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(54) Benævnelse: **KORROSIONSBESKYTTELSES-SAMMENSÆTNING**

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Description

The invention relates to a corrosion protection composition for coating surfaces, a corresponding layer structure having such a corrosion protection composition, the use of this layer structure for corrosion protection coating of a surface, a corrosion monitoring system, a corrosion protection system and a method of coating a surface to be protected against corrosion.

Every year, corrosion of metallic components results in enormous economic losses that are desirably avoided. For this reason, measures exist for increasing the corrosion resistance of metals, thus reducing the speed of corrosive attack to such an extent that damage to the relevant component during the service life thereof can be avoided. So-called passive corrosion protection includes all measures that have a shielding effect against corrosive media, for example by means of a suitable coat or coating of the material to be protected. Active cathodic corrosion protection works either with or without external current and is based on altering the potential of the metal to be protected so that it cannot correlate.

For example, EP 1 756 236 B1 discloses an electrically conductive and weldable, substantially solvent-free corrosion protection composition for coating metal surfaces. EP 1 337 350 B2 further discloses a color- and/or effect-producing multicoat lacquer, a method for production and the use thereof.

US 2014 / 0 151 596 A1 discloses a thermally conductive, corrosion-resistant coating composition for use as a substrate coating. The composition comprises a waterborne polyurethane polymer and at least one additive. The composition can also include thermally conductive particles, which can be carbon nanoplatelets and carbon nanotubes. The composition can contain the urethane component at 25-75% by weight and the carbon nanomaterial component at 4-10% by weight. The composition can contain as additional components a silane-based crosslinking agent and/or an ether-based coalescing agent.

It is the object of the invention to provide an improved corrosion protection composition, an improved layer structure comprising such corrosion protection composition, a corrosion monitoring system, a corrosion protection system and a method of coating a surface to be protected against corrosion. The objects addressed by the invention are solved by the features of the independent claims. Embodiments of the invention are specified in the dependent claims.

A corrosion protection composition for coating surfaces is specified, the composition having a first and a second filling component, the weight ratio of the first filling component and the second filler component being between 0.4 and 1.2 based on the total composition,

- the first filling component having carbon platelets and an (electrically - conductive) nanostructure component, the nanostructure component being selected from the group of nanotubes, nanowires and nanofibers,
- the second filling component having a polymer matrix.

The term "polymer matrix" is understood to mean the matrix into which the first filling component is preferably homogeneously embedded in the hardened state. The polymer matrix and the first filling component thus result in a composite material, and therefore the corrosion protection composition can also be referred to as a composite material.

In addition to the binder and an optional hardener, the polymer matrix can also contain dispersants. However, since the dispersant is not co-crosslinked, it was in principle not taken into account in the weight data (weight ratio of first filling component to second filling component). In this respect, in the context of the entire present disclosure, the term "second filling component" is understood in principle to mean only a combination of resin and (if present) hardener, which together form the polymer matrix in the hardened state. The chemical hardening agents required for this purpose are reaction partners and, together with the reaction resin, form the macromolecular plastic, i.e., the polymer matrix for the first filling component.

Embodiments of the invention could have the advantage of improving corrosion protection of surfaces, particularly metal surfaces. The carbon platelets could ensure, due to the hydrophobicity thereof, that they form a liquid barrier which prevents aqueous substances such as water itself or lye from even coming into contact with the metal surface to be protected. In turn, the nanostructure component could ensure, due to the electrical conductivity thereof, that electrons present in the metal are diverted away from the metal. The electrons, for example, are a result of the diffusion of positively charged metal ions into the aqueous environment, should liquid such as water have reached the metal surface despite the carbon platelets. The electron thus tapped by the nanostructure

component can therefore be transported away from the metal surface and react elsewhere with water and oxygen to form hydroxide ions.

If damage as far as the metal substrate occurs on an ordinary paint structure, corrosion products form at this location and the oxygen discharge migrates to their peripheral areas. It should be noted at this point that the hydroxide ion formed in the present case can react with the polymer matrix of the second filling component, as a result of which the polymer matrix could be destroyed in the long term. This infiltration process generates an exposed uncoated metal surface and is also referred to as "cathodic delamination". With the correct choice of carbon platelets and nanostructure component, cathodic delamination can now be suppressed and displaced to the surface of this layer. The metal surface thus remains largely protected against corrosion with a coating, but the overlying coating may nevertheless have to be restored from time to time, depending on the corrosion pressure. However, it should be easier and also more sustainable to restore the topcoat when corrosion occurs than to attempt to sand off the stressed areas and recoat with repair lacquers in the case of coatings that have undergone cathodic delamination.

As a result, hydroxide ions, for example, are formed in a minimized form remote from the metal, if at all, so that the site of metal ion formation is separated from the site of hydroxide ion formation. This separates the anodic and cathodic effect.

According to an embodiment, the weight ratio of the nanostructure component and the carbon platelet is between 2 and 4, particularly between greater than 3 and less than 4. The weight ratio of the first filling component and the second filling component can particularly be between 0.5 and 1 and preferably between 0.65 and 0.8. Said weight ratio of the nanostructure component and the carbon platelets could be advantageous because an optimal compromise can be achieved here between the liquid barrier effect of the carbon platelets and the increase in electrical conductivity by the nanostructure component. The carbon platelets lengthen the diffusion paths of the liquid molecules because, due to the hydrophobicity and compactness, the liquid molecules must migrate around the carbon platelets to reach the metal surface in the first place. However, too high a proportion of carbon platelets minimizes the electrical conductivity, which means that, in the event that liquid molecules do diffuse to the metal surface, the electrons generated during the subsequent formation of metal ions are not rapidly diverted away from the metal surface. As a result, hydroxide ions would be formed near the metal

surface, and this would eventually result in cathodic delamination with the formation of a free metal surface.

On the other hand, an increased proportion of the electrically conductive nanostructure component could ensure rapid removal of the resulting electrons away from the metal surface; however, due to the lack of barrier properties (e.g., hydrophobicity) of the electrically conductive nanostructure component, a large number of liquid molecules could diffuse to the metal surface. The aforementioned weight ratio of nanostructure component and carbon platelet could provide an optimal compromise here: on the one hand, a sufficiently high liquid barrier is provided and, on the other hand, in the event of liquid molecules diffusing on the metal surface, a sufficiently fast removal of electrons away from the metal surface is ensured.

It should be noted at this point that the use of as conductive as possible graphene platelets in coating formulations for corrosion protection of metals appears to be negative for corrosion protection, particularly in low concentration ranges between, for example, 0.001% by weight and 0.15% by weight. Any "corrosion protection" based on this would have to be based on the formation of thicker metal oxide layers on the metal surface due to catalyzation by conductive graphene, as well as on an oxygen and water barrier function, and additionally on a reduction in the water retention capacity as a result of the increase in hydrophobicity. Disadvantages in this case would be direct interparticle graphene-platelet contact as well as direct contact between the graphene component and the metal surface, since such contact would, in the case of graphene platelets that are as conductive as possible, accelerate the corrosion of the metal substrate at the above-mentioned concentration ranges.

By carefully selecting the above-described ranges of weight ratios (nanostructure component and carbon platelets, as well as first and second filling component), it should not only be possible to avoid accelerated corrosion effects for metal substrates when using the described "higher" concentrations of graphene or nanostructure component or mixtures thereof, but, in addition, favorable corrosion protection effects should be produced by adjusting, via the concentration ratios and thus the weight ratios, the ingress of hydrogen and oxygen to the metal surface and thus the corrosion rate in a specific ratio to the conductivity of the layer. If this is ensured, the electrons generated by corrosion processes can be diverted away from the metal surface into the primer coating, such that the oxygen discharge and generation of hydroxide ions causing cathodic delamination are

also displaced from the metal surface into this primer layer. The formation of a bare free metal surface by cathodic delamination and thus the increasingly accelerating ingress of water and oxygen are thus largely prevented. If, in contrast, the conductivity of the layer were set too high, this would cause the highly detrimental effect of accelerated corrosion of the metal substrate.

These novel corrosion protection aspects described in the foregoing can be implemented, e.g., by the present described primer layer, by using only mixtures of the first and second filling component with the described surface modifications, in defined ratios and correspondingly high application concentrations, which are necessary to produce the highest possible barrier effect against hydrogen and oxygen. In this case, the graphene and nanostructure components coming into contact with the metal surface to be protected should be helpful for diverting electrons formed by corrosion.

According to an embodiment of the invention, the nanostructure component is a carbon nanostructure component, wherein the carbon nanostructure component is selected from the group of single- or multi-walled carbon nanotubes, carbon nanowires and carbon nanofibers.

According to an embodiment of the invention, the carbon platelets are graphene platelets, wherein particularly their average thickness is between 1 nm and 30 nm or between 1 nm and 15 nm and/or their average equivalent diameter is between 0.2 µm and 200 µm, particularly between 0.5 µm and 20 µm or between 0.5 µm and 10 µm or between 0.5 µm and 5 µm.

Geometric equivalent diameter is understood to mean the determination of the diameter of a circle with the same geometric property (surface) as said carbon platelets, which are typically irregularly shaped. Graphene platelets are known as such from the prior art and consist of stacks of graphene layers, with the corresponding thickness being dependent on the number of layers. The values mentioned above with respect to the average thickness and the average geometric equivalent diameter can in this case represent an optimal compromise between mechanical stability during processing for the production of the corrosion protection composition and the overall hydrophobic as well as particularly barrier properties in the final product of the corrosion protection composition. If the graphene platelets are too thick and too small, lower barrier properties result in the end product despite high mechanical stability during processing, which means that, despite the hydrophobicity of the graphene platelets, the corrosion

protection composition's barrier effect against water is ultimately insufficient. In addition, due to the high thickness, the particle number ratio in relation to the proportion of nanotubes would be too low and the electrical conductivity of the corrosion protection composition would therefore be insufficient.

Conversely, graphene platelets with a large surface area could result in a high hydrophobicity and barrier effect of the corrosion protection composition, although in the case of platelets that are too thin, these same platelets could be mechanically destroyed during processing, thus reducing the overall system's hydrophobicity, which is actually guaranteed due to the large surface area. In the case of platelets with too large a surface area, it could additionally no longer be possible to achieve an as uniform and homogeneous as possible interspersion of the corrosion protection composition with the nanostructure component, since, in this case, exaggeratedly speaking, the surface to be protected is covered with platelets with a large surface area. Furthermore, at the same mass fraction, thinner (due to higher particle number) and larger graphene platelets (lower percolation concentration) exert a stronger influence on the conductivity of the coating, such that it is no longer largely determined by the nanostructure component and thus becomes more difficult to adjust or optimize.

Preferably, the nanostructure component serves to form an electrical percolation network. For example, if the nanostructure component has rod-shaped electrical conductors, the goal is electrical percolation in networks of the rod-shaped electrical conductors. If, in the specific example given above, the surface to be protected is covered with platelets that have a large surface area, however, there can no longer be any question of a preferably uniform and/or homogeneous and/or percolating distribution of the nanostructure component, since in this case there are large areas, formed by the platelets, around which the network of the nanostructure component must extend. The stated weight ratio of the nanostructure component and the carbon platelets takes all this into account and provides a range that ensures optimum corrosion protection.

According to an embodiment of the invention, the average aspect ratio of the nanostructure component is between 50 and 1500, particularly between 50 and 500 or 70 to 200 or 100 to 200. This could have the advantage of thereby maximizing the conductivity of the corrosion protection composition for a given mass fraction of the nanostructure component. In the example of carbon nanotubes, nanotubes that are too short could reduce the overall conductivity for a given mass fraction, and nanotubes that

are too thin could break too easily during processing (e.g., in the course of ultrasonic dispersion), which would thus also result in nanotubes that are too short again. Nanotubes that are too thick, on the other hand, would also reduce the overall conductivity due to the increase in material at a given weight ratio between the nanostructure component and the carbon platelet, since in this case the total number of individual tubes is reduced and thus the number of individual conduction paths is limited.

According to an embodiment of the invention, the second filling component comprises particles of an active corrosion protection component, wherein the proportion of the particles is between 0.1 and 0.75% by weight based on the total composition, particularly is between 0.2 and 0.6 and particularly preferably between 0.3 and 0.5% by weight based on the total composition. The active corrosion protection component could ensure that, in the event of any corrosion taking place, a compact metal-oxide-containing layer forms over the metal substrate, blocking the ingress of water and oxygen to the metal substrate surface, but also blocking the leaching of further metal ions from the substrate surface. Experiments have surprisingly shown that the above-mentioned range of the weight fraction of the particles of the active corrosion protection component improves the corrosion protection properties of the corrosion protection composition. This aspect, which is important for the anodic corrosion process, thus appears to occur in parallel with the protection against cathodic delamination, meaning that the two aspects appear to complement each other in a useful, synergistic way with respect to an improved corrosion protection effect. Too much active corrosion protection component material worsens the corrosion protection properties of the composition and too little material does not contribute to any improvement in the corrosion protection properties, which is why here, too, specific and defined concentration ranges should be observed to achieve the greatest possible corrosion protection within the overall concept presented.

According to an embodiment of the invention, the active corrosion protection component is selected from the group of phosphates and orthophosphates and their derivatives, particularly from the group of phosphates and orthophosphates and their derivatives, which are based on calcium, zinc and strontium.

According to an embodiment of the invention, the active corrosion protection component is selected from the group and their derivatives of calcium phosphate, calcium orthophosphate, calcium aluminum orthophosphate, calcium magnesium orthophosphate, strontium aluminum polyphosphate, strontium aluminum

polyphosphate, zinc phosphate, zinc orthophosphate, zinc aluminum polyphosphate, zinc molybdenum orthophosphate, zinc aluminum orthophosphate.

According to the invention, the carbon platelets and/or the carbon nanostructure component have a silane functionalization, the degree of functionalization being 5% to 90%, particularly 10% to 60% and further preferably 20% to 40%. Alternatively or additionally, the carbon platelets and/or the carbon nanostructure component have a polyether functionalization, the degree of functionalization being 5 to 90%, particularly 10 to 60% and further preferably 20 to 40%. In general, the degree of functionalization can be determined, for example, using TGA (thermogravimetric analysis). Determining the degree of functionalization is known from the prior art.

The silane component can be selected from an olefinically reactive silane component, particularly vinyltrimethoxysilane, 3-methacryloxypropyltrimethoxysilane, or an epoxy-functional silane component, particularly 3-glycidyloxypropyltrimethoxysilane and mixtures thereof.

In particular, polyether functionalization could have the advantage of improving the wettability of the surfaces of the carbon platelets and/or the carbon nanostructure component with respect to the second filling component. In this respect, the first filling component can be dispersed into the second filling component with less energy input and also in finer particles, without the need for further foreign polymers, which would ultimately weaken the final corrosion protection composition as a result of a less compact, softer polymer matrix structure and the associated lower barrier properties against water and oxygen, as well as against electrolytes. This, in turn, could mean that functionalization could thus improve mechanical stability and resistance to liquid molecule penetration and cathodic delamination due to the possibility of dispensing with further foreign polymers to increase the surface wettability of the first filling component.

For non-functionalized or non-surface-modified carbon platelet/nanostructure component mixtures, the ratio of water and oxygen barrier to conductivity is substantially determined by the ratios and concentrations of both carbon components. If a surface modification is now carried out with silane and/or specific polyether components, the conductivity of the particles and thus of the resulting primer layer can be controlled depending on the modification level and silane/polyether component ratio, but without significantly influencing the barrier properties thereof. Another advantage of surface modification of the carbon platelet/nanostructure component mixture could be improved

compatibility with the binder matrix, resulting in a more homogeneous primer layer, without the formation of agglomerates and avoiding larger amounts of dispersant and stabilizing additives. Both aspects could in turn lead to a more compact layer, having an increased water and oxygen barrier which is favorable in terms of corrosion protection. On account of the aspects mentioned, the use of suitably surface-modified carbon platelet/nanostructure component mixtures, as well as the optimization of the conductivity or resistance of the resulting primer layer according to the invention, is a positive aspect for implementing the described corrosion protection concept.

Because the primer layer has adjustable conductivity, by performing polarization it can also be used in the field of heavy duty corrosion protection. By using, for example, impedance measurements, it is possible to carry out online monitoring of the corrosion state of the metal substrate, such that, in a particularly preferred application of the novel concept, the polarization automatically activates when the online monitoring registers increased corrosion processes on the metal substrate. In this way, by virtue of the concept described above, self-regulating intelligent corrosion protection systems will become commercially available.

According to an embodiment of the invention, the polymer matrix comprises a reaction resin, particularly a reaction resin selected from the class of epoxy resins, polyester resins and acrylate resins. The result is a corrosion protection composition, the second filling component of which is optimally connected to the first filling component, and indeed has embedded the first filling component, due to chemical, optical or thermal hardening. Preferably, the polymer matrix is also matched to the metal surface to be coated, so that there is also excellent adhesion between the corrosion protection composition and the metal surface to be protected.

According to an embodiment, the specific surface resistance of the corrosion protection composition is between 10^3 and 10^6 ohms, particularly between 10^4 and 10^5 ohms. In particular, when using multi-walled carbon nanotubes in combination with graphene platelets, this may reflect the optimal range, which allows for both a sufficiently high liquid barrier and optimal dissipation of electrons.

In a further aspect, the invention relates to a layer structure comprising a first layer and a second layer, the first layer having the corrosion protection composition as described above and the second layer being a topcoat layer. The topcoat layer additionally

protects the layer of the corrosion protection composition against mechanical and atmospheric influences.

For example, the first layer has a layer thickness between 5 µm and 60 µm, particularly between 8 µm and 50 µm and further preferably between 15 µm and 40 µm. The second layer can have a layer thickness between 10 µm and 300 µm, particularly between 20 µm and 200 µm and further preferably between 30 µm and 100 µm.

The layer thicknesses selected represent an optimum compromise between good corrosion protection capabilities on the one hand and the material costs involved on the other. While additional material could improve the corrosion protection properties of the layer structure, there is a risk that adhesion and leveling defects could occur here if the layer thicknesses are too high. Moreover, above a specific minimum layer thickness of the individual layers, this improvement is usually only the case to a very limited extent and would be disproportionate to the necessary costs involved in terms of the additional material that would be required for the corresponding increased layer thickness of the first and/or second layer.

According to an embodiment, the second layer comprises electrically conductive particles, wherein the specific surface resistance of the second layer is between 1% and 30% of the specific surface resistance of the first layer. This could have the advantage that, as a result of the higher conductivity of the second layer, the electrodes are immediately transported further thereinto, thus avoiding the formation of additional potentials between the first and second layer. This property could become particularly important when performing polarizations so that a significant voltage drop does not occur between the second and the first layer. The reduction of oxygen could therefore likewise be shifted to the surface of the second layer.

According to an embodiment, the electrically conductive particles are inorganic, particularly oxidic, particularly selected from tin oxides containing indium, fluorine and antimony or mixtures thereof. This could have the advantage that, as a result of introducing inert conductive materials, contact potentials which themselves influence the corrosion processes do not form. Introducing particles of noble metals such as copper or silver would be of particular concern, since these could very much accelerate the dissolution of the less noble substrate metal, such as iron, steel or aluminum, when exposed to aqueous electrolytes. When introducing metal particles that are less noble than the substrate, such as aluminum or zinc particles in the case of a steel substrate,

these in turn would preferably corrode under aqueous electrolyte exposure and would convert into oxides or hydroxides. Conductivity would then be lost, and in addition, an affected layer would become hydrophilic due to the formation of oxides and hydroxides, which in turn could severely weaken the barrier effect against the penetration of aqueous electrolytes.

In a further aspect, the invention relates to the use of the above-described corrosion protection composition and particularly of the described layer structure for the corrosion protection coating of a surface.

In a further aspect, the invention relates to a corrosion monitoring system comprising the layer structure described above, a material to be monitored having a surface, the first layer being applied to the surface, and a device for frequency-dependent determination of the impedance using at least one measuring electrode and a counter electrode, one of the two electrodes being in contact with the second layer or the first layer and the other of the electrodes being in contact with the material, furthermore preferably the electrode on the surface of the second layer being implemented via an electrically conductive elastomer without the use of an electrolyte. The system further comprises an impedance measuring unit and/or analyzer for determining the corrosion and/or permeation occurring in the layer structure from the impedance determined depending on frequency.

For example, the device for frequency-dependent determination of the impedance can have a plurality of the measuring electrodes or the counter electrodes, wherein the second layer is divided into a plurality of domains that are electrically insulated from one another, wherein each of the domains is contacted with one or more corresponding electrodes of the plurality of electrodes, wherein the evaluation unit for determining the corrosion occurring in the layer structure from the frequency-dependent impedance determined is designed specifically for each of the domains.

In general, the device for frequency-dependent determination of the impedance can have a plurality of the measuring electrodes or the counter electrodes, wherein these are arranged spatially separated from one another at different positions of the second layer, wherein the evaluation unit is designed for determining — in particular spatially (two-dimensionally) resolved with respect to the surface to be monitored — the corrosion occurring in the layer structure from the frequency-dependent impedance determined specifically using one or more of the plurality of electrodes.

As mentioned above, the second layer is divided, for example, into a plurality of domains that are electrically insulated from one another, wherein each of the domains is contacted with a corresponding electrode of the plurality of electrodes, wherein the evaluation unit for determining the corrosion occurring in the layer structure from the frequency-dependent impedance determined is designed specifically for the domains.

Firstly, a fundamental advantage of the corrosion monitoring system could be that the corrosion state of the surface to be monitored (material to be monitored) can be determined in a simple and non-destructive manner. If the frequency-dependent determination of the impedance is now performed over a large electrically conductive coherent second layer, the information regarding corrosion and/or permeation is obtained as an integral response over the area under consideration. This could provide at least a rough indication of the extent to which corrosion of the surface to be monitored has progressed.

If, however, the second layer is divided into the plurality of domains that are electrically insulated from one another, the measurement result of the frequency-dependent determination of impedance could be determined information about the actual local corrosion properties of the surface to be monitored. In this context, local means a domain-based spatial limitation of the area with respect to which the impedance is recorded. This could have the further advantage that an assessment of the corrosion that has taken place can be limited locally in such a way that corresponding repair work — if necessary — on the corroded surface is then likewise possible in a very locally limited way. This principle applies analogously when using individual electrodes or electrode groups which are arranged in particular on an electrically insulating surface. In this case, each electrode or electrode group can be used to determine the impedance specifically for a spatially limited area of the surface to be monitored.

Generally speaking, the corrosion monitoring system can have means for ensuring that sequentially different electrodes or groups of electrodes are used to determine the impedance. As a result, spatially resolved information is obtained regarding the corrosion and/or permeation of the surface to be monitored.

In a further aspect, the invention also relates to a corrosion protection system comprising the above-described layer structure or the above-described corrosion protection composition, a metallic and electrically conductive surface to be protected, the first layer being applied to the surface, and a polarization device having a first and a

second electrode, the first electrode being in contact with the surface and the second electrode being in direct contact with the first layer or indirectly with the first layer via a conductive layer arranged on the side of the first layer facing away from the surface, the polarization device being designed to polarize the first layer positively with respect to the surface by means of the electrodes. This corresponds to the principle of active corrosion protection, according to which the corrosion protection properties of the layer structure are further enhanced on account of the polarization.

In a further aspect, the invention relates to a method of coating a surface to be protected against corrosion, the method comprising applying the above-described corrosion protection composition as a dispersion on the surface to be protected and hardening the corrosion protection composition located on the surface.

It should be noted that the above-described embodiments and variants can be combined with one another in any manner, as long as such combinations are not mutually exclusive. In particular, the following combinations are disclosed, each in the weight ranges indicated above. The preferred ranges are: Weight ratio of the nanostructure component and the carbon platelets between greater than 3 and less than 4; weight ratio of the first filling component and the second filling component between 0.65 and 0.8; average thickness of the carbon platelets as graphene platelets between 1 nm and 15 nm; average geometric equivalent diameter of the carbon platelets as graphene platelets between 0.5 µm and 5 µm; aspect ratio of the nanostructure component between 100-200; proportion of particles between 0.3 and 0.5% by weight based on the total composition; degree of functionalization of the carbon platelets and/or the carbon nanostructure component between 20% and 40%; specific surface resistance of the corrosion protection composition between 10^4 and 10^5 ohms; layer thickness of the first layer between 15 µm and 40 µm; layer thickness of the second layer between 30 µm and 100 µm.

Exemplary combinations:

Nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection

component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component,

epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanowires as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanowires as nanostructure

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nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanofibers as nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanofibers as nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium magnesium

orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium magnesium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the

polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, polyester resins at least as part of

the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with calcium phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with strontium aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional

silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc aluminum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion

protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc aluminum polyphosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc molybdenum orthophosphate as corrosion protection component, polyester resins at

least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc orthophosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, acrylate resins at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, epoxy resin at least as

part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, epoxy resin at least as part of the polymer matrix, with an optional olefinically reactive silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional polyether functionalization; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional epoxy-functional silane component; nanotubes as nanostructure component, optionally with zinc phosphate as corrosion protection component, polyester resins at least as part of the polymer matrix, with an optional olefinically reactive silane component.

A preferred exemplary variation would be a combination as follows: The nanostructure component is carbon nanotubes, wherein the weight ratio of the nanostructure component and the carbon platelets is between greater than 3 and less than 4, the weight ratio of the first filling component and the second filling component is between 0.65 and 0.8, and wherein the carbon platelets and/or the carbon nanostructure component have a silane functionalization with a degree of functionalization between 20% and 40%.

Embodiments of the invention are explained in more detail below with reference to the drawings, in which:

Figure 1 is a schematic view of a corrosion protection composition;

Figure 2 is a schematic view of a layer structure with a metal surface to be protected, a corrosion protection composition and an optional topcoat layer;

Figure 3 shows results for layer structures when subjected to immersion in an aqueous solution;

Figure 4 shows results for layer structures when subjected to immersion in an aqueous solution;

Figure 5 shows results for layer structures when subjected to immersion in an aqueous solution;

Figure 6 shows results for layer structures when subjected to immersion in an aqueous solution;

Figure 7 shows results for layer structures when subjected to immersion in an aqueous solution without and with polarization;

Figure 8 is a schematic view of a corrosion monitoring system;

Figure 9 is a schematic view of a corrosion protection system and

Figure 10 is a flow chart for a method of coating a surface to be protected against corrosion.

In the following, elements that are similar to one another are marked with the same reference signs.

Figure 1 is a schematic view of a corrosion protection composition comprising a first filling component and a second filling component, the first filling component having carbon platelets 102 and a nanostructure component 104 and the second filling component being denoted by reference sign 106 and having a polymer matrix. The weight ratio of the first filling component and the second filling component is, for example, between 0.4 and 1.2.

For example, the polymer matrix 106 comprises a hardened reaction resin, which particularly comprises a reaction resin selected from the class of epoxy resins, polyester resins and acrylate resins. In the state shown schematically in Figure 1, for example, the reaction resin is hardened by polymerization or polyaddition.

For example, the weight ratio of the nanostructure component and the carbon platelets is between 2 and 4, but preferably between greater than 3 and less than 4. Without loss of generality, it is further assumed that for this example the nanostructure component comprises multi-walled carbon nanotubes. Instead of multi-walled carbon nanotubes, single-walled carbon nanotubes, carbon nanowires or carbon nanofibers are also possible.

The carbon platelets are in particular so-called graphene platelets, i.e., structures which have an average geometric equivalent diameter particularly between 0.5 µm and 5 µm, and are between 1 nm and 15 nm thick. Each graphene platelet consists of a plurality of layers of graphene.

As shown schematically in Figure 1, the graphene platelets 102 are preferably contained in the composition 100 in such a concentration that they significantly increase

the diffusion paths of any liquid molecules that may penetrate the composition 100. Without loss of generality, it is assumed in the following that the liquid is water and, in this respect, the liquid molecules are water molecules.

The hydrophobicity of the composition 100, which is increased by the graphene platelets 102, additionally greatly reduces the water retention capacity of the layer, for example, which should greatly reduce the corrosion-facilitating intercalation of water and electrolytes.

In the above example, if the water molecules now penetrate the corrosion protection composition 100, the diffusion path of the water molecules is increased to such an extent due to the selected concentration of graphene platelets that penetration of the water molecules through the composition 100 from top to bottom is in fact prevented.

The purpose of the carbon nanotubes 104 can be seen in Figure 2, which shows a layer structure that is applied on a layer 200 to be protected. In the following, it is assumed without loss of generality that the layer 200 is a metal layer, for example an iron plate with an iron surface.

The corrosion protection composition 100 is applied on the metal surface of the layer 200. An optional topcoat layer 202 is arranged on the layer of corrosion protection composition 100 to protect it against mechanical influences and further atmospheric influences.

Corrosion of iron, for example the surface of the layer 200, starts in most cases when water molecules (H_2O) come into contact with the metal. This then causes positively charged iron ions to diffuse into the aqueous environment and the electrons remaining in the metal 200 can react with water and oxygen O_2 to form hydroxide ions OH^-. The hydroxide ions then form iron(II) hydroxide with the iron ions. Further redox reactions also eventually lead to the formation of the rust-brown iron(III) hydroxide.

The corrosion protection composition 100 minimizes the risk of corrosion since, firstly, the graphene platelets increase the above-described diffusion path of the water molecules to such an extent that contact of the water molecules with the metal surface 200 is largely avoided. If this nevertheless takes place over prolonged periods of time, the carbon nanotubes 104 contained in the corrosion protection composition ensure, on account of the electrical conductivity thereof, that the electrons released when the iron ions are released, particularly when an iron oxide layer is formed, are transported away from the metal 200. In this way, illustratively speaking, the hydroxide formation no longer

occurs on the metal 200, but somewhere remote from the metal, within, or preferably on the surface of, the layer of the corrosion protection composition 100. This ensures a strong counteraction against the formation of hydroxide ions, the alkaline destruction of the polymer matrix at the interface between the metal 200 and the layer of the corrosion protection composition 100, the formation of a free metal surface that is not protected from corrosion by a coating, and thus ultimately the cathodic delamination.

However, as described above, this could cause the hydroxide ions to react with the polymer matrix 106, particularly if the discharge of oxygen to the surface of the layer of the corrosion protection composition 100 is not successfully shifted. These processes are possible if the corrosion pressure becomes very high due to excessive exposure to electrolytes and/or if the layer of the corrosion protection composition 100 has a conductivity that is insufficient for the exposure to electrolytes. In this case, the polymer matrix 106 could be damaged over time. This may then lead to cohesive failures within the corrosion protection composition, in which the surface of the metal 200, at least to a large extent, remains protected from so-called cathodic delamination by a thinner but still largely present layer of the corrosion protection composition 100.

The latter, however, is less critical than metal corrosion, which results in the formation of a metal surface that can be freely accessed by electrolytes and oxygen over a large area. Furthermore, by reapplying the corrosion protection composition to the metal surface, this kind of corrosion can be "repaired" in a relatively simple manner when the layer of the corrosion protection composition 100 is applied in accordance with the invention.

In the schematic representation of Figure 2, the corrosion protection composition 100 (the associated layer) further optionally has particles of an active corrosion protection component 204, which, apparently synergistically, by forming compact iron oxide layers, inhibits the release of iron ions and thus the anodic processes, wherein the proportion of the particles is particularly between 0.1 and 0.75 percent by weight based on the total composition of the corrosion protection component 100. In the specific example, it is zinc molybdenum orthophosphate (hereinafter referred to as ZMP) with a zinc content between 53.5 and 56.5%, a phosphorus content as PO_4^3 of 37 to 40% and a molybdenum content as MO_3 of 1.2 to 2.2 %.

The following Figures 3 to 6 show experimental results for different layer structures with different compositions of corresponding corrosion protection compositions 100, in

each case when subjected to immersion with 5% NaCl solution. Immersion with 5% NaCl solution simulates a highly corrosive process, which is further accelerated by deliberately damaging the layer structure at a specific location, so that oxygen and the aqueous electrolyte can enter almost unhindered at said point, thus allowing the corrosion process to start. This experimental procedure makes it possible to assess within short periods of time (not exceeding 72 hours) the actual corrosion resistance of the selected corrosion protection composition in the event of damage to the layer structure.

The layer structure used in the following corresponds to the layer structure of Fig. 2, with a further topcoat layer being applied on top of the layer 202. In the following, the layer 202 is referred to as the "1st topcoat" and a layer applied to the layer 202 on the side facing away from layer 100 is referred to as the "2nd topcoat".

The following procedure was followed for the experiments described below:

Production of the 1st topcoat: For the 1st topcoat formulation, Araldite EP GZ7071 x75 (10%) 4.4 g is homogenized with stirring. Then, 3.62g Aradur hardener 423 XW60 (10%) is added, applied and dried for 12h at room temperature. The application of the 1st topcoat on the layer 100 is selected so that the layer 202 has a dry film thickness of approx. 20 µm.

Details of Araldite GZ7071x75 (Huntsman Advanced Materials GmbH; Switzerland) are as follows: Epoxy index (ISO 3001) 1.50-1.67 [eq/kg], epoxy equivalent (ISO 3001) 600-670 [g/Eq], solids content (ISO 3251) 74.0-76.0 [%], viscosity 25 °C (falling ball viscometer, ISO 12058-1) 8000-13000 [mPa s]. Details of the hardener are as follows: Aradur 423 XW 60; (Huntsman Advanced Materials GmbH; Switzerland), amine value (ISO 9702) 122-138 [mg KOH/g], solids content (ISO 3251) 59-61 [%], viscosity 25 °C (rotational viscometer), ISO 3219) 800-1400 [mPa s].

Production of the 2nd topcoat: For the 2nd topcoat formulation, Bayhydrol A145 (45%) 38.54 g is homogenized with stirring. Then, 8.83 Desmodur hardener N3900 is added, applied and dried for 12h at room temperature. The application of the 1st topcoat on the layer 100 is selected so that the layer has a dry film thickness of approx. 40 µm.

Details of the binder Bayhydrol are as follows: Bayhydrol A145; OH-functional polyacrylate dispersion (Covestro Deutschland AG), acid value (DIN EN ISO 2114) 10 ± 3 mg KOH/g, viscosity at 23 °C (D = 41.28 s-1; DIN EN ISO 3219/A.3) 950 ± 550 mPa·s. Details of the hardener Desmodur are as follows: Desmodur N 3900; aliphatic polyisocyanate resin based on hexamethylene diisocyanate (Covestro Deutschland AG), NCO content

(M105-ISO 11909) 23.5 ± 0.5 wt.%, viscosity at 23 °C (M014-ISO 3219/A.3) 730 ± 100 mPa·s.

Production of the layer having the corrosion protection composition 100, hereinafter also referred to as the "primer coating" or "primer":

The substances listed in the following table are used as components.

Primer layer	Zinc-rich primer	Carbonaceous primer	Carbonaceous primer with 0.5% zinc phosphate
Zinc dust	0.6	0.0	0.0
Epoxy binder (10%)	4.4	4.4	4.4
Butyl acetate	0	45	45
Acetone	0	25	25
Efka 4050 (40%)	0	0.89	0.89
Graphene platelets	0.0	0.15	0.15
Nanotubes	0.0	0.45	0.45
Zinc particles	0	0	0.006
Hardener Aradur (10%)	3.62	3.62	3.62

(Data in each case as weighted sample/g)

The nanotubes are multi-walled carbon nanotubes produced by catalytic chemical vapor deposition (CCVD). The mean diameter of the tubes (transmission electron microscopy, TEM) is 9.5 x 10-9 m, the mean length (transmission electron microscopy, TEM) is 1.5 µm, and the carbon content (thermogravimetric analysis; TGA) is 90%.

The graphene platelets have a mean particle diameter of < 2µm and a mean platelet thickness of 10-15 nm. The zinc phosphate particles have a Zn content of 53.5-56.5%; phosphorus content as PO43- 37.0-40.0; molybdenum content as MoO3 1.2 -2.2%. The zinc dust has an average grain size of 3.5 µm (spherical grain shape) with a content of Zn-total 99% and Zn-metallic 96%.

The epoxy binder is Araldite® GZ7071x75 (Huntsman Advanced Materials GmbH; Switzerland), epoxy index (ISO 3001) 1.50-1.67 [eq/kg], epoxy equivalent (ISO 3001) 600-670 [g/Eq], solids content (ISO 3251) 74.0-76.0 [%], viscosity 25 °C (falling ball viscometer, ISO 12058-1) 8000-13000 [mPa s].

The polyamidoamine hardener is Aradur® 423 XW 60; (Huntsman Advanced Materials GmbH; Switzerland), amine value (ISO 9702) 122-138 [mg KOH/g], solids content (ISO 3251) 59-61 [%], viscosity 25 °C (rotational viscometer), ISO 3219) 800-1400 [mPa s].

While stirring, the quantities of the components indicated in the above table for the respective primer formulations are homogenized and subsequently dispersed using ultrasound (ultrasonic finger and UP400 S processor from Hielscher; with 0.7 cycles and 100% amplitude) for 1 hour with the temperature controlled at 25 °C. The dispersant EF-KA 4050 is added to support the dispersion. The relevant quantity of Aradur hardener is then added, applied and dried for 12h at room temperature. The application is selected so that the layer 100 has a dry film thickness DFT of approx. 20 µm.

The result is a corrosion protection composition that has a polymer matrix which, in addition to the binder and the hardener, also contains the dispersant.

Figures 3-6 show the results of subjecting a metal plate (steel substrate) coated with the primer layer and the two topcoat layers to immersion with 5% NaCl solution at room temperature for 24h, 48h, and 72h, respectively. In each case, the immersion takes place in an area 302 delimited by a circular cylindrical test container, and, to accelerate the corrosion in the center 300 of the area 302, the "corrosion protection" consisting of the primer layer and the two topcoat layers was removed selectively, through a 2-mm hole. At this location 300 the free metal of the metal plate on which the corrosion protection was applied is basically visible. The layer structure is therefore as follows: Metal plate (structural steel) corrosion protection, with the corrosion protection having the following layers: Primer coat, 1st topcoat layer, 2nd topcoat layer.

After the specified immersion time, the test container glued on with silicone and containing the NaCl solution was removed. After drying, TESA 4651 adhesive tape was applied to the area subjected to immersion and subsequently torn off. Where shown in the figures, the torn-off adhesive tape is identified by reference sign 304.

Fig. 3 a)-f) show the immersion results for different types of corrosion protection. In each case, the 1st and 2nd topcoat layer are present; differences exist only with regard to the primer layer. In order from top left to bottom right: a) reference system without first filling component and without active corrosion protection component; b) reference system with zinc primer ("zinc-rich primer"); c) reference system with ZMP but without first filling component; d) reference system with graphene platelets but without active corrosion protection component and without nanotubes; e) reference system with nanotubes but without graphene platelets and without active corrosion protection component; f) system with graphene platelets and nanotubes but without active

corrosion protection component. The data relate in each case to a carbon component/binder solid body ratio of 0.75/1.

In the order of Fig. 3a)-3f), the specific surface resistance of the primer layer in ohms is as follows: 1.6 E+11; 4.0 E+10; 1.4 E+11; 1.6 E+04; 4.9 E+03; 1.6 E+04.

In the case of Fig. 3f), the weight ratio of the nanotubes and the carbon platelets is 3 and the weight ratio of the first filling component and the second filling component is approx. 0.75, taking into account the concentrations of the epoxy binder and the hardener.

It can be seen in Fig. 3 that the differences with respect to the detached areas between 24h, 48h and 72h of immersion are clearly pronounced for the respective reference systems: non-pigmented reference system (Fig. 3a), reference system with zinc primer (Fig. 3b), reference system with ZMP (Fig. 3c), reference system with graphene primer (Fig. 3d) and reference system with CNT primer (Fig. 3d), compared with the system with graphene platelets and nanotubes.

For example, in Fig. 3a), the primer layer has become almost completely detached after 72 hours — the bare metal is visible. In Fig. 3b), the degree of detachment initially appears to be lower. However, the application and tearing off of the adhesive tape 304 shows, due to the adhesion of the coating, that the primer layer has become detached over a large area here, too.

The system with graphene platelets and nanotubes (Fig. 3f) also shows, based on the test with the adhesive tape, that detachment has occurred. However, a closer look at the affected area reveals that the detachment in the system with graphene platelets and nanotubes has occurred due to cohesive failures within the primer layer, whereas, in the reference samples, detachment has occurred due to cathodic delamination directly on the metal surface. As a result, the corrosion of the reference samples accelerates as immersion duration increases, while, for the system with graphene platelets and nanotubes, only comparatively small free metal surfaces are created during immersion.

It follows that in the system with graphene platelets and nanotubes, due to the electrical conductivity of the nanotubes and the barrier effect, as well as the hydrophobicity of the graphene platelets with respect to the penetration or retention of water, when subjected to immersion with a 5% NaCl solution there is a significant inhibition of cathodic disbondment, which is what causes the detachment. In addition, the cathodic processes, i.e., the discharge of oxygen into the primer layer pigmented with

carbon components, are shifted. Overall, the system with graphene platelets and nanotubes increases corrosion resistance.

Fig. 4 a-d) show the immersion results for the layer structures of primers with different nanotubes/graphene platelet ratios when subjected to immersion with 5% NaCl solution, each at a weight ratio of carbon components to the polymer matrix of 0.75.

After the specified immersion time, the test container glued on with silicone and containing the NaCl solution was removed and, after drying, TESA 4651 adhesive tape was applied to the area subjected to immersion and subsequently torn off. The resulting detached coating areas are shown comparatively in Fig.4 for different CNT/graphene platelets ratios (Fig. 4a ratio 1:3; Fig. 4b ratio 1:1; Fig. 4c ratio 3:1; Fig. 4b ratio 4:1). In the order of Fig. 4a)-4d), the specific surface resistance of the primer layer in ohms is as follows: 4.6 E+04; 1.5 E+04; 1.6 E+04; 1.1 E+04.

It can be seen that the differences with respect to the detached areas between 24h and 48h of immersion are large, but then change only a little between 48h and 72h. Comparing the results between the samples primed with different CNT/graphene platelet ratios in regard to the detached areas, the structure with a 3:1 ratio of CNT to graphene exhibits a significantly reduced detached area compared with the other three samples.

Fig. 5a) and 5b) show the immersion results for the layer structures of primers without the addition of ZMP (Fig. 5a) and with 0.5% ZMP (Fig. 5b) when subjected to immersion with 5% NaCl solution, each at a weight ratio of carbon components to the polymer matrix of 0.75. The weight ratio of CNTs to graphene platelets was 3:1.

After the specified immersion time, the test container glued on with silicone and containing the NaCl solution was removed and, after drying, TESA 4651 adhesive tape was applied to the area subjected to immersion and subsequently torn off.

Here, too, it can be seen that the differences with respect to the detached areas between 24h and 48h of immersion are somewhat larger than between 48h and 72h. Comparing the results between the differently primed samples with regard to the detached areas, the structure with a 3:1 ratio of CNT to graphene platelets, which structure additionally contains 0.5% ZMP, exhibits a further improvement with regard to the detached area in comparison with the sample without ZMP. In addition, further experiments (not shown here) have shown that, particularly above a proportion of 0.9% ZMP, an increase in the detached areas occurs. This result demonstrates the synergistic effect of inhibiting anodic corrosion processes with the supplementary addition of an

active corrosion protection pigment, if added in the correct dosage to the primer formulation according to the invention.

Fig. 6a) and 6b) show the immersion results for the layer structures of primers with the addition of 0.5% ZMP, where, in the layer structure of Fig. 6b, the nanotubes and graphene platelets have a silane surface modification. Immersion was carried out by subjecting the layer structure to immersion with 5% NaCl solution, in each case at a weight ratio of the carbon components to the polymer matrix of 0.75. The weight ratio of CNTs to graphene platelets was 3:1.

Surface modification of the nanotubes/graphene platelet mixture was carried out by dispersing 0.15 g of graphene and 0.45 g of CNT in a solvent mixture consisting of 45 g of butyl acetate and 25 g of acetone with the addition of 0.6 g of polypropylene glycol (molecular weight 725 g/mol) for 120 min using an ultrasonic finger and cooling at room temperature. Subsequently, 0.36 g of a reactive silane component was added and gently stirred for 15 minutes using a magnetic stirrer to homogenize and thoroughly mix the sample, which was then heated to 70 °C for a further 15 minutes with gentle stirring, again brought to room temperature, and finally dispersed for 15 minutes using an ultrasonic finger. Vinyltrimethoxysilane (VTMO), 3-methacryloxypropyltrimethoxysilane (MEMO) and 3-glycidyloxypropyltrimethoxysilane (GLYMO) were used as reactive silane components. The best results in terms of corrosion protection effect were obtained with the double-bond functional reactive silane components vinyltrimethoxysilane (VTMO) and 3-methacryloxypropyltrimethoxysilane (MEMO).

The reason for silane modification of nanotubes and graphene platelets is as follows: A closer inspection reveals the relatively high content of the dispersing additive Efka 4050 in relation to the binder content; this additive is helpful for stabilizing the CNTs and graphene particles in the epoxy primer formulation. These contents of free foreign polymers, i.e., not bound in the binder matrix, can disrupt the compactness of the polymer matrix and thus of the corrosion protection composition, which often manifests in characteristics such as higher permeability of components relevant to the corrosion process, such as oxygen, electrolytes and water. Silane modification eliminates the need for dispersing additives.

Comparing the results in Fig. 6 between the surface-modified nanotubes/graphene platelets mixture (Fig. 6b) and the corresponding nanotubes/graphene platelets mixture

without surface modification (Fig. 6a), there is evidently reduced infiltration for the sample with the surface-modified mixture.

Below are the results produced under the influence of electrostatic polarization between the steel substrate and the 3:1 nanotubes/graphene platelets primer layer with the addition of 0.5% ZMP. If a metal substrate is negatively polarized in an adequate manner, the leaching of positive metal ions is suppressed. In addition, the intercalation of metal ions can be suppressed when the primer layer is positively polarized. Accordingly, polarization experiments were carried out in which the 3:1 nanotubes/graphene platelets primer layer was positively polarized with respect to a reference electrode, whereas the steel substrate was negatively polarized. A platinum wire and an immersion of the entire structure with 5% NaCl solution was used as the reference electrode and a potential of approximately 0.28 V was applied between the anode and the cathode.

The structure was in turn subjected to 24h immersion at room temperature with 5% NaCl solution. The detachment was evaluated by tear-off, again by using adhesive tape, after removal and drying of the coating areas subjected to immersion. The sample correspondingly subjected to immersion without polarization was used as a comparison.

Observing the results obtained in Fig. 7, the sample that was subjected to immersion under polarization (Fig. 7b) exhibits less damage around the damage location than the sample subjected to immersion without polarization (Fig. 7a). This result proves that the described coating structure with the conductive primer layer containing a mixture of nanotubes/graphene platelets is excellently suited for polarization and thus for heavy duty corrosion protection, for example in off-shore applications.

Fig. 8 shows a corrosion monitoring system 901 comprising the layers already discussed with respect to Fig. 2. The metal surface 200 is coated by the layer 100 of the corrosion protection composition. Optionally, the layer 100 is coated by the topcoat layer 202 and thus protected. To determine the corrosion of the metal surface 200 and/or the layer 100, a device 902 for frequency-dependent determination of the impedance using at least one measuring electrode and a counter electrode is used. One of the two electrodes is electrically contacted with the layer 202 or the layer 100, and the other of the electrodes is contacted with the material having the metal surface 200.

In impedance spectroscopy, the AC electrical resistance of the system being examined is measured and evaluated in a particularly broad frequency spectrum (generally in the frequency range from MHz to mHz). The flowing currents in impedance

spectroscopy are so weak that there is no danger of the measurement causing corrosion or polarization.

It should be noted that, for example, the topcoat layer 202 itself does not have to be electrically conductive for the impedance measurements to be carried out. Non-conductive cover layers make an additional contribution to the total impedance and in impedance spectroscopy this is included in the measurement result.

The topcoat layer 202 or the layer 100 can be contacted via preferably an electrically conductive elastomer, which is applied to the relevant layer.

To locally determine the corrosion properties, the topcoat layer 202 is preferably subdivided into domains 904 that are electrically insulated from one another, as shown by way of example in Fig. 9. This is useful for electrically conductive topcoat layers. As a result, the currents acting during impedance spectroscopy are distributed to those domains 904 which are in close proximity to the corresponding local electrode 900. This allows a local statement to be made with regard to the corrosion protection properties in the area of said domains. It is useful if, in this case, the domain-like topcoat layer 202 is still coated with an additional protective layer so that the penetration of liquids, e.g., water, is prevented or hampered in the region of the domain boundaries (drawn with exaggerated thickness in Fig. 9).

Instead of making contact via electrically conductive elastomers, it is also possible to make contact via painted or imprinted electrically conductive comb or finger electrodes, which are arranged particularly on the topcoat layer in order to influence the corrosion protection properties of the primer layer as little as possible. The fingers of the electrodes can be controlled preferably individually by means of the device 902 for carrying out an impedance measurement. This also results in impedance measurement results which can be assigned to the area of the layer structure that is located below the particular finger being used.

Fig. 9 shows a corrosion protection system 1101, comprising the layers already discussed with respect to Fig. 2. The metal surface 200 is coated by the layer 100 of the corrosion protection composition. Optionally, the layer 100 is coated by the topcoat layer 202 and thus protected. A polarization device 1100, for example in the form of a voltage source, particularly a power supply for providing DC voltage, comprises two electrodes 1101 and 1102. One of the electrodes 1101 is contacted with the material of the surface

200 to be protected and the other of the electrodes, indicated in Fig. 10 by reference sign 1102, is connected to the layer 100.

If the optional topcoat layer 202 is also electrically conductive, the electrode 1102 can also be connected to the topcoat layer. It is also possible that another electrically conductive layer is present on the layer 100, in which case the electrode 1102 is electrically connected to said layer. This further electrically conductive layer would be located between layer 100 and layer 202 if the layer 202 is present.

The polarization device 1100 is now set such that, by means of the electrodes, the first layer 100 is positively polarized with respect to the surface 200 of the material to be protected.

Fig. 10 shows a method for coating a surface to be protected against corrosion, such as the surface 200 of Fig. 2. The method begins in step 500 with the dispersing of the first and second filling component, i.e., particularly the nanotubes, graphene platelets, and the polymer binder to be used to produce the polymer matrix. The polymer binder can, for example, comprise unsaturated polyesters in a vinyl monomer for producing unsaturated polyester resins, or bisphenol A or other monomers for producing epoxy resins.

Dispersing is preferably carried out with energy input, e.g., by means of stirring and/or ultrasound. By way of example, dispersion takes place in the presence of solvents such as acetone and butyl acetate.

Depending on the polymer binder used, it can be provided with the associated hardener shortly before application (step 502), or the dispersed mixture can be irradiated with UV light or heat, for example, after being applied in step 502. In any case, the appropriate hardening is carried out in step 504, this hardening resulting from a chemical reaction with the hardener, or by means of UV curing or heat-induced curing. The result of this is called the layer of the corrosion protection composition, or the "corrosion protection composition".

List of reference numerals

100 Corrosion protection composition

102 Carbon platelets

104 Nanostructure component

106 Polymer matrix

200 Material to be protected

202 Topcoat layer

204 Particles of an active corrosion protection component

300 Exposed location

302 Area

304 Adhesive tape

900 Electrode

901 Corrosion monitoring system

902 Device for frequency-dependent determination of impedance

904 Domain

1100 Polarization device

1101 Electrode

1102 Electrode

Patentkrav

1. Korrosionsbeskyttelses-sammensætning (100) til belægning af overflader, hvilken sammensætning har en første og en anden fyldekomponent, hvor vægtforholdet mellem den første fyldekomponent og den anden fyldekomponent ligger mellem 0,4 og 1,2 beregnet på hele sammensætningen, idet

- den første fyldekomponent har carbonlameller (102) og en nanostrukturkomponent (104), hvor nanostrukturkomponenten (104) er valgt fra gruppen af nanorør, nanotråde og nanofibre,
- den anden fyldekomponent har en polymermatriks (106),
- carbonlamellerne (102) og/eller carbon-nanostrukturkomponenten (104) har en silan-funktionalisering eller en polyether-funktionalisering, idet funktionaliseringsgraden udgør 5 % til 90 %, især 10% til 60% og mere foretrukket 20 % til 40 %.

2. Korrosionsbeskyttelses-sammensætning (100) ifølge krav 1, hvori

- vægtforholdet mellem nanostrukturkomponenten (104) og carbonlamellerne (102) ligger mellem 2 og 4, især mellem større end 3 og mindre end 4, og/eller
- vægtforholdet mellem den første fyldekomponent og den anden fyldekomponent ligger mellem 0,5 og 1 og især mellem 0,65 og 0,8.

3. Korrosionsbeskyttelses-sammensætning (100) ifølge krav 1 eller 2, hvori nanostrukturkomponenten (104) er en carbon-nanostrukturkomponent (104), hvilken carbon-nanostrukturkomponent (104) er valgt fra gruppen af enkelt- eller flervæggede carbon-nanorør, carbon-nanotråde og carbon-nanofibre.

4. Korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav, hvori carboinlamellerne er graphenlameller, idet deres gennemsnitlige tykkelse især udgør mellem 1 nm og 30 nm eller mellem 1 nm og 15 nm, og/eller deres gennemsnitlige geometriske ækvivalente diameter udgør mellem 0,2 µm og 200 µm, især mellem 0,5 µm og 20 µm eller 0,5 µm og 10 µm eller 0,5 µm og 5 µm.

5. Korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav, hvori nanostrukturkomponentens (104) gennemsnitlige aspektforhold ligger

mellem 50 og 1500, især mellem 50 og 500 eller 70-200 eller 100-200.

6. Korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav, hvori den anden fyldekomponent omfatter partikler (204) af en aktiv korrosionsbeskyttelseskomponent, idet andelen af partikler udgør mellem 0,1 og 0,75 vægtprocent beregnet på hele sammensætningen, især mellem 0,2 og 0,6 og særlig foretrukket mellem 0,3 og 0,5 vægtprocent beregnet på hele sammensætningen, idet eventuelt

- den aktive korrosionsbeskyttelseskomponent er valgt fra gruppen af phosphater og orthophosphater og derivater deraf, især fra gruppen af de phosphater og orthophosphater og derivater deraf, som er baseret på calcium, zink og strontium, idet den aktive korrosionsbeskyttelseskomponent eventuelt er valgt fra gruppen og derivater deraf af calciumphosphat, calciumorthophosphat, calciumaluminiumorthophosphat, calciummagnesiumorthophosphat, strontiumaluminiumpolyphosphat, zinkphosphat, zinkorthophosphat, zinkaluminiumpolyphosphat, zinkmolybdænorthophosphat, zinkaluminiumorthophosphat.

7. Korrosionsbeskyttelses-sammensætning (100) ifølge krav 1, hvori silan-komponenten er valgt blandt en olefinisk reaktionsdygtig silankomponent, især vinyltrimethoxysilan, 3-methacryloxypropyltrimethoxysilan, eller en epoxid-funktionel silan-komponent, især 3-glycidyloxypropyltrimethoxysilan og blandinger deraf.

8. Korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav, hvori polymermatriksen (106) omfatter en reaktionsharpiks umfasst, især en reaktionsharpiks valgt fra klassen af epoxyharpikser, polyesterharpikser og acrylatharpikser.

9. Korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav, hvori korrosionsbeskyttelses-sammensætningens (100) specifikke overflademodstand udgør mellem 10^3 og 10^6 ohm, især mellem 10^4 og 10^5 ohm.

10. Lagstruktur omfattende et første lag og et andet lag (202), hvori det første lag har korrosionsbeskyttelses-sammensætningen (100) ifølge et af de foregående krav, og det andet lag er et dæklaklag, idet eventuelt

- det første lag har en lagtykkelse mellem 5 µm og 60 µm, især mellem 8 µm og 50 µm og mere foretrukket mellem 15 µm og 40 µm, og/eller
- det andet lag (202) har en lagtykkelse mellem 10 µm og 300 µm, især mellem 20 µm og 200 µm og mere foretrukket mellem 30 µm og 100 µm.

11. Lagstruktur ifølge krav 10, hvori det andet lag (202) indeholder elektrisk ledende partikler, idet det andet lags specifikke overflademodstand udgør mellem 1% og 30% af det første lags specifikke overflademodstand, idet de elektrisk ledende partikler eventuelt er uorganiske, især oxidiske partikler, især valgt blandt indium-, fluor- og antimon-holdige tinoxider eller blandinger deraf.

12. Anvendelse af korrosionsbeskyttelses-sammensætningen (100) ifølge et af de foregående krav 1-9 og især af lagstrukturen ifølge et af de foregående krav 10-11 til korrosionsbeskyttelses-belægning af en overflade.

13. Korrosionsovervågningssystem (901) omfattende

- lagstrukturen ifølge et af de foregående krav 10-11,
- et materiale (200), der skal overvåges, med en overflade, idet det første lag er påført på overfladen,
- et apparat til frekvensafhængig bestemmelse af impedansen med mindst en måleelektrode og en modelektrode, idet en af de to elektroder (900) står i kontakt med det andet lag eller det første lag, og den anden af elektroderne står i kontakt med materialet, idet det endvidere foretrækkes, at elektroden realiseres på overfladen af det andet lag over en elektrisk ledende elastomer uden anvendelse af en elektrolyt,
- en impedans-måleenhed og/eller analysator til bestemmelse af den i lagstrukturen optrædende korrosion og/eller permeering ud fra den frekvensafhængigt bestemte impedans.

14. Korrosionsovervågningssystem (901) ifølge krav 13, jbori apparatet til frekvensafhængig bestemmelse af impedansen har et stort antal måleelektroder eller modelektroder, og disse er anbragt rumligt adskilt fra hinanden i forskellige

stillinger i det andet lag, idet bedømmelsesenheden er udformet til bestemmelse af den i lagstrukturen optrædende korrosion ud fra den frekvensafhængigt bestemte impedans under specifik anvendelse af en eller flere af det store antal elektroder (900), idet det andet lag (202) eventuelt er opdelt i et stort antal elektrisk indbyrdes isolerede domæner (904), idet hvert af domænerne står i kontakt med en tilsvarende elektrode blandt det store antal elektroder, idet bedømmelsesenheden er udformet specifikt for domænerne til bestemmelse af den i lagstrukturen optrædende korrosion ud fra den frekvensafhængigt bestemte impedans.

15. Korrosionsbeskyttelsessystem omfattende

- lagstrukturen ifølge et af de foregående krav 10-11 eller korrosionsbeskyttelses-sammensætning (100) ifølge et af de foregående krav 1-9,
- et metallisk og elektrisk ledende materiale (200), der skal beskyttes, med en overflade, idet det første lag er påført på overfladen,
- en polarisationsindretning (1100) med en første (1101) og en anden (1102) elektrode, idet den første elektrode står i kontakt med materialet, og den anden elektrode direkte står i kontakt med det første lag eller indirekte med det første lag over et på den bort fra overfladen vendende side af det første lag anbragt ledende lag, idet polarisationsindretningen er udformet til ved hjælp af elektroderne at polarisere det første lag positivt i forhold til overfladen.

16. Fremgangsmåde til belægning en overflade, der skal beskyttes mod korrosion, hvilken fremgangsmåde omfatter:

- påføring af korrosionsbeskyttelses-sammensætningen (100) ifølge et af de foregående krav 1-9 som dispersion i ikke udhærdet tilstand på den overflade, der skal beskyttes,
- udhærdning af korrosionsbeskyttelses-sammensætningen (100), der befinder sig på overfladen.

17. Anvendelse af korrosionsbeskyttelsessystemet ifølge krav 15 og/eller korrosionsovervågningssystemet (901) ifølge et af kravene 13-14 som generelt sensorsystem, især som kapacitivt sensorsystem til anvendelse som

nærhedssensorer på overflader på belagte komponenter og materialer af enhver art.

5

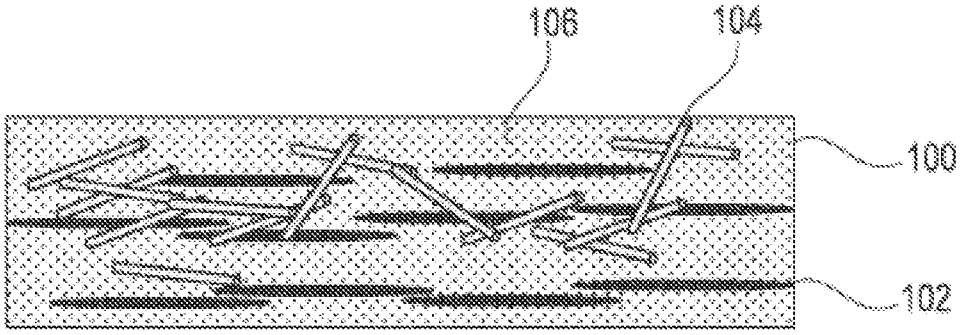


Fig. 1

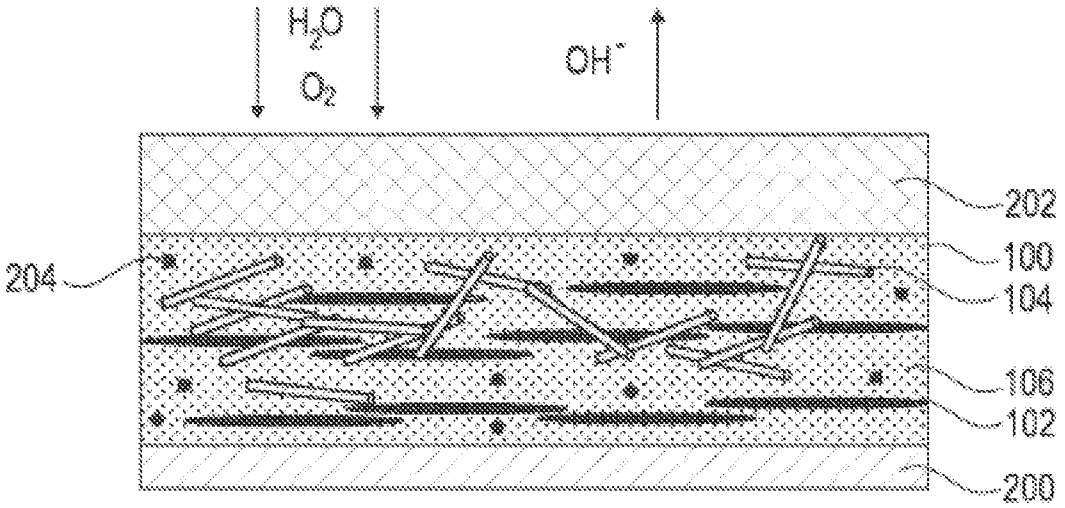


Fig. 2

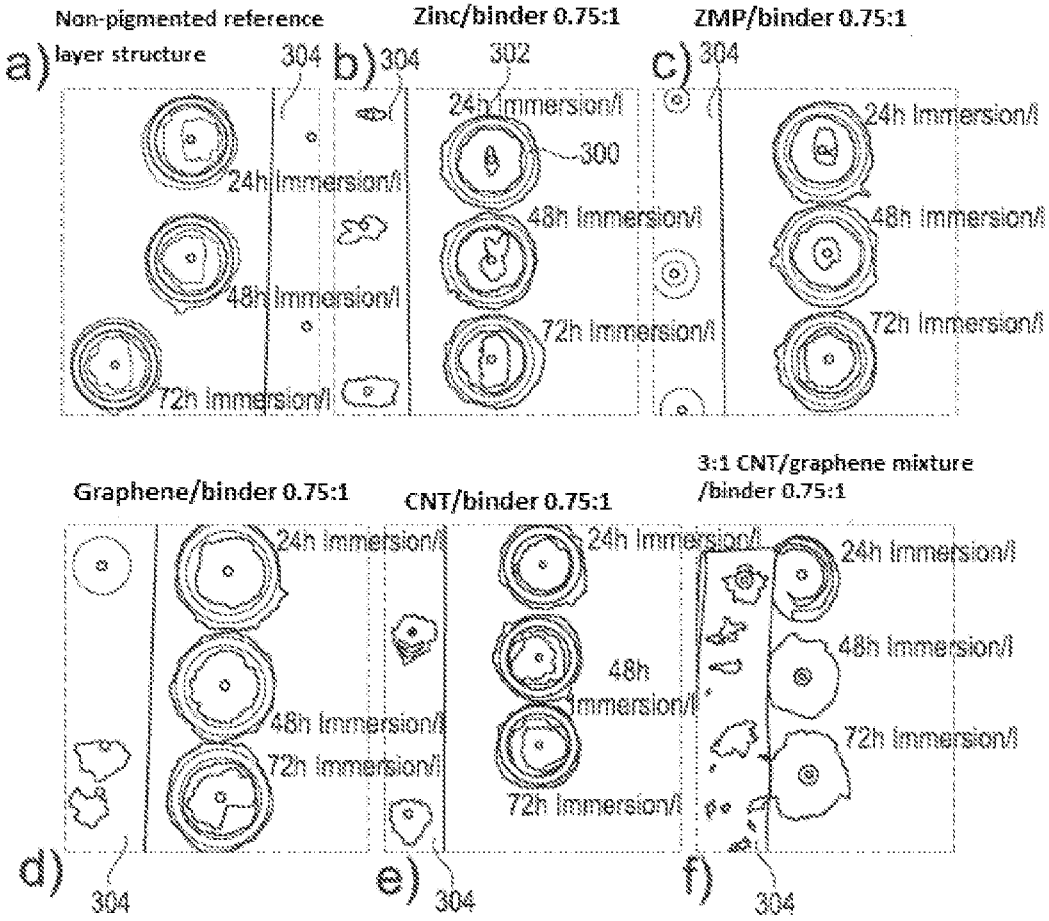

Non-pigmented reference
layer structure
Zinc/binder 0.75:1
ZMP/binder 0.75:1
Graphene/binder 0.75:1
CNT/binder 0.75:1
3:1 CNT/graphene mixture
/binder 0.75:1
a)
b)
c)
d)
e)
f)
304
302
300
24h Immersion/l
48h Immersion/l
72h Immersion/l

Fig. 3

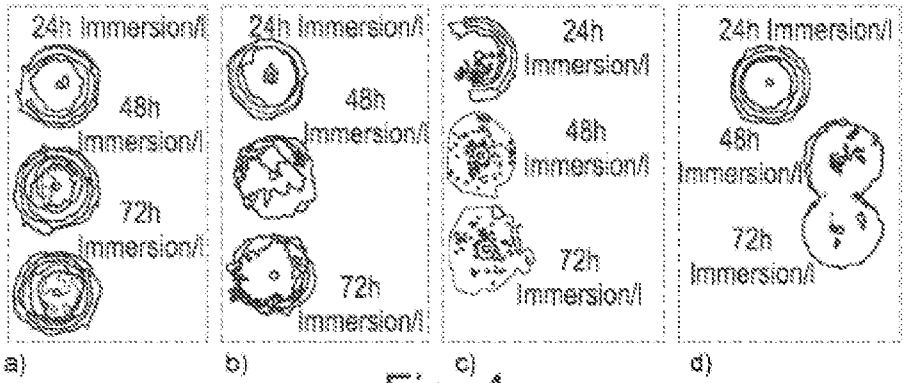

24h Immersion/l
48h Immersion/l
72h Immersion/l
a)
b)
c)
d)

Fig. 4

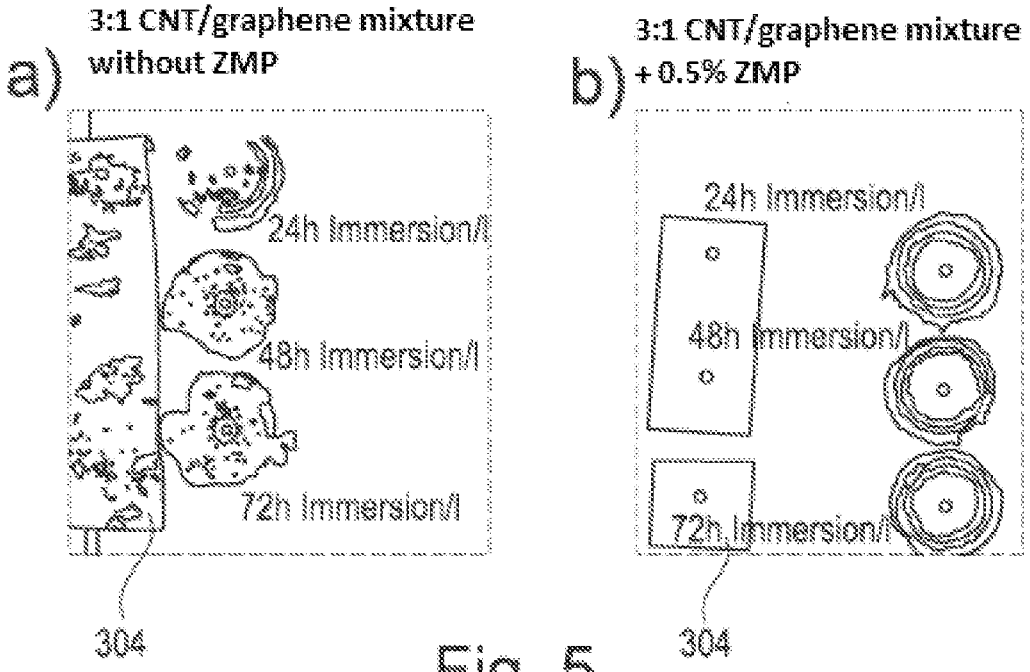

a)
3:1 CNT/graphene mixture without ZMP
24h Immersion/l
48h Immersion/l
72h Immersion/l
II
304
b)
3:1 CNT/graphene mixture + 0.5% ZMP
24h Immersion/l
48h Immersion/l
72h Immersion/l
304

Fig. 5

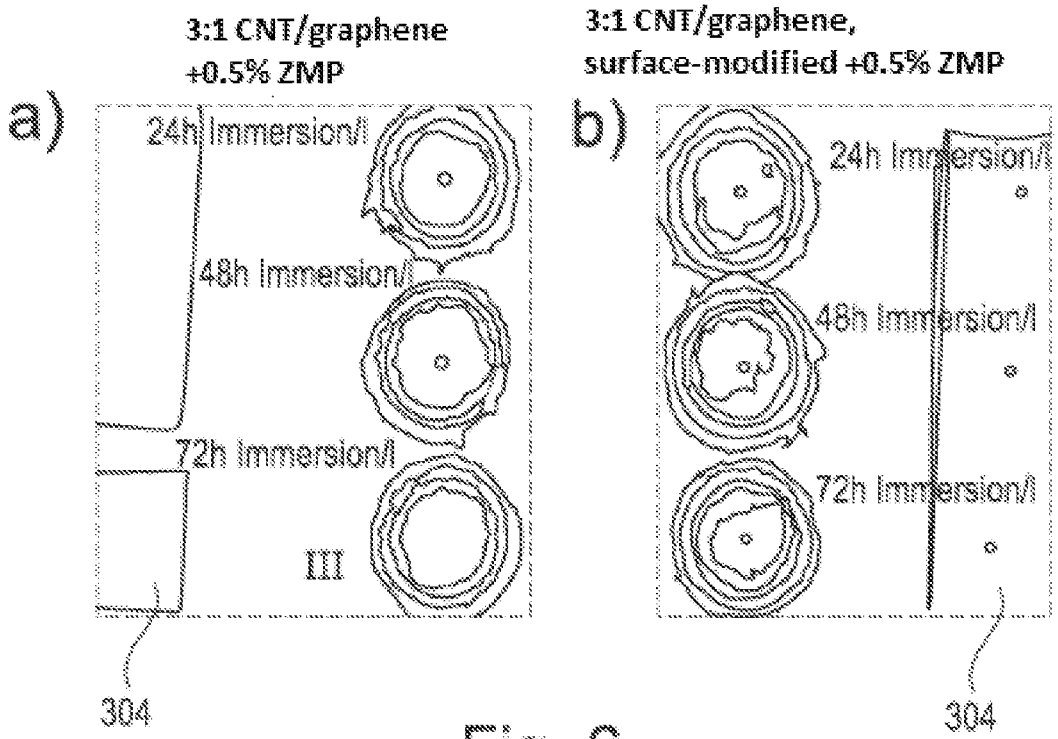

a)
3:1 CNT/graphene +0.5% ZMP
24h Immersion/l
48h Immersion/l
72h Immersion/l
III
304
b)
3:1 CNT/graphene, surface-modified +0.5% ZMP
24h Immersion/l
48h Immersion/l
72h Immersion/l
304

Fig. 6

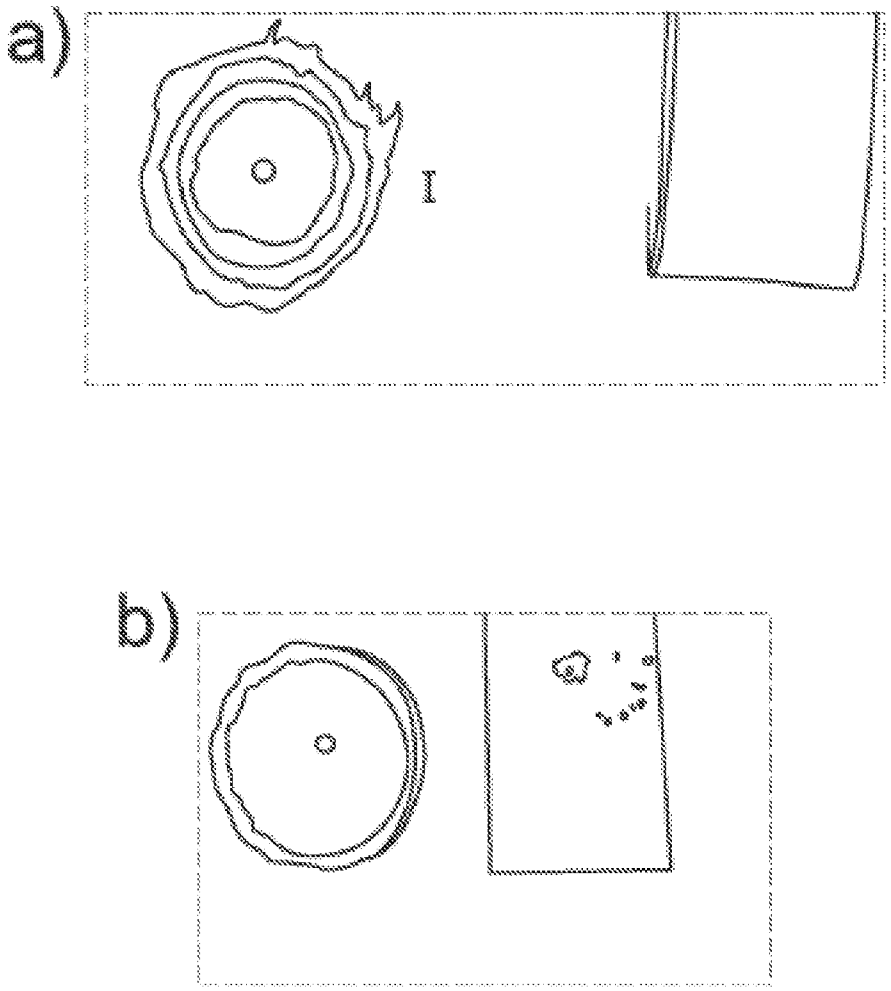


Fig. 7

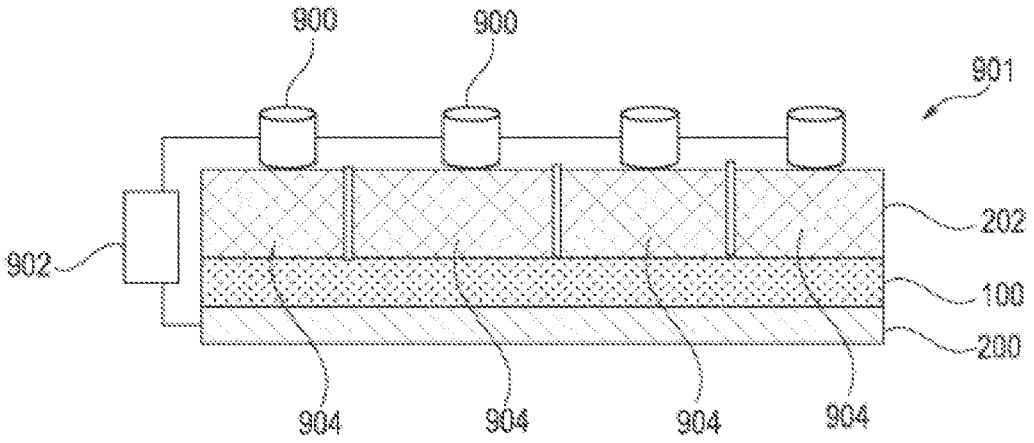


Fig. 8

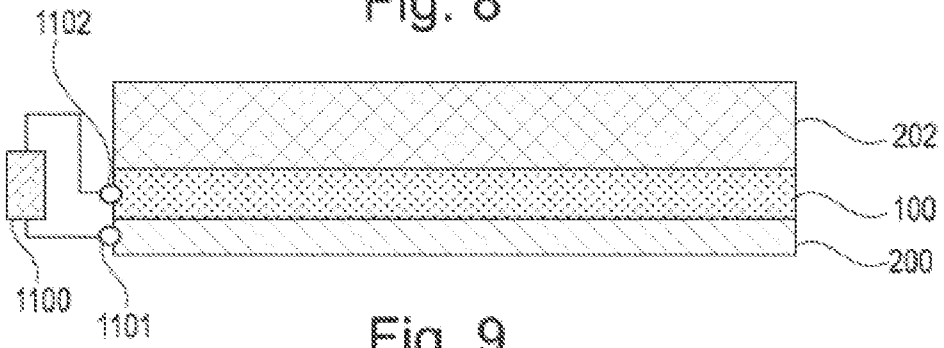


Fig. 9

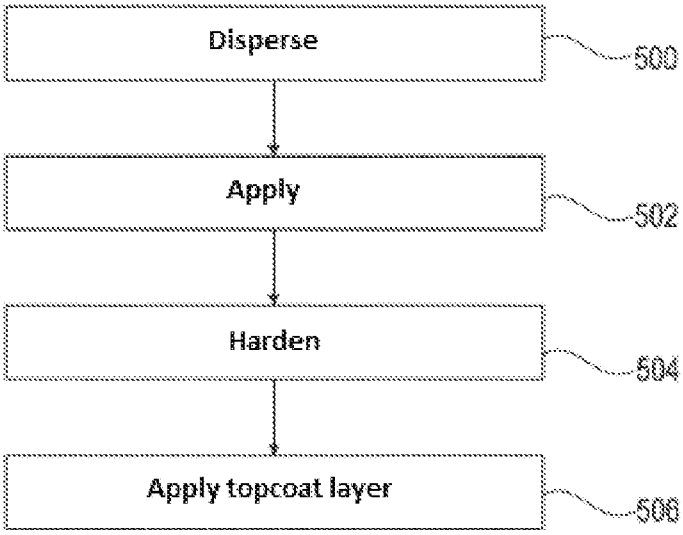


Fig. 10