PRINZ OPTICS GLAS PLUS

Coatings that alter
the functional properties of substrates

White Paper

Surface coatings
on glass and non-glass substrates

October 2024

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Optical coatings on glass make it possible to optically influence a natural or artificial light source through filtering.

Functional coatings on glass – but also on metals and plastics – make it possible to change the physical and biochemical properties of substrate surfaces in order to expand their functions.

Coatings: Possibilities and techniques

1. Glass coatings for optical light filtering

make it possible to influence natural and artificial light sources.

More specifically, they enable the modification of incident light radiation, which in turn shifts the light spectra when conversion filters are used, for example, or, in the case of colour effect glass, “transforms” a “white” light into almost any spectral colour (see our Dichroic Filters white paper).

Many technical applications require the use of only certain parts of the spectrum, whereby IR and UV filters are used for this, for example. The transparency of glass can be precisely adjusted in line with a given application. The range in which this parameter can be influenced is generally between 250 and 1600 nanometres (UV / VIS / NIR). Optical filters made of glass for technical applications are used in science, medicine and industry, as well as in sensor technology (see our Optical Filters white paper).

2. The >functional< coating of glass, metal and plastic changes the surface properties of these substrates.

Here, wafer-thin transparent, translucent and even opaque layers are applied. Unlike optical coatings, functional coatings are not solely used to achieve a targeted optical modification of incident light or penetrating light. The function here is based on the interaction that occurs upon contact between the molecules or atoms bonded in the coating and external influences such as UV light, electrical charges, bacteria or an input of mechanical energy. Depending on the type of coating in question, the result will be a photocatalytic, electrically conductive, antimicrobial or impact-absorbing effect.

2.1 Substrate

Glass: Standard thicknesses					
Float glass	2 mm	3 mm	4 mm	5 mm	6 mm
Borofloat	1,1 mm	2 mm	3,3 mm	5,5 mm	6,5 mm
Clear glass	2 mm	3 mm	4 mm	5 mm	6 mm
Metal thicknesses in accordance with specifications / customer requirements					
Standard sizes for dip coating					
Minimum	In mm range depending on the material				
Maximum	Gross 1,150 x 850 mm / net 1,080 x 800 mm				
Finished components Coating with spraying and flow coating, depending on the customer’s specification					

2.2 Materials for functional coatings

Organometallic coatings

A large group of the raw materials used are organometallic compounds of the oxides that form the layers. Their high degree of reactivity and interlinking make it possible to manufacture coating solutions that wet the substrates well. The conversion of the reactants into oxides during curing occurs at relatively low temperatures.

A sub-group of these organometallic compounds are alkoxides from TiO2, ZrO2, SiO2 and the mixtures of these. They are used to produce optical interference filters using the sol-gel method. A special aspect of interference coating involves the lack of absorption. More specifically, the amount of incoming light is split into a transmitted and a reflected ray. The interference effect depends on the light's angle of incidence.

Organometallic compounds based on tin make it possible to manufacture electrically conductive coating layers with low electrical resistance.

Lustre colours are another group of the organometallic compounds that are used. These create a metallic shine with a high degree of reflection on the substrate surface. Titanium and iron compounds, among others (including precious metals such as gold and platinum), are used to manufacture metallic mirror coatings.

Angular-independent optical behaviour is achieved through the application of pigment solutions. The large group of coating solutions produced from dispersions stand out through the fact that the pigments are usually applied with an optical binder with optimised adhesion. When ceramic pigments are used, the temperature resistance of the resulting coating will be very high. The special pigments enable the desired physical, chemical or biological function, whereby the binder ensures homogeneous distribution and sufficient adhesion of the pigments on the substrate. Along with numerous oxides such as ZnO, TiO2 and SnO2, minerals including spinels, CoAl2O4 (blue) and (MgFeCu)Al2O4 (black) are also used.

Dispersion processes, such as wet grinding (e.g. in agitator ball mills), are used to manufacture transparent ceramic pigment dispersions.

The material groups mentioned last above enable the creation of coatings that absorb at least a part of the incident light ray and in this manner convert the transmitted light ray. Most of the light energy here is converted into heat.

A combination of interference and absorption coatings are used in order to reduce part of the optical filter's angular dependence.

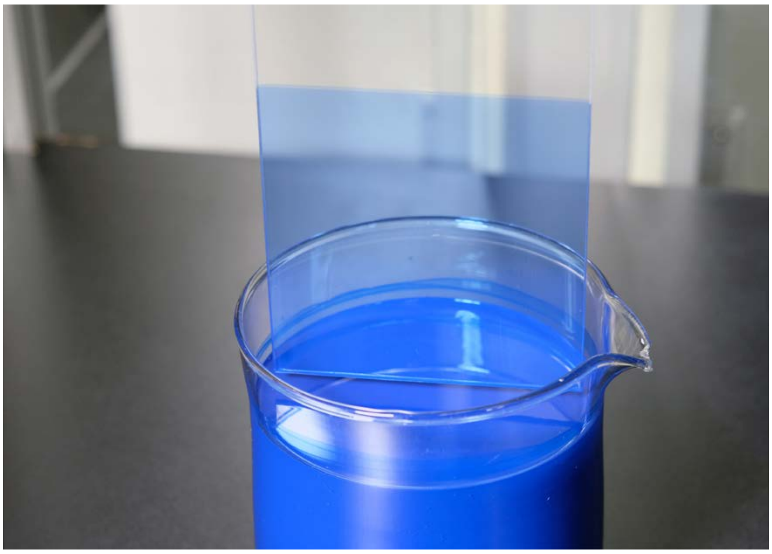
Organic coatings

The group of organic coatings has completely different properties. Along with classic glass varnishes, conductive polymers with pigments are used here, or else coatings that contain pigments and link and harden at room temperature. These might take the form of colloidal silver or silver needle paint, as well as light-scattering or chromophoric components. The organic coatings stand out through the variety of colour and lustre effects they create, in particular when used for design purposes. Coating and hardening ensue when the solvent evaporates and the reactants are linked. This generally occurs at room temperature, or at a maximum temperature of 150 °C. The process results in lower scratch resistance and adhesive strength compared to oxidic layers. With a range between 1 and 30µm, the layer thicknesses are much higher than those produced with the dip coating method.

2.3 Method for applying functional coatings Sol-gel dip coating

Method

With this liquid coating method, the object is dipped in a coating solution. A homogeneous coating with an adjustable layer thickness is then created through the controlled and steady withdrawal of the object from the solution. In the traditional sol-gel dip coating process, the coating solution reacts with water in the air, which leads to gelation and the formation of layers.



Finally, a thermal treatment, or firing process, converts the integrated networked gel on the substrate surface into an oxidic state. The even linking during the gelation process results in very homogeneous layer thicknesses with deviations of only a few nanometres.

Suitable substrates for this method are glass, metal and plastic; the layer thicknesses range from 30 nm to a few µm at curing temperatures of up to 180°C.

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Sol-gel spin coating method for coating the inside of a sphere

With our spin coating method, which is a special further development of the sol-gel coating process, it is possible to apply an interference filter to the inner surface of a glass sphere. Here, a combined spinning and swivelling movement enables the creation of very homogeneous multilayer systems in a glass sphere.

Dichroic coating of the inside of a glass sphere

Flow coating

Flow coating is a simple procedure that does not require complex and expensive equipment and systems. With this method, a dosing unit spreads the coating solution across the surface of the object in a gravity flow and in a controlled manner.

Coating times here are short and it is possible to apply large amounts of coating as well. The properties of the layers correspond to those that result from the dip coating method.

Flow coating of glass

The substrate must be suitable for wetting and have a flat surface (no flanges) in order to ensure a homogeneous layer thickness throughout.

The layer thickness here is similar to that achieved with the dip coating method, but it can only be controlled by adjusting the concentration levels of the coating solution. Though it is homogeneous relatively speaking, the layer thickness may be less homogeneous than is the case with the dip coating method.

Spraying

This method involves spraying atomised coating solutions under pressure out of a nozzle. The aerosol, which is accelerated by the air stream, hits the substrate surface and forms a layer on it. In some cases, the evaporation of the solvent is followed by a linking and thermal curing process.

The coating solution must be adapted to the spraying process, and the powerful air stream requires an environment that is completely clean. This method enables homogeneous coating on surfaces with complex shapes.

The layer thicknesses can range from 0.2 to 20 µm per individual layer. The layers are, however, less homogeneous than is the case with the dip coating or flow coating method. Interior coating of hollow vessels is possible, but it depends on the geometry of the object in question. The equipment and systems needed for this are relatively simple and high coverage rates are possible as well.

Spray coating of glass

Spray pyrolysis

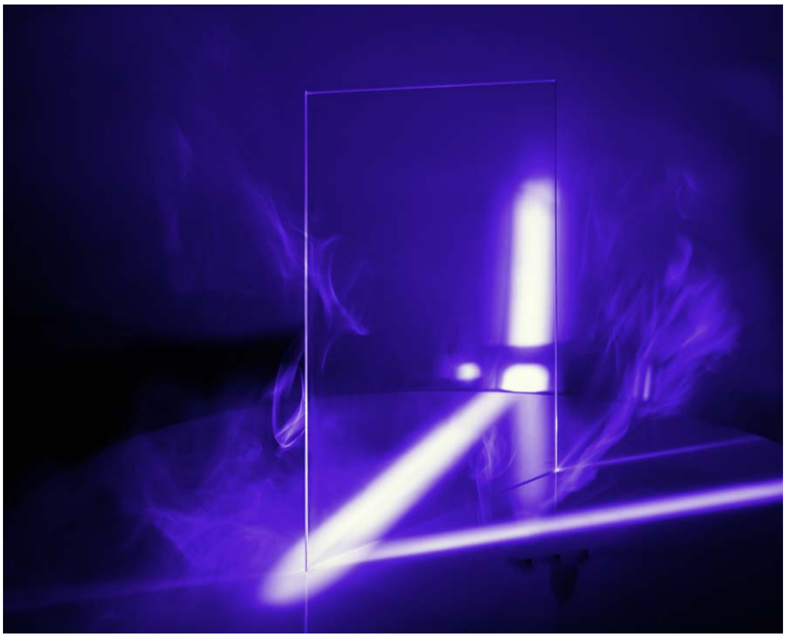
This special form of the spray coating process involves spraying a coating solution containing tin onto a glass substrate heated to a temperature of more than 500 °C. The aerosol is split, the organic material evaporates and an oxidic layer crystallises on the substrate, whereby the structure of this layer is different from that of a dipped sol-gel layer. With this method, the glass used must display a high level of stability with regard to temperature changes.

In the case of a tin oxide coating, the smallest sheet resistance that can be achieved here is 10 ohms per square, with high heat reflection and electric conductivity. The process technology used here does not require a vacuum.

3. Possibilities and applications in products

3.1 Photocatalytically active coatings

von Glas- und Metalloberflächen bewirken unter Einwirkung von UV-Licht die Reinigung von Luft sowie die Tilgung von Keimen und Gerüchen, zum Beispiel auf Textilien.



Photocatalytic coating of glass

The photocatalytic coating method uses light to break down to the molecular level harmful substances such as smoke or unpleasant odours. This method can be used on glass and various metals.

Here, surfaces with a length of up to approx. one metre are coated in a dip coating process, while very large surfaces are coated using the spray coating process.

Process: Dip coating, spray coating

Application examples

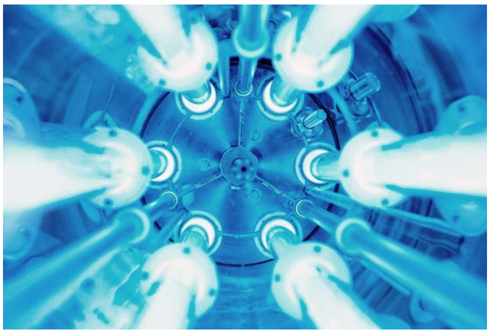
Degradation of odours or pollutants

The removal of odours (e.g. on textiles), or the degradation of pollutants and germs on glass and metal parts, is achieved by coating with photocatalytically active titanium dioxide (TiO_2) in the anatase crystal modification under the influence of UV light.

Catalytic cleaning of shirts

Water purification

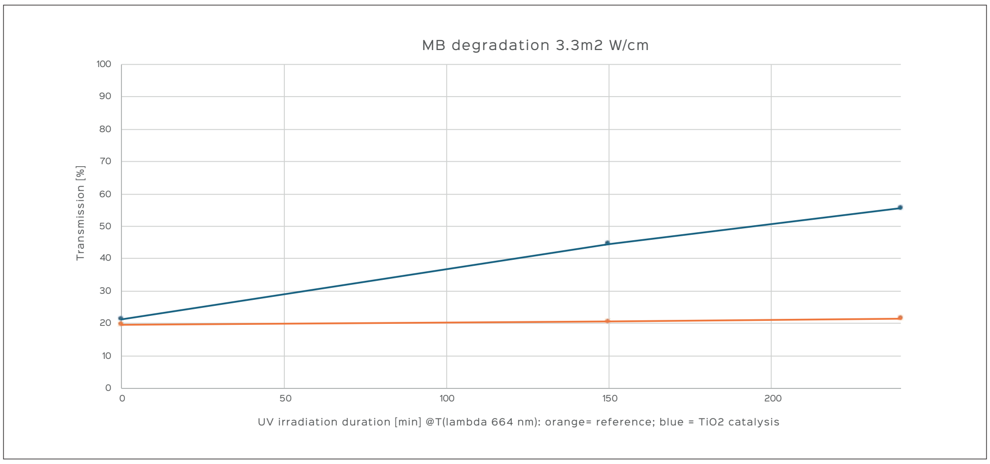
The purification of water is carried out by photocatalytically active reactors. The water to be cleaned flows around the TiO_2-coated large-area filters under irradiation with UV light.



UV irradiation for water treatment

Structures with the largest possible surface area are used for this purpose in order to achieve the best possible purification effect. The structure of the layers is also designed in a manner that ensures that these themselves have a large specific surface area. This makes it possible for the UV cleaning mechanism to achieve a high level of efficiency.

The photocatalytic effect of the coating is achieved in line with tests in accordance with the DIN 52980 standard. The effectiveness of the surface with regard to activities that degrade organic molecules is determined by irradiation with UV light of a sample that is in contact with a methylene blue aqueous solution. A second sample with the same methylene blue aqueous solution that does not contain a photocatalyst is used as a reference.



Degradation of methylene blue by means of photocatalytic activity of a metal surface coated with TiO_2.
As the duration of UV irradiation increases, the solution becomes decolourised (blue curve); the transmission increases.

3.2 Electrically conductive coatings

on glass and polymer surfaces are electrically conductive and transparent. The application can be done without tempering as well as at a high temperature.

Without tempering
Glass and plastic are given

- an anti-static function to dissipate electrical charges on glass surfaces (explosion protection)
- a sensory function to forward measurement data.

onductive polymer coatings

- Have a surface resistance in the KΩ to MΩ range and are made of electrically conductive, transparent polymers
- Are suitable for temperature-sensitive plastic surfaces
- Offer an anti-static function for glass components
- The substrates are coated at low temperature
- by spraying, flow coating and dipping, with the final hardening taking place at room temperature

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High-temperature application

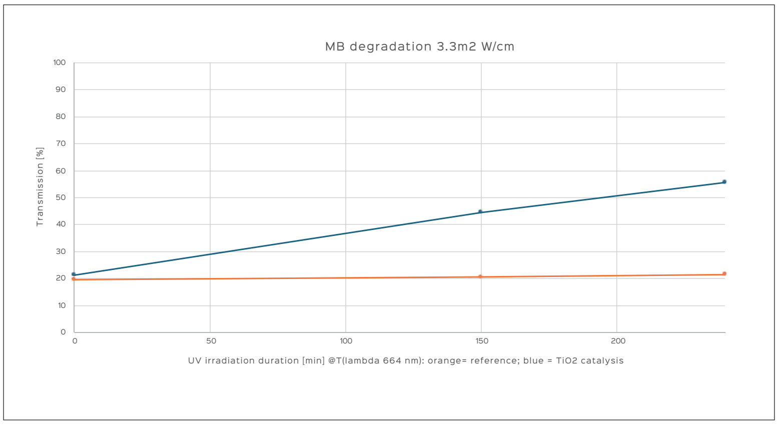
gives glass surfaces an electrically conductive tin oxide coating

Process: Dipping or spraying

Type: Organic layer / Pigment coating

Hardening: At room temperature (organic) / At up to 580 °C, thermal, using a heat regulator (pigment-based)

Thermally temperable



Transmission spectrum of tin oxide

Application examples

Chemical plant engineering

Electrostatic coating of plant components in explosion protection areas

Electrically heated reactor with ATO multiple coating

Display manufacturing

Special display applications, electromagnetic shielding (ESD) and protective glass (for laser devices, for example) can be implemented/manufactured with the help of a coating containing tin oxide (ATO, blue ITO) that is applied using the dip coating method. Conductivity is in the range of 1 to 10 kΩ, and the gentle curing process means that more thermally sensitive types of glass, such as clear glass, can be coated as compared to the spray pyrolysis method.

3.3 Shatter protection coatings

are applied to the outside of glass components used in chemical plants and systems, for example on tubes and reactors. The polymer layers, which are between 1 and 3 mm thick and are made of polyurethane, protect glass against mechanical stress – for example when chemical equipment is installed or equipment and systems are cleaned. The coatings are transparent and have no intrinsic colour up to an operating temperature of approx. 120 °C.

The shatter protection layers can be combined with anti-static coatings in order to prevent induced electrical charges when components are cleaned with cloth.

Coated curved glass component with shatter protection coating

Reactor with shatter protection coating on the outside
and additional anti-static coating

3.4 Antimicrobial coating

Glass surfaces (e.g. touchscreens) that are used in sterile environments often have an antimicrobial coating applied to them. A commercial coating solution based on the sol-gel method is used here. Silver ions integrated into the coatings keep germs off the screen surface. The manufacturer has verified the biological effectiveness of the coating.

Process: Dipping or spraying
Type: Sol-gel coating
Hardening: 150 °C with air
Operating temperature: Max. 350 °C (oxidation of silver)
Not thermally temperable.

3.5 Scattering layers and intensity filters

A defined degree of scattering is achieved by bonding ceramic or organic particles in a transparent solution matrix. The size and number of particles in combination with the set layer thickness influence the scattering effect and the gloss level of the coated glass.

A grey filter is used if light intensity is to be reduced in a defined and even manner. The colour and contrast of the incidental light are not influenced.

Process: Dipping
Type: Pigment coating, glass varnishHardening: 400 °C to 500 °C with air, or up to 150 °C in the case of organic varnishes

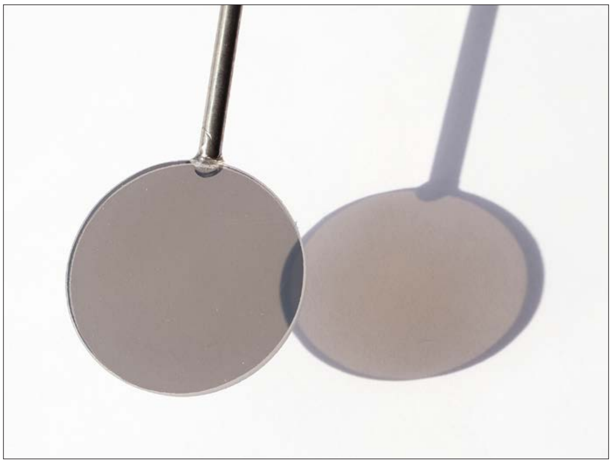
Application examples for scattering layers

Milk glass, control panels

Scattering layer (lower part of the glass pane) for creating a milk glass effect

Application examples for intensity filters

Photography, camera technology



Grey filter

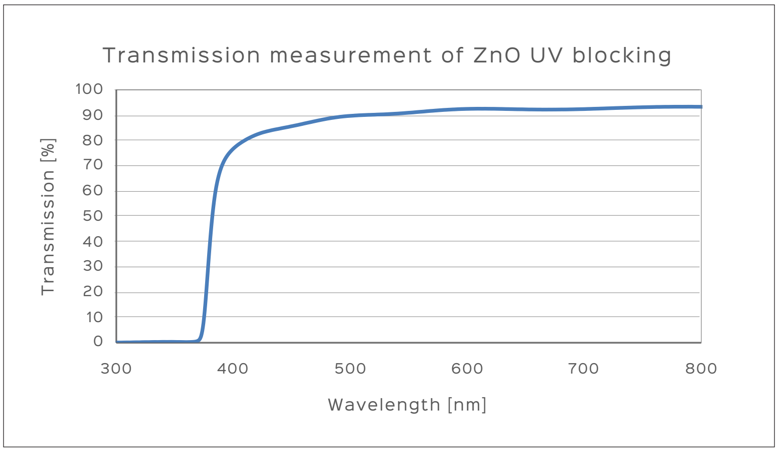
Lighting technology

Parcel logistics

3.6 UV filters

UV filters that reflect a defined UV range can be manufactured using interference coating, as is described in our Optical Filters white paper.

Another possibility for producing UV blocking filters is offered by coating with a pigment-based coating solution with zinc oxide (ZnO). Up to a wavelength of 365 nm, no UV light will be transmitted here.



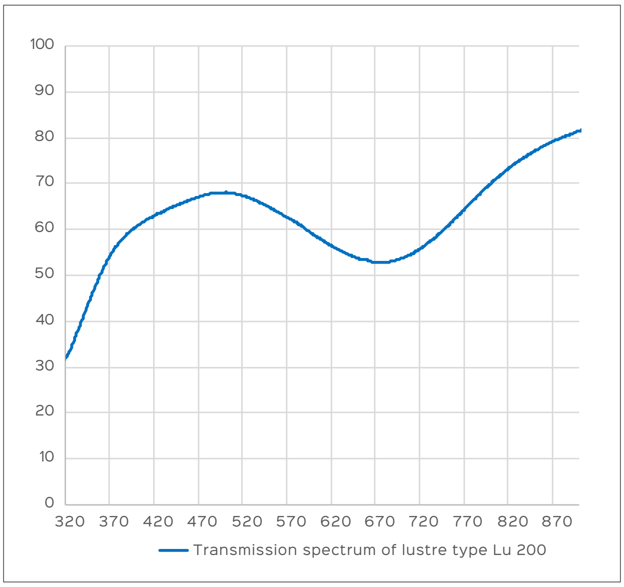
Transmission spectrum of a zinc oxide coating with a ZnO dispersion

Process: Dipping
Type: Pigment coating
Hardening: 480 °C, thermally
Thermally temperable

Application example:
Coating of CDMT lamps

3.7 Conversion filters (lustre)

Lustre colours stand out through their broad colour palette, high degree of reflection and brilliant metallic shine. The organometallic solutions are applied using the dip coating or spray coating method and cured in a traditional thermal process. The colour change (conversion) is achieved through absorption. One of the lustre sub-groups are precious metal compounds, which can be used to produce gold rim coatings on porcelain and functional glass for everyday use, for example.



Transmission spectrum of lustre type Lu 200

Process:

Dipping

Type: cLustre coating

Hardening: 480 °C to 680 °C, thermal

Application examples:

Automobile lamp coating Decorative coating

UV protection (amber glass)

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3.8 Decorative coatings

Organic colours and varnishes have a polymer basis and contain organic pigments that lend them their colour and enable them to perform the desired functions. They are applied with the dip coating or spray coating method and can be hardened using different techniques.

Standard decorative varnishes dry in the air when the solvent evaporates. High-performance varnishes for functional glass and packaging glass or jars contain either UV or thermal initiators. The latter are activated at temperatures around 120 °C and bring about the chemical linking and hardening of the layer. As a result, some of these special varnishes are chemically stable and dishwasher-safe.

Process:
Dip coating or spray coating
Type: Organic pigment coating
Hardening: UV, room temperature or 150 °C

Application example:

Cladding glass for light sources, lamp covers

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4. Customer-specific development:

Consulting – Project Development – Implementation

Our broad range of coatings and the expertise that results from our experience enable us to develop customised solutions for all surface coating applications. For this purpose, the laboratory and production facilities, as well as the experienced coating experts of PRINZ OPTICS and GLAS PLUS, are available.

Our technical systems and equipment

- Agitator ball mill, batch mill (batch size 6 kg), laboratory dispersion unit (1 kg)
  Ultrasonic dispersion
  Planetary ball mill
  Screening technolog
- Spraying method
  Hot spraying (spray pyrolysis)
  Varnishing booth
  System technologies for interior coating of hollow vessels
- Flow coatingn
  Coating machines for interior coating
- Heating procedures
  Convection ovens
  Radiation heating units

Agitator ball mill

Our measurement laboratory

- Luminous flux measurement (1-metre integrating sphere
- Colour coordinate measurement
- Transmission, reflection and absorption measurements with a diode arra spectrometer
- Ellipsometry
- Particle size measurement with DLS
- Lux measurement
- recise geometry measurements, profile projector
- Scratch test, scrubbing machine
- Taber abrasion test
- Climate test chamber

Integrating sphere – 1 m diameter

Consulting and service

If you have any questions regarding how to use coated glass and how to implement relevant projects, PRINZ OPTICS and GLASS PLUS can offer appropriate services for this – from lighting consultation, optical measurements and the construction of models to the production of custom products and the provision of project management services.

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