TDMA
TITANIUM DIOXIDE MANUFACTURERS ASSOCIATION

INFORMATION SHEET

12 September 2025

Nanomaterials and titanium dioxide

Key information related to nanomaterials and titanium dioxide (TiO_2)

- More than 98% of TiO_2 placed on the market are non-nano forms used as a pigment which scatters visible light, giving it the ability to impart whiteness, brightness, and opacity.
- Less than 2% of TiO_2 placed on the market is a nanoform which have different properties for specialised applications such as industrial catalysts.
- Due to their small size, TiO_2 nanoforms scatter only a small amount of visible light and therefore do not offer any benefits as a pigment.
- Multiple EU scientific bodies have reiterated that the various nanomaterial definitions are a size definition only and do not necessarily imply any hazard.
- Most scientific studies on the safety of TiO_2 have been carried out on specialised TiO_2 nanoforms and care should be taken in drawing conclusions on pigmentary or other TiO_2 nanoforms based on studies on a single TiO_2 nanoform.
- Pigmentary TiO_2 contains a range of particle sizes including some particles in nanoscale size. These nanoscale particles have been taken into account in the scientific studies on the pigmentary forms.
- It is important not to double count the impact of the nanoscale particles by using studies on specific nanoform to model the nanoscale particles in pigmentary TiO_2.
- TiO_2 nanoforms are produced by specialised process and not by milling of pigmentary TiO_2 to a smaller size.
- There are several differing definitions of a nanomaterial in various regulations in the European Union (EU) and around the World leading to significant confusion.
- TiO_2 particles agglomerate in both air and water, making it rare for them to exist as single particles in these environments.

The objective of this document is to provide clarity and guidance in this area for scientific and regulatory purposes including a glossary of the many different terms used in this area.

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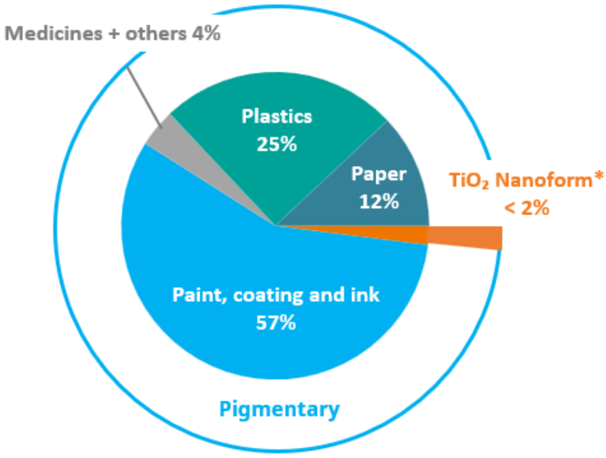
Background

Over 98% of titanium dioxide (TiO_2) is manufactured to serve as a pigment in a wide variety of important products such as paints and plastics. To be effective as a pigment, the constituent particles size must be much larger than nano particles. However, a very small percentage of TiO_2 is intentionally manufactured as a nanoform in different manufacturing processes to be used for highly different purposes than pigmentary TiO_2. The small constituent particle size and special properties of TiO_2 nanoforms gives them unique characteristics that play an important and innovative role in a range of mostly industrial applications.



*Meeting the EU Recommendation of a nanomaterial of 50% less than 100nm by number

The largest historical use of TiO_2 nanoforms is as a critical element in industrial emission control catalysts to improve air quality by controlling these emissions at source. Other useful innovations include use as a UV filter, solar energy technologies and improving the efficiency of lithium batteries in terms of both their capacity and lifetime. Europe is currently the world leader in exporting TiO_2 nanoforms products across the globe for innovative solutions, often in the areas of sustainability.

In recent years, concerns have been raised related to the safety of nanomaterials in general leading to many scientific studies and regulatory initiatives, particularly in the European Union (EU). The main concerns relate to the very small size of particles potentially causing harm to humans or the environment. Nanomaterial definitions provide only a size threshold, but size does not imply a hazard. The current evidence does not suggest a health concern for TiO_2 nanoforms (1).

TiO_2 is most often sold in a powder or particulate form and for that reason, it is often linked with nanomaterials in scientific and regulatory contexts, however less than 2% of the TiO_2 on the market meets the EU recommended definition of a nanomaterial.

Conversely, the vast majority of TiO_2 on the market are pigmentary non-nano forms providing the most effective white opacifier to conceal or hide the surface on to which it is applied. In addition to providing opacity by scattering visible light, TiO_2 also absorbs and scatters ultraviolet (UV) energy to protect articles such as plastics and window frames from UV degradation. To do this, pigmentary TiO_2 requires particles large enough to provide such coverage and light scattering properties and as such are not considered nanoforms.

Exposure or contact with TiO_2

In most consumer applications, the TiO_2 particles are dispersed in a liquid such as paint or imbedded in a solid matrix such as plastic preventing actual exposure to the particles themselves. The inhalation of dust by workers who are manufacturing or handling TiO_2 including in downstream factories is a risk generally addressed through worker exposure regulations at national and local levels primarily through dust restrictions. There are a number of best practices to prevent the release of dust or where that is not possible, using local exhaust ventilation and equipping employees with appropriate personal protective equipment (PPE).

Oral exposure to TiO_2 is possible through medicines, toothpaste and food, where authorised, but this only applies to specific high purity non-nano pigmentary forms.

TiO_2 nanoforms are only produced in a limited number of factories and mainly used in specialised industrial applications such as for emissions reduction from air and therefore there is a very low risk of exposure to consumers. The only exception is the use of TiO_2 nanoforms as a UV filter in sunscreens and other cosmetics where rigorous studies have been undertaken and reviewed by the EU Scientific Committee on Consumer Safety (SCCS) which concluded that TiO_2 nanoparticles are unlikely to penetrate human skin to reach viable cells or organs (2).

Toxicological properties of nanomaterials

The definition of nanomaterial is about size and not hazard. Multiple EU scientific bodies have reiterated that the various nanomaterial definitions are a size definition only and do not necessarily imply any hazard. For example, the EU Guidance on the implementation of the Commission Recommendation 2022/C 229/01 on the definition of nanomaterial produced by the EU Joint Research Centre (JRC) states that "nanomaterials can be hazardous, or not, and a definition based only on size properties cannot differentiate between hazardous and non-hazardous materials" (1).

Toxicological properties of TiO_2

TiO_2 is chemically inert and insoluble in water as well as most strong acids or alkali and will remain in the TiO_2 chemical form unless it undergoes vigorous chemical treatment. Therefore, any biological effects of TiO_2 are not related to the chemistry of TiO_2 but related to particles. The main concern for TiO_2 is inhalation due to the chance of exposure to particles by workers handling TiO_2 powders.

In 2020, the European Commission classified certain forms of TiO_2 as a category 2 carcinogen by inhalation according to Regulation (EC) No 1272/2008 on classification and labelling (CLP) (3). The only evidence for this was a single animal study which was carried out using a specific and unique TiO_2 nanoform under excessive lung overload conditions where the particle clearance mechanisms in the lung were significantly impaired due to the overload. This classification was annulled by the General Court of the European Union in November 2022 and then confirmed by the European Court of Justice (ECJ) when appeals were dismissed in August 2025.

Other studies have shown that there are differences in the inflammatory response in the lung, mainly related to a higher response for some specific TiO_2 nanoforms. It should be noted that inflammation is a normal physiological reaction to remove foreign material or particles entering the lung and is not necessarily hazardous.

Many studies claim that the biological properties of nanomaterials are impacted by the physicochemical properties. For example, nanomaterials with a smaller constituent particle size and higher surface area would have a greater biological interaction. The TDMA has not found any such relationship for TiO_2 in the many studies undertaken to date.

Test items used in scientific studies with TiO_2

There are many thousands of studies on the safety of TiO_2 and a very common weakness is the poor identification or justification of the appropriateness of the sample of TiO_2, which limits the reliability of the study. For example, when investigating the safety of TiO_2 used as a food additive, only the limited number of high-purity, non-surface treated forms of TiO_2 put on the market for food uses are relevant. However, many oral ingestion studies have used samples not representative of food grade TiO_2 without verifying this was intentional and explaining how this unrelated form is appropriate for the purpose.

The different definitions of nanomaterials

There are several differing definitions of a nanomaterial including from the International Standards Organisation (ISO) (4) and in various regulations in the EU. This leads to significant confusion, and the TDMA along with other bodies have been calling for a harmonised definition in the EU. In France, manufacturers and importers must submit an annual declaration of quantities and uses of substances at nanoscale which also includes a definition, which differs from the definition in the EU.

In general, the different definitions consider constituent particles in the range of 1 to 100 nm to be nanoscale though some include a specific threshold for the number of particles less than 100 nm. The TDMA follow the 2022 EU recommendation (5) for the definition of a nanomaterial and the older slightly different binding EU REACH Regulation (6) for the definition of a nanoform, where possible. They are both similar including the threshold of 50% of particles less than 100 nm by number. Other small differences in the definition do not impact whether TiO_2 forms meet the definition. The EU is planning to update the definition of a nanoform in EU REACH to make it consistent with its 2022 recommendation.

EU Definitions	Impact for TiO_2 in the EU
Recommendation (5)	Only TiO_2 nanoforms meet these definitions due to having 50% or more of constituent particles by number less than 100 nm
REACH (6)	
Cosmetics regulation (7)	The definition includes reference to being insoluble or biopersistent and having dimensions from 1 to 100 nm. The annexes of the regulation include separate descriptions of TiO_2 (nano) and other TiO_2/pigmentary. The TiO_2 (nano) for use as a UV filter includes a range of conditions including purity, rutile form, surface treatment and the agglomerate/aggregate particle size. TiO_2 is insoluble and it is common practice to apply the EU recommended definition of having 50% or more of constituent particles by number less than 100 nm to distinguish between pigmentary and TiO_2 nanoforms for cosmetics.

Food labelling and novel food (8)	This engineered nanomaterial definition does not include a threshold for constituent particle size though a threshold of 50% by number was proposed by the European Food Safety Authority (EFSA) for the specification of E 171/TiO_2 (9) which is consistent with the EU recommendation.
Declaration of substances at nanoscale in France (10)	The definition refers to intentionally produced at nanometric scale with a minimum of 50% of particles by number with one or more external dimensions in the size range 1 nm - 100 nm and therefore only TiO_2 nanoforms meets this requirement.

*The authorization for using E 171 as a food additive in the EU was recently withdrawn though safety has since been confirmed in other regions and by the World Health Organisation (WHO). Only pigmentary non-nano TiO_2 is used as a food additive.

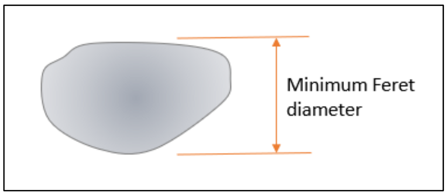
Measurement of the constituent particle size

Measurement of the constituent particle size is critical to determining if a TiO_2 meets the definition of a nanomaterial and is also important in ensuring a form of TiO_2 product is optimal for a specific application. There is often significant variance in the methods of measurement of the constituent particle size leading to different results. Analytical experts in the TDMA have studied this extensively and have developed and published reproducible results using transmission or scanning electron microscopy (TEM or SEM), as recommended in most EU guidance (11) (1), versus other methods of measurement.

Even though most definitions refer to the particle size distribution of constituent particles by number, the particle size distribution of pigmentary TiO_2 is often measured by volume as it is more useful for the effectiveness as a pigment. The two measures of particle size distribution are not directly comparable as shown in the table below.

	Pigmentary TiO_2	**TiO_2 nanoforms**
Typical median constituent particle size by **number** (nm)	100 – 250	5 - 80
Typical median constituent particle size by **volume** (nm)	150 - 300	6 - 100

To determine the constituent particle size from irregular shapes in TEM or SEM images, a methodology needs to be applied. The Commission Recommendation (5) and REACH definition (6) refer to having 50% or more with one or more external dimensions in the size range 1 nm to 100 nm.



The JRC Guidance on the implementation (1) notes that the term 'external dimension' is more precise than 'particle size' and recommends the minimum Feret diameter or the maximum inscribed circle. The minimum Feret diameter is a measure of the size of an object along a specified direction. The TDMA has found it more reliable to assess the constituent particle by the minimum Feret diameter.

Mass based constituent particle size distribution – This is difficult to measure by collective methods such as analytical centrifuge or dynamic light scattering (DLS) due to the strong agglomeration/aggregation properties of TiO_2. Estimation of the mass-based particle size distribution from TEM or SEM measurement is possible, but due to the limited number of particles measured and the two-dimensional image, the margin of error can be high. For these reasons, the TDMA prefers to avoid estimating or reporting the mass-based constituent particle distribution, although it is possible to calculate a value for the agglomerated/aggregated particles.

Measurement of agglomerate/aggregate particle size

The agglomerate/aggregate particle size will depend on the conditions of the TiO_2 including whether it is air or a liquid dispersion, or the amount of dispersion energy applied by techniques such as sonication to forcibly disrupt agglomerates and aggregates, particularly for agglomerates as they are more-weakly bound. The best indicator of the degree of agglomeration/aggregation is the ratio of agglomeration/aggregation particle size and the constituent particle size.

Shape of TiO_2 constituent particles

Most TiO_2 constituent particles are more or less spherical though some specific nanoforms are elongated with an aspect ratio up to around 8. TiO_2 exists rarely in other forms such as platelets and rods.

Crystal forms

Rutile is harder with a higher opacity, making it the most widely used pigment in paints and plastics, representing approximately 90% of TiO_2 production. In contrast, anatase is less dense, less hard, and less opaque, giving a softer bluer tone with less UV absorption. It is typically used in applications such as food additives, medicines, and specialty papers.

Surface-treatment

TiO_2 is often surface treated with inorganic and/or organic substances to provide specific properties such as improved dispersion, compatibility and reduced photoactivity to improve durability of downstream products. The most common inorganic surface treatments are aluminium, and silica based that are used to flocculate the material in the manufacturing process to allow filtration. Organic surface treatments are less common and are normally applied as the outermost layer.

TiO_2 in fibre form

The definition of a fibre depends on the context. For toxicity, it normally refers to a substance fulfilling the World Health Organisation (WHO) fibre definition which is a diameter < 3 µm, length > 5 µm and aspect ratio ≥ 3. There are some specially manufactured TiO_2 in fibre form meeting the WHO definition, but these are very rare. There are also non-fibre elongated forms of TiO_2 which have a length of up to around 300 nm and therefore are 15 times shorter than the WHO length criteria of 5 µm. Fibres meeting the WHO definition may pose a hazard, but this is not applicable to TiO_2 except in these rare specialty cases.

All forms of TiO_2 are covered by the EU REACH joint submission, however, the individual registrants of TiO_2 in fibre form have separately submitted a partial opt-out and therefore these end points are not covered by the joint submission of the lead registrant. There is also a separate self-classification of TiO_2 in fibre form as hazardous in a separate notification to the ECHA Classification and Labelling Inventory under the EU Classification and Labelling Regulations (CLP).

Manufacture of TiO_2

The two main methods to manufacture pigmentary TiO_2 are the sulfate process and the chloride process. The sulfate process involves the digestion of natural or upgraded titanium ores in sulfuric acid to form $TiOSO_4$, hydrolysis to precipitate titanium dioxide hydrate and calcination to grow the TiO_2 crystals to the required size and crystal phase, either anatase or rutile. The chloride process involves chlorination of natural or upgraded titanium ores to form titanium tetrachloride ($TiCl_4$) followed by gas phase oxidation at high temperature. The chloride process can only produce pigmentary rutile.

The manufacturing method of nanoforms can vary significantly and may be different from pigmentary forms. The control of the constituent particle size is very important to produce the correct properties of the TiO_2 and is a key part of the manufacturing process. Note that TiO_2 nanoforms are not produced by re-sizing or milling larger pigmentary forms to smaller particles as they are manufactured directly in nanoform as described below.

Anatase TiO_2 nanoforms which are often used as catalysts supports, for applications such as the elimination of nitrogen oxides from the flue gases of power plants and waste incineration plants as well as exhaust gases from automobiles and in emerging usages in e-fuel or batteries. They are made by hydrolysis of titanium oxide sulfate, $TiOSO_4$, to give constituent particles of 3-6nm. These particles are subsequently grown to the desired size by calcining at temperatures below 600°C and in some cases doped with certain other elements. This is much less than the 900°C needed to prepare pigmentary anatase TiO_2. This process has an impact on the surface characteristics due to the higher amount of sulfate and hydrated surface retained at these lower calcining temperatures.

Rutile TiO_2 nanoforms, which are often used in sunscreen, may be manufactured either by treating sodium titanate with hydrochloric acid or by hydrolysis of $TiCl_4$ or its derivatives. This results in constituent particles between 1nm and 10nm which are subsequently grown to the desired size by heat treatment.

Some TiO_2 nanoforms are manufactured by the specialised flame pyrolysis process using $TiCl_4$ in a hydrogen and oxygen flame. This manufacturing process is used for the production of specialised TiO_2 nanoforms with mixed anatase/rutile crystal phase that are highly aggregated and used mostly as a catalyst. This manufacturing process is uniquely used for TiO_2 nanoforms and is not used for pigmentary forms. The most common example is P25, which is often referred to as NM105, as this nomenclature was used in the EU Joint Research Centre (JRC) Nanomaterials Repository as part of a wide range testing programme.

Glossary of terms related to TiO_2

The section includes a glossary of common terms and their relevance for TiO_2. As there are multiple and confusing terms in this area, the TDMA have also developed preferred terminology which is based as much as possible on EU regulations and guidance.

TDMA preferred terminology	
Pigmentary TiO_2	TiO_2 with less than 50% of constituent particles by number less than 100 nm that is mainly used for its high opacity.
TiO_2 nanoform	TiO_2 with 50% or more of constituent particles by number less than 100 nm.
Constituent particle size	The size of the smallest possible identifiable individual particles inside an agglomerate and aggregate.
Agglomerated/aggregated particle size	The size of the bound or fused particles which depends on the conditions of measurement.
Surface-treated TiO_2	A modification of TiO_2 particles at the surface of the particles with a surface-treating agent.
Weakly adsorbed surface coated TiO_2	An organic compound that is coated on the TiO_2 and may readily be removed.

Aerodynamic diameter - The diameter of a sphere of density 1 g/cm³ with the same terminal velocity due to gravitational force in calm air, as the particle, under the prevailing conditions of temperature, pressure and relative humidity (12). This parameter considers the density and shape of an airborne particle and how fast it will fall compared to a hypothetical sphere with a density of 1000kg/m³. A particle with a lower density and irregular shape will have a larger aerodynamic diameter. The EU classification of certain forms of TiO_2 (3) included a criterion for aerodynamic diameter though this classification was annulled and no longer applies. The aerodynamic diameter is much larger than the constituent particle size as they bind together in agglomerates due to attraction between the particles. Extensive TiO_2 producer testing of individual pigmentary and nano grades of TiO_2 shows that the vast majority of TiO_2 put on the market does not meet the aerodynamic diameter criteria hazard.

Anatase – A crystal form of TiO_2 representing around 10% of global production. Anatase has a tetragonal structure with TiO_6 octahedra that retain their orientation in all repeats. Compared to rutile, anatase is less dense, has a lower hardness and a lower refractive index of 2.55. It does not melt but transforms into rutile form when heated above approximately 900°C. It is also less opaque with a softer bluer toned colour with less UV absorption. It is typically the anatase form of TiO_2 that is used in food, medicines, cosmetics and specialty paper such as bank notes. Both pigmentary anatase and rutile may be made by the sulfate process.

Aspect ratio – The ratio of the width to the height of a particle. Most TiO_2 has an aspect ratio of around 1.2 which means it is spheroidal. A perfect sphere has an aspect ratio of 1.0. Some special TiO_2 nanoforms have an aspect ratio of up to 8. The EU regulation on UV filters for sunscreen in cosmetics (7) specifies a maximum aspect ratio of 4.5, as this was the maximum for which data was submitted for the safety evaluation. It is sometimes called the form factor.

Aggregate - A particle comprising of strongly bound or fused particles (EU Recommendation). The surface area of an aggregate is smaller than the sum of the surface areas of the particles of which it is comprised. Some specific TiO_2 nanoforms produced by the flame spray pyrolysis process are highly aggregated but most TiO_2 is only slightly aggregated. TiO_2 particles are mostly agglomerated.

Agglomerate - A collection of weakly bound particles or aggregates where the resulting external surface area is similar to the sum of the surface areas of the individual components (5). TiO_2 is mainly in the form of agglomerates in both air and water due to attraction between the particles. Some specific TiO_2 nanoforms are highly aggregated though these aggregates also agglomerate.

Agglomerate size – The size of the agglomerate. As the degree of agglomeration will depend on the energy applied to disperse the particles and therefore the conditions of the measurement must be specified.

Basis substance – The substance in the form of particles on which a surface treatment is applied (13). In the case of surface treated TiO_2, this is the TiO_2 itself.

Brookite – A natural, orthorhombic crystal form of TiO_2 that is not commercialised.

Bulk form – This term is often used to describe the non-nanoform of a material that also has nanoforms. The TDMA prefer to use the terms pigmentary or non-nanoform instead of bulk as the latter can be confusing. Bulk typically refers to unpackaged or loose materials often stored in a silo or transported in a bulk tanker or in a bulk cargo ship. Bulk material in practice could also be a nanomaterial.

Chloride process - One of the two main production routes for TiO_2 that involves the chlorination of natural or upgraded titanium ores to form titanium tetrachloride ($TiCl_4$) followed by gas phase oxidation at high temperature. The chloride process can only produce pigmentary rutile.

Constituent particle – The smallest possible identifiable individual particles inside an agglomerate and aggregate (5). As TiO_2 is normally agglomerated, the constituent particle size of the agglomerate is the determinant of whether a TiO_2 form meets the EU definition of a nanoform and is normally measured by electron microscopy. Sample preparation and the way of particle counting are important prerequisites for correct estimation of constituent particle size due to strong agglomeration and broad particle size distribution of TiO_2.

Crystal form – A description of the ordered arrangement of molecules or atoms. In the case of TiO_2, it is the arrangement of the titanium (Ti) and oxygen (O) atoms in TiO_2. TiO_2 comes in two main crystal forms, anatase and rutile. TiO_2 can also come in brookite form, but this is not commercialised. The different crystal forms of TiO2 have different physical properties which influence their application areas (see Anatase and Rutile). Hence, for non-catalytic applications, it is very important to have only one of the crystal phases present. The TDMA have not seen any difference in toxicological properties between anatase and rutile.

Doping - This is the intentional introduction of other chemical elements or dopants during manufacture which are normally to help manufacturing and influence properties such as the crystal form. For example, in the production of pigmentary TiO_2, by both sulfate and chloride processes, dopants such as salts of aluminium, alkali metals and phosphates are added to ensure that the products have an optimum constituent particle size distribution for light scattering, are not significantly aggregated and to ensure the desired crystal phase is obtained. Furthermore, an aluminium doped structure provides lower photoactivity of the final products.

E 171 - The food additive identity number assigned to TiO_2 in the EU (14). Only pigmentary TiO_2 is used as a food additive. E 171 is specially manufactured TiO_2 form and has a detailed specification which is mainly related to the purity. Though not specified, it is typically a non-surface treated anatase form.

Feret diameter - A measure of a size along a specified direction and is a method to determine the constituent particle size from electron micrograph images. The TDMA normally report the constituent particle size distribution by the minimum Feret diameter as it is recommended by JRC Guidance on the implementation of the definition of a nanomaterial (1).

Fibre – This can have different meanings but for toxicity, it normally refers to a substance fulfilling the World Health Organisation (WHO) fibre definition which is a diameter < 3 µm, length > 5 µm and aspect ratio ≥ 3 (15). More information is provided in the section on fibres.

Fine particles - There is no formal definition, but fine particles are generally considered have a diameter of 2.5 µm. Some publications refer to fine particles for pigmentary TiO_2 to differentiate it from ultrafine or TiO_2 nanoforms. To avoid confusion, the TDMA prefer the term pigmentary TiO_2.

Flame pyrolysis – This is specialised process for the flame pyrolysis of titanium tetrachloride ($TiCl_4$) in a hydrogen and oxygen flame. This manufacturing process is used for the production of specialised TiO_2 nanoforms with mixed anatase/rutile crystal phase that are highly aggregated and used mostly as a catalyst.

Form – A structure of a substance. TiO_2 comes in many different solid forms including different crystal structures, shapes and sizes. Surface treatment can also result in different TiO_2 forms including hydrophobic forms.

Form factor - The ratio of the width to the height of a particle which is more commonly called the aspect ratio.

Grade - A grade of TiO_2 is generally linked to a product specification and is not necessarily a different form. This can also be called the trade name. Many applications have specific specifications which are often linked to industry standards reflecting the applications such as purity for food or to preventing poisoning of catalysts. Many of these additional tests are expensive and time consuming and therefore only products sold in these markets are tested and specified according to this grade. There are reasons such as following an acquisition or merger of two producers, that trade names are retained even though they are produced on the same production line and are very similar to other products as customers are familiar with them. Another example is a development sample name that is used in the development of a pharmaceutical and written into the drug approval scheme and therefore cannot be easily changed.

Grafted – This is the strong bonding of organic surface treating agents to TiO_2 where the substance chemically reacts with the TiO_2 surface.

Hydrodynamic diameter - In practice for TiO_2, it is the diameter of the agglomerated/aggregated TiO_2 in a liquid suspension. The diameter will depend on the applied dispersion energy for suspension preparation and the strength of agglomerates.

INS171 - The food additive identity number assigned to TiO_2 in the International Numbering System for Food Additives (INS). The identity number of the EU is E 171. Only pigmentary TiO_2 is used as a food additive. INS171 is specially manufactured TiO_2 form and has a detailed specification which is mainly related to the purity. Though not specified, it is typically a non-surface treated anatase form.

Microform – There is no formal definition, but this is normally referring to pigmentary TiO_2 where the median particle size is greater than 100 nm and is sometimes used to differentiate from TiO_2 nanoforms. To avoid confusion, the TDMA prefer the term pigmentary TiO_2.

Microscale particle - There is no formal definition, but this is normally referring to a particle from 0.1 to 100 µm.

Nanoform – A form of a natural or manufactured substance containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm (6). It is based on the older and slightly different EU recommendation from 2011. The TDMA prefer to use the term TiO_2 nanoform as it is legally defined in the EU REACH Regulation.

Nanoparticle – A particle with all external dimensions in the nanoscale where the lengths of the longest and the shortest axes of the nano-object do not differ significantly (4). For TiO_2, a nanoparticle could be a small particle in pigmentary TiO_2 or from a TiO_2 nanoform. For this reason, the TDMA prefer TiO_2 nanoform to describe an intentionally manufactured grade meeting the EU recommendation for a nanomaterial.

Nanoscale - The length range approximately from 1 nm to 100 nm (4).

Particle - A minute piece of matter with defined physical boundaries (5).

Pigment – An insoluble powder used to add color or change visual appearance.

Primary particle – The original source particle of agglomerates or aggregates or mixtures of the two (4). This could vary from the constituent particle which is identified in the material being evaluated. The EU definition (1) refers to the constituent particle to reduce the uncertainty due to potentially different interpretations of the primary particle size. The TDMA prefers to use the constituent particle.

Rutile - A crystal form of TiO_2 representing around 90% of TiO_2 production. Rutile has a tetragonal structure and the TiO_6 octahedra are turned through 90° with a twist of 45° between layers. Compared to anatase, the rutile structure is more closely packed and hence denser, harder and more abrasive with a higher refractive index of 2.73. It is also more opaque and less photoactive. It can be manufactured by both the sulfate and chloride processes.

Secondary particle – The aggregated and/or agglomerated particles. The TDMA avoids this terms and prefers to use agglomerate for the typical particle of TiO_2 as it is difficult to distinguish between the aggregate and agglomerate.

Sulfate process – One of the two main production routes for TiO_2 that involves the digestion of natural or upgraded titanium ores in sulfuric acid to form $TiOSO_4$, hydrolysis to precipitate titanium dioxide hydrate and calcination to grow the TiO_2 crystals to the required size.

Surface area – The total area of the external surface of a solid plus the internal surface of its accessible pores per unit mass. This is normally measured according to the Brunauer, Emmett and Teller (BET) (16). The specific surface area of TiO_2 ranges from 5 to 350 m^3/g.

Surface coating – In the TiO_2 industry, the terms surface coating and surface treatment are commonly used interchangeably. The TDMA prefers to use the term surface treatment for consistency with EU REACH. See the definition of surface treatment.

Surface functionalization – Surface functionalization or treatment is one of the characterisation parameters for nanoforms in the EU REACH regulation (6). An example of surface functionalisation could be to surface treat to make it hydrophobic.

Surface modification – The modification of the surface of a particle. The TDMA prefers the term surface treatment for clarity.

Surface-treating agent - Substance reacting with the surface of the base substance which is the substance used as the starting material in the surface-treatment process (13).

Surface-treated TiO_2 – A modification of TiO_2 particles at the surface of the particles with a surface-treating agent (6). Most TiO_2 is surface treated and this can result in different TiO_2 forms with different properties. A common inorganic example is aluminium sulfate, which reacts with the surface to deposit a bound alumina surface layer when neutralised with a base. Octylsilane is an example of an organic surface-treating agent that reacts and is grafted to the TiO_2 surface. Under the EU REACH regulation, there are several requirements for surface-treated substances, particularly for TiO_2 nanoforms.

Trade names – A commercial name for a TiO_2 grade. See TiO_2 grade for further information.

Weakly adsorbed surface coating – An organic compound that is coated on the TiO_2 and may readily be removed. As it is not strong bound to the surface, it is not considered a surface treated substance under EU REACH (13). The TDMA consider this a chemical mixture for the purposes of the EU REACH Regulation and CLP (17).

Ultrafine - There is no formal definition, but it has been referred to as particles with an aerodynamic diameter of 100 nm or less and is sometimes used as a technical term for micronised (jet-milled) material. However, due to the strong adhesive forces, it is difficult to impossible to disperse TiO_2 particles to this size and handling of the material results in much larger, agglomerated particles. The aerodynamic diameter should not be confused with constituent particle diameter. To avoid confusion, the TDMA prefers the term TiO_2 nanoform for materials with constituent particle external dimensions below 100nm.

Volume specific surface area (VSSA) – The surface per unit volume which is included as an additional property for screening purposes in the EC nanomaterial definition (5). A material with a VSSA less than 6 m^2/cm^3 shall not be considered a nanomaterial. A material with a VSSA less than 60 m^2/cm^3 shall not be considered a nanomaterial. However, this property is only applicable for assessment of particulates if the surface is non-porous. The VSSA of TiO_2, both pigmentary and in nanoform, may range from 20 to 1000 m^2/cm^3 due to the presence of porous inorganic surface treatments and therefore this property is not applicable when determining if a material meets the EC definition. This is determined by the constituent particle size only.

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About the TDMA

The Titanium Dioxide Manufacturers Association (TDMA) is a sector group of the European Chemical Industry Council (Cefic) and represents the leading producers of titanium dioxide (TiO_2). TDMA is a non-profit organisation established in 1974 and dedicated to promoting the safe use and benefits of TiO_2 to society.