Overview of XG Sciences and Our Materials

Nanomaterials that improve batteries, coatings, films, and composites

Agenda

- About XG Sciences
- About Graphene Nanoplatelets ("GNP")
- Potential GNP Application Areas
- Discussion of Issues and questions

XG Sciences' Mission is to

1. Manufacture and sell graphene nanoplatelets as a bulk material in ***commercial quantities*** at ***economical costs***
2. Offer value-added products based on our materials and manufacturing process
   - **Electrode materials** for ultracapacitors and batteries
   - **Films and "papers"** for electronics applications
   - **Coatings, inks and dispersions**

XGS Distinguishing Strengths

1. We are the world leader and first-to-market with low cost, high volume graphene nanoplatelets
2. Our network of investors, partners and customers is very strong
3. Our scientists have ten years of experience with our materials
4. Our proprietary manufacturing processes give us the lowest cost, control over end-products, and are applicable to other materials, such as low-cost nano-silicon
5. Our platform products like XG Leaf benefit from our scale and cost structure

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Growing a World-class Business – Top Talent

Experienced Managers

- **Mike Knox**, CEO – 5 previous startups in manufacturing, software and services. All sold to larger companies
- **Scott Murray**, VP Operations – 30 years eng. & mfg. management experience
- **Rob Privette**, VP Energy Markets – 25 years hands-on engineering experience with energy storage and conversion systems
- **Corinne Lyon**, Controller – a CPA with 25 years of experience in public and private accounting

Leading Scientists

- **Dr. Larry Drzal**, PhD, Chief Scientist – University Distinguished Professor at MSU, 27 patents, 375 papers, Air Force technology advisor, worldwide reputation
- **Dr. Liya Wang**, PhD, VP, R&D – 30 years of experience with advanced materials, batteries and capacitors
- **Dr. H. Fukushima**, PhD – inventor of basic processes, material scientist
- **Dr. Inhwan Do**, PhD – inventor of energy materials, energy applications senior scientist

founders

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Snapshot of XGS Now

- ✓ Spin-off from MSU
- ✓ Five+ years old
- ✓ 30 Employees
  - ✓ *7 PhD*
  - ✓ *3 Masters*
- ✓ Two locations
  - ✓ *Manufacturing (25K ft^2)*
  - ✓ *R&D (10K ft^2)*
- ✓ 550+ customers in 32 countries
  - ✓ *1 in production, a few more close*
  - ✓ *~80 universities and labs*
- ✓ Several overseas distributors
  - ✓ *Korea*
  - ✓ *Japan*
  - ✓ *Taiwan*
  - ✓ *China - coming soon*
  - ✓ *EU – coming soon*

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5 Years of Manufacturing Focus

- ✓ Over $8 million spent so far
- ✓ Pilot Plant (7,000 ft^2) in 2008
- ✓ Commercial Equipment & scalable production methods
- ✓ Multiple products
  - ✓ Bulk powder
  - ✓ Dispersions
  - ✓ XG Leaf

- ✓ **25,000 square foot facility**
- ✓ **Current manufacturing capacity = 80 tons/year**
- ✓ **Lowest prices ~ $40 - $50 kg /tonnage quantities**

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XGS Development Capabilities

- ✓ Energy storage laboratory
- ✓ Materials characterization
- ✓ Coatings and films
- ✓ Dispersions and functionalization
- ✓ Composites
- ✓ Process development

Current staffing – 9 scientists and technicians

Materials Science, Chemistry, Chemical Engineering, Electrochemistry, Electrical Engineering

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XGS Research Partner – Michigan State University

Recognized as one of the top 40 Worldwide Research Universities

- ✓Twelve years of research in xGnP
- ✓30+ peer-reviewed papers
- ✓14 researchers and staff
- ✓Many patents/applications
- ✓Composite Materials Center
- ✓Military Composite Vehicle Center

XGS has licensed a portfolio of existing IP and will acquire more as discoveries are made. Exclusive Worldwide License Terms

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Strategic Investors, Partners, & Licensees

- Hanwha Chemical – an investor in XGS and is a development partner.
- POSCO – an investor in XGS and is a development partner. Also, a non-exclusive licensee of our manufacturing processes and a long-term supply partner.
- Cabot Corporation – a non-exclusive licensee of our production processes and a development partner.

World-Wide Customer Base

- ✓ Shipping sample materials since early 2010
- ✓ Many customers are developing applications
- ✓ 550+ customers / 32 countries
- ✓ Applications include nanocomposites, energy storage, electronics & lubricants
- ✓ We are developing our own proprietary electrode formulations

posco
Hanwha
SHOWA DENKO
General Motors
NESSCAP ULTRACAPACITORS
SAMSUNG
CABOT
HONDA The Power of Dreams
Henkel
GOODYEAR
Argonne NATIONAL LABORATORY
BOEING
PPG
PPG Industries
3M
A123 SYSTEMS
HUNTSMAN Enriching lives through innovation
LOCKHEED MARTIN
SEKISUI SEKISUI CHEMICAL CO., LTD.

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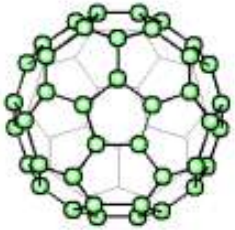
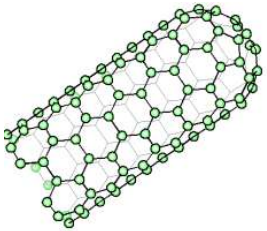
About Graphene and Graphene Nanoplatelets

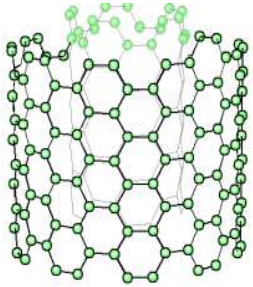
Various Forms of Nano-Carbon



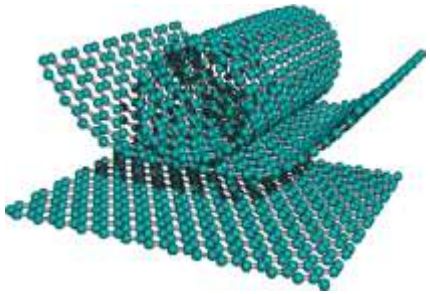
Fullerene



Single Wall Carbon Nanotube



Multi Wall Carbon Nanotube

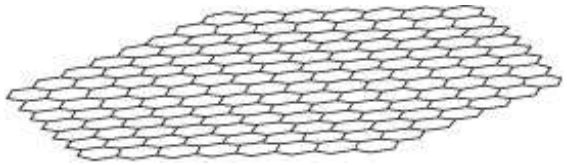


Graphene – Basic Building Block

- ✓ Graphene is a single layer, two dimensional aromatic macromolecule with sp^2 bonded network of carbon atoms
- ✓ Zero band gap electronic structure with low electrical resistivity 50 X 10^{-6} ohm cm.
- ✓ Highly thermally conductive [3000 W/m^{o}K theoretical]
- ✓ Natural Graphite or Synthetic

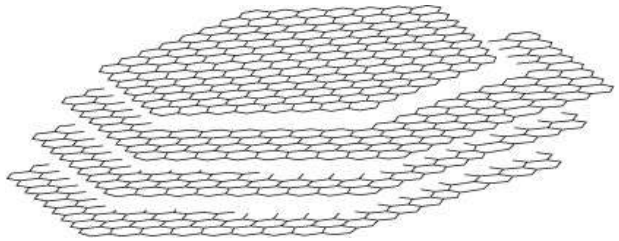
What is Graphene?

A single layer of carbon atoms, or
“an atomic-scale honeycomb lattice of carbon atoms.”



What is a Graphene Nanoplatelet?

A particle consisting of multiple layers of graphene. Also can be thought of as an ultrathin particle of graphite, normally with thickness < 100 nanometers



Synthesis of Graphene

- Chemical Growth – epitaxial growth or Chemical Vapor Deposition on foils or wafers

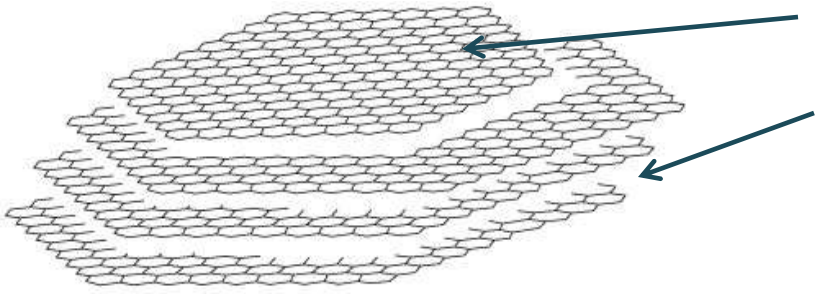
Synthesis of Graphene Nanoplatelets

- Mechanical exfoliation of Graphite
  - Nobel Prize winning method
  - $$$$$$$$ very expensive if manual methods are used
- Oxidation to Graphite Oxide ("GO")
  - Exfoliation in water
  - Reduction to graphene >> "deformed graphene"
- Direct intercalation & exfoliation
  - Many known intercalants
  - Thermal exfoliation or expansion is usual

Not all Graphene Nanoplatelets are the same: size & shape & edge chemistry control properties

THICKNESS

1. Mechanical strength
2. Handling
3. Electrical & thermal Properties
4. Loading wt%
5. Cost



SURFACE & EDGES

1. Electrical conductivity
2. Dispersion quality
3. Mechanical properties
4. Hydrophobic / hydrophilic

1. Barrier Properties
2. Mechanical Properties
3. Cost

DIAMETER

Different grades and sizes for different applications – 3 grades now offered:

- Grade H: 50 - 80 m^2/g – in 5, 15 or 25 micron diameters
- Grade M: 120 -150 m^2/g – in 5, 15 or 25 micron diameters
- Grade C: small diameter particles 300, 500, 750 m^2/g

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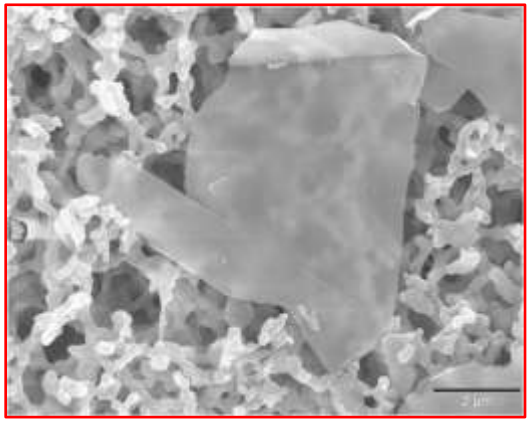
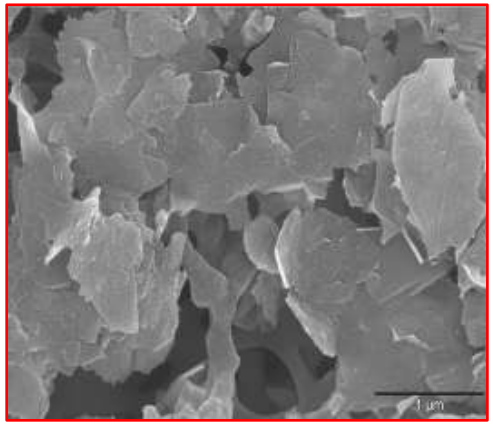
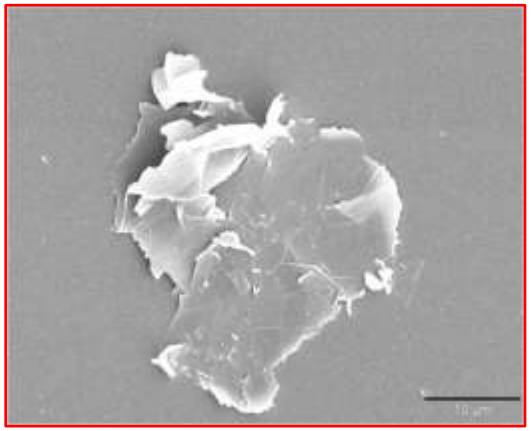
xGnP™ Graphene Nanoplatelets – H/M Grade



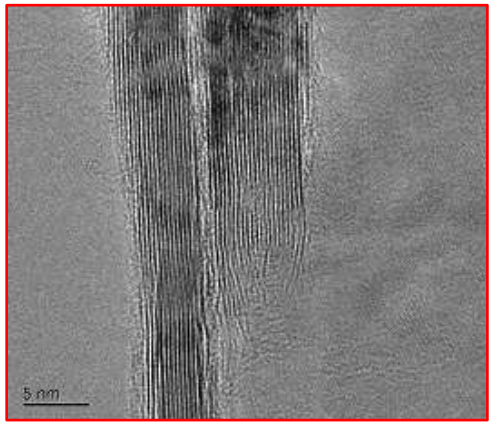
Single Platelet



Bulk Powder

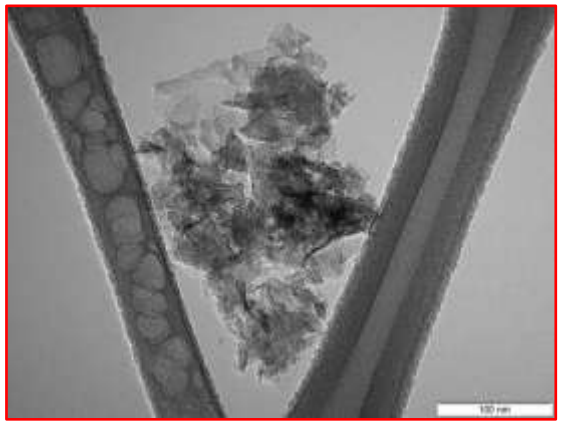
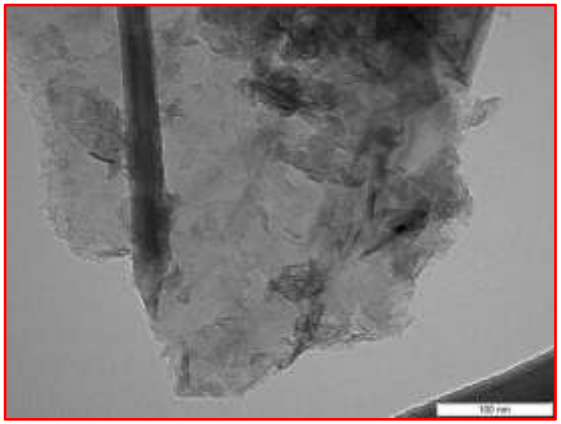
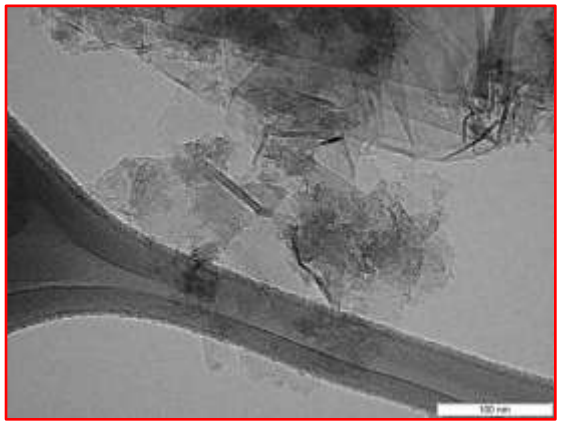


Typical Agglomeration



Edge View - Two Platelets

xGnP™ Graphene Nanoplatelets – C Grade

TEM images showing typical presentation as agglomeration of sub-micron platelets. Grade C shows very high surface area and macro-porosity.

XG Sciences Product Offerings

1. xGnP Graphene Nanoplatelets (bulk dry powder)
   a) Grade H – 15 nm thick, surface area of 50 – 80 m^2/g
   b) Grade M – 6 nm thick, surface area of 120 – 150 m^2/g
   c) Grade C - < 2 microns, surface area of 300, 500 or 750 m^2/g
2. Dispersions
   a) Aqueous
   b) IPA
   c) Organic solvents
   d) Resins and custom
3. Now introducing XG Leaf – sheets for electrical, thermal or barrier properties
4. Coming soon - electrode formulations
   a) Anode for li-ion
   b) Supercapacitor

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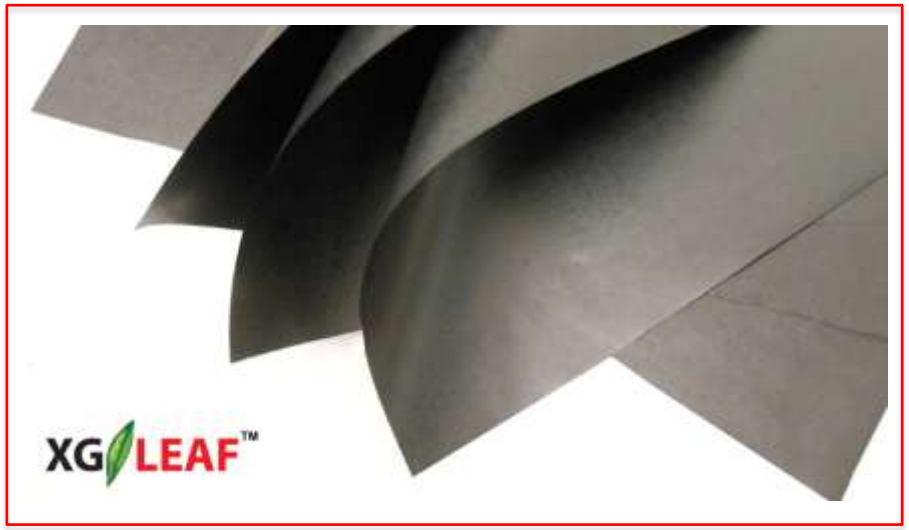
XG Leaf: a major new product line



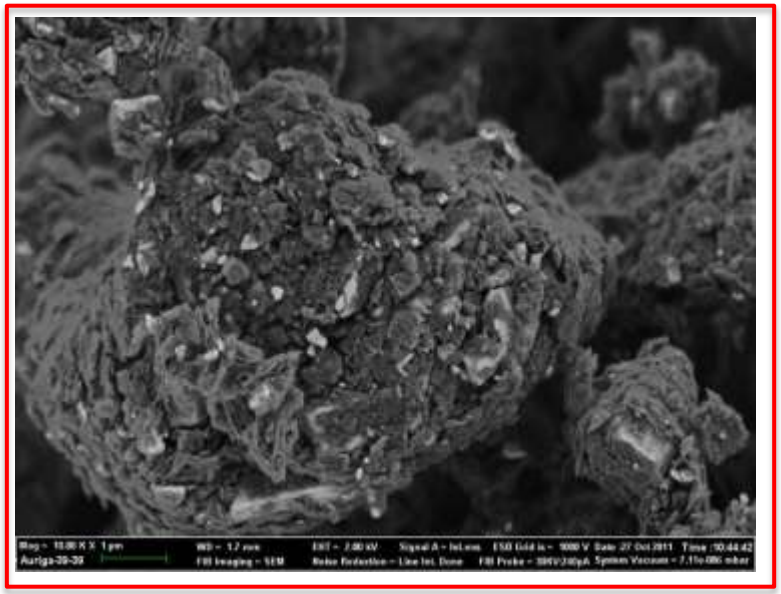
Unique process has been demonstrated in lab

- Flexible to produce many different formulations
- Flexible to produce many different thicknesses
- Good control over properties ranging from electrical to mechanical

Now scaling to meet customer demand

Now sampling four different products to customers

New: XG-SiG™ Silicon Graphene Composite Materials for Li-ion Batteries



Low-cost, high performance:

- ✓ High Reversible capacity: 800 mAh/g
- ✓ First cycle efficiency: 80%
- ✓ Enhanced cycle life
- ✓ Bulk material behaves like other carbon powders – easy to process

Energy Storage Development Partners

Commercial

- Major OEMs
- Major Battery Manufacturers
- Major Supercapacitor Manufacturers
- Material precursor suppliers (e.g. Silicon)
- Industrial R&D consortium (e.g. American Lead Acid Battery Consortium)
- Fraunhofer Germany

US Government

US Department of Energy

- Argonne National Lab (ANL)
- Lawrence Berkeley NL (LBNL)
- Oak Ridge National Lab (ORNL)
- Los Alamos National Lab (LANL)

DOD

- Air Force Research Lab
- Army Research Lab

Lux Research Releases Top 10 Innovative Companies Profiled in Q3 2012

Potentially disruptive technologies for drug delivery, low-cost solar, cheaper LEDs, novel graphene materials, and efficient grid storage highlight Lux Research's Q3 list

XG Sciences – Positive – Advanced Materials
Despite increasing competition from a handful of new entrants to the graphene space, XG remains the low cost leader and also boasts the most impressive business execution to date via its strategic relationships with Cabot, Hanwha Chemical, and Posco.

http://www.businesswire.com/news/home/20121002005573/en/Lux-Research-Releases-Top-10-Innovative-Companies

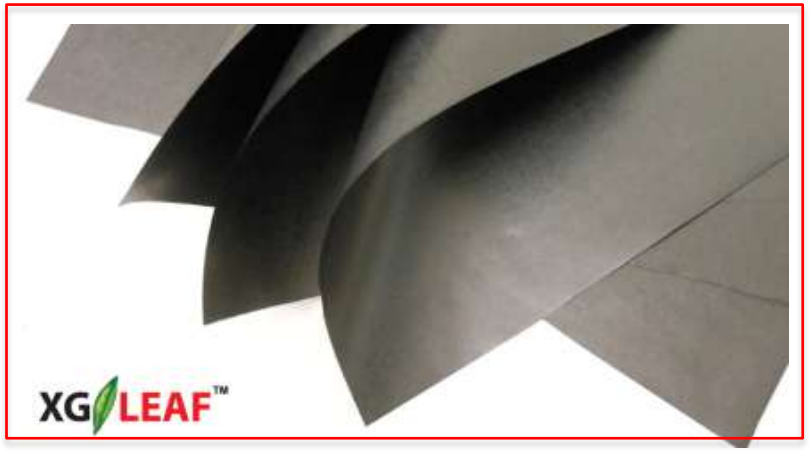
Potential Application Areas

Major Application Areas for GNP

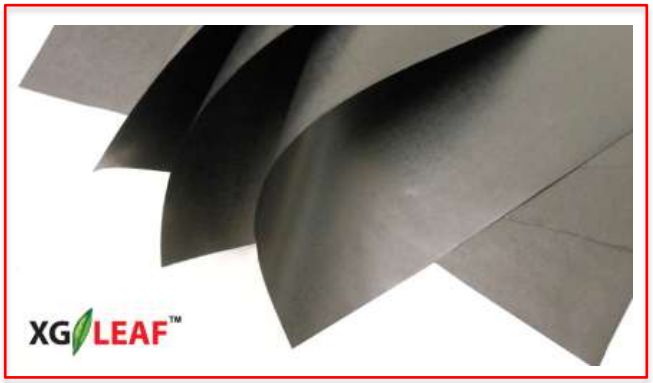
- XG Leaf sheets
- Electrodes
- Nano-additive for composite systems
  - Polymeric composites
  - Metal matrix
  - Concrete
  - Lubricants
  - Thermal management/cooling fluids
  - Phase-change systems
  - Drilling fluids and muds
- Substrate for active materials

XG Leaf Sheets

- Thermal – heat dissipation and heat spreading
- Electrical – EMI shielding
- Resistive Heating – de-icing or radiant heating
- Structural – blast resistance, mechanical support in composite laminations
- Electrodes



XG Leaf - Properties



- ✓ Porosity & Density can be controlled
- ✓ Reinforcement with polymers is possible at 5 to 50 wt%

- Thickness from 30 – 200 microns
- Surface Resistivity ~ .15 ohm/sq
- Thermal conductivity:
  - In-plane: ~ 400 W/(m·K)
  - Through plane: ~ 1 W/(m·K)
- Max Operating Temperature can be tailored: 150 – 450 ° C
- Mechanical strength can be tailored through use of various fibers
- EMI shielding: 25 – 65 db in .1 to 3 Ghz range

Electrodes

Two Main Focus Areas:

- Supercapacitors
  - Funded by US Air Force: develop very high energy density
- Lithium-ion battery anode materials
  - Silicon-graphene composite : low-cost, high performance
  - Funded by US Department of Energy

Thermoplastic Composites

Target property improvements – electrical, thermal, barrier & mechanical property (modulus, compressive strength, impact resistance) goals

Example applications:

- Automotive exterior body parts – lower CTE, improved modulus, improved impact resistance
- Electrostatic painting – replace conductive coatings now used

Thermoset Composites

- Inks & Pastes – electrical & thermal property goals
- Coatings – electrical (ESD, EMI shielding), anti-corrosion, barrier
- Structural Epoxy – improved mechanical properties, surface properties
- Structural (SMC, BMC, Vinyl Esters) – all of the above, plus blast resistance

Concrete

Goal is to use xGnP as an additive to enhance impact resistance, compressive strength, barrier properties of "super-strong" concrete.

Lubricants

The idea of using graphite in lubricant systems is not new. However, graphene nanoplatelets may offer a different property set.

xGnP has been shown to:

1. Increase tool life by 30 – 50% when added to Minimum Quantity Lubrication systems used in machining operations (cutting, grinding, boring tools)
2. Our C-grade materials are among the best anti-wear additives available for lubrication systems

Other Composite Applications

1. Phase-change systems – university research has shown that xGnP enhances properties of parafin-based phase change materials.
2. Thermal fluids (heating or cooling)