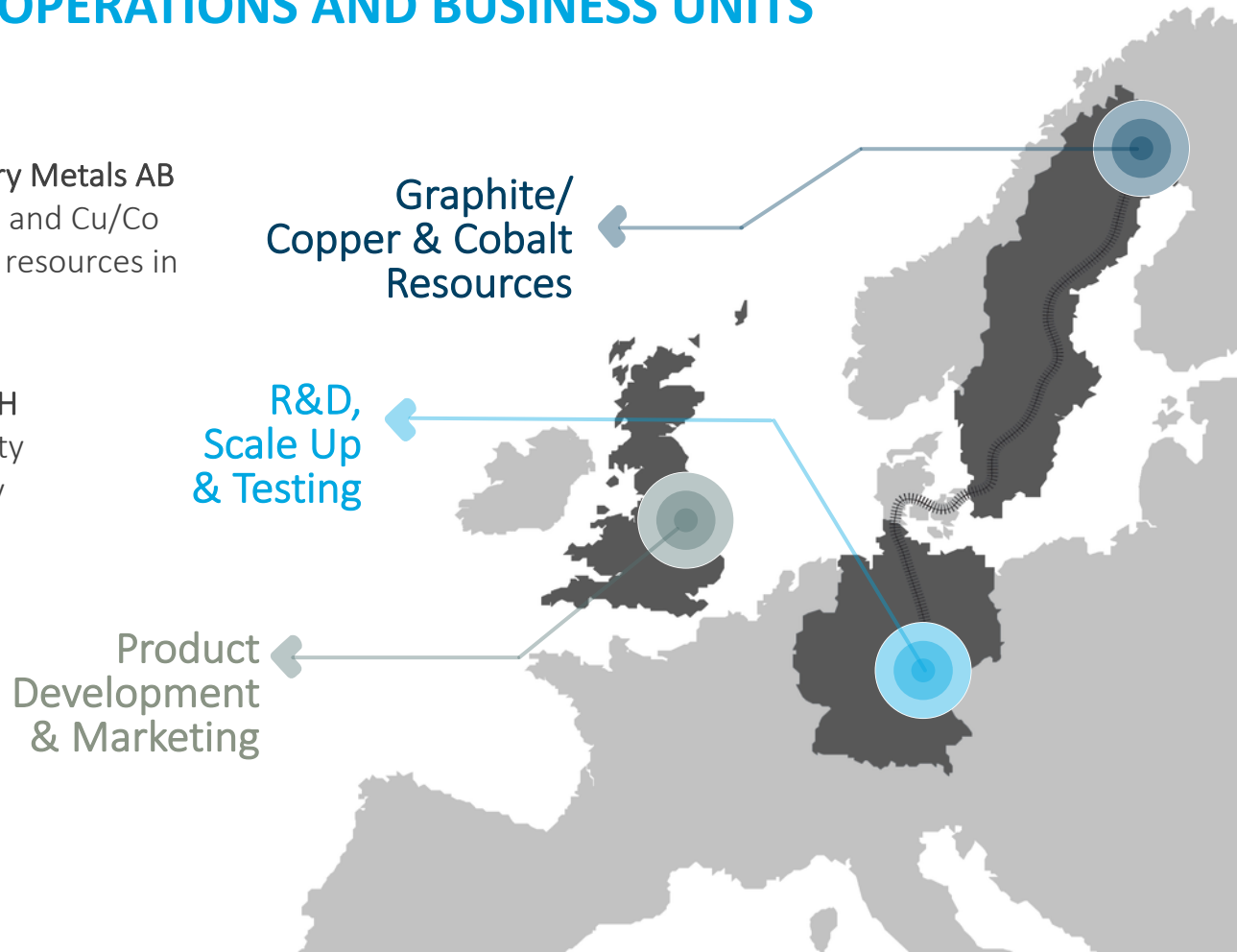
# Talga Resources

Vertically integrated  
advanced materials  
technology company

# ▶ TALGA'S EUROPEAN OPERATIONS AND BUSINESS UNITS

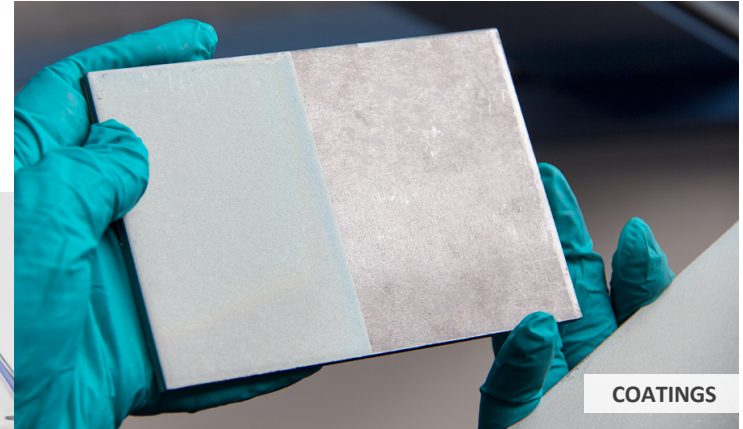
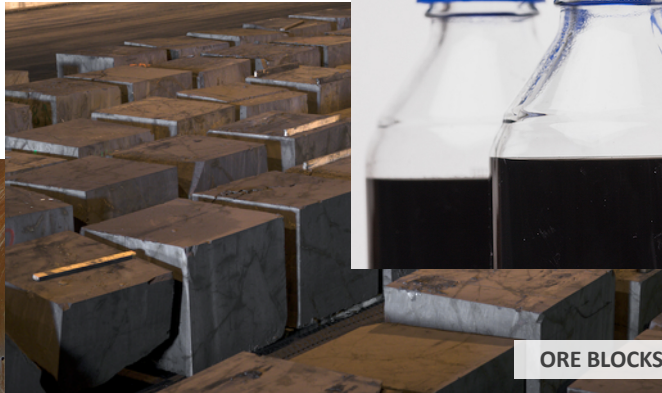
Vertically Integrated Supply Chain

- ▶ **Talga Graphene AB/Talga Battery Metals AB**  
Swedish 100%-owned Graphite and Cu/Co projects. Highest grade, largest resources in Europe
- ▶ **Talga Advanced Materials GmbH**  
100%-owned test process facility located in Rudolstadt, Germany
- ▶ **Talga Technologies Limited**  
R&D, Product Development and Marketing team located in Cambridge, UK





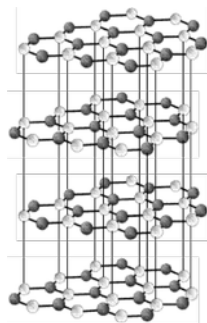
# ▶ FULLY INTEGRATED GRAPHENE PRODUCT SUPPLY CHAIN



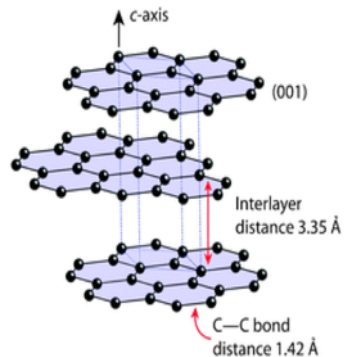
Some current collaborations include:



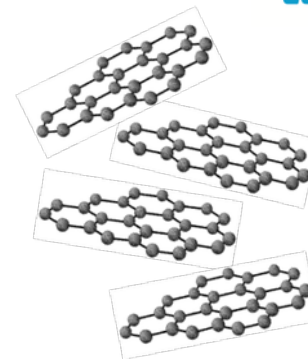
# ▶ GRAPHITE TO GRAPHENE CONVERSION



Graphite

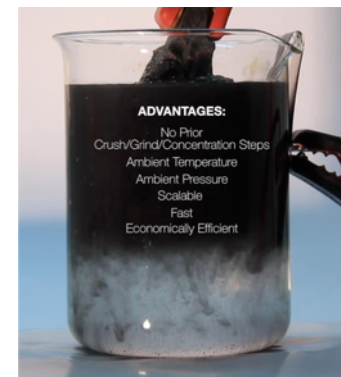
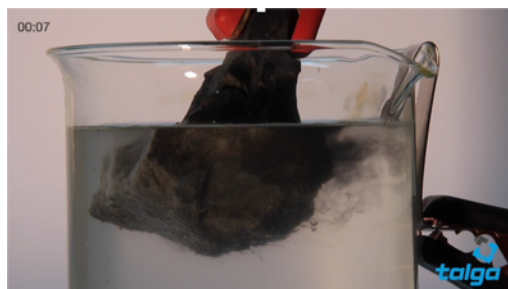


EXFOLIATION



Graphene

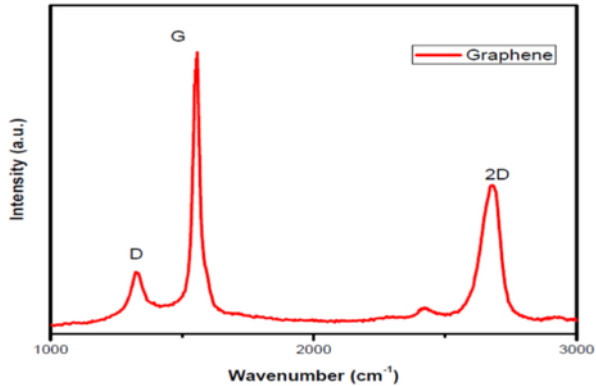
## TALGA'S UNIQUE EXFOLIATION ROUTE



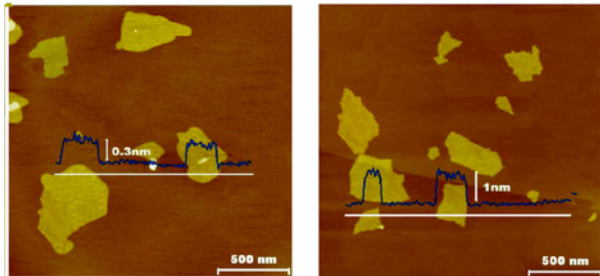
## ▶ QUALITY OF TALGA GRAPHENE

Electrochemical – exfoliation process produces high quality, conductive graphene

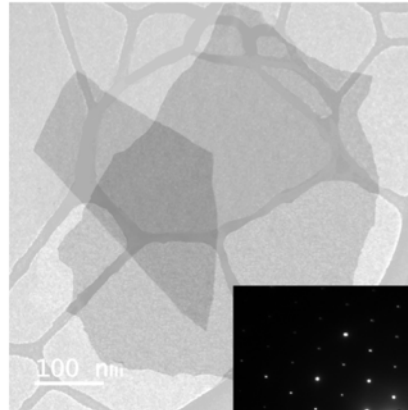
# RAMAN SPECTROSCOPY



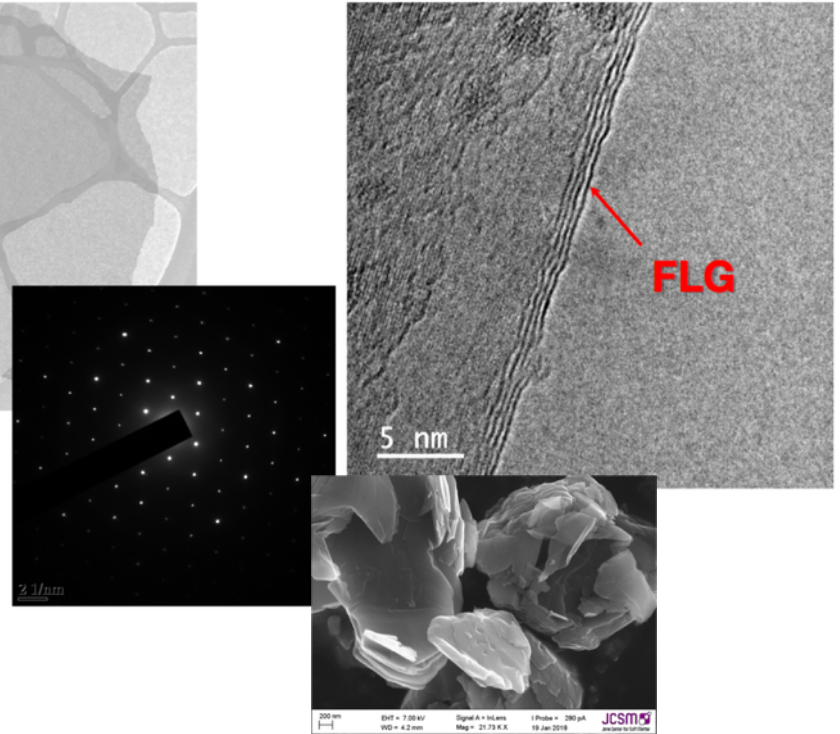
## ATOMIC FORCE MICROSCOPY



## TRANSMISSION AND SCANNING ELECTRON MICROSCOPY (TEM / SEM)



Few Layer Graphene  
Talphone®



## Talga Graphene Nano platelets (GNP)

# TALGA TECHNOLOGIES PRODUCT DEVELOPMENT

Our functionalised products have applications across four key sectors



## ENHANCED COATINGS

**Protective, High Performance, Functional & Nano Coatings**

Eco-friendly Cr(VI)-free based pre-treatment coatings for multi metals

Pre-fabrication and post fabrication primers & anti-corrosion coatings

Marine anti-fouling systems

Low friction coatings



## COMPOSITES & RESINS

**High Strength, Low weight & Conductive CFRC & two pack Resins chemistry**

High strength carbon fibre reinforced plastic systems

Conductive plastics and polymers composites

Lightening strike protection and EM shielding

Thermal Interface Materials, Conducting adhesive & Inks



## ENERGY STORAGE

**Batteries, Conductive Inks & Fuel Cells**

Next generation higher performance lithium-ion battery anodes

Conductive additives

Flexible, printable batteries for 'IoT' and 'Wearable' devices

PEM-FC-BPP coatings & membrane



## CONSTRUCTION

**High strength, thermal & electrically conductive building materials**

Combined graphite and graphene mixtures for high strength building materials

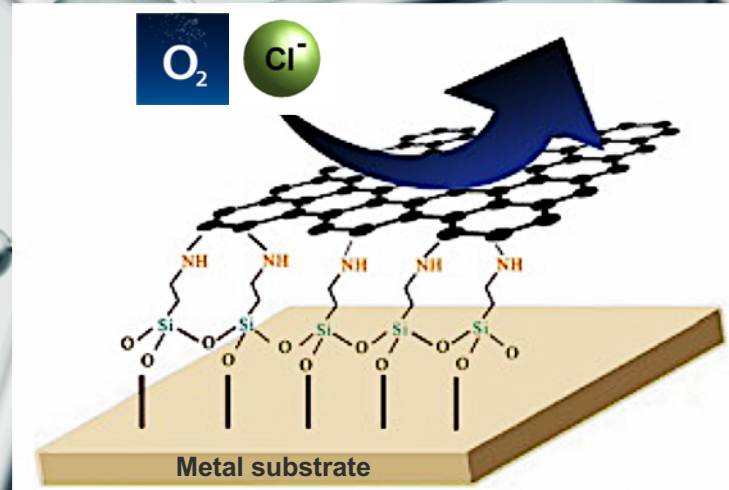
Thermally conductive screeds for de-icing systems

Electrical conductive flooring, wall panel systems combined with heating or cooling systems



# Graphene coatings technology

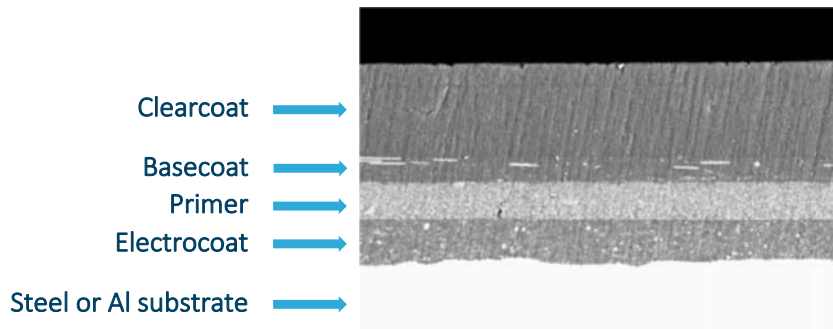
Proprietary chemical  
functionalisation to tailor  
graphene into higher  
performance coating



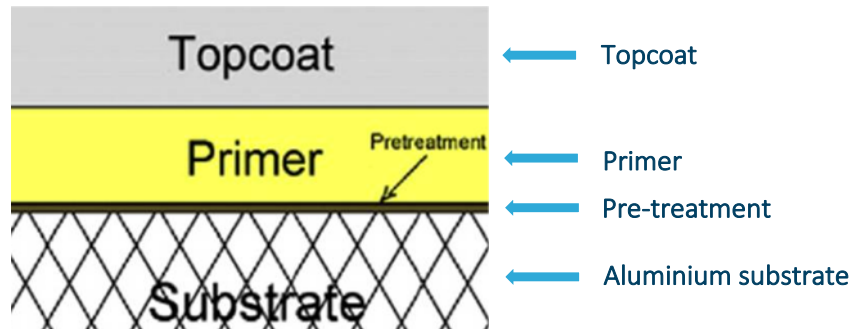
# CHALLENGE OF GRAPHENE FOR COATING APPLICATIONS

Diverse substrates and layered system requirements for adhesion and compatibility

## AUTOMOTIVE



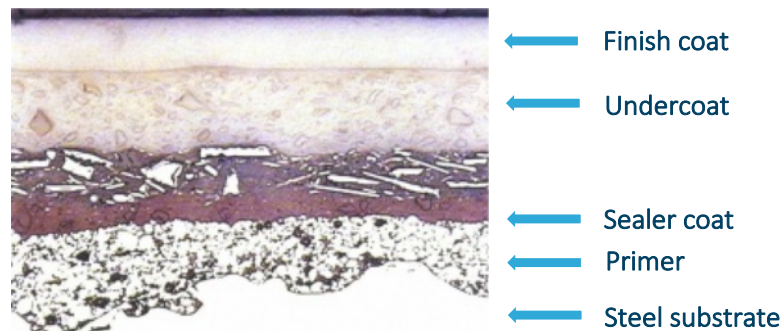
## AEROSPACE



## CONSTRUCTION

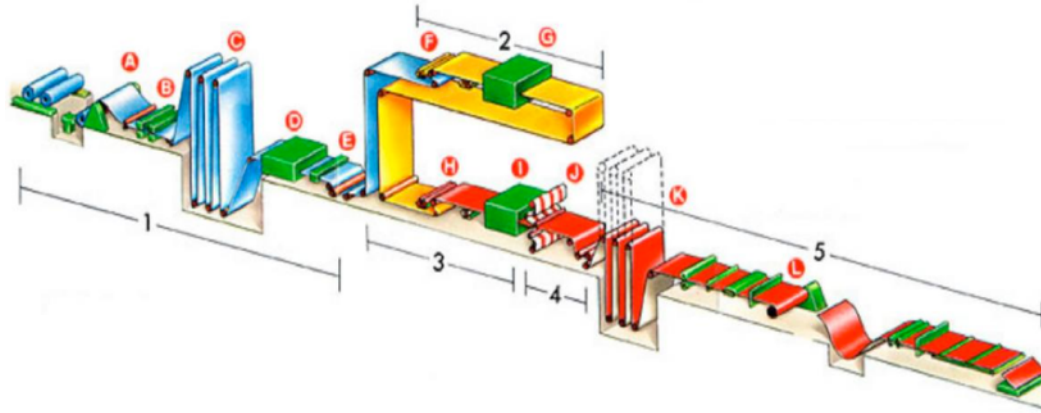


## MARINE

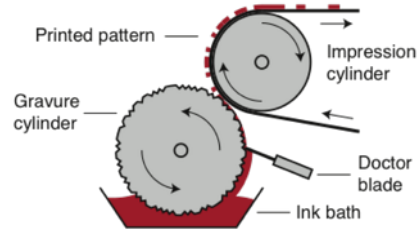


# ► CHALLENGE IN DIVERSE COATING APPLICATION METHODS

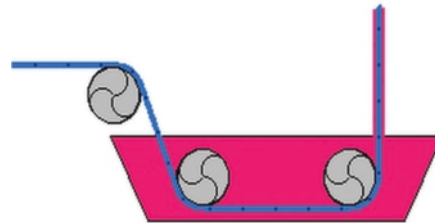
## COIL COATING



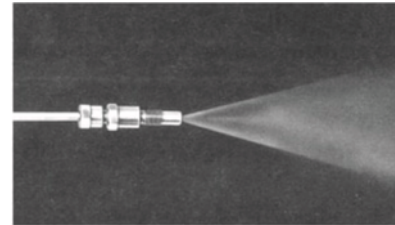
## GRAVURE



## IMMERSION/DIP

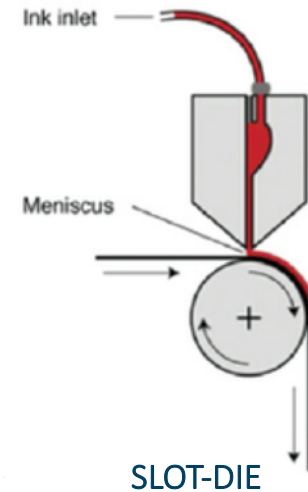


## SPRAY COATING



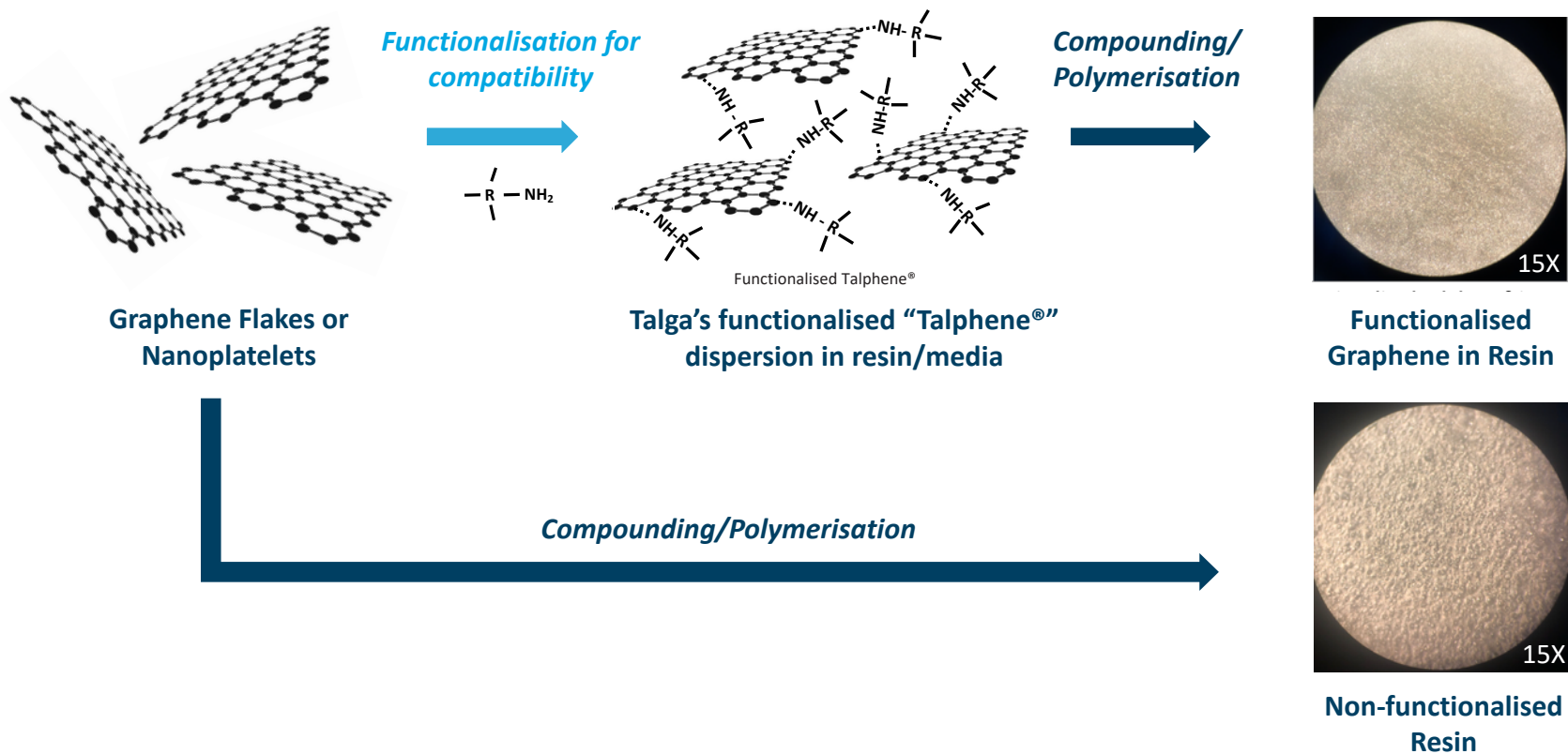
## INDUSTRIAL PROCESS REQUIREMENTS

- Water based system – Environmental
- Faster Line speed – High Throughput
- Shorter Curing time – Radiation
- Reduced Peak Metal Temperature (PMT)



# ► FUNCTIONALISATION OF GRAPHENE IS CRITICAL FOR INCORPORATION

Dispersion enabled by customised functionalisation according to the system chemistry



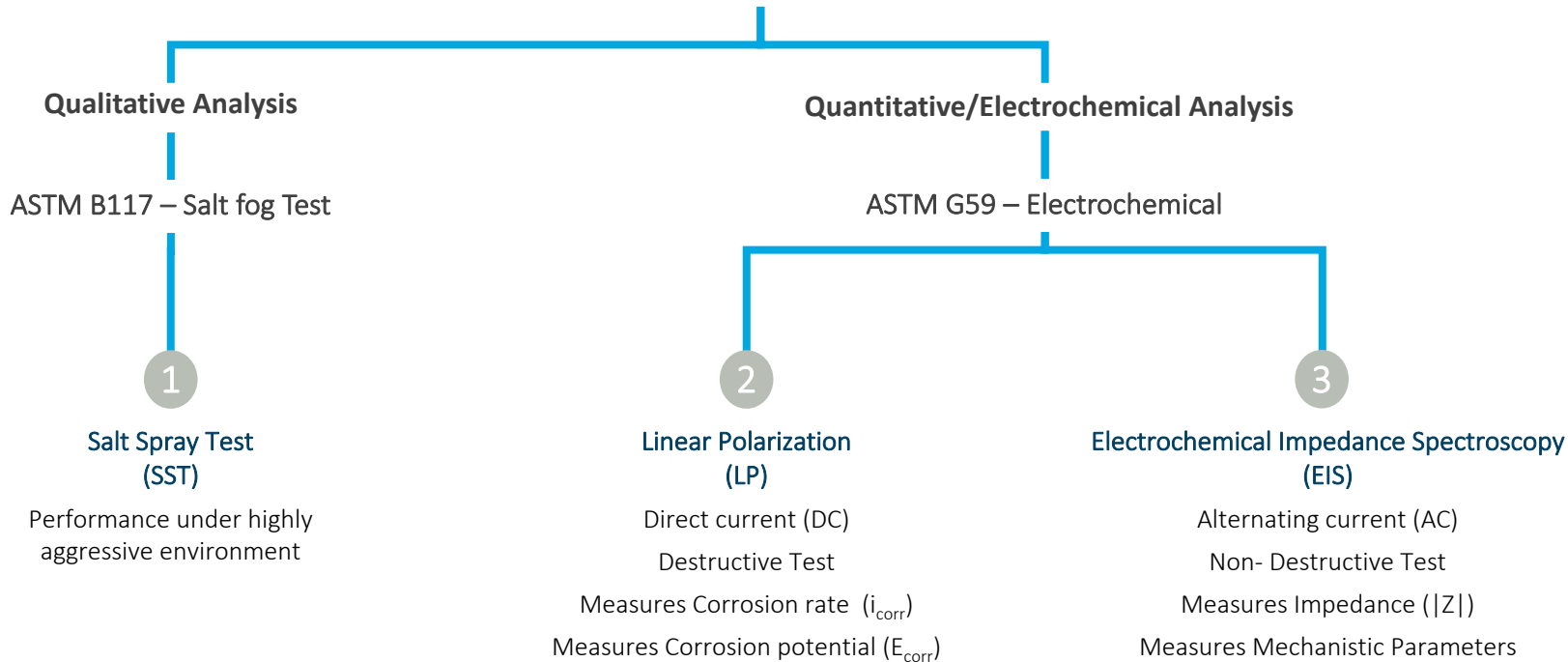


# CORROSION TESTING FOR PROTECTIVE COATINGS

Standard tests required for commercialisation



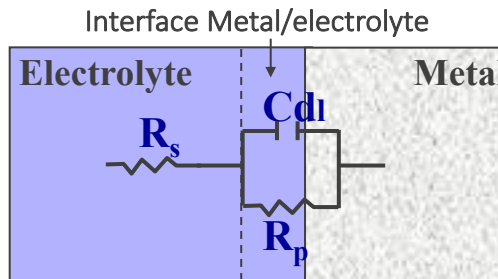
## CORROSION TESTING FOR COATINGS



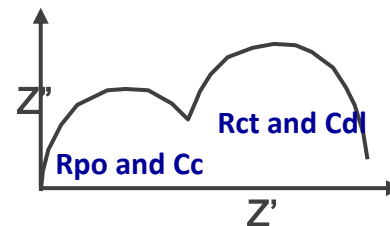
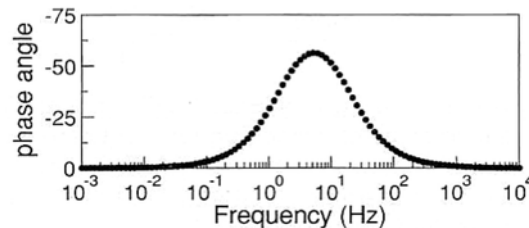
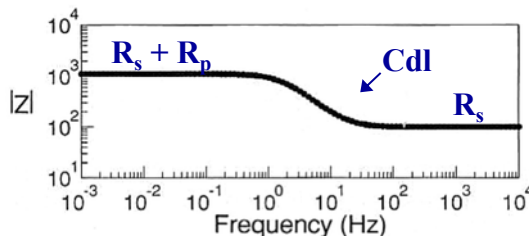
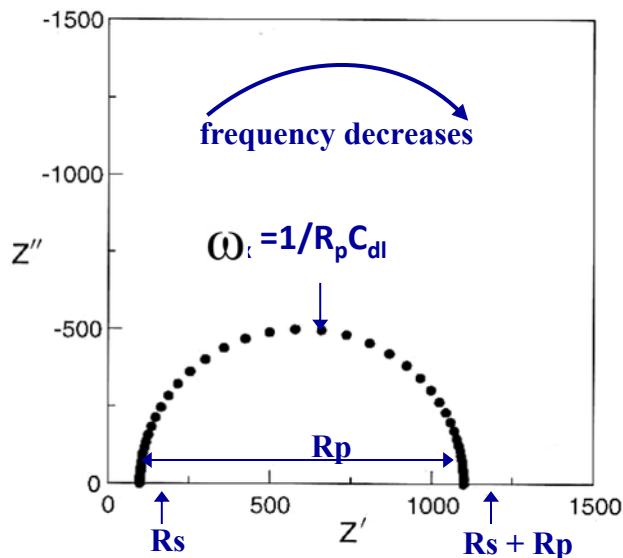
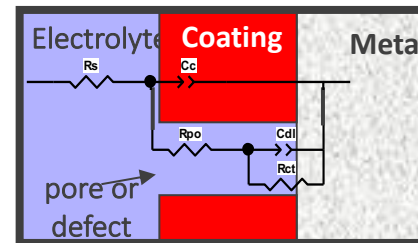
# ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

ASTM-G59- Non destructive – Coated products with pore/defect

Equivalent circuit for a simple corroding system with an electrolyte resistance



Interface  
Metal/ Coating /electrolyte



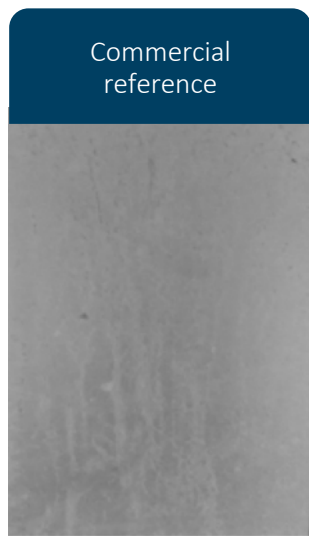
- Water uptake
- Evaluate coating resistance/capacitance
- Corrosion underneath the coating
- Blistering-delamination
- Quantification of substrate area non-protected?

# ► SALT SPRAY & ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY TESTING

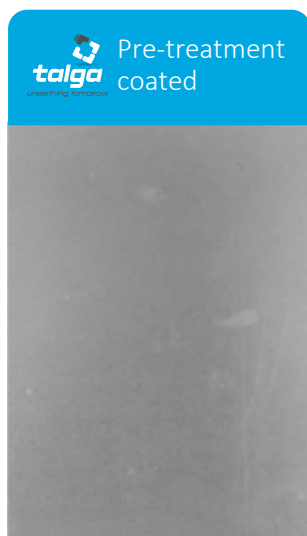
Talphen® on GI passivation shows lowest corrosion current compared to reference panels



After 72 hours accelerated corrosion (salt spray)

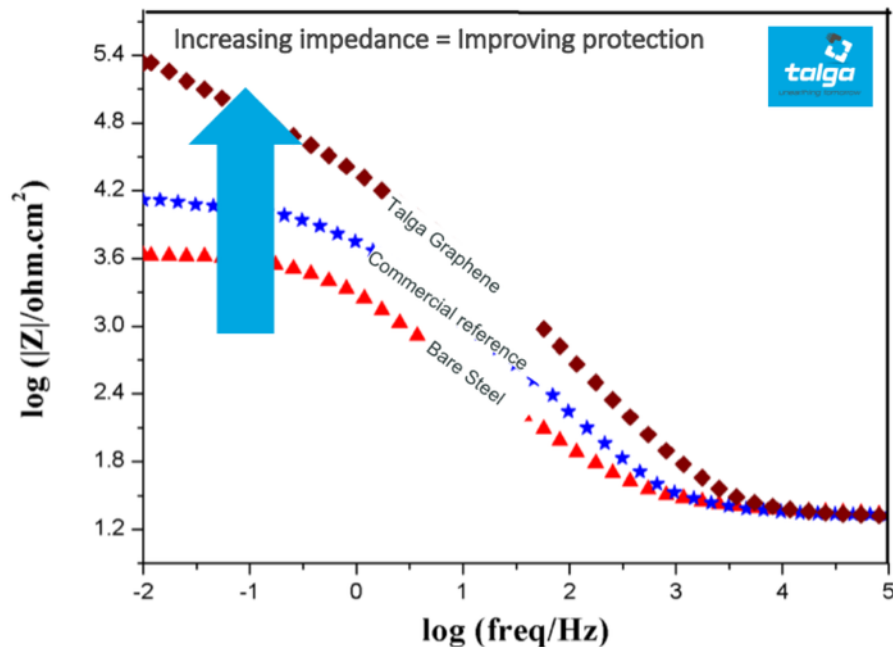


Commercial reference



Pre-treatment coated

ASTM B117 Standard



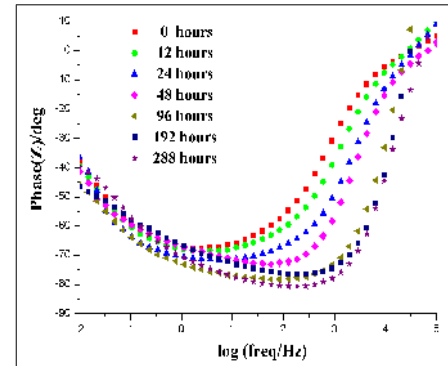
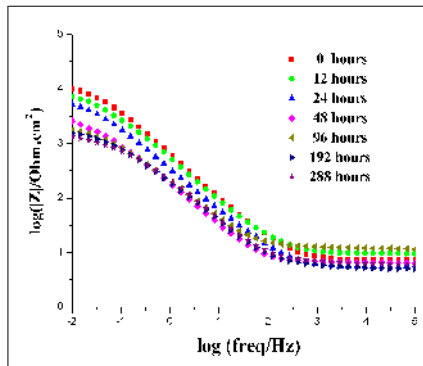
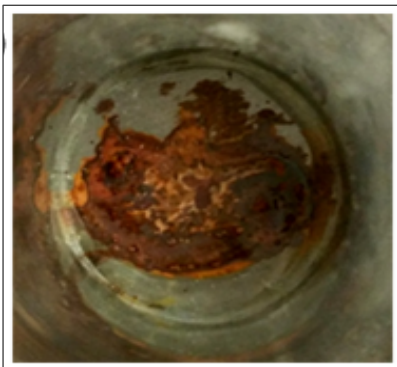
ASTM G59 Standard

# ▶ ANTI-CORROSION EFFECT OF 'TUNED' FUNCTIONALISED GRAPHENE

Talphone® – Break point Frequency

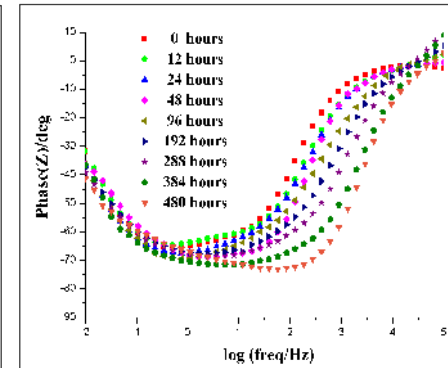
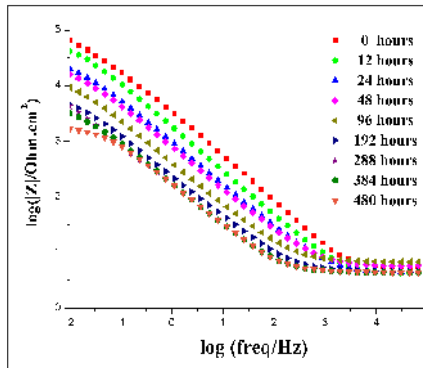
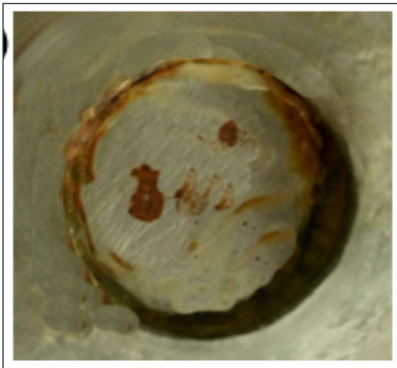
After 288 Hours

ASTM G59 Standard



After 480 Hours

With functionalised  
Talphone® coating





# ► ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

## Talphen® – Break point Frequency

Break point frequency is the point at which the coating **changes its behaviour** from a purely capacitive one to a **purely resistor** one. In other words, it is the point at which the metal begins to interact with the solution.

Occurs when  $f = 45^\circ$

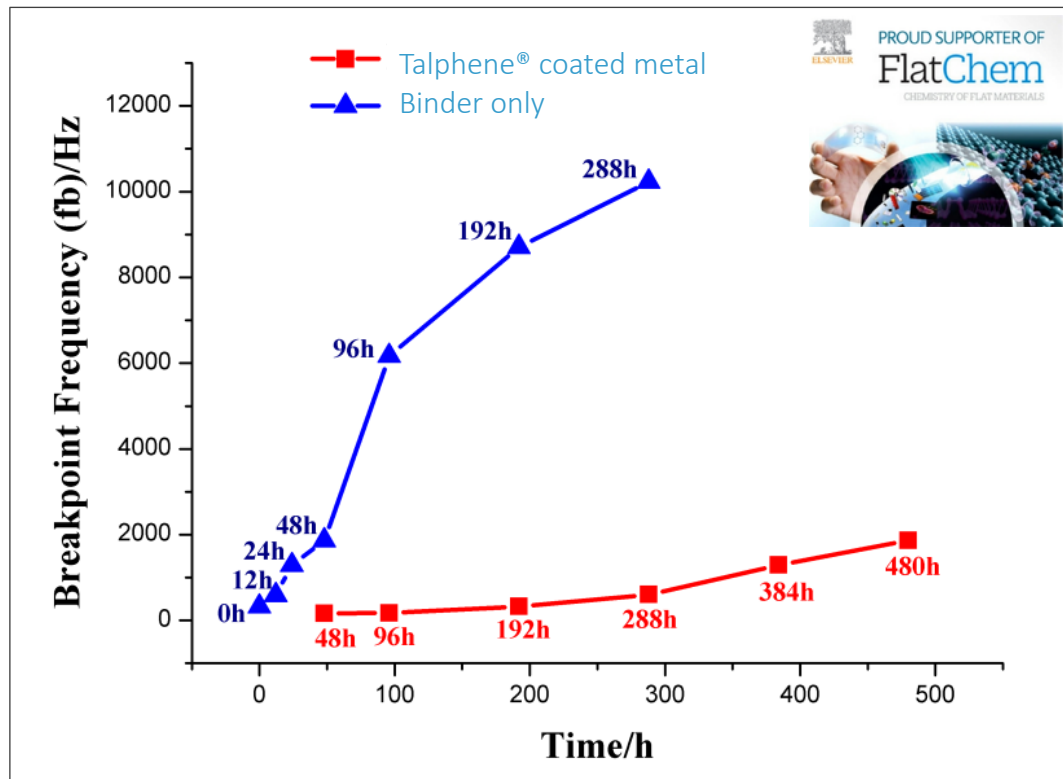
Mathematically

$$f_h = \frac{1}{2\pi\epsilon\epsilon_0\rho_o} \frac{A}{A_o}$$

OR

$f_h \propto$  Metal Area interacting  
with electrolyte

Breakpoint frequency vs Time



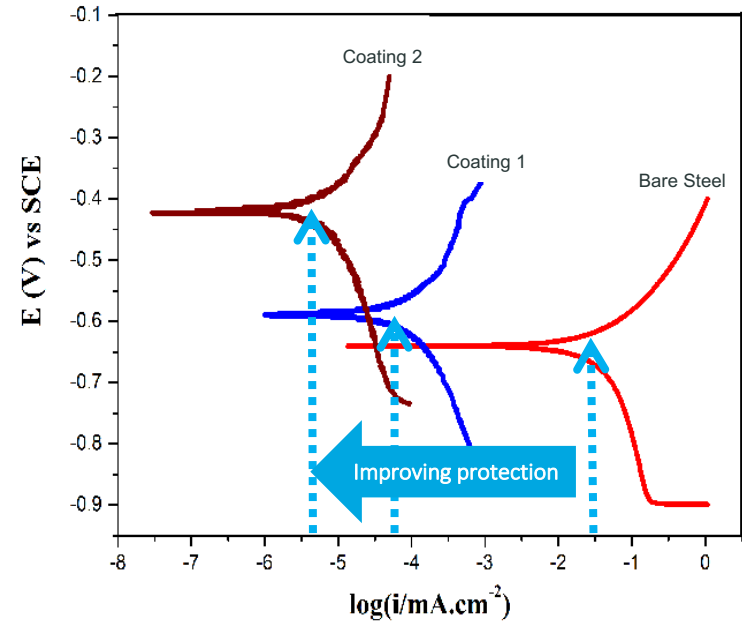
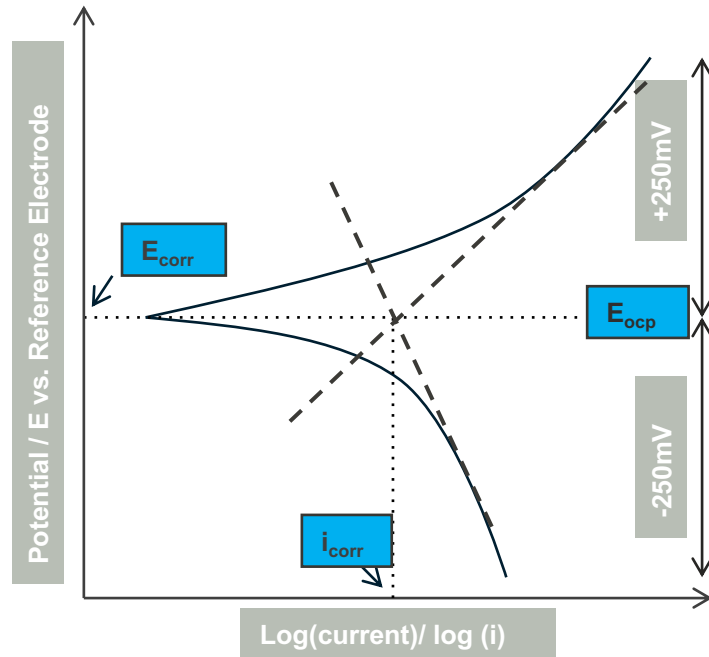
# ▶ LINEAR POLARISATION TEST – CR-STEEL

ASTM G59 Linear Polarisation Direct Current Destructive Test measuring corrosion rate & potential (tendency)

$I_{\text{corr}} \propto$  Corrosion Rate

$E_{\text{corr}} \sim$  Corrosion Tendency

Corrosion Rate (mpy) =  $\frac{0.13 I_{\text{corr}} (\text{Eq. Wt})}{d}$



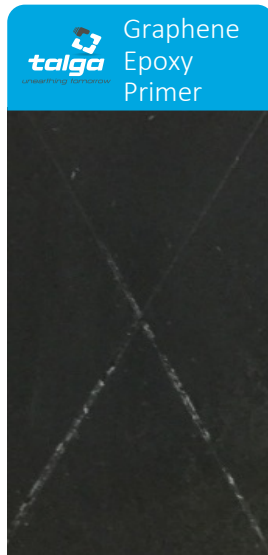
# TALPHENE® IMPROVES EPOXY BASED PRIMER



Significant increase in corrosion protection on commercial epoxy at increased loadings

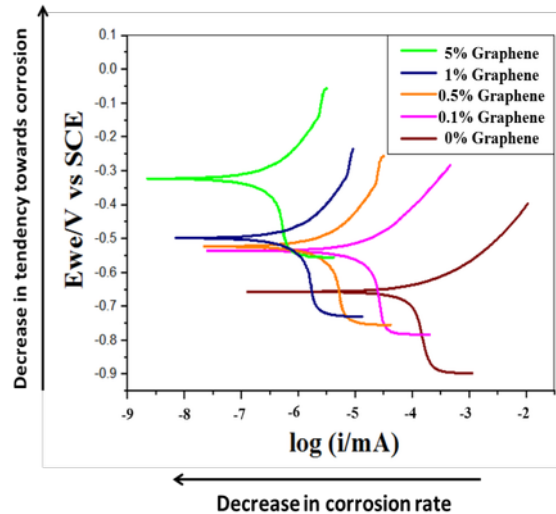
1

After 1,500 hours  
accelerated corrosion



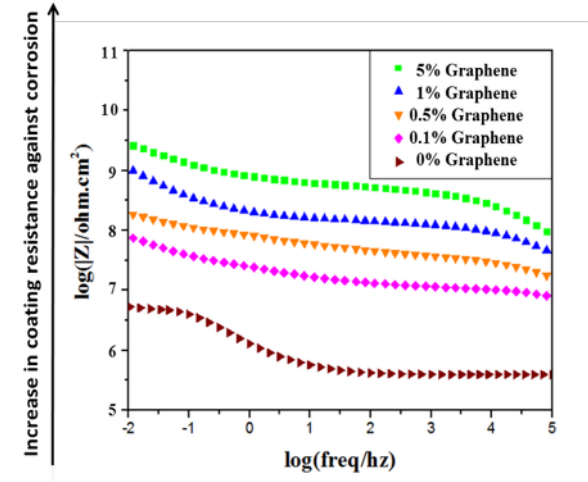
2

Linear  
Polarisation Test



3

Electrical  
Impedance Test

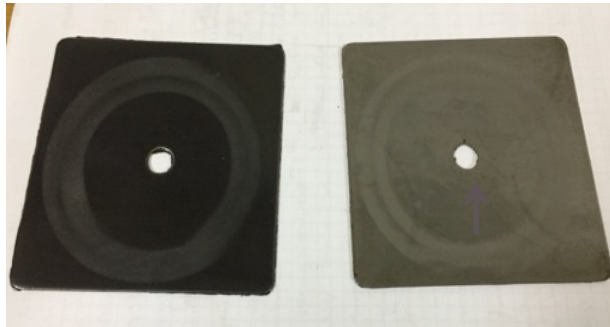


3.5% NaCl, Neutral pH

# TALPHENE® IMPROVES EPOXY MECHANICAL PROPERTIES



Improvement in  
Abrasion resistance by 82%

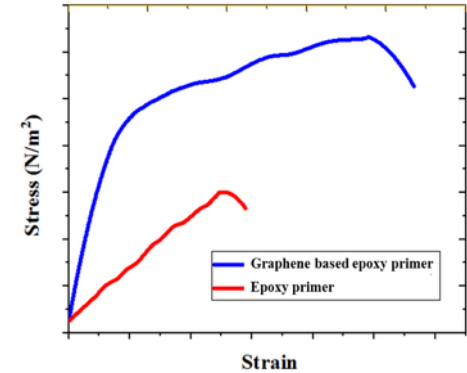
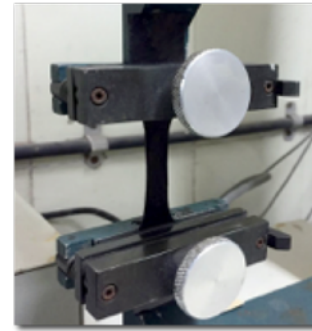


Talga Graphene/Epoxy  
coated Steel Panel

Epoxy coated Steel Panel

Abrasion resistance test under ASTM D4060

Improvement in Tensile strength by  
160% and Elongation by 95%



Tensile and Elongation test under ASTM B882



- Graphene platelets have morphology and electro-chemical characteristics suitable for creating new and powerful additives for coatings
- Talga has demonstrated that low loadings of graphene can provide significant increases in anti-corrosion performance and mechanical properties
- However to disperse correctly and provide corrosion protection mechanisms for targeted performance, graphene should be 'tuned' via functionalisation
- Talga uses proprietary electrochemical exfoliation and functionalisation processes to convert its natural graphite into graphene dispersions and additive products
- Work underway with a number of industry and academic partners in testing and development to scale up customer graphene enhanced products towards commercialisation

## CONTACT US

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