

## Outline of Typical Nano Materials

### 1. Fullerene

Item	Outline	Item	Outline
Selling grade particle diameter	Secondary particle: 20 ~ 40 $\mu\text{m}$ . Primary particle: 0.7 ~ 1 nm.	Types of usage	Mixed into epoxy resin. No surface treatment.
Domestic usage quantities in 2006	Approximately 2 tons.	Merits of using nano material	Enhanced restitution performance, lightweight, enhanced strength.
Applications	Sports usage: 100%. Racket, golf club, etc.	Future markets	Usage quantity will not change much. There will be more value added applications, with growth in use as a metal substitute.
		Future applications	Expectations in fuel cells and solar cells. Good prospects in bio medicine and cosmetics.

\* Fullerene is the generic term used for carbon cluster, where  $C_{60}$  is the representative substance. Carbon molecule consists of 60 atoms and has icosahedral (soccer ball type) structure. Carbon molecules are also found consisting of 70, 76, 78, 96 and 240 atoms, etc. The molecular diameter of  $C_{60}$  is 1nm (diameter of carbon skeleton is 0.7nm). Because of the high electron acceptability, it is highly conductive. Also by combining with resin, strength can be increased and weight can be reduced, thus it is seeing wider use in badminton and tennis rackets, etc. Moreover, various research is progressing in order to use its various characteristics, such as using cell toxicity which breaks DNA in attacks on cancer cells, or in cosmetics expected to have an active oxygen reduction function.

## 2. Single-Wall Carbon Nanotube

Item	Outline	Item	Outline
Selling grade particle diameter	Diameter : 0.8 ~ 1.4nm. Length : 100 ~ 1000nm. Catalyst residual ratio (in SWCNT products): • Unrefined goods ... < 35wt%. • Refined goods ... < 15wt%. • Ultra pure goods ... < 5wt%. Specific surface area: 400 ~ 1000m <sup>2</sup> /g.	Types of usage	Mixed into resin or ceramics.  There are examples of grades where surface is modified using fluorine.
Domestic usage quantities in 2006	Approximately 100 Kg.	Merits of using nano material	Lightweight, conductive.
Applications	Research and development in progress.	Future markets	High price and instability of material properties may hinder its spread in the market.
		Future applications	High speed operating transistors, fuel cells, hydrogen gas storage, etc.

\*Single-Wall Carbon Nanotube (SWCNT) consists of coaxial tube of single wall in hexagonal carbon network. The structure is cylindrical which is acquired by rolling graphite plane. It is synthesized by using methods like arc process, CVD process etc. and a catalyst is used during the process. Various properties are being found one after the other, and research and development is carried out aiming at increasing the utility value.

## 3. Multi-Wall Carbon Nanotube

Item	Outline	Item	Outline
Selling grade particle diameter	Fiber diameter: 40 ~ 90nm. Length: several tens μm.	Types of usage	Mixed into resin for semiconductor tray. Presently, no surface treatment is being done. In the future, depending on the usage it is highly possible that it will be chemically modified.
Domestic usage quantity in 2006	Approximately 60 tons. (approx. 30 tons are imported)	Merits of using nano material	Conductivity, high mechanical strength, heat conductivity, electromagnetic shielding (GHz area), smoothness of molded products.
Applications	Semiconductor tray: 90% Other (conductive paste etc.): 10%	Future markets	150 tones in 2010.
		Future applications	Conductive paste, ITS use, capacitor, fuel cell, garments, and catheters in medical field.

\* Multi-wall Carbon Nanotube (MWCNT) consists of coaxial tube of multi wall in hexagonal carbon network. Diameter ranges from 10 ~ 100nm. Presently used for high conductivity, it is also used as antistatic in containers used for transporting semiconductor or silicon wafer used in semiconductor factories. Its use is growing.

#### 4. Silver / Silver + Inorganic particle

Item	Outline	Item	Outline
Selling grade particle diameter	Silver nano particle : 3 ~ 7nm. Silver + inorganic particle : 0.4μm. Silver + inorganic particle : 100nm. Silver + inorganic particle : 10nm.	Types of usage	In the final product, the conductive paste is supported by hardened resin. Mixed into resin or fiber, it is also dispersed in paints. No surface treatment.
Domestic usage quantities in 2006	Silver nano particle: Approximately 100 Kg.  Silver + inorganic particle: Approximately 500 tons (100 nm product approximately 50 tons, 10nm product several tons).	Merits of using nano material	Silver nano particle: Get conductivity from small quantity. Form microcircuits. Silver + inorganic particle: With the expansion in specific surface area, antimicrobial effect is increased.
Applications	Silver nano particle: Used 100% as joining / wiring material in electronic devices.  Silver + inorganic particle: 100% as antimicrobial (mixed into resin: 60%, mixed with fiber: 15%, paints: 15%, others: 10%).  <u>Specific usage examples</u> Fiber...garments, bedding, masks, etc. Daily use products...kitchenware, toilet articles, bathroom, umbrella, slippers, etc. Leather...footwear, insole, belt, etc. Water treatment...automatic vending machine piping, etc. Home electronics...air-conditioner filter, exhaust fan, washing machine, refrigerator, vacuum cleaner, rice cooker, telephone, PC, etc. Sports...clothes, shoes, etc. Other...toy, medical care/hygiene, cosmetic container, building material, civil engineering, etc.	Future markets	Silver nano particle: With increasing market share of conductive paste, its market share may grow several tons per year.  Silver + inorganic particle: Strong growth of around 10%.
		Future applications	Silver nano particle: Expectations for its use in large screen display due to conductive ink, anisotropically-conductive film, sensors, optical memory, liquid crystal display element, nano magnet, environmental catalyst, fuel cell catalyst, pharmaceutical product, etc.  Silver + inorganic particle: The development of high efficiency antibacterial agents will create new uses.

\* (1) Due to antimicrobial action and application of silver, there is growing use of silver nano particle / silver + inorganic particle in daily use goods, kitchenware, sealed food containers, etc.

(2) Compared to organic substances, inorganic substances generally excel in mechanical and chemical characteristics like heat resistance, hardness, difficult to corrode, etc. They also have characteristics like transparency, conductivity or insulating properties, and electric storage, etc.

(3) As an inorganic particle, it is used by silica, alumina, titanium oxide and zeolite. It is microparticulated to 100nm or less to support silver.

## 5. Iron

Item	Outline	Item	Outline
Selling grade particle diameter	Metal magnetic powder. PC data backup tape: 45nm. Business video tape: 100 ~ 260nm.	Types of usage	Mixed into resin, used to coat base material of tape etc.
Domestic usage quantities in 2006	200 ~ 300 tons.  Magnetic powder amount used: 1,000 tons (It is estimated that about 20 ~ 30% is nano size).	Merits of using nano material	Enhanced memory density.
Applications	PC data backup tape: 30%  Business video tape: 70%	Future markets	Trend towards less usage quantity. Less usage quantity due to progress in thinner films.
		Future applications	No new use is forecast. The present uses may continue.

## 6. Carbon Black

Item	Outline	Item	Outline
Selling grade particle diameter	16 ~ 50nm. Particles less than 20nm are defined in industries.	Types of usage	Mixed into rubber. Mixed into resin. Dispersed in ink. Toner is pulverized after mixing into resin. There are examples of surface treatment of functional group in paint grade.
Domestic usage quantities in 2006	Approximately 830,000 tons.	Merits of using nano material	Enhanced conductivity and coloring properties. Cost reductions are expected with less usage of additives.
Applications	Tire: 95%. Pigment: 4%. Conductivity usage: 1%.  Minute particles 20nm or less are mainly used in pigments, and conductivity (combined with resin or elastomer and used in conductivity functions like antistatic, etc. For example, fuel cap or fuel feed pipe etc.).	Future markets	Flat, or slight decrease. Small increase in conductivity usage of particles 20nm or smaller.
		Future applications	Developments for fuel cell and cosmetics. In the minute particle field, demand will grow for use in domestic high quality tires (in lightweight and highly rigid tires, there are expectations for improved vibration control and fuel efficiency etc. for vehicles).

\* Almost spherical unit particles that consists of 100,000 ~ 1 billion carbon atoms unite mutually to form carbon block aggregate. It is formed due to incomplete combustion of oil or gas; all carbon blocks formed are nano particles. It is used in various applications like providing conductivity or coloring properties for rubber or resin.

## 7. Titanium Oxide

Item	Outline	Item	Outline
Selling grade particle diameter	Very minute particles (rutile type), mainly for cosmetics: 15nm ~ 100nm.	Types of usage	Dispersed in paints, mixed into resins.  Cosmetics: Surface treatment by silicon etc. Toner: Surface treatment by silane coupling agents. Automobile paints: Surface treatment by alumina, zirconia.
Domestic usage quantities in 2006	Total titanium oxide quantity: approximately 240,000 tons (of that, very minute particles (100nm or less) usage is approximately 1,250 tons).  * Domestic production: approximately 2,500 tons (50% of this exported).	Merits of using nano material	Ultra violet cut, charge adjustment, enhanced light resistance, and photo catalyst (anatase type), etc.
Applications	Cosmetics : 60% Toner : 33% Automobile paint : 5% Other* : 2% *...fire retardant, photo catalyst, other.	Future markets	Increased annual usage at several %.
		Future applications	Cosmetic usage is increasing. Toner usage is increasing along with increases in photo copiers/ printers. There are also expectations for use in large display anti-reflection films.

\* Titanium oxide (TiO<sub>2</sub>) has higher refractive index than diamond, does not absorb visible rays, and is highly chemically stable. Thus it is widely used in raw material of paints and cosmetics as white pigment and ultraviolet absorbing agent. There are three types of crystal structures of titanium oxide (anatase, rutile and brookite), but industrially used ones are anatase and rutile. Rutile is the most stable, and anatase transforms to rutile on overheating. Titanium oxide exhibits UV shielding effects on nano particulation, thus rutile is widely used in the cosmetics field especially in sunscreens. Anatase has photocatalytic functions (has self cleaning under sunlight, air cleaning, water quality improvement and antimicrobial and antimold functions), thus there are expectations for expanded demand for use in various paints.

## 8. Alumina

Item	Outline	Item	Outline
Selling grade particle diameter	General purpose grade: 50 $\mu$ m. 100nm or less is mainly custom made. Cosmetic grade (Alumina cut into plates) ... Average particle diameter: 0.6 $\mu$ m ~ 10 $\mu$ m, Average thickness: 60nm ~ 0.3 $\mu$ m.	Types of usage	Mixed into resin / ceramics.  No surface treatment.
Domestic usage quantities in 2006	Total alumina usage: approximately 270,000 tons (100nm or less: approximately 700 tons).	Merits of using nano material	Chemically stable. Mechanical strength enhancement. Electrical insulating.
Applications	Electronic components, sealant, ceramics, cosmetics, etc.	Future markets	Grade 100nm or less is expected to grow to around 1000 tons.
		Future Applications	Composite materials in the electronics field. Possible expansion for polishing, coloring, and fuel cell.

\* Alumina ( $Al_2O_3$ ) is a white crystalline powder, obtained by burning aluminum hydroxide. It is chemically stable and mechanically strong and strong electrical insulating characteristics. It is used in fields such as raw material of ceramics like porcelain / mechanical components / electrical components, and in grinding / abrasives and fire resistant items. There are expectations for use of nano grade in various electronic components.

## 9. Cerium Oxide

Item	Outline	Item	Outline
Selling grade particle diameter	<p>Abrasive agent grade... average particle diameter: 0.6 ~ 2.5<math>\mu</math>m (cerium oxide content percentage: 55.8%)</p> <p>Semiconductor polishing grade... average particle diameter: 0.22 <math>\mu</math>m</p>	Types of usage	<p>Polishing agent is dispersed in water and used.</p> <p>There are examples of some users adding dispersion stabilizer.</p>
Domestic usage quantities in 2006	<p>2 ~ 3 tons.</p> <p>Total use is approximately 6,000 tons.</p> <p>Approximately 30 tons is estimated for semiconductor polishing agents that have small particle diameters. However, for 100nm or less, it is 2 ~ 3 tons.</p>	Merits of using nano material	<p>There are benefits of nanosize in improved polishing performance by miniaturization of semiconductor circuit.</p>
Applications	<p>Polishing agent: 70 ~ 80% (Breakdown: liquid crystal glass and photo mask are 70 ~ 80%, with remaining for hard disk and glass lens) Other: 30 ~ 20% (Breakdown: Ultraviolet cut glass, exhaust gas catalysts for automobiles)</p> <p>Nano size is sought for semiconductor polishing. Especially for ILD (Inter-Layer Dielectric) and STI (Shallow Trench Isolation).</p>	Future markets	<p>Liquid crystal glass has strong demand in the entire market, thus overseas usage is increasing. However, there was only a small increase domestically due to overseas transfers of production bases. Nano size semiconductor usage also increased marginally as domestic production bases decreased.</p>
		Future Applications	<p>There is advancing maturity of polishing agent usage.</p> <p>There is research regarding its use as fuel cell electrolyte, cosmetics employing UV blocking function, etc.</p>

\* Cerium Oxide (CeO<sub>2</sub>) has high oxygen storage capacity and a high UV shielding functionality. Presently it is widely used as a polishing agent. Especially nano particle is used as a semiconductor polishing agent.



## 10. Zinc Oxide

Item	Outline	Item	Outline
Selling grade particle diameter	Cosmetic grade : 30 ~ 40nm Other grades : 20 ~ 35nm  * Cosmetic grade is mainly shifting to 20 ~ 30nm.	Types of usage	Dispersed in solvent, mixed into cosmetics base materials.  Silicon etc. is used for surface treatment in cosmetics, and there are examples where silica is used.
Domestic usage quantities in 2006	Total zinc oxide usage: Approximately 77,000 tons.  (of this, approximately 480 tons for superfine particles of 100nm or less)  * Very minute particle production quantity is about 600 tons (of this, 120 tons is exported).	Merits of using nano material	UV block. Improved transparency. Antimicrobial and deodorant effects due to expansion of specific surface area.  * Particles size of 20nm or less is not possible with present technology.
Applications	Cosmetic products : 80% Other : 20% (pharmaceutical, fiber, paints, etc.)	Future markets	Growing several % per year.
		Future Applications	There are expectations for use in transparent conduction film. Substitute material for rare metal ITO (Indium Tin Oxide).

\* Zinc oxide (ZnO) is industrially manufactured by vaporizing metal Zinc and then by air combustion. Particle diameter is 0.1 $\mu$ m and it is in the form of fine powder. It is insoluble in water and has transparency and piezoelectricity. Since particles are very minute, it is important as a white pigment. It is also a raw material for pharmaceuticals, cosmetics etc. Nano particle of zinc oxide exhibits UV shielding effects similar to titanium oxide. When compared with titanium oxide, it excels in features like transparency; hence it is used in cosmetics, especially in sunscreens, by combining it with titanium oxide. There are also expectations for its use as electronic material in the future.

## 11. Silica

Item	Outline	Item	Outline
Selling grade particle diameter	Dry Silica... Hydrophilic grade: 7 ~ 22nm Hydrophobic grade: 7 ~ 15nm  * 100% of dry silica consists of only nano particles.	Types of usage	Mixed into rubber / resin. Dispersed in solvent.  There are examples of hydrophilic grade being surface treated by silanol base, and hydrophobic grade being surface treated by siloxane.
Domestic Application in 2006	Approximately 13,500 tons.  * Approximately 27,000 tons of dry /silica is manufactured, 50% is exported.	Merits of using nano material	Improved rubber strength, improved insulation / flow / color / water resistance, thickener, anti settling agent, stabilizing agent, anti static, etc.
Applications	Silicon rubber filler : 57% FRP : 11% Paint : 10% Other : 22% (Toner, ink, fiber, fiber, pharmaceuticals, cosmetics, agricultural chemicals, etc.)	Future markets	There is a wide range of uses, and growth is firm at several % per year.
		Future Applications	Maturation of existing usage. Possibility of expansion in adhesive agent use, wax, polishing use, food product use, etc.

\* Dry Silica is used in various products and applications, like reinforcement of resin, thickening of paints etc. (prevents dripping) and polishing of semiconductor wafer. It is largely used as an additive agent in silicon rubber to increase the chemical stability or resistance to change in temperature. That is why it is used in packing material under harsh environments such as engine rooms in the automobile industry. Further, in electronic devices it is used in protective covering material and mobile phone keypads because of its features like electrical insulation and durability. Since all grades of dry Silica consist of particle diameter of 100nm or less, its market can be called a nano scale market. Silica minute particles are also used in a wide range of products: paint, ink, cosmetics, agricultural chemicals, etc.

## 12. Polystyrene

Item	Outline	Item	Outline
Selling grade particle diameter	General purpose grade : 20μm Cosmetic grade : 0.1μm Liquid crystal spacer : 2 ~ 10μm	Types of usage	Mixed into resin. Mixed / dispersed into cosmetics base material. (No surface treatment)
Domestic usage quantities in 2006	General purpose product: approximately 330 tons Cosmetic product: approx. 10 tons Liquid crystal spacer: approximately 3.2 tons	Merits of using nano material	FRP low contraction properties. Anti settling agent. Light diffusing agent for anti-reflection. No nano benefit in the liquid crystal field.
Applications	General purpose product... FRP / cultured marble : 90.9% Cosmetic product : 3.0% Other : 6.1% (Light diffusing agent for anti-reflection, toner additive agent, etc.)	Future markets	General purpose products are competing with acrylic, so growth cannot be expected.  LCD spacer is expected to show quantitative growth, but there are no needs for particle 100nm or smaller.
		Future Applications	Nano polystyrene that contains dyes for inkjets are being developed, but issues remain regarding light resistance and coloring properties.

\* Structural formula  $-\text{[CH}_2\text{-CH(C}_6\text{H}_5\text{)]}_n\text{-}$  : Polystyrene is one of the five general purpose resins, is pliable and has excellent electrical characteristics (insulation), hence widely used in home electrical appliances (TV case, air conditioner cladding, CD case, etc.), office equipment, food packaging, toys, and daily use goods  
Polystyrene nano particles are used for light diffusing agent for anti-reflection in displays by using its refractive index, and also in cosmetics (provides smoothness to foundation, etc.).

### 13. Dendrimer

Given below is the outline of two types of dendrimer products that are sold in the domestic market.

Item	Outline	Item	Outline
Selling grade particle diameter	Particle diameter: 20 ~ 30nm. Dendrimer consisting of polymer + dendrimer: size is 2 ~ 3 nm but actually it is in the form of film made with cohesion of particles. It exists in approximately 100nm size.	Types of usage	Paper coating: Dispersed in liquid, and coated on paper surface. Dispersed in cosmetics.
Domestic usage quantities in 2006	Domestic usage quantity: approximately 50 tons. “Polymer + dendrimer” 30 tons is produced, but only several tons of that is dendrimer.	Merits of using nano material	Reduce “viscosity” or paper coating, and “rheology” control. Improved “water repellency”, “oil repellency” and “durability” in foundation.
Applications	Paper coating. Cosmetics (used mainly in liquid foundation)	Future markets	For the next few years, quantitative market size will be about the same level as currently.
		Future Applications	Existing applications of paper coating will grow. In cosmetics usage, the present foundation usage share is growing (however, there is little quality used as dendrimer). There are possibilities in medical related use, fuel cells, etc.

\* Dendrimer is one of the high-polymer materials called dendritic polymer (where the structure is accurately controlled) or hyperbranched macromolecule. Structural control is easier compared to general macromolecules; hence it is possible to synthesize chemical compounds in different shapes and sizes using various combinations of these structural elements. There are expectations for its application in fields like bio and material sciences. It is attracting attention in fields like drug delivery, gene transfer, catalyst action, energy & light capture, and photo activation, reference material of molecular weight and size, and nano scale science. Application in fields like surface coating of paper and in some cosmetics has started in Japan.

#### 14. Nano Clay: Highly Pure Bentonite:

Main component is montmorillonite (abbreviated as MMT)

Item	Outline	Item	Outline
Selling grade particle diameter	High purity grade: 15 ~ 20 $\mu\text{m}$ (secondary particle) Standard particle diameter of montmorillonite, the main component: 1nm x 100nm	Types of usage	Dispersed in solvent.  For many products, surface treatment is not carried out. However, it provides high viscosity and thixotropy* <sup>1</sup> in water systems, by modifying silane chemical compound that has long chain alkyl base and by giving it partial hydrophobic properties.
Domestic usage quantities in 2006	Bentonite usage: 700 ~ 800 thousand tons (of this, high purity product usage approximately 250 tons)	Merits of using nano material	Anti settling agent, thixotropic, viscosity control, etc.
Applications	Anti settling agent for agricultural chemicals : 40% Paints : 40% Cosmetics : 10% Other : 10% (pharmaceuticals, food additives, catalysts, toxic substance remover, bath additive, etc.)	Future markets	Highly pure substance has a relatively favorable market.
		Future Applications	There are expectations for its use in containers and packaging (PET bottles etc.), by using its nano composite and gas barrier qualities.

\* “Nano clay” is the term for a product in which the purity of “bentonite” is increased and particle diameter is made to the sub micron level. The main component of bentonite is “montmorillonite: MMT”. The size of MMT itself is thickness 1nm, length 100nm in a scale shape. MMT belongs to a group of minerals called smectite, and hydrite, hectorite, saponite, and stevensite are minerals which have similar properties, but almost all sales are of MMT. Further, “bentonite” generally is defined to have particle diameter (secondary particles) of 2 $\mu\text{m}$  or less, and its average particle diameter is submicron. “Nano clay” is widely used in anti settling agents for agricultural chemicals, and in paints, cosmetics, pharmaceuticals, food additives, catalysts, etc. In the future, there are expectations that by adding to resins it will form nano composite material having new functions.

\*<sup>1</sup>...Thixotropy:

Among the softening phenomenon of a body due to stress, thixotropy refers to that which recovers. It occurs in many colloid type substances. Especially by making the thick emulsion or suspension to flow by stressing, it is softened. That is, viscosity is lowered. However, if the flow is stopped, it is again thickened. Almost complete recovery is possible in some case and only part recovers in others. (from Great Chemistry Dictionary, Kyoritsu Shuppan Co., Ltd. (1980))

## 15. Carbon Nano Fiber

Item	Outline	Item	Outline
Selling grade particle diameter	Fiber diameter : 150nm Fiber length : 10 ~ 20 $\mu$ m	Types of usage	Mixed into resin.
Domestic usage quantities in 2006	60 ~ 70 tons.	Merits of using nano material	Improved heat conduction rate. Conductivity. Lubricating property. Contributes mechanical strength.
Applications	Lithium secondary battery : 50% Other : 50% (Additive substance in resin, etc.)  * It is being applied in 20% of lithium batteries	Future markets	It is forecast to grow to around 200 tons in 2010.
		Future Applications	Expanded use which aims at enhanced mechanical strength (sports, wind power generation blades, etc.). There are also hopes for use in fuel cells.

\* Carbon nano fiber is a nanometer level fiber. Multiple hexagonal mesh surfaces consisting of carbon atoms are layered longitudinally to synthesize this fibrous carbon material. This structure is different from carbon nano tube structure. It has attracted attention as an absorption material of hydrogen gas or methane gas, and as a field emission material. Presently it is widely used in electrodes of lithium secondary batteries which are used in mobile phones.

## 16. Pigment Minute Particles

Item	Outline	Item	Outline
Selling grade particle diameter	10 ~ 100 nm	Types of usage	Pigments are used by dispersing into the solvent.
Domestic usage quantities in 2006	About 800 tons (Out of the 34,881 tons annual production of organic pigments, it is estimated that approx. 800 tons are less than 100nm).  *When transparency is sought also in general applications of the pigment, products of about 100nm are used in some cases. However, quantitative knowledge is difficult as there are no statistics.	Merits of using nano material	With the use of nano technology in pigment, demands for high resolution can be satisfied by both inkjet and liquid crystal applications.
Applications	Breakdown of 800 tons of organic pigments of 100nm or less...  For ink jet: 100 tons approx.  For liquid crystal color register: 700 tons approx.	Future markets	Will expand with the popularization of ink-jet printers. Liquid crystal applications will also be firm due to expansion of the market.
		Future Applications	As the demand for high resolution picture rises, use of nano will increase with the use of inkjet and liquid crystal.

\* Pigment is a generic name for fine powder that is used for coloring which is insoluble in water or oil. There is a wide range in size of pigment particles, from several nm to several mm. Depending on their components, pigments are divided into 2 types: inorganic pigments and organic pigments. Presently, pigments with nano technology are used in ink for inkjet or color register for the manufacturing process of liquid crystal.

## 17. Acrylic Minute Particles

Item	Outline	Item	Outline
Particle size of sales grade	5 ~ 10 $\mu$ m	Types of usage	For optical diffusion, it is used by mixing into resins. For paints and inks, it is used by diluting with a solvent.
Domestic usage quantities for the 2006	Around 2,250 tons (of the domestic production of 3,000 tons, 750 tons is exported)	Merits of using nano material	Sub-microns are sought for usage in cosmetics. Its benefit is that it improves skin texture.
Applications	Displays (LCD, etc.) : 55% Paints and inks : 20% Anti blocking agent :15% Cosmetics : 8% Other : 2% (toner additive, etc.)	Future markets	Considering the total market, because of the growth in usage in LCD displays, there is steady growth at around 10% per year. However, nano grade is only growing marginally.
	*Submicron grade is used for cosmetics and toner.	Future applications	There are future expectations in the ink jet field. There is development of 60-90nm particles containing dyestuff.

\* It is the generic name for the resin of which the principal ingredients are the derivatives of mainly acrylic acid ( $\text{CH}_2=\text{CH}-\text{COOH}$ ) and methacrylic acid ( $\text{CH}_2=\text{C}(\text{CH}_3)-\text{COOH}$ ). Having features like transparency and toughness, it can be used in paints and inks by making into miniature particles. At present, nano particles are not in circulation, but as polystyrene resin which is used in cosmetics decreases, expansion in usage as nano particles in acrylic is expected. There are also expectations from development for usage in ink jets, etc.



## 18. Liposome

Item	Outline	Item	Outline
Particle size of sales grade	<p>Liposome for cosmetics 100 ~ 300nm / 100nm or less</p> <p>* As for the DDS (Drug Delivery System), each pharmaceutical company that purchases phospholipids derivatives carries out its liposomization. The particle diameter adjusted for the function of DDS is estimated as 100nm or less.</p> <p>* However, it is uncertain whether liposomization is done for all grades of the drugs.</p>	Type of Usage	<p>Dispersion to cosmetic liquid, lotion, cosmetic water, etc.</p> <p>There are examples of selling products in which the functional elements are adjusted beforehand, though surface treatment is not done.</p> <p>Combination example: Coenzyme Q10, high density ceramide, mandarin orange peel extract, n-acetylglucosamine, tocopherol, <math>\alpha</math>-lipoic acid, vitamin C derivative, etc.</p>
Domestic usage quantities in 2006	<p>Total: 1 ton ~ 1.2 tons</p> <p><u>Breakdown</u> DDS grade: 200 ~ 300 kilograms</p> <p>Liposome for cosmetics: 800 ~ 900 kilograms</p>	Merits of using nano material	<p>With DDS, the effect of drug is improved and side effects are reduced by reaching the cells and internal organs.</p> <p>In cosmetics, hydrophobic functional components are made hydrophilic, skin affinity is improved, and also active ingredients that penetrate inside the skin are released.</p>
Applications	<p>Drugs: 20% approx. Cosmetics: 80% approx. Food: Small quantity</p>	Future markets	<p>DDS use is governed by development conditions of the drug. Demand for approx. About 100 kilograms of demand can be expected if only one product becomes popular.</p> <p>The market for cosmetic use can be expanded with the combination of new functional components.</p>
		Future applications	<p>Use in foods is possible. There are examples of beauty foods.</p>

\* Liposomes are spherical shells of bilayer membrane of lipids. Though the size depends on the production method and conditions, its diameter is in the range of 20 ~ 100nm. It has the basic structure of a biomembrane, and research and development is being carried out for its application in Drug Delivery System and biosensors, etc.

## 19. Platinum Nano Colloid

Item	Outline	Item	Outline
Particle size of sales grade	Average particle size: 2 ~ 10 nm Sold as colloids having 0.5 ~ 4% density of noble metals.	Type of Usage	It supports ceramics as a catalyst. PVP (polyvinyl pyrrolidone) and PAA (sodium polyacrylate), etc. are used as colloid making agents. Can be directly added to food products. Examples of surface treatment are sodium polyacrylate, citric acids, pectin. etc.
Domestic usage quantities in 2006	90 kilograms approx.	Merits of using nano material	In catalyst usage, the catalyst activation is improved and catalyst life is extended by increase of surface area by applying nano. In food usage, there are expectations for antioxidation effects.
Applications	Catalyst : 90% Other : 10% (biosensor, food, etc.)	Future markets	Catalysts have growth potential including usage in automobiles. However a specific quantitative forecast is difficult.
		Future applications	There are expectations for use as catalysts for automobiles, fuel battery catalysts, in ultra pure water for washing semiconductors, etc.

## 20. Quantum Dot

Presently the domestic sale of quantum dot is limited to as a reagent for research.

Item	Outline	Item	Outline
Particle size of sales grade	10 ~ 20nm (Core materials are cadmium selenide, tellurium cadmium selenide etc.).	Type of usage	Though it is used as a reagent for research, its mode of usage is uncertain. As for the structure, core material (cadmium, etc.) is covered with zinc oxide and then coated with polymer.
Domestic usage quantities in 2006	Several kilograms	Merits of using nano material	It is effective in time limit detection research due to its fluorescence application.
Applications	Reagent for research: 100% (Marking substance for proteins and antibodies)	Future markets	Though its market as reagent for research will continue to expand, its quantitative forecast is difficult.
		Future applications	There are expectations that its uses will expand into bio-imaging, bio-measurement, photosensitizing agent, in-vitro diagnosis of cancer etc., diagnosis of retina separation, drug kinetics research, etc.

\* Quantum dot is a structure in which the electron is confined in a 3 dimensional structure of nanometer area (several nm ~ 20nm), mainly by crystal growth or micro fabrication of the semiconductor. When the quantum dot is used as fluorescent substance, luminescence intensity is highly stable as compared to conventional fluorochrome, or it can be used as a cell marker or marker for anatomy of minute organisms because of its property to change the fluorescence wave length with respect to the particle size. Presently the domestic sale of quantum dot is restricted to as a reagent for research. Other than the above mentioned, application of quantum dot in quantum computer that can carry out very high speed calculations is also being investigated.

## 21. Nickel

Item	Outline	Item	Outline
Particle size of sales grade	<p>Average particle diameter: 0.2<math>\mu</math>m</p> <p>(Purity of the nickel ultra fine powder is 99.9% or more).</p> <p>* Many users demand customizing the making of fine particles regarding the basic grade. Therefore, almost all the products of nickel ultra fine powder are nano level (100nm or less) products.</p>	Type of usage	<p>Mounted in electronic components as multilayer capacitor.</p> <p>Mixed into resin when used in paste form.</p>
Domestic usage quantities in 2007 (Predicted amount)	1,200 tons approx.	Merits of using nano material	It is cheaper than silver-palladium paste.
Applications	Electrode material of laminated ceramic condenser: 100%	Future markets	<p>The amount used domestically will surely increase.</p> <p>In 5 years it will increase from the present 1,200 tons to 2,000 tons.</p>
		Future applications	It is predicted that it will be widely used as a laminated ceramic condenser in mobile phone, PC, digital camera, thin screen TV, etc.