Global Nanomaterials Opportunity and Emerging Trends

Lucintel Brief

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Executive Summary

Nanomaterials Overview

Nanomaterials Competitiveness

Market Trends and Opportunity

Growth Opportunities in 2011 and Beyond

Conclusions

About Lucintel
Executive Summary

- Global nanomaterials industry reached $1.7 B in 2010, with an average annual growth rate of 10.4% over last five years.
- 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
- By 2016, nanomaterials market is expected to reach $ 5.8 B (23% CAGR), boosted by increasing use in health care and energy storage industry.
- High potential applications for nanomaterials in next 5 years are: field lamination display (FED), drug delivery and biofuels.
- Companies with innovation capability will sustain and gain market share in future.
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Applications of Nanoclay and Carbon Nanotubes

Nanoclay
- 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
- Timing belt covers in automotive
- Scratch resistant coatings in automotive and aircraft frame & body

Carbon Nanotubes
- 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
- Use in bottling of O2 and CO2 sensitive products (beer and cold drink bottles)
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Creating the Equation for Growth
## Current and Potential Applications

<table>
<thead>
<tr>
<th>Transportation</th>
<th>Construction</th>
<th>Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine &amp; Fuel Systems</td>
<td>Conductive Flooring</td>
<td>Meat &amp; Food Packaging</td>
</tr>
<tr>
<td>Scratch Resistant Exterior Parts and Coatings</td>
<td>Pipes</td>
<td>Computers &amp; Electronics</td>
</tr>
<tr>
<td>Car Interior</td>
<td>Insulating Materials for Roofs &amp; Thatches</td>
<td>Medicines &amp; Pharmaceuticals</td>
</tr>
<tr>
<td>Aircraft Structure &amp; Framing</td>
<td>House &amp; Building Siding</td>
<td>Beer Bottles</td>
</tr>
<tr>
<td>Wear Resistant Paints &amp; Coatings for Defense Vehicles</td>
<td>Self Cleaning Windows</td>
<td></td>
</tr>
</tbody>
</table>

Creating the Equation for Growth
### Current and Potential Applications

<table>
<thead>
<tr>
<th>Consumer Goods</th>
<th>Electrical &amp; Electronics</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home appliances</td>
<td>Sensors</td>
<td>Anti-foul coatings for marine ships</td>
</tr>
<tr>
<td>Sporting goods &amp; toys</td>
<td>Semiconductors</td>
<td>Industrial equipment to increase strength</td>
</tr>
<tr>
<td>Furniture &amp; others</td>
<td>Hard disk storage in computers</td>
<td>Fire resistant clothes</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td></td>
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<tr>
<td>Battery electrodes</td>
<td>Body implants</td>
<td></td>
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<tr>
<td>Fuel cell membranes</td>
<td>Medical devices</td>
<td></td>
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<tr>
<td>Supercapacitors</td>
<td>Dental filling materials</td>
<td></td>
</tr>
<tr>
<td><strong>Health Care</strong></td>
<td></td>
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</tr>
</tbody>
</table>

**Others**
- Anti-foul coatings for marine ships
- Industrial equipment to increase strength
- Fire resistant clothes
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## Cost and property analysis of nanomaterials with respect to other materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Strength</th>
<th>Modulus</th>
<th>Price</th>
<th>Weight</th>
<th>Surface Area</th>
<th>Wear Resistance</th>
<th>Barrier Property</th>
<th>Electrical Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanomaterials</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Ceramic</td>
<td>●</td>
<td>●</td>
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<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Kevlar (Aramid)</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Glass Fibers</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Carbon Fibers</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

### Key Insights

- Nanomaterials have the highest strength, modulus, wear resistance, barrier property and electrical conductivity when compared with other materials.
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External forces shaping the Nanomaterials industry: Future innovations in this space will drive the growth of nanomaterials

- Global platforms
- Technical service
- Partnership
- Application development
- High perceived value
- Awareness

- Material specialization
- Processed raw materials

- Environmental & human safety regulations
- Govt. subsidy

- Competition from emerging economies
- Consolidation
- Non-traditional/new entrants
- Focus/specialization

- R&D and Innovation to reduce cost
- Cost effective technology
- Process improvement
- Quality control
- Capital

- Technical Service
- Specialization
- Efficiency
- Value-added
- Marketing

- Skills
- Location

- Global recession
- Political instability

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Creating the Equation for Growth
Global nanomaterials distribution ($ mil) by regions in 2010

- 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

Drivers For Nanomaterials Investment
- Emerging Applications: It is expected that nanomaterials to be extensively used in emerging applications like water treatment, drug delivery, nanomedicines, etc.
- Price: Decrease in price of nanomaterials may take place due to advanced production techniques.
- Patents: The number of patents regarding manufacturing of nanomaterials is increasing year after year.

Top 3 Market Segments Region wise:
- North America: E&E, Health & Personal Care, Energy Storage Devices
- Europe: Health & Personal Care, E&E, Transportation
- RoW: E&E, Transportation, Packaging

Trend and forecast in nanomaterials shipment ($ B): 2005-2016

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

Creating the Equation for Growth
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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:

- Health care
- Energy storage
- Electrical & Electronic
- Transportation
- Construction

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 the Global Nanocomposites Industry

**Trend A**
- Growing demand for high strength, durable structural materials

**Trend B**
- New material development and product design

**Trend C**
- New and emerging market applications

**Trend D**
- Falling nanocomposites prices

**Trend E**
- Huge expansion by existing suppliers and new entrants

**Trend F**
- Government support and R&D funding
Growing demand for high strength, durable materials will create good future opportunities for nanocomposites.

Properties | Carbon/Aramid / Glass fibers | Carbon nanotubes /nanoplatelets
--- | --- | ---
Strength | | 🌒
Weight | 🌒 | ⬜
Impact Resistance | 🌒 | 🌒
Brittleness | 🌒 | 🌒

- Very high
- High
- Medium
- Low/ NA

New and exciting uses for nanotubes:
- Aircraft wings and fuselages
- Boat hulls
- Sports cars
- Baseball bats, hockey sticks, and skis
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

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 large-scale 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

Global leaders increasing manufacturing capacity

**Arkema**

- Arkema has scheduled a production facility for carbon nanotubes with the capacity of 400 tons per year to start in 2011 in France

**Bayer**

- Bayer Material Science opened a carbon nanotube pilot facility in Germany, boosting annual capacity by 200 tons
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)

Key Insights

- In past 5 years, a huge amount has been invested in nanotechnology R&D by the USA and European countries
- Japan shows a considerable inclination towards nanotechnology development, spending ~$1 B in nanotechnology R&D in 2010
- Global expenditures for nanotechnology R&D expected to grow @ ~23% until 2016

Growing nanotechnology market will boost the growth of nanocomposites

Global nanotechnology market is approximately $16 billion in 2010, and is expected to grow by 11.5% average annual growth rate until 2015
Government funding for nanotechnology is promoting R&D and driving growth in nanocomposites production

In several countries, governments are running nano-programs to promote nanotechnology

<table>
<thead>
<tr>
<th>Country</th>
<th>Nano-program</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>Nano 2012</td>
<td>To develop technology to design and produce the next generation of integrated circuits</td>
</tr>
<tr>
<td>Germany</td>
<td>Nano Initiative Action Plan</td>
<td>Improve the interface between research and implementation, and to open up new markets</td>
</tr>
<tr>
<td>Finland</td>
<td>FinNano</td>
<td>Allocated fund of approx $95 M for research and innovation (2005-2010)</td>
</tr>
<tr>
<td>Norway</td>
<td>NANOMAT</td>
<td>To develop world leading research to provide a basis for innovation and growth, and to promote commercialization (budget approx $100 M for 2002-2016)</td>
</tr>
</tbody>
</table>
Growing uses of nanocomposites in transportation industry will create huge demand in future

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

- 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-particle-reinforced
- Nano-clay CFRP for barrier upgrading
- Metal-Ceramic nanostructured bulk composites
Huge Potential of Nanocomposites in Future Power Trains

- Nano-fibers and channels for fuel injection
- Corrosion resistant paints & coatings
- Nano-scale material for catalytic converters
- Nanopore fuel & oil filter
- Polymer nanocomposite sensors
- High density & power nanocomposites
- Nanocomposite based hydrogen storage
- Nano-enabled batteries
## Emerging applications for nanomaterials

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Size of Opportunity</th>
<th>Key Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Emission Display (FED)</td>
<td>CNT is used as light emitter in FED</td>
<td>Large</td>
<td>High luminance, high contrast, high light efficiency, wide view angle</td>
</tr>
<tr>
<td>Body Armor</td>
<td>Can be used for defense and military purpose for protection of body</td>
<td>Medium</td>
<td>Greater safety, light weight and skid resistance</td>
</tr>
<tr>
<td>Water Purification</td>
<td>Used as antimicrobial agent</td>
<td>Medium</td>
<td>Light weight porous materials for water filtration, enhanced performance for purification</td>
</tr>
</tbody>
</table>
### Emerging applications for nanomaterials: Cont....

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Size of Opportunity</th>
<th>Key Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug Delivery</td>
<td>Used for improving the treatment of cancer</td>
<td>Medium</td>
<td>Enhanced mechanism for treating the infected cells</td>
</tr>
<tr>
<td>Bio Fuel Cell</td>
<td>Can be used as electrodes in bio fuel cell</td>
<td>Medium to Large</td>
<td>High enzyme loading, overcomes limitation of small dimensions and large specific surface area</td>
</tr>
</tbody>
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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 the heavy downturn experienced in 2009.
• The 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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About Lucintel

- Lucintel is the leading global management consulting & market research firm for aerospace, marine, energy, construction, consumer goods, transportation, chemical, and composites industries.

- Lucintel creates your equation for growth and is committed to actionable results that deliver significant value and long term growth to our clients.

- Lucintel has been creating measurable value for over 10 years and for more than 1000 clients in 70 + countries worldwide.

Lucintel has an extensive toolkit to address key strategic questions for increasing your company’s profitability and market presence.

**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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