

Creating the Equation for Growth

Global Nanomaterials Opportunity and Emerging Trends

Lucintel Brief

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Executive Summary

- Global nanomaterials industry reached \$1.7 B in 2010, with an average annual growth rate of 10.4% over last five years
 - Top 10 players are ~80% of global nanomaterials market
 - Nanoclay and carbon nanotubes are dominant materials representing ~90% of market value
- North American nanomaterials industry accelerated by ~25% in 2010 and Europe by ~22%, while Asia and other regions grew by ~32% in 2010, driven by:
 - Active participation of government in nanotechnology R & D funding
 - Advancement in production process
 - Heavy investment in R & D by major players
- Global Nanomaterials market is forecast to become a \$6.1 billion in 2016
 - Expected to grow at a CAGR of 23% during 2011-2016
 - Driven by health and personal care , energy and electrical and electronics application
 - Emerging applications include: field lamination display (FED), drug delivery and biofuels
- Healthcare and energy industry expected to surpass E&E in size over coming 2-3 years, driven by nanotechnology advancements in biomedical field and solar energy field



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Nanomaterials: Definition



Nanomaterials are 1000's time smaller than human hair

Nanomaterials are multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometers (nm)
In this report nanomaterials which are 2 or 3

dimensions less than 100 nm are included for study

| Dimensions | Nanomaterials |
|-------------|--|
| 3 dimension | Particles, quantum dots, hollow spheres, etc |
| 2 dimension | Tubes, wires, platelets, etc |
| 1 dimension | Films, coatings, multilayer, etc |



Types of nanomaterials







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Nanomaterials road map

| | 2004 | 200 | 8 2012 | 2016 | 2020 |
|------------------|------|-------|----------------------------|-------------------|--------------|
| Nanoclay | | | | | |
| Carbon Nanotube | | | | | |
| Metal Nanopowder | | | | | |
| Quantum Dots | | | | | |
| Fullerenes | | | | | |
| Dendrimers | | | | | |
| Graphenes | | | | | |
| | | Note: | Industrial Demonstrator | Industrialization | Market Entry |
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Applications of Nanoclay and Carbon Nanotubes



Use in bottling of O2 and CO2 sensitive products (beer and cold drink bottles)



Use in food and packaging industries



Use in motor compartment of vehicle for casting and connectors



Use in wire and cable applications

Carbon Nanotubes

Nanoclay



Timing belt covers in automotive



Scratch resistant coatings in automotive and aircraft frame & body



EMI/RFI shielding & coatings in electronic devices to control radiation



CMP slurries in electronic chips and wafers to enhance conductivity



Diagnostics and imaging in healthcare to enhance clarity in X-ray films



Current and Potential Applications



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Current and Potential Applications



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Cost and property analysis of nanomaterials with respect to other materials

| Materials | Strength | Modulus | Price Competi tiveness | Weight | Surface Area | Wear Resistance | Barrier Property | Electrical Conductivity |
|------------------------------------|----------|---------|------------------------------|------------|-----------------|--------------------|---------------------|----------------------------|
| Nanomateri als | | | \bigcirc | \bigcirc | \bigcirc | | | |
| Ceramic | | | | | | | | |
| Kevlar (Aramid) | • | | | | | • | | |
| Glass Fibers | | | | | | \bigcirc | | |
| Carbon Fibers | • | • | | | | | | |
| High I Medium Low-Medium Low Least | | | | | | | | |
| Key Insights | | | | | | | | |

Nanomaterials have highest strength, modulus, wear resistance, barrier properties and electrical conductivity relative to other materials



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Geographical breakdown for nanomaterials

Global nanomaterials distribution (\$ mil) by regions in 2010



Key Insights

- North America and Europe were the two largest markets for nanomaterials in 2010
- European region has significant use of nanomaterials in pharmaceuticals, as many pharmaceutical companies are based in Europe
- Good growth of nanomaterials was witnessed in Asia region during last 5 years due to:
 - Government support
 - Continued environmental consciousness
 - Expected increase in demand for specialty materials



Nanomaterials Market: Trend and Forecast



Electrical & Electronics (E&E) market witnessed a robust growth due to large price decrease of carbon nanotubes and increase in mass production of nanomaterials

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Packaging

Transportation

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Energy Storage

Devices

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Health care industry is expected to gain market share and overtake E & E segment in size over next five years

Growth opportunities for nanomaterials in various applications -lealth care Energy storage CAGR (2011-2016) **Electrical 8** Electronic Transportation Construction

Market Size (US\$ M)

Key Insights

- Nanomaterials have great potential in electrical and electronics applications because of their extraordinary electrical conductivity
- Global recession induced cost/price sensitivity in E & E segment, given its potential to reduce manufacturing costs and increase product competitiveness
- Packaging is another important segment, mainly flourishing in North America and Western Europe
- Energy segment is expected to pick up a nice pace in coming years @ double digit growth rate



Emerging trends in global nanomaterials and nanocomposite industry



Growing demand for high strength, durable materials will create good future opportunities for nanocomposites



New material development and product design



Nanoledge Inc. developed prepreg containing nanotubes

- Nanotubes used to boost mechanical properties
- Developed for experimental use in boat hull



New Piranha using Zyvex Nanomaterials

 Reduced weight while greatly increasing payload and cruising range



Harbor Composites designed nanotube aircraft

 Impart additional strength and durability to ordinary composites and make them even more appealing



Velozzi's Supercar will use nanotube composites - structural parts

• Objective to improve properties and reduce weight



Technical developments in CNT promise further capacity expansion and price reduction

Trend in percentage fall in multiwall carbon nanomaterial cost: 2005-2010



Key Insights

•CNT prices have fallen substantially, from more than \$150 per gram in 2000 to under \$50 per gram today (2010)

•Improved manufacturing and largescale production by CVD process enabled the drop in price

•Current technical developments in carbon nanotube fabrication may encourage further increase in production capacity and reduction in prices





Recent raw material production expansion plans are indicative of strong demand in the sector



Arkema Group

- Fulcrum SP Materials & Arkema to jointly produce improved damage resistant nanocomposites
- Capacity expansion for CNT production in 2011



Showa Denko K.K.

- Developed VGCFTM-X, a new grade of CNT for resin composite design
- Began construction of 400 ton/yr plant in 2009 at Oita



Bayer AG

- Opened a large carbon nanotube (CNT) pilot facility in Leverkusen, boasting annual capacity by 200 tons
- Invested €22 million in the operation located at Chempark in Leverkusen



Government funding for Nanotechnology in USD M \$ (2005-2009)



Growing nanotechnology market will boost the growth of nanocomposites

Key Insights

- In past 5 years, a huge amount has been invested in nanotechnology R&D by US
 and European countries
- Japan Japan has shown strong interest in nanotechnology development, spending
 ~\$1 B in nanotechnology R&D in 2010
 - Global expenditures for nanotechnology
 R&D expected to grow @ ~23% until
 2016



Growing uses of nancomposites in transportation industry will create huge demand in future

Nanostructured polymer composites for transparent Tragholme

Nanoflakes for SMC used in larger structures body molding Nano-structured Mg sheet and extrusions for light weight hang-on parts

> Nanoparticles for wear resistant tires; adherent long running tires

Scratch resistant paints Nanostructure control of multi-material welds

Nano- enabled LED lights



Potential Applications of Nanocomposites in Aircraft, though market remains nascent due to certification and overall slow adoption

Special coatings / adhesives with self repair mechanisms Carbon nanotubes for improved mechanical, electrical and thermal properties (resin, adhesives) Nanofillers for PIEZO-paints, coatings, and fibers

Micro-particlereinforced

> Nano-clay CFRP for barrier upgrading

Metal-Ceramic nanostructured bulk composites



Huge potential of nanomaterials in future power trains





Emerging applications for nanomaterials

| Application | Description | Size of Opportunity | Key Drivers |
|---------------------------------|--|------------------------|---|
| Field Emission Display (FED) | The CNT is used as light emitter in FED | Large | High luminance, high contrast, high light efficiency, wide view angle |
| Body Armors | Can be used for defense and military purpose for protection of body | Medium | Greater safety, light weight and skid resistance |
| Water Purification | Used as antimicrobial agent | Medium | Light weight porous materials for water filtration, enhanced performance for purification |



Emerging applications for nanomaterials

continued.....

| Application | Description | Size of Opportunity | Key Drivers |
|------------------------|--|------------------------|---|
| Drug Delivery | Used for improving the treatment of cancer | Medium | Enhanced mechanism for treating the infected cells like cancerous cell |
| Bio Fuel Cell | Can be used as electrodes in bio fuel cell | Medium to Large | High enzyme loading, Over comes limitation of small dimensions and large specific surface area |
| Wind Turbine Blades | Carbon nanotubes can be used to make larger and lighter rotor blades, thereby sustainably optimizing energy generation. | Medium to Large | Light weight High strength |
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Conclusions

- The nanomaterials market is expected to grow at about 23% annual rate until 2016
- Top 6 players have secured two-thirds of global nanomaterials market shipments; high opportunity for new players to enter this growth market
- Decline in demand in 2009 for nano-enabled products in the automotive industry, such as automotive lubricants, catalytic converters, sensors and filters, among others, drove the heavy downturn in market opportunities for nanomaterials such as multi-wall carbon nanotubes (MWNTs) and ceramic nanoparticles
- Health care and energy markets were two main application areas which helped the global nanomaterial industry recover from downturn experienced in 2009
- Healthcare industry is expected to surpass the electronic and electric industry in size over the coming 2-3 years, driven by nanotechnology advancements in biomedical field
- North America will remain the market leading region for several years as it has significant ongoing R & D activities in nanomaterials
- It is expected that nanomaterials will broaden their markets as they enter into more applications such as drug delivery, armor, defense equipment, weapons, nanomedicines and the like

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- Lucintel is the <u>leading global management consulting & market</u> <u>research firm</u> for aerospace, marine, energy, construction, consumer goods, transportation, chemical, and composites industries.
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- Visit <u>http://www.lucintel.com/imovie/</u> for a short 3.5-minute movie on Lucintel solutions.

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Key Questions

- Is market space / opportunity of current product offerings sufficiently robust?
- Markets are focus for many: how can my company profitably differentiate?
- Based on our core skills, where should we focus?
- Should we build or buy? Is build even an option?
- What game changer actions exist and/or is a more incremental approach best?
- What is the order sequence of market entry segments / products?

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