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# GRAPHENE LEADERSHIP SUMMIT

NOVEMBER 10-12, 2020 A VIRTUAL EVENT





# The Need For Dispersion and the Science Behind It

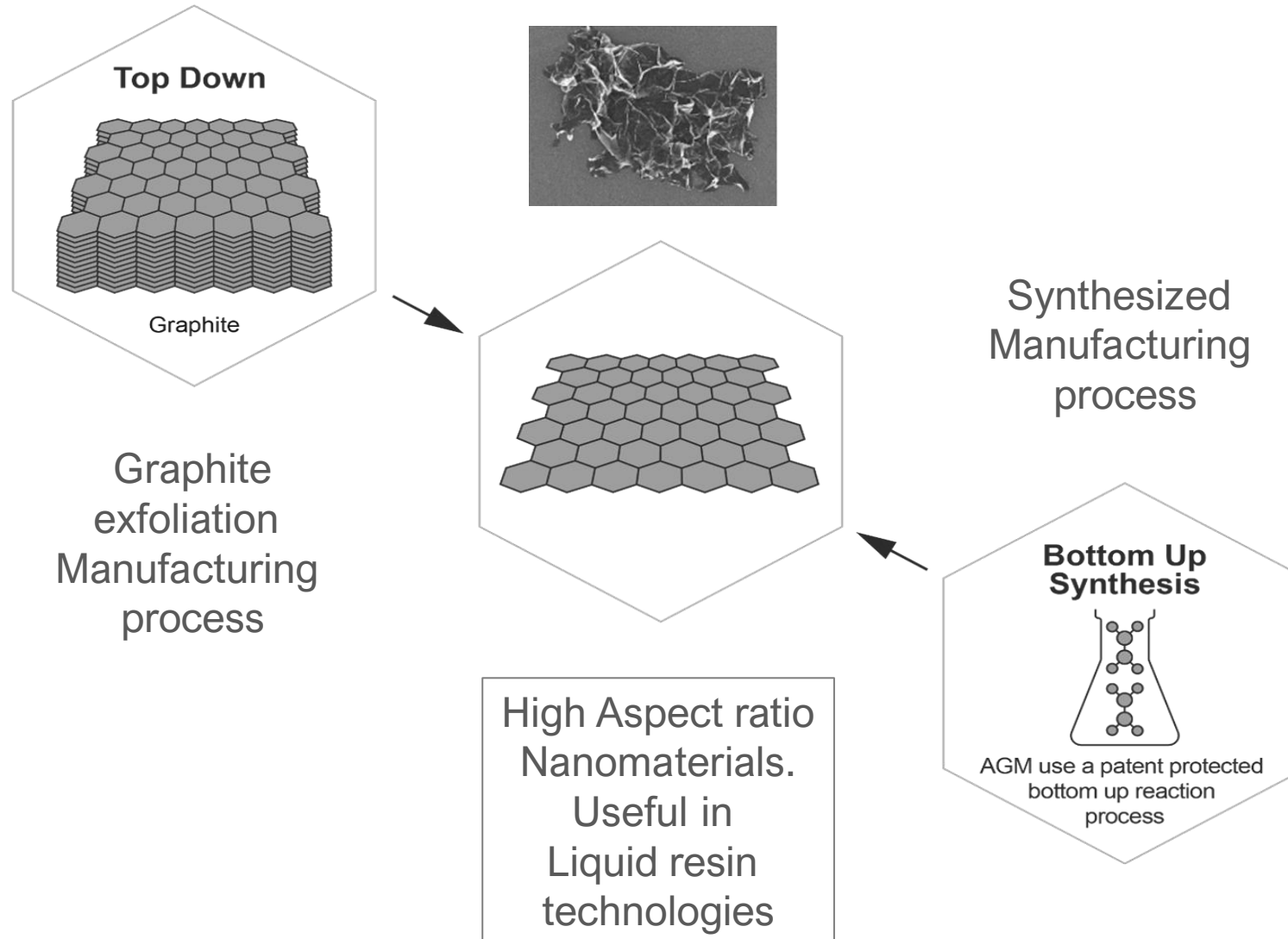
Adrian Potts  
CEO, Applied Graphene Materials plc



GRAPHENE  
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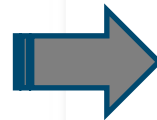
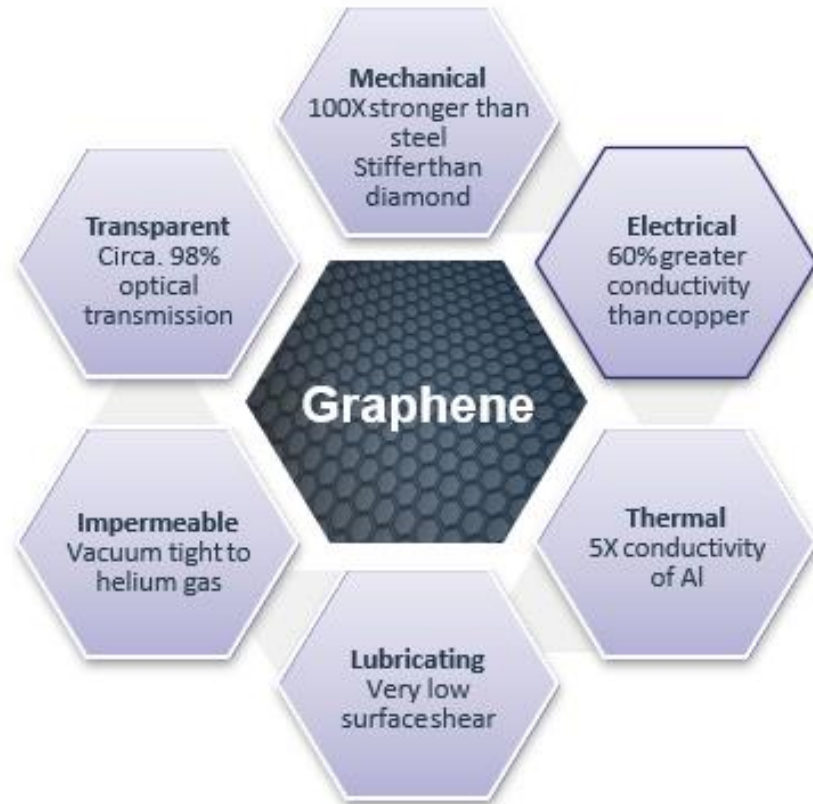
[www.nasampe.org](http://www.nasampe.org)

# • GRAPHENE NANOPATELETS

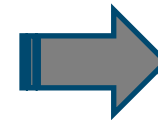


- AGM A-GNP's
- Number of layers can be controlled using different substrate catalysts and growing/reaction parameters
- Gives large surface area and high purity
- Offers a solid approach for consistent batch to batch high quality Graphene

# • GRAPHENE ATTRIBUTES



Use in real applications



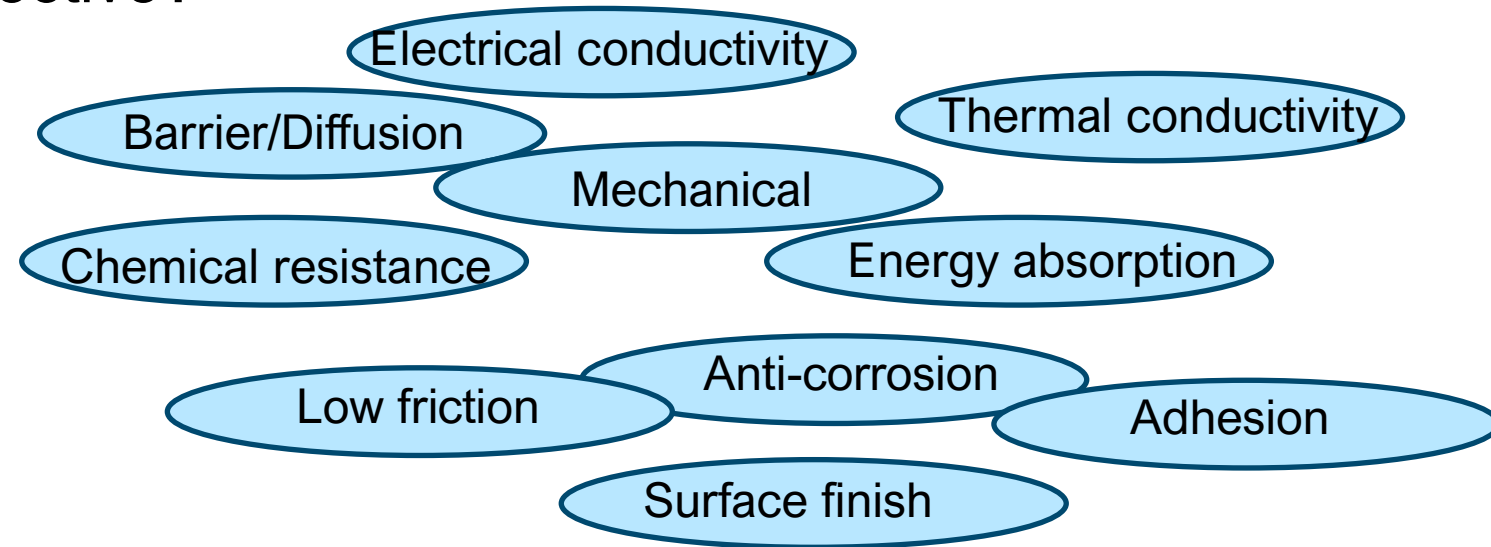
## AGM Application Technology

- Commercial value of graphene lies in the ability to robustly transfer its intrinsic properties into other materials
- To create higher value materials and products which possess specifically enhanced characteristics
- AGM utilizes differentiated application technology to create both standardized and end-use specific customized solutions for a range of applications

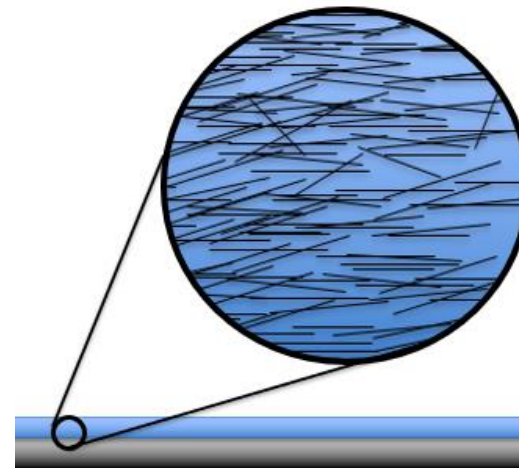
- **REALIZING PERFORMANCE**

- What is the performance objective?

- Coatings
- Composites
- TIM's
- Adhesives
- Printing



- Common thread – A need for separated array of high aspect ratio nanoplatelets
  - Organized
  - Random



- **REALIZING PERFORMANCE**
- Challenges with nanoplatelets
  - Going straight in with powders.....
    - Risks Agglomeration
    - Risks Crashing out of formulation
    - Risks Incompatibilities with emulsions
    - Risks related to safe use of HARN powders
- Dispersions for nanoplatelets
  - Key enabler to deliver materials
- Standard products
  - Liquid resins
  - Water
  - Solvents
  - Range of graphenes
- Custom dispersions



- **REALIZING PERFORMANCE**

- Typical matrix types using graphene for composites and coatings
- Epoxies
- PUs
- Toughened systems
- BMIs
- Cyanate Esters
- PFAs
- FST prepreg matrix resins
- Vinyl Esters for pultrusion and SMC
- Range of solvents
- Water



Liquid matrix technology lends itself well to dispersing graphenes

- **PRACTICALITIES**

## Why Graphene?

What could Graphene do for product enhancement?

What form of graphene might work?

What am I hoping to achieve?

## How?

How could I best format the material I'm trying to use to add performance?

How could I best introduce graphene?

How can I avoid failure?

## What?

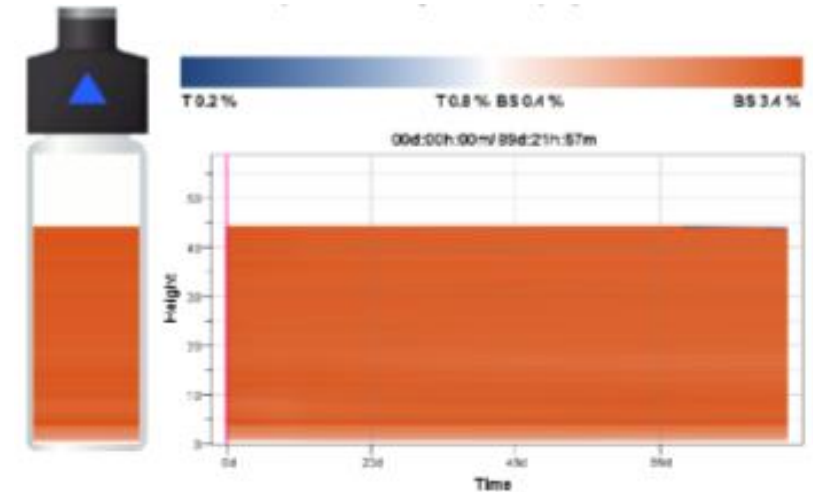
If powder, am I OK with using HARNs?

If a dispersion, what would be best option to use to deliver graphene into the target material?

Is media compatible? Is it part of the host material formulation?

- **PRACTICALITIES**

- General dispersion use
  - **Understanding End-user's process is key!**
  - **Compatibility** – will graphene addition upset the balance of the rest of the formulation?
  - **Balancing the addition of high aspect ratio, high surface area material**
  - **Sufficient binder resin to coat everything?**
  - **Is graphene replacing something else?**
  - **Loading level in dispersion and dilution to suit**
  - **What happens to the rest of the dispersion?**
  - **Use the dispersion for reaction purposes?**
  - **Viscosity**
  - **Particle size**
  - **Stability**
  - **Settling / Agglomeration / Re-dispersion**



- **PRACTICALITIES**

- Dispersion loading level

- **Considerations.....**

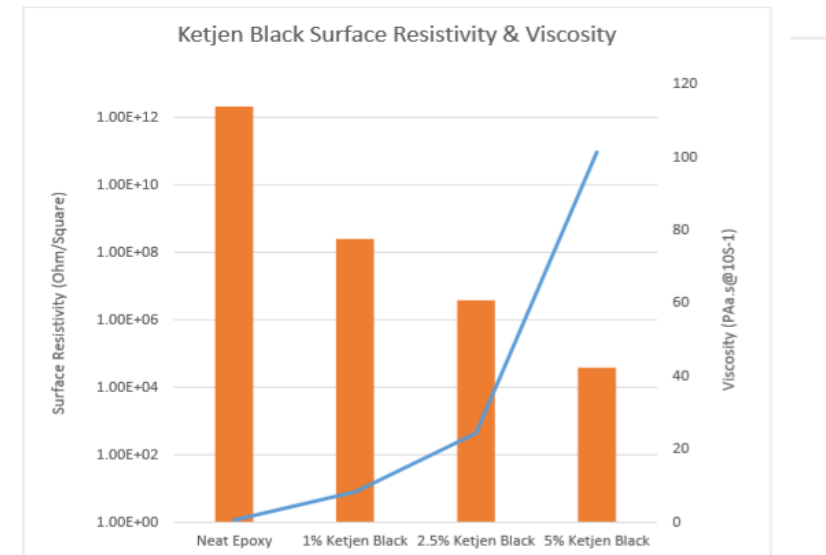
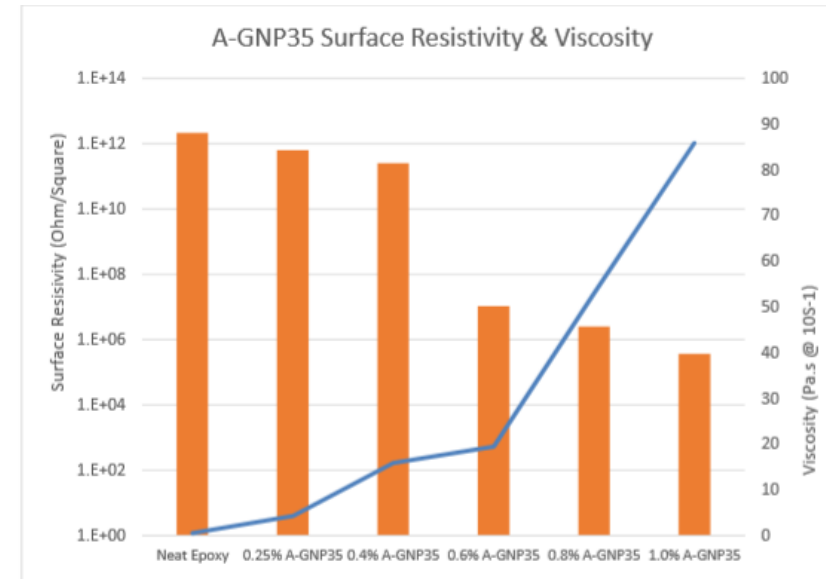
- **Loading level vs graphene type vs viscosity -> impact on formulating flexibility vs. other fillers for a fixed particle size range**

- **Loading level vs end use performance – example delivery of electrical conductivity**

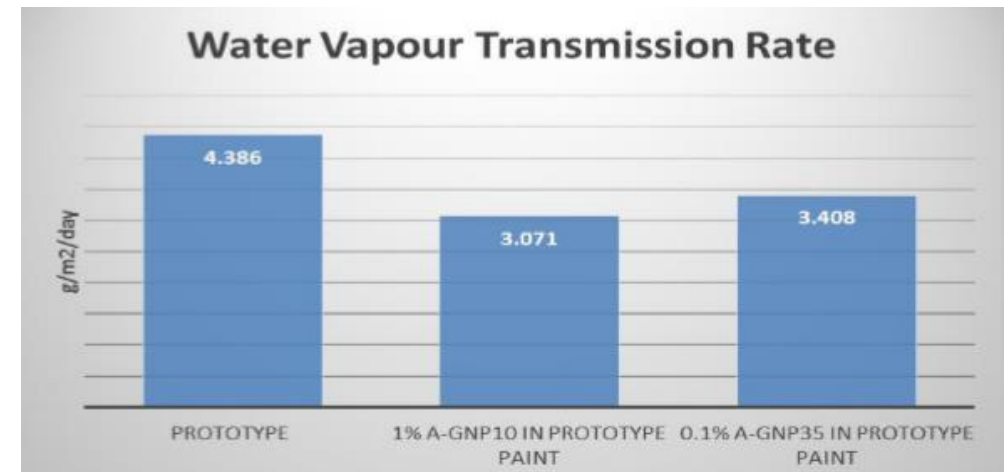
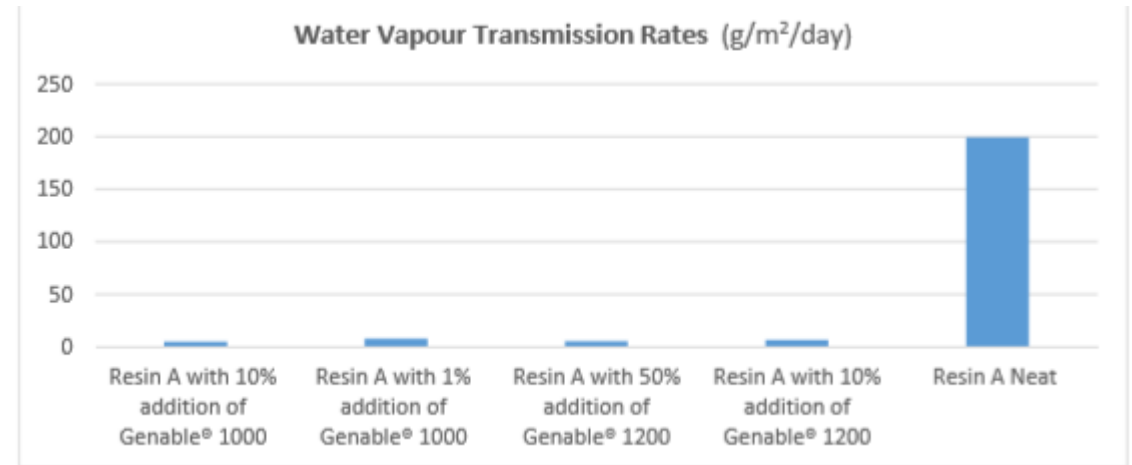
- **Balancing**

- Loading level
- Processibility
- End use performance
- Effectiveness / Efficiency

Loading level



- **PRACTICALITIES**
- Loading level considerations
- Loading level of graphene solids
- Impact of graphene in the rest of the formulation – Simple vs complex
- Example – water vapour transmission rate
- Other aspects:-
  - Surface area of platelets
  - Chemistry on platelets
  - pH of dispersion
  - Host formulation and workable viscosity window
  - Dispersibility into formulation
  - Process - Best point to add materials?



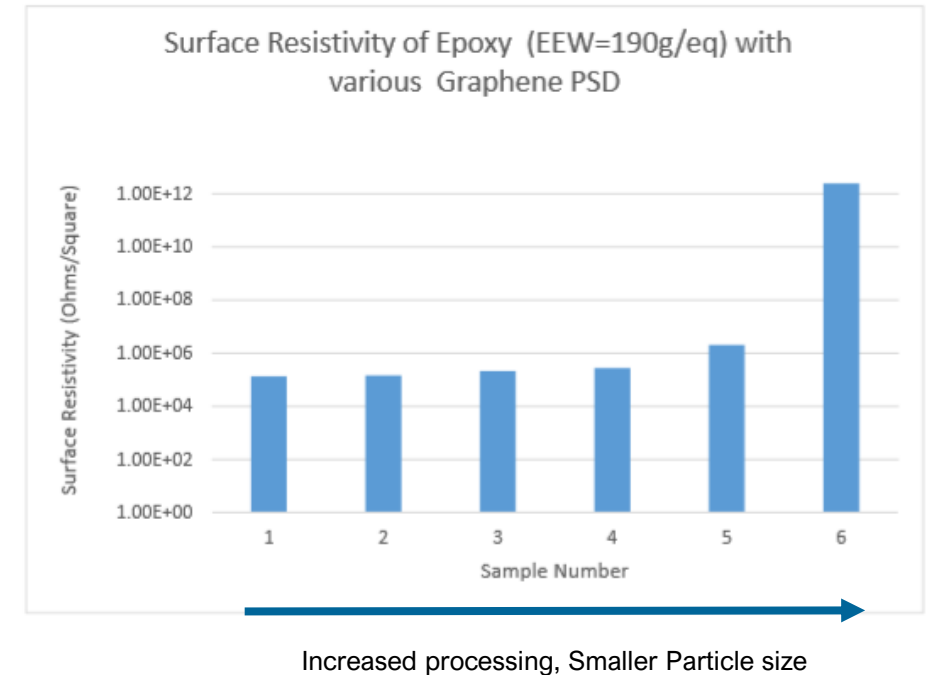
- **PRACTICALITIES**

- Particle size distribution
- **How does particle size distribution impact the end application?**
- **Aspect ratio is a key attribute**
- **Impact in composites.....**
- **Fiber diameter vs graphene particles vs volume fraction**
- **Impact in Coatings.....**
- **Aspect ratio for barrier performance and tortuosity**
- **Impact on Conductivity? Mechanical?**

Increased processing  
↓

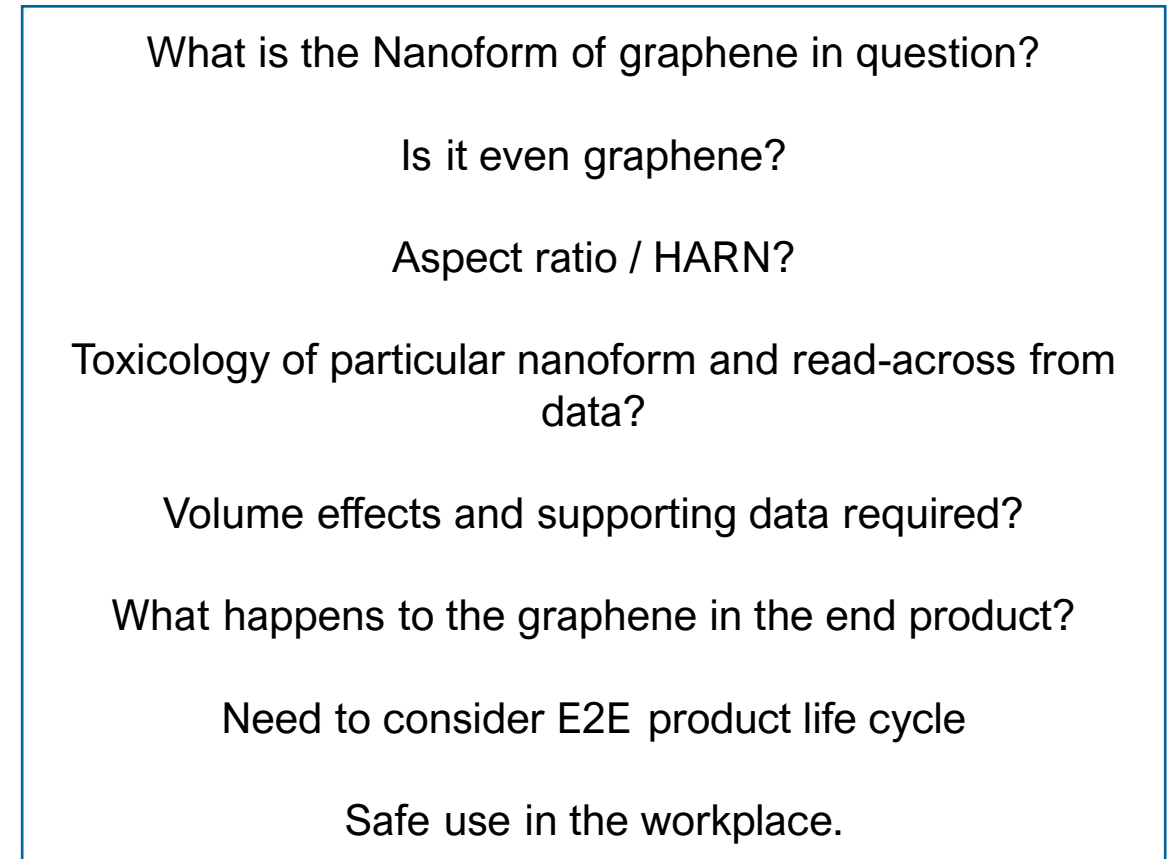
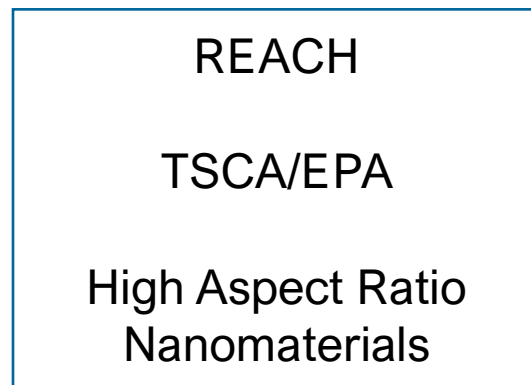
Epoxy resin (EEW=250 g/eq)	Dx(10) ( $\mu\text{m}$ )	Dx(50) ( $\mu\text{m}$ )	Dx(90) ( $\mu\text{m}$ )
1	4.75	47.7	141
2	0.03	5.74	14.1
3	0.03	4.42	10.6
4	0.37	4.25	12.8
5	0.02	3.25	10.6
6	0.02	1.86	6.44

EEW=190 (g/eq)	Dx(10) ( $\mu\text{m}$ )	Dx(50) ( $\mu\text{m}$ )	Dx(90) ( $\mu\text{m}$ )
1	36.2	154	382
2	4.52	43.6	146
3	2.06	34.6	103
4	0.72	25.2	71.6
5	0.02	1.28	25.9
6	0.02	0.886	21.7



- **PRACTICALITIES**

- Safe nanomaterials handling



## • DISPERSION END USE APPLICATIONS

- Prepreg solutions
- Dispersed graphene nanoplatelets in epoxy prepregs



- Body panels
- Composite tooling
- Enhanced fracture toughness, longevity, surface finish

- Wet winding solutions
- Dispersed graphene nanoplatelets in winding resins
- Microcracking performance



- Diffusion barrier
- [https://video.buffer.com/v/5f766e6b90079455542ad7f2?utm\\_content=buffer2df39&utm\\_medium=social&utm\\_source=linkedin.com&utm\\_campaign=buffer](https://video.buffer.com/v/5f766e6b90079455542ad7f2?utm_content=buffer2df39&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer)

## • DISPERSION END USE APPLICATIONS

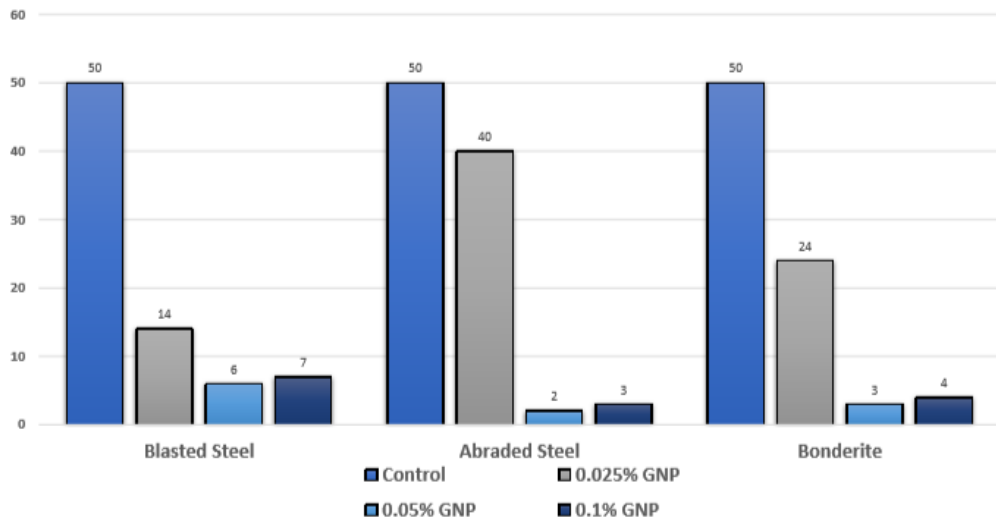
- Scope:- Work with major automotive Tier 1
- *“We can see positive directional improvements in key mechanical properties of composites systems. Encouragingly, other mechanicals investigated did not show significant change as compared to baseline numbers”*
- Areas of substantial performance gain include:-
  - ✓ Tensile Strength and Modulus improvements
  - ✓ Flexural Strength and Modulus improvements
  - ✓ Impact performance improvements







- Coatings Technology
- Graphene dispersions into coatings for anti-corrosion, barrier, chemical resistance







- DISPERSION END USE APPLICATIONS
- Exceptional anti-corrosion performance with dispersed

Neutral Salt Spray after 1000 hours – Creep Assessments



	4% Zinc Phosphate (Control)	4% Zinc Phosphate + Genable® 1001
1000 Hours		
2000 Hours		
3000 Hours		

	Control (Primer Only) In-house primer + 8% Zinc Phosphate	In-house primer + Genable® 3001
1000 Hours		
4000 hours		

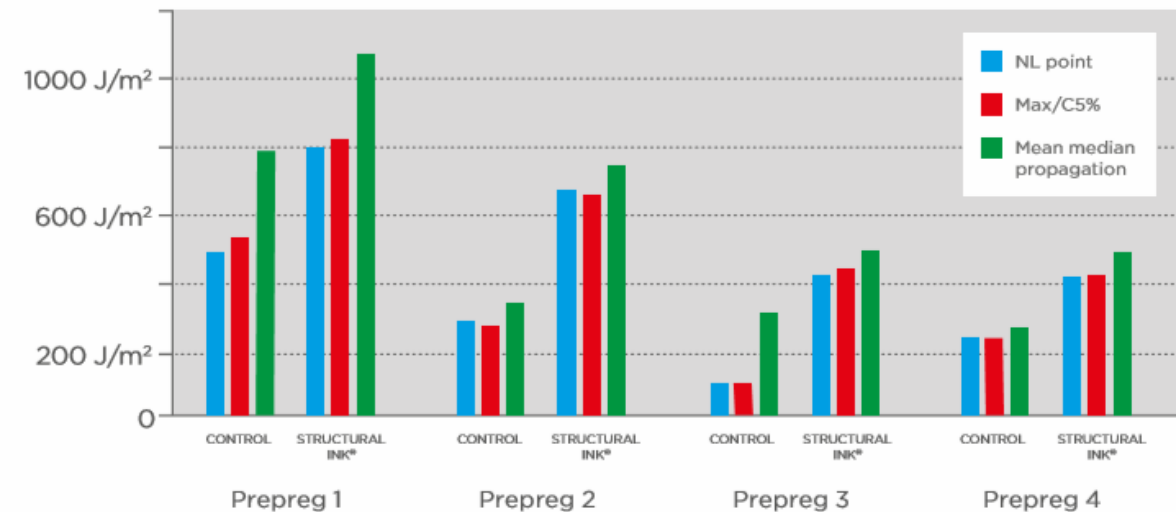
ASTM G85-94 test method

### • SUMMARY

- Fundamental to success with graphene nanoplatelets – achieving a great dispersion in the final product
- Use of additive dispersions enables ease of use, formulator flexibility and safe deployment
- Achievement of correct loading levels, viscosity, PSD etc can achieve outstanding performance results



Increases Fracture Toughness



# Thank you

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