

March 2013

**NanoSurveillance:
Commonly Used Engineered
Nanomaterials in the United States
A Market Landscape Analysis**

Final Report

Prepared for

Charles Geraci

Nanotechnology Research Center
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Executive Summary

Nanotechnology is widely portrayed as a critical driver of future economic growth and as a means to solving some of humanity's most vexing challenges. Because of its incredibly broad range of prospective uses, nanotechnology has the potential to impact virtually every industry, from aerospace and energy to healthcare and agriculture. The Woodrow Wilson and nanowerk.com inventories of nanotechnology-based products currently list 350-1,300 consumer products, produced by 580-2,300 companies located in an estimated 32 countries. While nanotechnology has the potential to create entirely new industries and products, there are uncertainties surrounding the impact of these novel materials on workers and consumers who are exposed in different scenarios. In successive governmental and academic reviews, the need to understand the hazards of nanomaterials has been emphasized, and a large number of scientific publications have reported the results of investigations of the potential toxicity of nanomaterials in many different systems, with a range of outcomes.

The purpose of this task order was to provide a preliminary market summary based on available literature and web sites. RTI International reviewed existing information and summarized it for NIOSH. Among the specific tasks in this order, RTI aimed to identify the commercial manufacturers and distributors of commonly used engineered nanomaterials in the United States. In this analyses, specific information (i.e. location by U.S. state or foreign country, CEO contact information, and number of workers) on the engineered nanomaterials identified as immediate NIOSH interest was included. Information from university, nonprofit, and federal agency research and development was not included as part of this market landscape analysis (e.g. non-commercial was excluded).

NanoSurveillance: A Market Landscape Analysis

1.1 Methodology

For the purposes for this task order, the following definition for “engineered nanomaterials” was used: raw material or formulated products that are on the commercial market today with improved functionality using some form of nanotechnology enabled material. The following classical “nanotechnology” definition was used as the basis for this task order: the study or control of materials at length scales below 100 nm where size restrictions enabled novel phenomena.

The following process was used to complete this project titled, “NanoSurveillance: Commonly Used Engineered Nanomaterials in the United States”.

1. Draft list of most commonly used nanomaterials
2. Consult with NIOSH to prioritize nanomaterials
3. Conduct a market landscape analyses using secondary market research on the prioritized nanomaterials
4. List high volume producers and users of nanomaterials
5. Estimate the number of workers involved
6. Forecast future market trends and recommend additional research of interest to NIOSH

1.2 Initial Remarks

The need to understand the hazards of nanomaterials has been emphasized, and a large number of scientific publications have reported the results of investigations of the potential toxicity of nanomaterials in many different systems, with a range of outcomes. Key to understanding the potential hazards are first an identification of the material chemistries, quantities produced, and locations of manufacturing and uses of such materials. While the nanotechnology industry is a global enterprise, the focus of this market landscape was on manufacturers of raw nanomaterials in the United States. There are approximately 10 different mass-produced engineered nanomaterials (i.e. greater than 1,000 tons produced on a yearly basis). “Mass production” is a term typically used to describe processes that are largely automated, and thus capital intensive. The economies of scale, logistics of material volume, and the market dictate when demand is worth the capital investment. The definition of mass production used here is at least 1,000 tons of nanomaterials produced, chosen because the production methods for these materials are primarily automated, and the volume (which translates roughly into 10-100 train cars depending on density) requires significantly greater complexity to manage. As the nanomaterial market grows in size, we anticipate the definition of mass production to shift to larger numbers to reflect commodity-like quantities. Well over a hundred other engineered nanomaterials are produced commercially at smaller scale or for research purposes at laboratory scale. Of the host of engineered nanomaterials currently produced commercially, the materials of most interest to NIOSH, selected for this project, were graphene,

1. NanoSurveillance

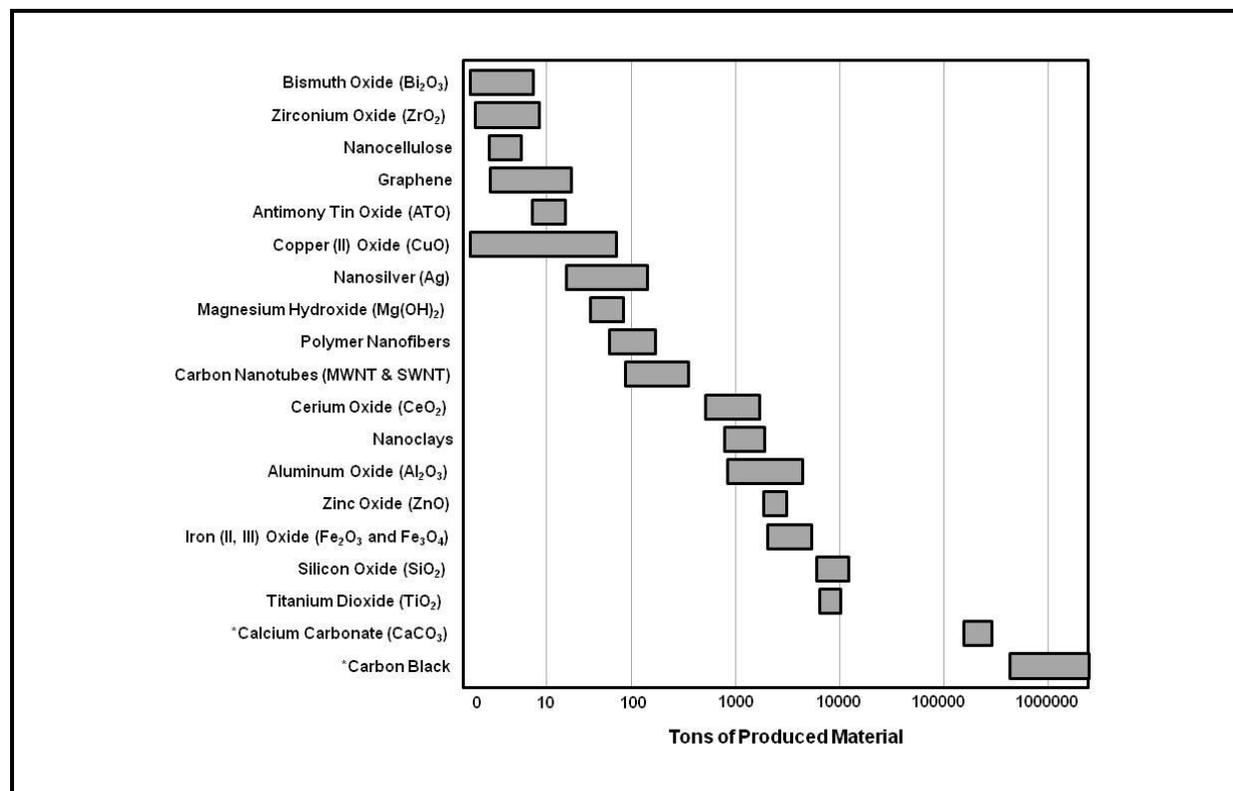
cellulose, silver, and titanium dioxide (TiO₂) – of which only TiO₂ is currently mass-produced globally. All four of these focal nanomaterials, identified by NIOSH as prioritized nanomaterials, are utilized in industry as both nanometer-sized particles and micrometer-sized materials. Manufacturers range from small companies with a single material focus to large multi-national, multi-product enterprises.

1.3 Commonly Produced and Used Nanomaterials

An initial estimated volume of produced engineered materials is indicated in the graph below. The y-axis lists the material-types and the x-axis denotes the quantity of material produced globally in units of tons. Note that the x-axis is a logarithmic scale. While these estimates reflect the volumes of nanomaterials produced globally, the country that has the largest contribution of production volume is the U.S.

The production and use numbers for all nanomaterials were verified by using at least two sources of information (typically market reports, supplemented by SEC filings and company websites) that relied on primary market research. While we did not directly do primary research (direct conversation with companies) for budgetary reasons, we focused on sources that used primary research within the past 2 years to be as accurate as possible. Thus, our report is limited by the validity of this secondary information.

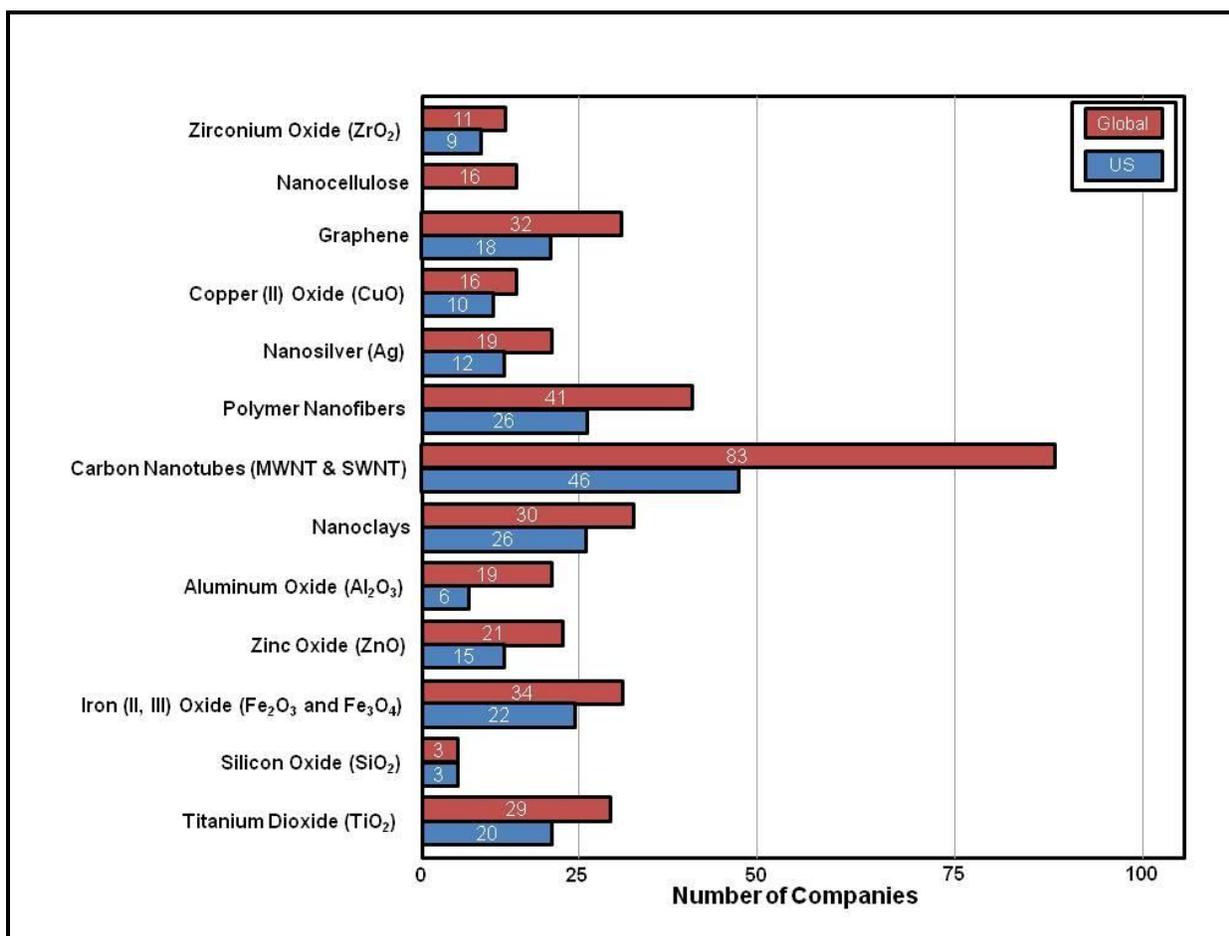
Figure 1-1. Commonly Produced and Used Nanomaterials



1.4 Commonly Produced and Used Nanomaterials in the U.S. and Global Markets

The graphic below portrays our preliminary findings on the number of companies that directly manufacture nanomaterials, broken out by material type. This does not include companies that purchase nanomaterials and subsequently incorporate them into intermediate components (e.g. inks, composite, films) or final products.

Figure 1-2. Commonly Produced and Used Nanomaterials in the U.S. and Global Markets.



1.5 Prioritized Engineered Nanomaterials

1.5.1 Nanocellulose

Cellulose is a fibrous, tough, water-soluble substance that is usually found in the protective cell wall of plants. It is extremely abundant on earth; however, it is only recently that cellulose has been utilized as a nanostructured material. The term used to designate cellulose on the nanometer size scale is nanocellulose.

Obtained by separating the fibers found in a variety of plant-based materials, nanocellulose has a high strength and modulus. In addition, it possesses a high thermal stability and is lightweight. Among its highly desirable optical properties, nanocellulose is transparent and has a high water binding capability. Due to its high aspect ratios and surface areas, nanocellulose is easily chemically functionalized and is relatively stable. In addition to its natural abundance, nanocellulose is quickly gaining attention within the “green chemistry” community due to its renewable, biodegradable, and biocompatible properties. This set of characteristics has triggered a profound interest in the application of nanocellulose to different sectors of the industry. The markets with the highest demand for nanocellulose are: cosmetics, paper coatings and packaging, medicine and pharmaceuticals, filtration, and thickening agents. In 2011, the first pilot plant for the production of nanocellulose was opened in Canada. This plant is able to produce nanocellulose at large scale, which will propel the industrialization of this technology. The availability will enable the use of nanocellulose in applications that demand significant amounts of material. Nanocellulose is produced at a rate of 3-6 tons produced per year, globally.

Figure 1-3. Images of nanocellulose production facility, nanocellulose raw material, and scanning electron micrograph image of cellulose fibers on the nanometer size scale (left to right).

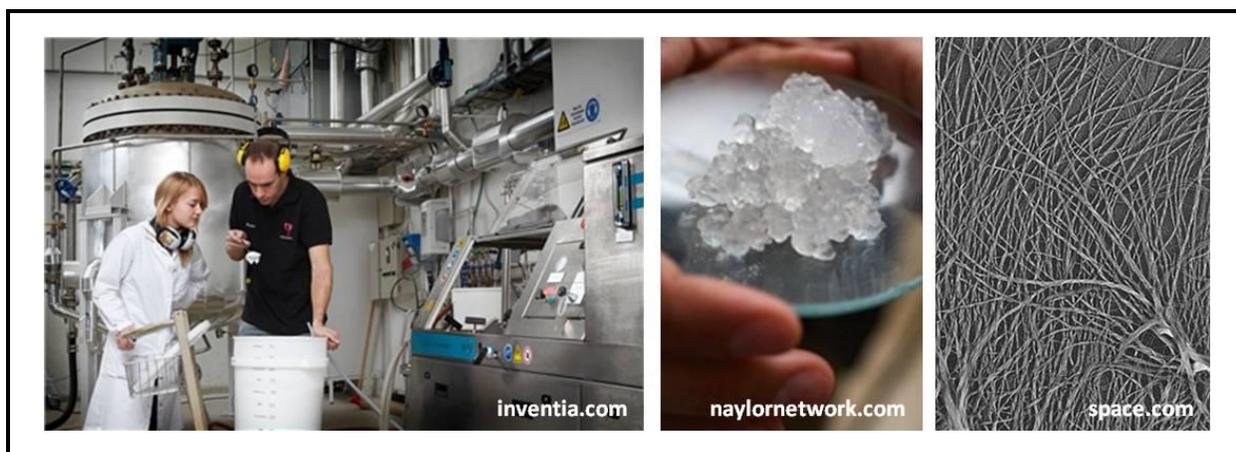


Table 1-1. The dominant manufacturers, distributors, and users of nanocellulose.

Manufacturer	Distributor	Dominant Users
Total companies surveyed: 18	Highly limited -initially same as the manufacturers	Industries: Composites Paper
Still heavily research-driven: plants newly opened or under construction to produce multiple tons/day	Sales channels TBD as plants come online	Filtration Coatings and Packaging Medicine
Companies include: Borregaard, Daicel Chemical, Green Core Composites	Companies include: Biovision technology, EMPA, Arboranano, Alberta Innovates-Technology, Melodea	Companies include: UPM-Kymmene, Jenpolymers
Companies involved in manufacturing and distributing: Rettenmaier, cellucomp, Celluforce, Finnish Centre for Nanocellulose Tech, Nanocellulose, FP Innovations, Innventia		

1.5.2 Nanosilver

Bulk silver has been used for thousands of years in a variety of applications. Most notably is its use as a biocide agent. In this particular application, it is thought that silver acts as a catalyst, disabling the enzyme that microbes (such as bacteria and viruses) need for oxygen intake without causing any damage to the human tissue. By extension, silver nanoparticles (a.k.a. nanosilver) are known to modulate cytokines involved in wound healing, giving them anti-inflammatory properties. This nanomaterial, which is particularly effective at absorbing and scattering light, has a color that depends upon the size and the shape of the primary particle. A decrease in size is associated with a red-shift and broadening of the plasmon-related absorption peak as well as their ability to enhance fluorescence.

Due to its interesting properties and the availability of various efficient synthesis methods, there has been a wave of commercially available silver nanoparticles and silver nano-enabled products. This widespread use has caused this material to be targeted as the main source of public exposure to nanomaterials and its possible side effects. As a result, special attention is being focused on its regulation. However, it may ultimately be receiving too much emphasize because, in reality, the number of potential workers and consumers exposed to nanosilver is minimal to date. In the near future, the production of silver nanoparticles is not predicted to increase considerably, but industry sectors such as cosmetics, medical, textiles, paints, pigments and coating, packaging and electronics can be predicted to continue to use silver – nano-sized or otherwise. Nanosilver is produced at a rate of 12-110 tons produced per year, domestically.

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Figure 1-4. Images of nanosilver production facility, nanosilver raw material, and transmission electron micrograph image of particles on the nanometer size scale (left to right).



Table 1-2. The dominant manufacturers, distributors, and users of nanosilver.

Manufacturer	Distributor	Dominant Users
Total US companies surveyed: 10	Predominately same as the manufacturers	Industries: Medical Coatings Textiles Packaging Biocide Anti-bacterial Anti-fungal Anti-viral Electronics
Most nanosilver producers also produce other nanopowder materials	Some large-scale distributors used	
Form factors: powder, colloid dispersion	A few formulate into inks, coatings or threads and resell	
Companies include: QuantumSphere, Inc.	Companies include: Novacentrix, Sigma-Aldrich, Ferro Corp, Sciessent	
Companies involved in manufacturing and distributing: Inframat, Nanocomposix, Dots UT Inc, Ocean Nanotech, Skyspring Nanomaterials		

1.5.3 Nano Titanium Dioxide

Titanium dioxide is one of the most abundant elements on the earth's crust and is the primary metal in minerals such as rutile and ilmenite. These minerals are particularly abundant in Australia and South Africa and are mined for use in the chemical industry. Upon mining, rutile and ilmenite go through extensive treatments to extract titanium dioxide and produce nanometer or micrometer sized powders. Nano titanium dioxide generally measures less than 100 nm, possesses excellent light scattering properties, and is photocatalytic at certain wavelengths. In addition, this nanomaterial can have its properties optimized based on various steps during the manufacturing process, which has already been exploited by different industry sectors.

At present, the major applications of this nanomaterial are in the cosmetics, pigments, paints, and coatings. Due to its light scattering properties, nano titanium dioxide has mainly been used to provide UV protection in cosmetics, food packaging, and clothing. However, due to these products' close proximity with the human body, the public has raised some concern for the potential secondary effect that the use of this nanomaterial might pose. Another major application for titanium dioxide has been as a catalyst. Nano titanium absorbs has been used to catalyze chemical reactions that degrade undesirable chemicals or microorganisms. Currently, this technology is available in the form of self-cleaning coatings and solutions and hair styling devices. Production of nano titanium dioxide is projected to have a mild increase through 2016. Additional markets may include plastics, energy, and environment cleaning. Nano titanium dioxide production occurs at a rate of 8,000-15,000 tons produced per year, domestically.

The TDMA (Titanium dioxide manufacturers association) estimates that ultrafine TiO₂ (i.e. < 100 nm) is about 1% of total TiO₂ production, and is produced in the same manufacturing facility as the larger pigmentary grade. They report ~15,000 tons produced in Europe (from a total 1.5 MM tons TiO₂). Total TiO₂ production in the United States is an estimated 1.45 million metric tons per year in 2007. There are only a handful of producers of TiO₂. These include DuPont ((DD), 20% share), Cristal (privately held, 13% share), Kronos ((KRO), 10% share), and Huntsman (HUN) and Tronox with around 8-9% market share each. Manufacturers in China make up 21% of the total market share.

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Figure 1-5. Images of nano titanium dioxide production facility, nano titanium dioxide raw material, and scanning electron micrograph image of particles on the nanometer size scale (left to right).



Table 1-3. The dominant manufacturers, distributors, and users of nano titanium dioxide.

Manufacturer	Distributor	Dominant Users
Total US companies surveyed: 16	Mixed supply chain with integrated firms and third parties	Industries: Sunscreen Food safety Catalysis Self-cleaning coatings Water treatment
Many nano-TiO ₂ producers are \$ billion multi-nationals	International nano-TiO ₂ producers sell into the US through distributors	
Typically manufactured as a powder	A few third party distributors formulate into dispersions	
Companies include: E I Du Pont De Nemours and Company, Tronox Inc	Companies include: Mach I, Sigma-Aldrich, Reade International, Ishihara Corporation, Showa Denko America	
Companies involved in manufacturing and distributing: Meliorum Technologies, Nanostructured & Amorphous Materials, Evonik Degussa Corp, Inframat Corp, SkySpring Nanomaterials, Nanoscale Corp, Nano-Oxides, Strem Chemicals, Kronos Worldwide		

1.5.4 Graphene

In 2004, Geim, with his colleagues, succeeded in isolating graphene flakes from highly oriented pyrolytic graphite (HOPG) by repeatedly applying and peeling off scotch-tape. Graphene is made of pure carbon, with atoms arranged in a regular hexagonal pattern and in a flat one-atom thick sheet. It possesses a high room temperature mobility and electrical and thermal conductivity. Furthermore, it displays high strength and curability for current density, high surface/weight ratio, and high light transparency. All of these characteristics make it very appealing to various industry sectors such as electronics, energy, aerospace, automotive, communications, sensors and composites.

Graphene is being considered a major breakthrough in carbon-based nanoelectronics. At present, it is in the electronics and data storage sectors. Research is focusing on platforms for the next generation

of microchips, biological sensors, and solar energy cells among others. In addition, there is the potential for graphene to replace carbon nanotubes in the composite sector.

Even though the production of graphene is expected to double by 2016, the market segmentation is not likely to change. The current expectation is that the major markets involved are electronics and composites. Graphene is produced at a rate of 3-12 tons produced per year, domestically.

Figure 1-6. Images of graphene production facility, graphene raw material, and scanning electron micrograph image of particles on the nanometer size scale (left to right).



Table 1-4. The dominant manufacturers, distributors, and users of nano graphene.

Manufacturer	Distributor	Dominant Users
Total U.S. companies surveyed: 18	Predominantly same as the manufacturers	Industries: Electronics High electrical conductivity and mobility Composites High Strength Improved dispersion
Dominated by small businesses, producing <10 tons per year	Sales occurring through individual company websites	
Companies include: Vorbeck Materials Corporation, Nanointegris, Inc., Angstrom Materials, Graphene Works, Inc., Graphene Frontiers	Companies include: Graphene Devices, Ltd., Graphene Energy, Inc., Cheaptubes, Nanospere	Companies include: IBM, Intel
Companies involved in manufacturing and distributing: HRL Laboratories, LLC, Graphene laboratories, XG Sciences, Xolve, CVD Equipment Corp, Nanotek Instruments		

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1.6 List of the High Volume Producers or Distributors of the Engineered Nanomaterials

The tables below summarize the main global producers of the four nanomaterials of interest: graphene, cellulose, silver, and titanium dioxide. The lists of global producers are separated into domestic and international tables. The domestic tables include company name, country and state, CEO, company address and phone number, website, estimated number of employees, and estimated annual revenue. The international tables include company name, country, CEO, company address and phone number, and website.

Table 1-5. High Volume Producers of Graphene: Domestic.

Company name	Country	US State	CEO	Address	url	# of Employees ¹	Revenue (in millions)
Angstrom Materials	USA	OH	Meishio Jang & Bor Jang	1240 McCook Ave. Dayton, OH 45404 T: +1 9376727100	www.angstrommaterials.com	0-10	\$0.490
Cheaptubes, Inc.	USA	VT	Mike Foley	112 Mercury Drive Brattleboro, VT 05301 T: +1 8022546969	www.cheaptubesinc.com	0-10	\$0.300
CVD Equipment Corp	USA	NY	Leonard A. Rosenbaum	1860 Smithtown Avenue Ronkonkoma, NY 11779 T: +1 6319817081	www.CVDequipment.com	51-200	\$31
Graphene Devices, Ltd.	USA	NY	Robert Anstey	138 Chapel Woods Williamsville, NY 14221-1868 T: 716 560-1507	http://www.graphenedev.com	0-10	\$0.400
Graphene Energy, Inc.	USA	TX	Dileep Agnihotri	7217 McNeil Dr, Suite 108 Austin, TX 78729 T: +1 5127407941	www.grapheneenergy.net	0-10	\$0.950
Graphene Frontiers	USA	PA	Mike Patterson	3160 Chestnut Street Philadelphia, PA T: +1 2155738196	http://graphenefrontiers.com/	0-10	\$0.081
Graphene Laboratories, Inc.	USA	NY	Elena Polyakova	79 Richmond Blvd Unit 1-A Ronkonkoma, NY, 11779 T: +1 5163828649	www.graphenelab.com	0-10	\$0.360
Graphene Works, Inc.	USA	GA	Walt de Heer	508 Claire Dr NE Atlanta, GA 30307 T: +1 678439 935	www.grapheneworks.com	0-10	\$0.310
HRL Laboratories, LLC	USA	CA	Art N Chester	3011 Malibu Canyon Road Malibu, CA 90265-4797 T: +1 3103175000	www.hrl.com	201-500	\$35
Intel Corporation	USA	CA	Paul S. Otellini	2200 Mission College Blvd, Santa Clara, CA T:+1 4087658080	www.intel.com	10,000+	\$54,000
International Business Machines Corp (IBM)	USA	NY	Virginia Rometty	P.O. Box 218 Yorktown Heights, NY 10598	www.ibm.com	10,000+	\$107,000
Nanointegris, Inc.	USA	IL	Elliot Garlock	3603 Haven Avenue Suite A Menlo Park, CA 94025 T: 1 847 6790667	www.nanointegriss.com	0-10	\$0.450
Nanosperse LLC	USA	OH	Art Fritts	2000 Composite Drive Kettering, Ohio 45420 T: +1 9372965030	www.nanospere.com	0-10	\$1.4
Nanotek Instruments, Inc.	USA	OH	Bor Z. Jang	1240 McCook Ave. Dayton, OH 45404	www.nanotekinstruments.com	11-50	\$0.860

¹ The number of employees is the total number of employees in the entire company and not the specific number of workers potentially exposed to the nanomaterial. Information for this metric was obtained through individual company websites, SEC filings, and market reports.

Company name	Country	US State	CEO	Address	url	# of Employees ¹	Revenue (in millions)
				T: +1 9373319881			
Texas Instruments, Inc.	USA	TX	Richard (Rich) K. Templeton	12500 TI Boulevard Dallas, TX T: 972-995-2011	www.ti.com	10,000+	\$13,700
Vorbeck Materials Corporation	USA	MD	John S. Lettow	8306 Patuxent Range #105 Jessup, MD 20794 T: +1 3014979000	www.vorbeck.com	11-50	\$2
XG Sciences, Inc.	USA	MI	Michael R. Knox	5020 Northwind Dr #212 East Lansing, MI 48823 T: +1 5172031110	www.xgsciences.com	11-50	\$2.8
Xolve, Inc.	USA	WI	Daniel Colbert	PO Box 417 Platteville, WI 53818 T: +1 6082344627	www.solve.com	0-10	\$0.150

Table 1-6. High Volume Producers of Graphene: International.

Company name	Country	CEO	Address	url
Azonano	UK			http://www.azonano.com
BASF	Germany	Kurt Bock	Carl-Bosch-Str. 38. Ludwigshafen, 67063, Germany T: +49 6216078780	http://www.basf.com
Aixtron	Germany	Rüdiger Von Rosen	Kaiserstr. 98 Herzogenrath, 52134, Germany	http://www.aixtron.com
Angewandte Mikro-Und Optoelektronik GmbH	Germany	Dr. Christian Moormann	Otto-Blumenthal-Straße 25 Aachen, 52074, Germany. T: +49 241 8867200	http://www.amo.de
Carben Semicon Ltd.	Russia	Dr. Pavel Lazarev	Miusskaya pl. 9 bldg. 5 Moscow, 125047, Russia T: +7 4952519998	http://www.ribtan.com/main.html
CrayoNano	Norway	Morten Frøseth	Otto Nielsens vei 12 NO-Trondheim, 7052, Norway	http://crayonano.com
Durham Graphene Science Ltd.	UK	Karl Coleman (CTO) Bryan Dobson (Chairman)	Mountjoy Centre Maple Block Stockton Road Durham, DH1 3LE, UK T: +44 (0)191 3342116	http://www.durhamgraphene.com
Fujitsu Laboratories	Japan	Masami Yamamoto (President)	4-1-1 Kamikodanaka Nakahara-ku Kawasaki-shi Kanagawa, 211-8588, Japan	http://www.fujitsu.com
Granph Nanotech	Spain	Cesar Merino Sanchez	Ctra. Madrid-Irún km. 244,8 Burgos, E09007, Spain T: +34 947 47 77 00	http://www.granphnanotech.com
Graphene Industries Ltd.	UK	Professor Andre Geim	24 Ellerslie Court Upper Park Road Manchester, M14 5RH, UK	www.grapheneindustries.com/
Graphenea Nanomaterials	Spain	Jesus de La Fuente	76 E-20018 Donostia San Sebastián, Spain T: +34 943 57 40 53	http://www.graphenea.com
Harbin Mulan Foreign Economic Trade Co.	China		No.431, 45-2 Bldg. Red-flag Example New district Harbin, 150056 China T: +86 45182379878	www.sino-graphite.com
Haydale	UK	Ray Gibbs	ECM2 Heol Cefn Gwrgan Port Talbot, SA13 2EZ, UK	www.haydale.com
HDPlas	UK	Tim Irwin		http://www.hdplas.com
Quantum Materials Corp	India	Stephen Squires	#190, 2nd Floor, 9th Cross, HMT Layout, R.T. Bangalore ,560 032, India T: +91 80 4091 4091	http://www.quantum-materials.in
Samsung Electronics Co., Ltd	South Korea	Lee Kun-hee	1320-10, Seocho 2-dong, Seoul, 137-857, South Korea T: +82 222550114	http://www.samsung.com
Singhal Exports	India	Pratik Singhal	T-77, 3rd Floor, B Block, Sumel Business Park, O/s New Cloth Market, Gujarat, 380002, India	http://www.singhalnanotech.com

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Table 1-6. High Volume Producers of Graphene: International. (continued)

Company name	Country	CEO	Address	url
Xiamen Knano Graphene Technology Co., Ltd.	China	Mr. Liping Zhao (Chairman) Dr. Guohua Chen (Chief Scientist)	24C, Haiguang Building, No. 33 Shuixian Road Xiamen, 361001, China T: +86n592 2684582	http://www.knano.com.cn
XP Nano Material Co. Ltd.	China	Michael R. Knox	9H,Morning 9 Center, No.29,Houjiang Dai Road, Xiamen, 361004, China T: +86 5925601404	http://www.nanocnts.com

Table 1-7. High Volume Producers of Nanocellulose: International, only.

Company name	Country	CEO	Address	url
Alberta Innovates-Technology	Canada	Stephen Loughheed	250 Karl Clark Road Edmonton, AB T:+1 780-450-5111	http://www.albertatechfutures.ca/
ArboraNano	Canada	Dr. Ron Crotogino Dr. Nicole Poirier (co-Directors)	570 St-John Blvd. Pointe-Claire, QC H9R 3J9 Canada T: +1 (514) 630-4101	http://www.arboranano.ca/
BioVision Technology, Inc.	Canada	Anne Savage Franey	35 Peter St. New Minas, NS Canada B4N 3L7 T: +1-902-847-1367	http://www.biovisiontechnology.com/
Borregaard	Norway	Per A. Sørli	PO Box 162 1701 Sarpsborg Norway T: +47 69 11 80 00	http://www.borregaard.com/
Cellucomp Ltd.	UK	Christian Kemp-Griffin	Unit 3, West Dock, Harbour Place, Burntisland, Fife, Scotland KY3 9DW T: +44(0)15 9287 0335	http://www.cellucomp.com/
Celluforce	Canada	Jean Moreau, CA	625, Président-Kennedy avenue Office 1501 Montreal (Quebec) Canada H3A 1K2 T: +1 (514) 3601023	http://www.celluforce.com
Daicel Chemical Ltd.	Japan	Misao Fudaba	14th Floor, JR Shinagawa East Building, 2-18-1, Konan Minato-Ku Tokyo Japan 108-8230	http://www.daicel.com/
EMPA	Switzerland	Gian-Luca Bona	Ueberlandstrasse 129 CH-8600 Duebendorf Switzerland T: +41 58 765 11 11	http://www.empa.ch
Finnish Centre for Nanocellulosic Technologies	Finland	Erkki KM Leppävuori	P.O. Box 1000, FI-02044 VTT Finland T: +358 20 722 111	http://www.vtt.fi/index.jsp

Table 1-7. High Volume Producers of Nanocellulose: International, only. (continued)

Company name	Country	CEO	Address	url
FP Innovations	Canada	Pierre Lapointe	570 St-Jean Blvd. Pointe-Claire, QC H9R 3J9 Canada T: +1 514 630-4100	http://www.fpinnovations.ca
Green Core Composites	Canada	Geoff Clarke	642 King Street West #200 Toronto, Ontario, Canada M5V 1M7	http://greencorenfc.com/

			T: +1-855-255-5422	
Innventia AB	Sweden	Birgitta Sundblad	Drottning Kristinas väg 61, Stockholm Sweden T: +46-8-676 70 00	http://www.innventia.com/en/
Jenpolymers Ltd.	Germany	Elisabeth Klemm	Wildenbruchstrasse 15 07745 Jena Germany T: +49 3641 548 283	http://www.jenpolymer-materials.de/
Melodea	Israel	Lea Carmel Goren	The Hebrew University of JerUSAlem	http://melodea.eu/default.aspx
Nanocellulose	India	N. Vigneshwaran	CIRCOT, Adenwala Road Matunga Mumbai Maharashtra India	http://www.indianexporters.com/NANOCELLULOSE-com-555692588.html
Rettenmaier	Germany	Josef Otto Rettenmaier	73494 Rosenberg Germany T: +49(0)7967 152-0	http://www.jrs.de/wEnglisch/index.shtml
UPM-Kymmene Ltd.	Finland	Jussi Pesonen	Eteläesplanadi 2 P.O. Box 380 FI-00101 FI-00130 Helsinki Finland T: +358 (0)204 15 111	http://www.upm.com/en/Pages/default.aspx

Table 1-8. High Volume Producers of Nanosilver: Domestic.

Company name	Country	US State	CEO	Address	url	# of Employees	Revenue (in millions)
Ferro Corporation	USA	OH	James F Kirsch	1000 Lakeside Avenue Cleveland, OH 44114-7000 T: +1 (216) 641-8580	www.ferro.com	5,001-10,000	\$2,160
Inframat Corporation	USA	CT	Robert Lee & Danny Xiao	151 Progress Dr Manchester, CT 06042	http://www.inframat.com	11-50	\$3.8
Nanocomposix Inc.	US	CA	Dr. Steven Oldenburg	4878 Ronson Court, Ste K San Diego, CA 92111 T: 1 858 5654227	http://nanocomposix.com	0-10	\$0.200
Novacentrix Corp	USA	TX	Charles Munson	200 Parker Road Austin, TX 78728	www.novacentrix.com	11-50	\$2.4
Ocean NanoTech, LLC	USA	AR	Andrew Wang	700 Research Center Blvd Fayetteville, AR 72701 T: 479-444-6028	www.oceannanotech.com	11-50	
QuantumSphere, Inc.	USA	CA	Kevin D. Maloney	2905 Tech Center Drive Santa Ana, CA 92705	http://www.qsinano.com	11-50	\$1
Sciessent, LLC	USA	MA	Paul Ford	60 Audubon Road Wakefield, MA 01880 T: 781-224-7101	www.sciessent.com www.agion-tech.com	11-50	\$4.4
Sigma-Aldrich Corporation	USA	MO	Rakesh Sachdev	3050 Spruce Street St. Louis MO 63103 T: +1 3147715765	http://www.sigmaldrich.com	5,001-10,000	\$2,510
SkySpring Nanomaterials, Inc.	USA	TX	Wenqing Cao	2935 Westhollow Dr., Houston TX 77082 T: +1 281-870-1700	www.ssnano.com	0-10	\$0.340
Dots Ut Inc	USA	IL	Yuri Didenko	2716 W. Clark Rd, Suite E Champaign, IL, 61822 T: +1 217-390-3286	www.utdots.com	0-10	\$0.050

Table 1-9. High Volume Producers of Nanosilver: International.

Company name	Country	CEO	Address	url
ABC Nanotech	Korea	Kjong-Man, Lee	L-5 Block Daedeok Techno Valley, 551 Yongsan-Dong, Yuseong-Gu Daejeon South Korea	www.abnananotech.com
Bio-Gate AG	Germany	Karl Richter	Neumeyerstraße 28-34 90411 Nürnberg Germany T: +49 (0) 91159724 8300	www.bio-gate.de

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Guangzhou Jiechuang Trading Co., Ltd.	China	Xinia Lin	R305 Yinyan Bldg, No25-27 Rd, Yanling, Tianhe Dist. Guangzhou, Guangdong, China 510507 T: +86-20-87226359	http://xuzhounano.en.alibaba.com/ http://www.gzjiechuang.com.cn
Hefei Quantum Quelle Nanoscience And Technology Co., Ltd.	China	Vinod Sapla	E35# New Station Industrial Park, Hefei, Anhui, China 230041 T: 86 551 4280850	http://qqnano.en.alibaba.com/ www.quantum-nano.com/en/ www.nanonickel.de
Henan Huier Nano Technology Co., Ltd.	China	Deguang Du	No.1, Lingbo Road, High-Tech Zone, Luoyang City, Henan Province, Luoyang, Henan, China T: 86-0379-60693936	http://nano.en.alibaba.com/ http://nanohuier.com/
Inspiraz Technology Pte. Ltd.	Singapore	Ivan Tan	19 Kallang Avenue Singapore 339410 T: 6297 0880	www.inspiraz.com.sg
NaBond Technologies Co., Limited	China	Helen Yu	Hi-tech Park, Nanshan district Shenzhen China 518000 T:+86-755-89801091	http://www.nabond.com/
Nano Silver Manufacturing Sdn Bhd	Malaysia	Ricky Sim	No.11, Jalan U5/11, Section U5, Bandar Pinggiran Subang 40150 Shah Alam, Selangor D.E. Malaysia T: +603-78457448	www.nanosilver.com.my
Nano Technology Inc	South Korea	NS Sung	290-19 Daehwa-dong, Daedeok-gu, Daejeon, South Korea, 306-801 T: 82-42-8620673	http://nanopowders.trustpass.alibaba.com
RAS Materials	Germany	Georg Maier	Nussbergerstr. 6b Regensburg 93059 Germany T: +49 941 60 71742	www.rasmaterials.com

Table 1-10. High Volume Producers of Nano Titanium Dioxide: Domestic.

Company name	Country	US State	CEO	Address	url	# of Employees	Revenue (in millions)
E I Du Pont De Nemours and Company	USA	DE	Ellen Kullman	1007 Market St. Wilmington DE 19898 T: +1 3027741000	www.dupont.com	10,000+	\$38,700
Evonik Degussa Corporation	USA	NJ	Thomas Bates	Bennigsenplatz 1. Parsippany NJ 07054 T: +1 49 21 165 0410	http://north-america.evonik.com	1,001-5,000	\$1,020
Inframat Corporation	USA	CT	Robert Lee & Danny Xiao	151 Progress Dr Manchester, CT 06042	http://www.inframat.com	11-50	\$3.8
Ishihara Corporation (U S A)	USA	CA	Shintaro Sekiguchi	601 California Street, Suite 1700, SF CA 94108 T: +1 415-421-8207	www.ishihara.com	0-10	\$1.3
Kronos Worldwide, Inc.	USA	TX	Steven L. Watson	5430 Lbj Fwy. Dallas, TX 75240 T: 972-233-1700	http://www.kronostio2.com	1,001-5,000	\$1,940
Mach I, Inc.	USA	PA	Bernard Kosowski	340 East Church Road King of Prussia PA 19406 T: +1 610 279 2340	www.machichemicals.com	11-50	\$20
Meliorum Technologies, Inc.	USA	NY	Jason E. Rama	620 Park Avenue #145 Rochester, NY 14607 T: +1 585 313 0616	www.meliorum.com	0-10	\$0.330
Nano-Oxides, Inc.	USA	UT	Anil Virkar	5395 W. 700 S. Salt Lake City, UT 84104 T: +1 801-355-1895	www.nano-oxides.com	0-10	\$0.250
Nanoscale Corporation	USA	KS	Bill Sanford	1310 Research Park Dr. Manhattan KS 66502 T: +1 7855370179	www.nanoscalecorp.com	11-50	\$3
Nanostructured & Amorphous Materials, Inc	USA	TX	John JG Huang	16840 Clay Road, Suite #113 Houston TX 77084 T: +1 2818586571	www.nanoamor.com	0-10	\$0.860
Reade International Corp	USA	RI	Charles Reade	850 Waterman Avenue East Providence, RI 02914	http://www.reade.com	11-50	\$6

				T: +1-401-433-7000			
Showa Denko America, Inc	USA	NY	Hideo Ichikawa	420 Lexington Avenue, Suite 2850, New York, NY 10170	http://www.showadenko.us	11-50	\$25
Sigma-Aldrich Corporation	USA	MO	Rakesh Sachdev	3050 Spruce Street St. Louis MO 63103 T: +1 3147715765	http://www.sigmaaldrich.com	5,001-10,000	\$2,510
SkySpring Nanomaterials, Inc.	USA	TX	Wenqing Cao	2935 Westhollow Dr., Houston TX 77082 T: +1 281-870-1700	www.ssnano.com	0-10	\$0.340
Strem Chemicals, Inc.	USA	MA	Mike Strem	7 Mulliken Way Newburyport MA 01950 T: +1 (978) 499 1600	www.strem.com	51-200	\$18.5
Tronox Incorporated	USA	CT	John D Romano	One Stamford Plaza 263 Tresser Blvd, Ste 1100 Stamford, CT 06901 T: +1-203-705-3800	http://www.tronox.com	501-1,000	\$162

Table 1-11. High Volume Producers of Nano Titanium Dioxide: International

Company name	Country	CEO	Address	Url
Avanzare Innovacion Tecnologica S.L.	Spain	Dr. Robert Gish	Antonio de Nebrija 8 Spain 26009 T: +34-941587027	http://www.avanzare.es
Cinkarna	Slovenia	Dr. Milan Medved	Kidričeva 26, 3001 Celje, Slovenia T: +386 (0) 3 427 60 00	http://www.cinkarna.si
Cristal	Kingdom of Saudi Arabia	Dr. Talal Al-Shair	Malik Road, King Abdulaziz Road, P.O. Box 13586 Jeddah, SA 21414 T: 966.2.224.8000	http://www.cristalglobal.com/home.aspx
Huntsman Tioxide	UK	Jon M. Huntsman	Haverton Hill Rd Billingham Teesside, UK TS23 1PS T: 01642 376300	http://www.huntsman.com/corporate/a/Home
Jiangsu Changtai Nanometer Material Co, Ltd.	China	Jinlong Wu	Tai East Rd, No.158 Tai Village, Jiangsu Province, China 213147 T: +86 (519) 3563658	http://www.chinananometre.com.cn/eintro.htm
Kemira OYJ	Finland	Wolfgang Büchele	Porkkalankatu 3 P.O. Box 330 FI-00101 Helsinki, Finland T: +358108611	www.kemira.com/
Metal Nanopowders Ltd.	UK	Isaac T. Chang	University of Birmingham Edgbaston, Birmingham, UK B15 2TT	http://www.metalnanopowders.com
Mitsubishi Gas Chemical Company, Inc.	Japan	Kazuo Sakai	2-5-2 Marunouchi Chiyodaku Tokyo, Japan 100-8324 T: +81-3-3283-5000	http://www.mgc.co.jp/eng
NaBond Technologies Co., Limited	China	Helen Yu	Hi-tech Park, Nanshan District Shenzhen, China 518000 T:+86-755-89801091	http://www.nabond.com
Nano Technology Inc.	Korea	Kwon, Tae-Won	290-19 Daehwa-Dong, Daejeon, Korea, 306-801 T+82-42-862-0673	http://www.nanocompound.com/eng
Nanum Nanotecnologia	Brazil	Joao Lourenço	Av. José Cândido da Silveira #2100, Minas Gerais, Brazil 31.170-000 T: +5531 3488-1595	http://www.nanum.com.br

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Table 1-11. High Volume Producers of Nano Titanium Dioxide: International (continued)

Company name	Country	CEO	Address	Url
NTBase	South Korea	Song, Gun-yong	Yubang-dong 770-2 Cheoin-gu, Gyeonggi-do, S Korea 449-934 T: +82 (31) 3223950	www.ntbase.net
Plasmachem	Germany	Alexey Kalachev	Rudower Chaussee 29 D-12489 Berlin Germany T: +49 3063926313	http://www.plasmachem.com
Precheza	Czech Republic	Ivo Hanáček Tomáš Procházka	Nábřeží Dr. E. Beneše 24 751 62 Přerov, Czech Republic T +420 581 252 111	http://www.precheza.cz/en
Sachtleben	Germany	Vernon S. Sumner	Dr.-Rudolf-Sachtleben-Straße 4 47198 Duisburg, Germany	www.sachtleben.de
Tecnan-nanomat	Spain	Ernesto Beibe	Área Industrial Perguita, C/A N° 1 31210, Los Arcos, Navarra, España T: +34 948 64 03 18	www.tecnan-nanomat.e
Umicore Nanomaterials	Belgium	Marc Grynberg	Kasteelstraat 7 B-2250 Olen Belgium T: +32 14 24 50 18	http://www.umicore.com/en/rdi
Xuan Cheng Jing Rui New Material Co.,Ltd	China	Xu Jing	Qilin Rd, Xuan Zhou Economic Development Zone, Xuan Cheng City, Anhui Province, China	http://www.jingruinano.com/en

1.7 High Volume Users of the Four Nanomaterials

The technology application grid (below) maps and rates the current applicability of the down-selected list of nanomaterials to the opportunities in specific markets. It is expected that nanomaterials will broaden their markets, particularly for emerging materials such as cellulose and graphene, as manufacturing plants come online and add capacity. This market growth tied to production volume can be seen in the past trends for incorporation of carbon nanotubes into composites and electronics, which witnessed a robust growth due to the large price decrease of carbon nanotubes and increase in mass production. External forces also will shape the growth of the nanomaterial industry. Workforce development, distribution channels, improvements in capital efficiency and regulation are among key external drivers.

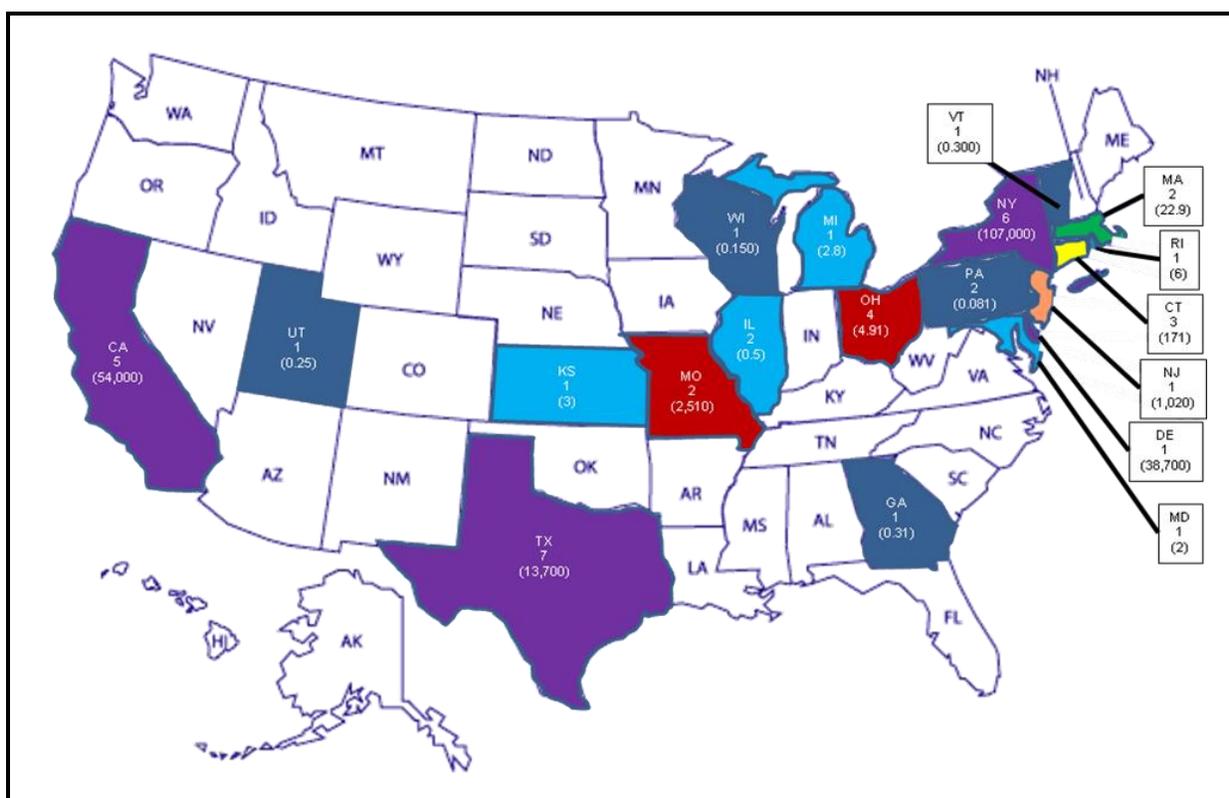
Table 1-12. High Volume Users of the Four Nanomaterials.

	Currently used	Under development	Speculative	
Industry	Graphene	Cellulose	Silver	Titanium Dioxide
Transportation				
Agriculture				
Building materials				
Cosmetics				
Electronics				
Energy				
Food				
Medical				
Paper				
Textile				
Water				

1.8 Graphene, Cellulose, Silver, and Titanium Dioxide Engineered Nanomaterial Producers in the U.S.

The heat map below gives a colored coded indication, based on secondary market research, of the range of occupational workers who may be exposed to any of the four nanomaterials: graphene, cellulose, silver, and titanium dioxide. Within each state, the number under the state abbreviation represents total number of companies in that State (by location of headquarters), that produce one or more of the selected nanomaterials. The value in parenthesis is total revenue millions of USD for companies in nanotechnology in that State.

Figure 1-7. Heat map of the producers of graphene, cellulose, silver, and titanium dioxide engineered nanomaterial in the United States. The legend gives a colored code indication of total number of employees in each state who work with the aforementioned nanomaterials types.



Color Code	Total No. of Employees
Dark Blue	0-10
Light Blue	11-50
Green	51-500
Yellow	501-1,000
Orange	1,001-5,000
Red	5,001-10,07
Purple	10,000+

1.9 Estimated Number of Workers Involved for Each Nanomaterial

We estimated the number of workers exposed to each particle-type using the following equation:

$$W_{\text{exposed}} = \Sigma (W_{\text{total}} \times \%_{\text{nano}})(\%_{\text{R\&D/production}}) \quad (1.1)$$

Where:

W_{exposed} is the estimated number of workers exposed to the nanomaterial,

W_{total} is the estimated total number of workers in the company,

$\%_{\text{nano}}$ is the percentage of the company believed to be in the “nanotechnology” business,

$\%_{\text{R\&D/production}}$ is the percentage of workers in the R&D and production force in the company

Prioritized nanomaterial	Estimated number of workers exposed (W_{exposed})
Graphene	600-700
Silver	1,200-1,800
Titanium dioxide	2,100-2,500
Cellulose	No US workers, to date

These are early stage estimate based on secondary market research. Additional research would need to be performed for more accurate information on number of workers exposed to titanium dioxide, silver, cellulose, and graphene nanoparticles or nanomaterials.

The criteria used to estimate the number of workers exposed to each nanomaterial-type is described below:

- Nanomaterial centric start-up companies are assumed to have 100% of their business in “nanotechnology”
- Small to medium companies are assumed to have 25-75% of their business in “nanotechnology” depending on their market shares
- Large companies are typically not nanomaterial-centric; therefore, their “nanotechnology” business was assumed to range 10-20%
- Start-up companies and small companies were assumed to have 85-90% of their workforce involved in R&D laboratories or within their production facilities
- Medium and large companies were assumed to have 40-50% of their workforce involved in R&D laboratories or within their production facilities

1.10 Findings and Recommendations

Finding 1: There are approximately 10 types of nanomaterials produced in the 1,000s of tons amount on a yearly basis – most are metal oxides.

Recommendation: This type of secondary market analyses should be performed on the metal oxides, in addition the research already performed on titanium dioxide.

Finding 2: There needs to more clarity among nanomaterials mass-produced regarding the primary particle size and/or size range, i.e. are these mass produced materials in size ranges between 0-100 nm, 0-250 nm, or 0-1000 nm or other? And, does it matter?

Recommendation: A combination of primary and secondary research is needed to answer these important questions.

Finding 3: The majority of nanomaterials producers are small companies; therefore information regarding EH&S staff is difficult to find or may not exist.

Recommendation: Primary research is needed to gather this EH&S staff information.

Finding 4: The high volume products (i.e. titanium dioxide) are primarily manufactured by multi-national and multi-product companies.

Recommendation: Understanding which subset of workers are exposed to which nanomaterial product-type (i.e. raw particle vs. incorporated nano-product) is needed.

Finding 5: There is limited data around differentiating where company headquarters vs. manufacturing facilities are located in the United States.

Recommendation: Primary research is needed to gather the specific number of workers exposed to nanomaterials.

Finding 6: Value chain for nanomaterials is still nascent.

Recommendation: Primary research is required to understand which company participates along the nano-product value chain (i.e. manufacturer, distributor, or user) - the next step in this chain is formulators (an interesting but understudied area of research).

References

The Global Market for Nanomaterials 2002-2016: Production volumes, revenues and end user market demand, Future Markets, Inc. 2012 | www.futuremarketsinc.com.

The Global Market for Nanocellulose to 2017, Future Markets, Inc. 2012 | www.futuremarketsinc.com.