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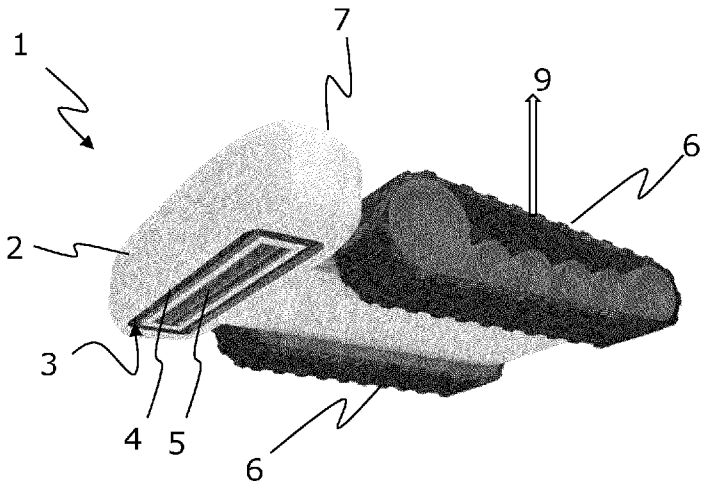

Fig. 1

(57) Abstract: A surface preparation apparatus (1) for removing coating (28) or contaminants from a surface of a coated structure (27), the apparatus comprising: - a housing (2) forming an incineration chamber (3), - an energizer (8) configured to direct an energy beam against a working point at the surface in the incineration chamber (3) and thereby provide a surface temperature above an incineration temperature by which excess matter is released from the surface and organic matter in the excess matter burns, and - a ventilation tract (20) with an inlet (21) in the incineration chamber (3) and configured to extract fumes and excess matter from the incineration chamber (3). To purify the excess matter, the apparatus further comprises an air supply (22) configured to inject air comprising oxygen into the incineration chamber (3).

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A SURFACE PREPARATION APPARATUS

INTRODUCTION

The present invention relates to an apparatus for cleaning a surface, e.g., for removing coating and contaminants from the surface of a structure, e.g., a bridge, ship, wind turbine, or a building, e.g., in combination with maintenance, e.g., applying new layers of coating.

BACKGROUND

Devices for removing coating from the surface of a structure by laser irradiation and for collecting the removed matter exist. Some devices use a laser irradiation apparatus for removing the coating by use of a laser gun. The structure could be a bridge, a building, a ship, a pipeline, and the like.

In maintenance of large constructions such as ships and bridges etc., coating is typically removed by abrasive processes, typically by blast cleaning with abrasives and/or water. The process typically takes place in uncontrolled and highly polluting conditions. The removal process generates a large amount of dust and/or waste and/or contaminated water containing flakes of organic and inorganic matter.

Workers may be exposed to dust during abrasive blasting cleaning and removal of coating. Although such processes are usually conducted outdoors, operators are normally forced to wear masks or respirators that cover the face, and the process is not encapsulated. On the contrary, removed matter and dust from the abrasive is spread into the environment.

For environmental and safety reasons, removing coating is normally handled with caution. Typically, the chips, flakes, and dust of paint and grit or water pollute the environment. While the grit and the excess matter material of the paint may be collected, it is only rarely cleaned or recycled.

Paint removal using thermal methods exists, e.g., where the paint is softened by heating. However, it is known that fumes may be generated and inhaled. For this reason, the lowest possible temperature is traditionally desired. In the known methods, the temperature is typically only raised to a degree where the paint is softened and can be released from the surface by scraping and no incineration takes place.

SUMMARY

It is an object to facilitate removal of coating and dust handling. It is a further object to facilitate purification of the excess matter material. It is a further object to facilitate increased safety, to protect the environment, and to reduce the costs and complexity in excess matter handling in connection with coating removal and other cleaning processes.

For these and other objects, the disclosure, in a first aspect, provides a surface preparation apparatus for removing coating or contaminants from a surface.

The apparatus comprises:

- a housing forming an incineration chamber,

- an energizer configured to direct an energy beam against a working point of the surface in the incineration chamber. The energizer is configured, by the energy beam, to release the coating, rust or other contaminants while creating a temperature sufficiently high to allow burning of organic matter,

- a ventilation tract with an inlet in the incineration chamber and configured to extract air and dust from the incineration chamber,

- an air supply configured to inject gas into the incineration chamber.

The following terms apply:

A surface preparation apparatus herein refers to an apparatus suitable for cleaning a surface for contaminants and/or removing coating and/or rust from a surface. The surface preparation apparatus could be movable over the surface by hand or by a moving structure, e.g., comprising wheels, belts, or a similar structure, e.g., in combination with a power-driven drive structure for moving the surface preparation apparatus over the surface, e.g., a servo motor system driving wheels or belts of the surface preparation apparatus.

The housing forms an incineration chamber which is a chamber which can encapsulate a combustion process at the surface of the object being cleaned. The incineration chamber facilitates generation of temperatures sufficiently high for such a combustion process and shields the process from ambient space. The housing may have any shape and size suitable for the purpose, and the incineration chamber is mainly formed between a cavity in the

housing and the surface being cleaned. The housing could be small, e.g., handheld and movable by hand, or it could be a larger housing to be moved by said moving structure.

By incineration is meant a treatment process that involves combustion of substances. It is a thermal treatment requiring oxygen and elevated temperature. The waste is converted into ash, flue gas and heat. The ash is mostly formed by the inorganic constituents of the waste and may take the form of solid lumps or particulates carried by the flue gas. The flue gases are typically created by combustion of organic matter.

The term energizer should herein be understood as one or more sources capable of delivering energy in one or more energy beams, i.e., it is configured to direct one or more energy beams against the working point of the surface. Particularly, the energizer is of a kind which increases the temperature of the surface while removing the excess matter. The increased surface temperature facilitates the burning of organic matter simultaneously with the release of the excess matter from the surface. This means that the energizer is configured to raise the temperature at the working point or point of impact. Particularly, it can raise the temperature at which the organic matter of the removed coating can burn. The energy beam may e.g., raise the temperature to more than 200 or 1000 degrees Celsius. Due to the thermal or energy impact, the coating is released from the surface, and at least a part of the organic matter is burned, e.g. in a process which vaporizes most of the organic substances and releases the inorganic substances as dust. The process therefore allows the disintegration of the organic particles that have left the surface due to the impact from the energy beam. The disintegration utilizes a combustion process and removes inorganic materials from the zone of combustion and allows for safe collection. The amount of solid removed matter to be treated can be reduced since the remaining solid matter is mainly inorganic matter. Accordingly, the process provides a purification of the excess matter.

By air supply, is herein meant a means to supply air, i.e., any gas mixture containing oxygen. To improve the incineration, the air supply maintains a sufficient oxygen level and a flow across the surface, and the ventilation tract extracts gas from the incineration chamber and thereby further facilitates a flow of air across the surface, continuous burning, and removal of fumes and excess matter.

The energizer may be configured to provide more energy beams against the surface, and the energy beams may have overlapped or non-overlapped impact points on the surface.

The energizer may be constituted by one or more lasers and the energy beams may thus be constituted by one or more laser beams, e.g., each having a focal point on or near the

surface and where the focal points are overlapping each other completely or partly, or where they do not overlap each other.

Excess matter herein refers to the solid matter being removed, i.e., typically chips, flakes, and dust of rust, coating, or contaminants. The excess matter typically contains organic matter and inorganic matter. Organic matter and inorganic matter typically burn at different temperatures, and by burning the organic matter but not the inorganic matter, purification takes place. Purified excess matter herein refers to excess matter having a lower content of organic matter than the non-purified excess matter. Preferably, the excess matter is free of organic matter. If needed, the excess matter is subjected to a further purification step, such as calcination.

Fumes are gas of the burned material, i.e., particularly fumes of burned organic matter.

The ventilation tract extracts air and dust from the incineration chamber and potentially separates dust therefrom, and the air supply injects gas into the incineration chamber. The gas being injected could be ambient air, or a specific mixture of gases including oxygen.

The ventilation tract may include a blower or fan of a kind known for exhaust removal, and it may be controllable such that suction at the inlet and/or pressure in the incineration chamber becomes controllable. Alternatively, the ventilation tract may be connectable to a powered ventilation system which can create a low pressure and thus suction at the inlet in the incineration chamber.

The air supply could be a source of pressurized gas containing oxygen. The air supply may comprise a compressor and/or a pressure bottle, or the air supply may simply be a blower providing a flow of ambient air into the incineration chamber. The blower could be controllable to allow control of the pressure and flow speed of the gas being added to the incineration chamber. The gas being added could be oxygen enriched and may therefore contain more than the average 21 pct. oxygen found in ambient atmosphere.

The present disclosure, in contrast to known methods, combines thermal impact and an air supply configured to inject gas into the incineration chamber. This facilitates burning particularly of organic matter, and potentially increases generation of heat and fumes. However, it also allows combustible matter, i.e. typically organic matter, to be separated from non-combustible matter, i.e. typically inorganic matter, and thereby purifies the excess matter. The generated fumes of combusted matter can be removed with the non-combustible matter by the ventilation tract, and the amount of dust is reduced to that constituted by the non-combustible matter. In practice, and by precise control of the air supply, the ventilation

tract, and/or the energizer etc., the amount of excess matter may be reduced and may contain less organic matter since organic matter is burned inside the incineration chamber.

The gas may be preheated to avoid cooling of the coating. This may improve the ability to burn the coating in the incineration chamber and it may avoid excessive lowering of the temperature in the incineration chamber when gas is added by the air supply.

The air supply may be arranged to provide the gas in a flow extending in thermal convective contact with the ventilation tract. The apparatus may define a counter flow heat exchanger where the extracted gas is cooled down by use of the injected compressed air, which on the contrary is heated before being injected into the incineration chamber.

The surface preparation apparatus may include a motion structure which can move the housing over the surface, and it may be configured to move the housing over surfaces and at locations where human operators normally have no free access. The motion structure may include magnetic attraction means for holding the housing, e.g., on vertical or overhead surfaces, and it may include power driven means, e.g., including a servo system for moving the housing. The motion structure could be remote controlled and/or it could be pre-programmed to allow pre-definition of a pattern of movement. Additionally, the motion structure may include logic control, e.g., including artificial intelligence configured to define a pattern of movement for autonomous operation of the surface preparation apparatus. This may include the use of sensors, e.g., vision, for detecting the cleanliness of the surface.

When the energizer is a laser, it may be configured to create a plume from the excess matter by energy of a laser beam. The plume may be a plasma plume containing smoke and contaminants from the surface of the coated structure. Undisturbed, the plume will normally project essentially vertically above the working point where the laser heats the surface. A particularly good combustion can be created by disturbing the plume such that it deflects from the essentially vertical, undisturbed, orientation.

The plume may be disturbed and thus deflected by use of the air supply or by use of suction in the ventilation tract or both by use of the air supply and the suction in the ventilation tract.

Deflection of the plume by a flow of air from the air supply requires that this air creates an air flow in the incineration chamber. On the other hand, such an air flow may influence the temperature, and high temperature is desirable for establishing a good combustion. For this reason, it may be an advantage to apply the air from the air supply in a manner whereby its influence on the temperature is reduced. This may reduce cooling of the surface of the coated structure by the injection of air and thereby improve the combustion. It has been found that

this may be accomplished in different ways, referred to as a), b), c), and d) below. These different ways of reducing the impact of the air on the temperature can be implemented separately or in combination.

a) The air supply may be arranged to direct a stream of air from an air injection point towards the plume. The air supply may e.g., comprise one or more nozzles which provide a pointed stream of air directed against the plume, and not directed against the surface, i.e., typically a short distance above the surface of the coated structure, e.g. about 1 cm from the surface, such as 5-15 mm from the surface. Particularly, this distance is suitable in combination with a mainly laminar flow. Since the air is injected into the incineration chamber at a distance from the surface, and not directly pointed against the surface, the impact on the temperature of the surface is reduced.

b) The air supply may be arranged to create the stream of air such that it is mainly a laminar flow along a line between the nozzle and the plume. In this way, heat exchange may be reduced between the surface of the coated structure and the air in the stream of air, and that prevents or reduces cooling of the surface by the stream of air injected by the air supply. Mainly laminar, herein means that more than 50 pct. of the air injected by the nozzle is laminar, e.g. 60, 70 or 80 pct. of the flow.

c) Further, to reduce heat convection between the stream of air and the surface of the coated structure, the air supply may be arranged to create the stream of air such that it is essentially parallel to the surface of the coated structure. The air supply may be arranged to create the stream of air such that a centre line of the stream is displaced relative to the surface of the coated structure. In one embodiment, the air supply comprises a nozzle placed less than 5 cm. from the working point, pointing towards a point between 1 and 2 cm. above the working point and being placed at a similar distance from the surface of the coated structure such that it points in a direction parallel to the surface.

d) The apparatus may comprise a heating structure configured to heat the stream of air before it reaches the plume. This may further prevent unintended cooling of the surface due to heat convection with the injected air. The heating structure may comprise a heat exchanger configured for convection of thermal energy with the extracted fumes and excess matter from the incineration chamber to thereby reduce energy consumption. In this manner, the fumes and excess matter transfer heat to the injected air. The heat exchanger could e.g., comprise a counter flow heat exchanger, e.g., where the air which is to be injected flows coaxially within, or outside a tube which conducts the extracted fumes and excess matter.

If the apparatus is configured for movement in a working direction, then the working point may be in a vertical plane perpendicular to the working direction and separating the air injection point and the inlet. In this manner, the ventilation inlet is on one side of the plume and the air injection point is on an opposite side of the plume, and both the ventilation and the air supply may facilitate displacement of the plume and improve the combustion.

The air supply may be configured to displace the plume towards the inlet of the ventilation tract. The displacement may be caused by the injected air and/or by suction in the ventilation tract.

A plume sensor may determine a plume orientation signal representing an orientation of the plume. In this embodiment, the air supply and/or suction in the ventilation tract may be controlled based on the plume orientation signal.

The plume sensor may comprise a vision system with a camera and software configured for recognition of the plume and the orientation of the plume. The software may include an artificial intelligence network trained based on a plurality of orientations of plumes and corresponding measurements, where the measurements are indicative of a content of soot.

For detecting the plume orientation and displacement of the plume, the incineration chamber may comprise a light source and a camera arranged on opposite sides of the working point to thereby capture images of the plume with backlighting.

The surface preparation apparatus may comprise at least one sensor configured to provide a measured value of a process parameter in the incineration chamber. Additionally, the surface preparation apparatus may comprise a controller configured to provide a control setting for the energizer, the ventilation tract, and/or the air supply based on the measured value.

The measured value may e.g., indicate one or more of: content of an organic compound in the excess matter, temperature in the incineration chamber or ventilation tract, or a content of oxygen, carbon dioxide, or carbon oxide in the fumes or in the incineration chamber. Such values can be measured using standard sensors e.g., known from combustion engines, e.g., a lambda sonde. Such sensors could be in the incineration chamber, e.g., near the surface, or it could be in the ventilation tract.

The controller may be configured to provide a control action which controls the air supply, the ventilation tract, the energizer, or optionally other controllable features such as a servo drive moving the housing over the surface.

The controller may e.g., increase air flow from the air supply and thereby the amount of oxygen injected into the incineration chamber when the measured value of carbon oxide exceeds a threshold or is outside a certain band. In this case, the control action relates to control of the air supply, and may include a setting for a blower or a setting for a throttling valve etc.

The control may e.g., be based on the formula $v=-x*\beta$

Where v is the flow speed of air from the air supply, -x is a constant and β is a percentage of CO_2 measured in the incineration chamber.

The controller may e.g., change the power of the energizer when the measured value of a temperature in the incineration chamber is outside a certain band. In this case, the control action relates to control of the energizer, and may, if the energizer is a laser, include a setting, e.g., an electrical signal, controlling the power or the focus point size of the laser or other parameters determining the power, e.g., an oscillation width or speed of the laser spot etc.

The controller may e.g., change pressure at the inlet or in the incineration chamber by controlling a blower of the ventilation tract when the measured value of a temperature in the incineration chamber is outside a certain band or if a content of excess matter is outside a band. In this case, the control action relates to control of a blower connected to the ventilation tract or for a throttling valve at the inlet to the ventilation tract etc.

The controller may comprise a CPU and a data storage, the data storage comprising a process data set with at least one type of coating or contaminant to be removed from the surface and a corresponding reference parameter, the reference parameter being comparable with the measured value. The controller may be configured to provide the control settings based on a comparison between the reference parameter and the measured value. Accordingly, the data storage may contain different sets of data, where one set of data pertains to one type of coating or one family of coating types, e.g., to a specific epoxy containing coating or to a combined system containing several different binder types. In each set of data, bands, or thresholds for comparison with the measured value may be defined, and corresponding control actions may be defined.

The reference parameter may, e.g., comprise a desired temperature range and corresponding control settings for at least one of the energizer, the ventilation tract, and the air supply. The CPU may then be configured to use that control setting as the control action or for defining the control action.

An example could be that one data set defines an epoxy type of paint, a coating thickness, and a temperature range between 700 and 800 degrees Celsius. The control setting could e.g., be a specific power level of the energizer, a particular air flow in the ventilation tract, and a specific airflow provided by the air supply. The CPU may convert these settings into control actions, e.g., specific control commands for the energizer, the air supply, and the ventilation tract, e.g., specific voltages for controlling a throttling valve, or for setting the power of the energizer.

The controller may be configured to carry out an iterative operation cycle comprising multiple cycles where each cycle comprises:

- submitting control settings to at least one of the energizer, the ventilation tract, and the air supply,

- obtaining a measured value from the sensor,

- amending the control setting based on a comparison between the measured value and a reference parameter,

- preparing control actions based on the amended control settings and

-submitting carrying out the control actions, e.g., by submitting the amended control setting to at least one of the energizer, the ventilation tract, and the air supply.

The sensor may comprise at least one of:

- a vision system configured to detect a deviation between an image and a reference image,

- an oxygen, CO2, CO, or NOx sensor probe, and

- a temperature sensor probe.

These sensors could be placed at different locations in the incineration chamber, in the ventilation tract or at the surface of the object to be cleaned.

The sensor may be configured to determine the organic compound based on colour of the dust, e.g., by determining soot based on a grayscale etc.

The apparatus may comprise an outlet sensor configured to analyse the extracted air and to detect potential organic matter therein.

If the energizer is a laser, the laser-based energizer may be configured with a laser input for receiving laser energy from a laser source placed outside the incineration chamber. That may save space and reduce the weight of the housing, e.g., by placing the laser source away from the housing.

The air supply may comprise blower arranged to blow air from ambient space into the incineration chamber, i.e., the gas mixture may essentially correspond to atmospheric air with about 78 pct. nitrogen, 21 pct. oxygen and a remaining 1 pct of other substances.

The air supply may comprise a nozzle arranged to direct a stream of air directly towards the working point, and it may be arranged to create an airflow towards the inlet of the ventilation tract.

The controller may comprise a data set indicating a specific coating and/or a layer thickness and a corresponding control setting for at least one of the energizer, the ventilation tract, and the air supply. In this embodiment, the user may select the specific type of coating and/or the layer thickness in a machine interface, and the controller may, in response to the selection, initiate a process with the corresponding control settings.

In a second aspect the disclosure provides a method of purifying inorganic matter from a cleaned surface e.g., by use of said surface preparation apparatus. The method comprises:

- pointing an energy beam towards the surface until the excess matter is heated and released,

- applying a controlled gas mixture to the surface or to the energy beam while the excess matter is heated until at least a part of organic matter in the excess matter is burned,

- removing the inorganic matter and potential remedies of organic matter by suction.

Particularly, the controlled gas mixture may be ambient air containing at least 21 pct. Oxygen, and optionally, the oxygen level may be increased above 21 pct.

Also provided is a method of manufacturing a coating composition, said method comprising

a) Recycling inorganic matter from old coating compositions, and;
b) dispersing the collected inorganic matter in a binder matrix to form said coating composition.

In this manner, effective re-use and recycling of inorganic matter from old (used) coating compositions can be recycled into new coating compositions.

The step of recycling may suitably comprise performing the method according to the second aspect as described herein and collecting inorganic matter therefrom.

Suitably, the collected inorganic matter at the point of collection or at a later stage, is subjected to one of the following steps; filtering, milling, heat treatment or washing, before being dispersed in the binder matrix. Such steps allow the size and shape of the inorganic matter to be adjusted as required in the new coatings formulation as part of the general quality control procedure.

In a particular aspect, the collected inorganic matter is subjected to one of the before mentioned processes, before being dispersed in the binder matrix. As shown in the example below, calcination of the inorganic matter (i.e. heat treatment, preferably to a temperature above 100 degC) removes undesired colour from the inorganic matter, e.g. via removal of residual carbon black in the inorganic matter.

The binder matrix may be a physically drying binder system, where the binder components of the binder system in the dry coat are already present in the same form in the wet coating composition. There is no change in the binder composition or the molecular structure or size of the binder components. The coat is formed entirely by evaporation of solvents, leaving the binder molecules as chains coiled up and intertwined in the coat.

The binder matrix may also be a chemically hardening binder system, which is characterised in that the final binder molecules in the dry/cured paint film are not present in the wet film. In this instance, the relatively smaller binder component molecules (e.g. monomer) take part in a chemical reaction to form larger molecules, e.g. by chain extension, and possibly involving crosslinking binder components.

Examples of suitable binder systems are epoxy, polyurethane, polysiloxane, vinyl, acrylic, alkyd, silicone, silicates, silyl acrylate, metal acrylate, polyoxalate, polyester, rosin, non-aqueous dispersion binder, styrene copolymers, polyamide resins, oils such as linseed oil, castor oil, soy bean oil and derivatives thereof and hybrids and combinations of the materials.

The binder matrix may comprise a curable polymer selected from the group consisting of epoxy, polyurethane, polysiloxane, vinyl, acrylic, alkyd, and silicone polymers, or mixtures or blends thereof. In a particular aspect, the binder matrix comprises an epoxy-based binder system comprising:

one or more epoxy resins selected from bisphenol A, bisphenol F and Novolac; and

one or more curing agents selected from Mannich Bases, polyamidoamines, polyoxyalkylene amines, alkylene amines, aralkylamines, polyamines, and adducts and derivatives thereof.

In this method, the inorganic matter may be present in up to 90 % by dry weight of the total coating composition, such as up to 80% or 70 % or 60 % or 50 % or 40 % or 30 % or 20 % or 10 % by dry weight of the total coating composition.

The inorganic matter comprises oxides and silicates selected from the group consisting of elements of groups 1, 2, 4, 7, 8, 9, 11, 12, 13 and 14 and of periods 4 and 5 of the periodic table of elements according to the new IUPAC naming system, in particular oxides and silicates selected from alkali metals, alkaline earth metals, titanium, zirconium, manganese, iron, cobalt, copper, zinc, aluminium, silicium. More preferably, the inorganic matter comprises oxides and silicates selected from the group consisting of sodium, potassium, magnesium, calcium, strontium, barium, titanium, zirconium, iron, aluminium and silicon.

The inorganic matter typically comprises a material selected from the group consisting of magnesium silicate, aluminium silicate, potassium silicate, titanium dioxide, and iron oxide, or a mixture thereof. Due to the techniques used to obtain the inorganic matter, the inorganic matter may comprise or consist of inorganic particles, preferably inorganic particles of aluminium silicate or magnesium silicate, having an essentially spherical shape. In one aspect, the inorganic particles have an average diameter of less than 40 µm.

The present technology also provides a coating composition obtained, or obtainable by the method described herein.

A coating composition is also provided, comprising a binder matrix and inorganic matter, wherein the inorganic matter comprises or consists of inorganic particles, preferably inorganic particles of aluminium silicate or magnesium silicate, having an essentially spherical shape.

In this coating composition, the binder matrix may be as defined above, and/or the inorganic matter may be as defined above. Also in this coating composition, the inorganic matter may be present in up to 90 % by dry weight of the total coating composition.

LIST OF DRAWINGS

Fig. 1 illustrates a surface preparation apparatus;

Fig. 2 illustrates a cross section of the surface preparation apparatus;

Figs. 3-4 illustrate schematically the control of the incineration process;

Fig. 5 illustrates the surface preparation apparatus applied for removing coating from a surface of a ship;

Fig. 6 illustrates an embodiment of the surface preparation apparatus where the air supply defines a nozzle pointing towards the inlet of the ventilation tract;

Fig. 7 illustrates an alternative embodiment of the surface preparation apparatus;

Fig. 8 illustrates a laser beam directed towards a surface, and a resulting plume;

Fig. 9 illustrates a vision system for determining plume displaced by injected air and

Fig. 10 illustrates an embodiment of the surface preparation apparatus.

Figs. 11-16 are microscope or SEM photos in the analysis of inorganic matter.

DETAILED DESCRIPTION

Fig. 1 discloses a surface preparation apparatus 1 for removing coating or contaminants from a surface. Apparatus 1 comprises a housing 2 forming an internal incineration chamber 3, i.e., an area defined by a cavity and encapsulated within edge 4 of the opening.

The cleaning takes place at the surface of the object to be cleaned when an energy beam of an energizer 5 is pointed towards the surface. This beam could be a laser beam which ablates

the coating which is released from the surface as hot excess matter, typically in the form of flakes and dust.

Belts 6 are provided on opposite sides of the surface preparation apparatus and enable crawling over the surface. The belts thereby form a motion structure within the context of this disclosure. Alternative motion structures may e.g., include rollers and wheels of any kind suitable for moving the apparatus over the surface.

The disclosed belts 6 or alternatively wheels or similar drive structures are magnetic and allow vertical crawling of the apparatus or crawling up-side down with the upper surface 7 facing downwardly.

The energizer 5, e.g., a laser, is arranged to direct a power beam against a working point at the surface in the incineration chamber. An outlet for released matter is illustrated by the arrow 9.

Fig. 2 illustrates in a cross section, internal components of the apparatus. Ventilation tract 20 defines an inlet 21 in the incineration chamber and extract air from the incineration chamber during operation of the energizer 5. The air transports dust and other remedies from the coating removal process and thereby collects the removed matter via outlet 9. The collected matter may be carried to a place where the dust could be fragmented into inorganic and potentially organic matter and optionally regenerated e.g., for use in manufacturing of coating. The blower 22 provides fresh air from the intake 23 to the incineration chamber and thus forms an air supply 22 configured to inject gas from the nozzle 24.

Energizer 5 operates through an opening 25 in the housing, and skirt 26 extends about the opening. The skirt extends the incineration chamber to include the area between the surface of the coating 28 and the opening 25.

In the embodiment illustrated in Fig. 2, the surface preparation apparatus is designed to move on surface of the structure, i.e., on that part from which the coating has been removed. The apparatus moves in the direction indicated by arrow 32. In use, the apparatus crawls over the coated structure 27. Energizer 5, in this case a laser, is directed towards coating 28 which is removed by a thermal process. While the chips, flakes, dust, and other released matter are removed by ventilation tract 20, oxygen is added by the air supply 22 to the point where the coating is heated. This creates an incineration of organic matter which is removed by ventilation tract 20 as fumes. Accordingly, the matter provided at outlet 9 is solid dust of inorganic matter essentially free from organic matter, and fumes of combusted organic matter. By precise control of the incineration process, fumes may mainly contain

burned organic matter. Herein, we refer to the term "performance", as an expression of the ability to separate organic matter as fumes and inorganic matter as solid dust. A high performance relates to a low content of organic matter at outlet 9.

To improve the incineration process, the apparatus comprises a controller 29. The controller may be implemented using standard hardware circuits, using software programs and data in conjunction with a suitably programmed digital microprocessor or general-purpose computer, or a cloud computer, and/or using application specific integrated circuitry, and/or using one or more digital signal processors. Software program instructions and data may be stored on a non-transitory, computer-readable storage medium, or in the cloud, and when the instructions are executed by a computer or other suitable processor control, the computer or processor performs the functions associated with those instructions. Accordingly, the disclosure comprises software readable by computer means for carrying out the method and thereby providing the system for sensing a condition of a component.

The disclosed controller 29 communicates with the ventilation tract 20, with the energizer 5, and with the air supply 22. Additionally, the controller may communicate with a drive controller which again controls the motion structure 6. The Controller may further communicate with the sensor 30 and optionally also with the sensor 31. The sensors 30,31 measure different values of process parameters in the incineration chamber.

Based on the measured value, the controller calculates a control setting for the energizer, the ventilation tract, and/or for the air supply.

In one example, the value measured by sensor 30 indicates an organic compound in the dust. The sensor could e.g., include an optic sensor which, e.g., based on colour of the dust, determines organic content. Based on this content, the controller may instruct the air supply to increase or decrease the airflow from the air supply, to increase or decrease the power intensity of the energizer, and/or to increase or decrease the suction provided by the ventilation tract.

In another example, the value measured by sensor 30 indicates a content of NOx or Oxygen in the gas removed by the ventilation tract. The sensor could e.g., include a NOx or oxygen probe such as a Lambda probe or similar probe capable of measuring the proportion of oxygen (O2) in the gas.

The sensor 31 could be a temperature sensor which provides an additional input to the calculation of the increase or decrease in airflow from the air supply, power intensity of the energizer 5, and/or the suction provided by the ventilation tract 20.

The controller may work according to different principles, herein referred to as empirical principles, where the control settings originate from observation or experience and not from theory. Alternatively, the controller may work according to theoretical observations, or according to a combination between empirical and theoretic considerations.

In one example related to empirical control, a threshold is defined relative to one or more measured process parameters. Once a threshold is exceeded, the control setting, or settings are raised or lowered to a certain incremental value. This is a very simple way of controlling the incineration, however, not necessarily leading to the best performance, i.e., the best separation of organic matter as fumes and inorganic matter as solid dust. In another example of empirical control, a table of experienced, working, process parameters with corresponding control settings is developed and used by the controller.

In one example related to theoretic control, a mathematical transfer function is developed and implemented in a control system, e.g., in a proportional, differential, or integral, P, PI, PD, or PID controller and one or more process parameters are inserted as variables in the function which provides one or more control settings as a result. While this may be a more complex way of controlling the incineration, it may also lead to a higher performance.

Figure 3 is a block diagram illustrating the functions of the surface preparation apparatus.

In the block diagram, the blocks represent the following functions

Block A: Illustrates the excess matter is burning;

Block B: In block B, the quality of the burning is evaluated. If the burning process is acceptable, the sensor output is recorded in Block C. If the burning process is not acceptable, the sensor settings are read in Block D.

Block C: Represents recording of sensor output which is stored in database E.

Block D: In Block D, values are obtained by sensors S1-S8.

Block F: In Block F, the values from the sensors are analysed to determine a potential issue.

Block G: In Block G, the control settings are determined for influencing the burning process. After Block G.

The sensors are as follows:

S1: Combustion temperature measured at the working point of the surface being cleaned.

S2: Camera arranged to determine colour of excess matter and/or surface.

S3: intake airflow measurement. The airflow is created by the air supply.

S4: Intake air temperature – i.e., temperature of air from air supply.

S5: Exhaust airflow – i.e., airflow created by ventilation tract.

S6: Exhaust air temperature – i.e., temperature measured in the ventilation tract.

S7: Energy power, i.e., the amount of energy delivered by the energizer.

S8: Energy duty cycle, i.e., a duty cycle at which the energy is delivered by the energizer.

The blocks illustrate a control procedure for determining the control settings to provide a good performance, i.e., a low amount of residual organic matter in the excess matter. For establishing a good performance, not all the oxygen in the incineration chamber is burned. The residual gas partial pressure p-residual remaining in the incineration chamber is thus composed of air and gas obtained by a complete burning of the organic matter – this could be referred to as inert gas since it is typically unable to react further with oxygen.

Fig. 4 illustrates a block diagram in which process G and B are defined in further details specifically for control based on a temperature measurement. In This diagram, the Block F, i.e., where values from the sensors are analysed to determine a potential issue, depends on 7 different events as listed below:

1. Combustion temperature being at a specific level, e.g. 500 degrees Celsius.
2. Intake airflow from air supply 22 being at a specific level, e.g. 10 m^3/min.
3. Intake air temperature from air supply 22 being at a specific level, e.g. 500 degrees Celsius.
4. Exhaust airflow provided by the ventilation tract being at a specific level, e.g. 10 m^3/min.
5. Exhaust temperature in the ventilation tract being at a specific level, e.g. 200 degrees Celsius.

6. Energy level of energizer being at a specific level, e.g. 10 pct. of max power.
7. Energy duty cycle being at a specific level, e.g. 200.

Black H illustrates a process of checking if combustion temperature is within a desired range. This is triggered by Block F in case of event 1, 3 and 6. If it is within a desired range, the function Block I will be triggered. If the combustion temperature is not in the desired range, function Block J is triggered.

Block I illustrates a process of checking if the temperature is below a lower threshold. This function is executed for all issues of checking in Block H where Block H determines the combustion temperature to be within the desired range. Additionally, it is triggered by Block F in case of event 5. If Block I identifies the temperature not to be too cold, it triggers Block H to be repeated. If Block I identifies the temperature to be too cold, it triggers Block J.

Block J is a process in which energy level of the energizer is compared with a threshold of e.g. 90 pct. of max power. The threshold can be programmed freely. If the energy level of the energizer is above the threshold, the Block K is triggered, and if the energy level of the energizer is not above the threshold, the Block L is triggered.

Block K is a process in which the gas flow from the air supply 22 is increased.

Block L is a process in which the power level of the energizer is increased.

Block M illustrates an internal process executed in a CPU and defining when to execute Block H and I.

Fig. 5 illustrates apparatus 1 inserted for cleaning paint from an outer surface of a ship 40. The illustrated apparatus moves in a predefined pattern over the surface. Pattern 41 may be defined in controller 29 and the cleaning process may therefore be fully automatic. The separator may e.g., be carried by a vehicle on the ground such that the magnetically attached housing only contains the energizer 5, the ventilation tract 20, the air supply 22, the controller 9, and other features, e.g., the sensors 30, 31 etc. In this embodiment, the energizer may be an emitter configured to emit a laser beam generated by a laser source. The laser source may, like the separator, be carried by a vehicle 42 on the ground. This reduces the weight of the housing and enables safer and faster operation on vertical and overhead surfaces.

Example 1

The device is moved along a surface of steel coated with an industrial coating system (2-3 layers of various thicknesses up to a total dry film thickness of 700-800 microns). The coating systems can be comprised of various types of binders like epoxy, alkyd, silicone, polyurethane etc.

One or more lasers are operated with a power between 1500-20.000 watt at a set working distance for optimum focus through optimized focal lenses ensuring uniform beam-sizes. Lasers are prior to "hitting" the lenses passed to a galvo-scanner matched with the optics to oscillate in the desired pattern distributing the energy sufficiently to protect the substrate from damage. The total work-area of the laser system will be between 20-100 centimetres. The oscillating movement of the lasers will effectively remove the coating from the substrate leaving the bare steel, or aluminium with its original roughness/surface profile in a clean state as to enable application of new coating on the "prepared" surface.

The laser process at the surface is optimized by effectively removing the ablated material as well and adding air/oxygen gas mixture to the plasma to get the cleanest most optimal burn of the organic materials that make up around 50% of the coating-mass. The temperature/energy intensity is controlled as to only incinerate most of the organic matter (99%) leaving the inorganic ablated matter to be removed via vacuum as part of the exhaust process for further filtering and collection.

The contents of the solid matter depend on the type of coating removed but will contain: oxides and silicates selected from the group consisting of elements of groups 1, 2, 4, 7, 8, 9, 11, 12, 13 and 14 and of periods 4 and 5 of the periodic table of elements according to the new IUPAC naming system, in particular oxides and silicates selected from alkali metals, alkaline earth metals, titanium, zirconium, manganese, iron, cobalt, copper, zinc, aluminium, silicium. More preferably, the inorganic matter comprises oxides and silicates selected from the group consisting of sodium, potassium, magnesium, calcium, strontium, barium, titanium, zirconium, iron, aluminium and silicium.

Fig. 6 illustrates an embodiment of the surface preparation apparatus where the air supply 22 defines a nozzle 24 pointing towards inlet 21 of the ventilation tract 20. In this embodiment, the energizer 5 is a laser pointing a laser beam 62 against the working point 63. The laser comprises a laser optic 64 which in the specific embodiment is protected by a protective airflow in the surrounding air passage 65. The protective airflow prevents excess matter from sputtering back onto the optic 64.

In one embodiment, the protective airflow forms part of the air supply 22. In this case, air from the protective airflow contains oxygen which is used in burning organic matter in the excess matter, and the protective airflow may be combined with the airflow from the nozzle 24.

The nozzle 24 points towards the surface at an angle marked in Fig. 6 with β. This angle is in the range of 10-60 degrees and the surface reflects the airstream towards inlet 21. Correspondingly, inlet 21 of the ventilation tract 20 points towards the surface at an angle marked in Fig. 6 with γ. This angle is also in the range of 10-60 degrees – it could particularly be equal to β.

Fig. 7 illustrates in a cross section, an alternative embodiment of the surface preparation apparatus. Compared to the apparatus illustrated in Fig. 2, this embodiment is designed to move on the coating in the direction indicated by arrow 71.

The ventilation tract 20 defines an inlet 21 behind the working point relative to the direction of movement. The blower 22 provides fresh air from the intake 23 to the incineration chamber and thus forms an air supply 22 configured to inject a gas mixture, e.g. atmospheric air from the nozzle 24.

Fig. 8 illustrates a plume 80 extending from the working point 63 where the laser beam 62 hits the surface 27 or coating 28. The plume is displaced in a direction away from the nozzle 24 of the air supply 22. The displacement is due to the air flow from the nozzle. Due to the displacement, the plume approaches the inlet 21.

The plane 81 is illustrated vertically through the working point 63 between the nozzle 24 of the air supply and the inlet 21 of the ventilation tract. The plane illustrates the displacement towards the inlet 21 of the ventilation tract and away from the nozzle 24 of the air supply. More than 50 pct. of the plume, i.e., approximately 55-65 pct. of the plume is located to the left of the plane 81.

The nozzle 24 is designed to provide a primarily laminar flow illustrated by the dotted lines 82. The nozzle is arranged such that it passes the laser beam 62 before reaching the plume 80. The nozzle 24 points towards the plume at an angle marked in Fig. 6 with β. In Fig. 8, this angle is 0 degrees, i.e., the flow of air is parallel to the surface 27 and coating 28. The inlet 21 of the ventilation tract 20 points towards the surface at an angle marked in Fig. 6 with γ. To support the deflection of the plume illustrated in Fig. 8, this angle is the range of 10-60 degrees, e.g., between 50 and 60 degrees.

Fig. 9 illustrates a plume sensor comprising a camera 90 and a CPU 91. The CPU receives images from the camara which captures backlight images of the plume 80. The CPU operates an artificial intelligence network trained based on a plurality of orientations of plumes and corresponding measurements and outputs a signal indicating deviation from a desired plume orientation and optionally, outputting a control signal to at least one of the air supply and the ventilation tract to thereby control the airflow from the nozzle 24 of the air supply across the plume to the inlet 21 of the ventilation tract.

Fig. 10 discloses a surface preparation apparatus with belts 6 configured for crawling on the already cleaned bare steel surface.

The energizer 5, e.g., a laser, is arranged to direct a power beam against a working point located between the air supply 22 and the inlet 21 to the ventilation tract 20. In the illustrated embodiment, the inlet 21 is ahead of the air supply 22 in the direction of movement indicated by the arrow 32. The air, which is injected by the air supply, is guided towards the inlet to the ventilation tract in the direction of movement.

Analysis of laser ablated material

A sample of material obtained from the laser ablation process was subjected to analysis.

The sample was analysed by infrared spectroscopy (IR) and energy dispersive X-ray fluorescence (EDXRF). The sample was also examined by microscopy and scanning electron microscopy – energy dispersive x-ray spectroscopy (SEM-EDS).

Analysis results are shown in the table below.

Colour		Black
		Amount
		w/w
THF soluble part	Fragments originating from epoxy binder	1.9%
Soot		3.7%
Inorganic pigments	Magnesium silicate	94.3%

Aluminium silicate	
Titanium dioxide	
Iron oxide	
Sum	100%

Microscopic and SEM examination of the inorganic material showed different particles with a diameter up to approximately 130 µm, see FIgures 11-16. The colour of the particles in the normal microscope was black, grey and white. The black particles were slightly more uneven probably due to incomplete combustion.

The microscopic examination (both optical microscopy and SEM) showed presence of small spheric particles consisting of either aluminium silicate or magnesium silicate; the reason for the spherical shape (<40 µm) is most likely caused by a very high local temperature from the laser.

Figure 11 shows a microscopic photo of the inorganic material with a magnification of 200X. The diameter of the residue varies between 5-130 µm. The colour of the particles is grey, white and black. The spherical particles have a lighter colour compared to the more uneven black particles.

Figure 12 is another microscopic photo of the inorganic material with a magnification of 200X. The diameter of the residue varies between 5-130 µm. The colour of the particles is grey, white and black. The spherical particles have a lighter colour compared to the more uneven black particles.

Figure 13 is an SEM photo of the backscattered electrons of the inorganic matter. Both spherical and uneven particles are observed. The magnification is 200X.

Figure 14 is an SEM photo of the backscattered electrons of the inorganic matter. Both spherical and uneven particles are observed. The magnification is 500X. The spherical particles are aluminium silicate and magnesium silicate. The uneven particles are the dark ones seen in Figure 12. They consist mainly of magnesium silicate.

Figure 15 is an SEM photo of the backscattered electrons of the inorganic matter with 1000X magnification. The small spherical particles that are slightly brighter than the others are titanium dioxide.

Figure 16 is an SEM photo of the inorganic matter recorded of the secondary electrons (The surface of the particles).

Calcination of the inorganic matter showed that the black colour originates from soot from incomplete combustion as it disappears after the calcination. A light grey colour was obtained after the calcination at 500 °C.

Preparation of a paint composition

The paint may be prepared by any suitable technique that is commonly used within the field of paint production. Thus, the various constituents may be mixed together using a high speed disperser, a ball mill, a pearl mill, a three-roll mill etc. The paints according to the invention may be filtrated using bag filters, patron filters, wire gap filters, wedge wire filters, metal edge filters, EGLM turnoclean filters (ex. Cuno), DELTA strain filters (ex. Cuno), and Jenag Strainer filters, or by vibration filtration.

Typically, the solid components of the paint composition are mixed and ground. Thus, the calcinated inorganic matter was grinded before added to the paint composition.

The paint composition may be prepared as a one component paint or by mixing two or more components e.g. two pre-mixtures, one pre-mixture comprising the one or more binder components and one pre-mixture comprising the one or more curing agents. Or as a three component system where one pre-mixture comprises the one or more binder components and one pre-mixture comprises the one or more curing agents and a third container comprises the calcinated inorganic matter.

Examples

Preparation of steel panels

Steel panels were coated with 1x70 µm of the paint to be tested. The steel panels (10 cm x 15 cm x 1.6 mm) was cold rolled mild steel, abrasive blasted to Sa 3 (ISO 8501-1), with a surface profile equivalent to BN 9 (Rugotest No. 3).

Blister Box Test, continuous condensation according to ISO 6270-1

This method is performed in order to evaluate the water resistance of a coating system using controlled condensation. The panel surface with the coating system is exposed to 38±2°C,

saturated water vapour, at an angle of 15° to the horizontal. The reverse side of the panel is exposed to room temperature. At the selected inspection intervals during and after completion of exposure, blistering and rust are evaluated according to ISO 4628-2 and ISO 4628-3.

Salt Spray Test, according to ISO 9227/ASTM B117.

This method is performed in order to assess the corrosion resistance of metallic materials with permanent or temporary corrosion protection.

The neutral salt spray test applies to organic coatings on metallic materials. The operation conditions of the salt spray test were constant spray with 5% NaCl solution at 35°C. A scribe was prepared according to ISO 17872, cut down to the substrate.

At the selected inspection intervals during and after completion of exposure, blistering and rust were evaluated on both panel and around the scribe (in mm from centre), according to ISO 4628-2 and ISO 4628-3.

Gradient Ballast Tank Test, according to ISO 4628-2

Painted panels are mounted on to special panel holders which allow the panels to be in direct contact with water both on rear and front side. Once mounted, the rear side of the panel is exposed to water cooled to 20°C while the below part of the front side of the panel is immersed in artificial sea water at 35°C and the upper part of the front side of the panel is exposed to humid conditions with air at 35°C and 100% RH.

At regular intervals and/or at the end of the exposure the panels are evaluated for signs of blistering according to ISO 4628-2. Other signs of film deterioration, if existing, are also evaluated according to relevant standard.

Preparation of a test formulation

In a commercial product, Hempadur Quattro 17634, which is an epoxy primer, 33.3 % by weight of the fillers was replaced by the calcinated inorganic matter of the present invention.

The % by dry weight of the fillers in Hempadur Quattro is 59.9 %, so the content of inorganic matter of the present invention is 20.0 % by dry weight.

The paint was coated on steel panels and subjected to the blister box test and salt spray test as described above.

Example no.	Blister box test (6 months with inspection at 2 and 3 months)	Gradient ballast tank test (2 months test with inspection at 1 month)	Rust creep Max. value (mm) (2 months)	Rust creep Average (mm) (2 months)
1	No blisters	No blisters	2.42	1.89
2	No blisters	No blisters	3.75	3.04

The blister box test shows that no blisters were formed after 6 months testing, when replacing 33.3 % by weight of the filler in a commercial epoxy primer product.

The gradient ballast tank test showed no blisters after 2 months testing.

The salt spray test showed maximum and average rust creep values within an acceptable range for use of an epoxy primer in marine, in-land or coastal products, when replacing 33.3 % by weight of the filler in a commercial epoxy primer product.

CLAIMS

1. A surface preparation apparatus (1) for removing coating (28) or contaminants from a surface of a coated structure (27), the apparatus comprising:

- a housing (2) forming an incineration chamber (3),

an energizer (5) configured to direct at least one energy beam against a working point at the surface in the incineration chamber (3) and thereby provide a surface temperature above an incineration temperature by which excess matter is released from the surface and organic matter in the excess matter burns,

- a ventilation tract (20) with an inlet (21) in the incineration chamber (3) and configured to extract fumes and excess matter from the incineration chamber (3),

- an air supply (22) configured to inject air comprising oxygen into the incineration chamber (3).

2. The surface preparation apparatus according to claim 1, wherein the energizer is a laser configured to create a plume from the excess matter by energy of a laser beam.

3. The surface preparation apparatus according to claim 2, wherein the air supply is arranged to direct a stream of air from an air injection point towards the plume.

4. The surface preparation apparatus according to claim 3, wherein the air supply is arranged to create the stream of air such that it is mainly a laminar flow along a line between the nozzle and the plume.

5. The surface preparation apparatus according to claim 3 or 4, wherein the air supply is arranged to create the stream of air such that it is essentially parallel to the surface of the coated structure.

6. The surface preparation apparatus according to any of claims 3 - 5, wherein the air supply is arranged to create the stream of air such that a centre line of the stream is displaced relative to the surface of the coated structure.

7. The surface preparation apparatus according to any of claims 3 - 6, comprising a heating structure configured to heat the stream of air before it reaches the plume.

8. The surface preparation apparatus according to any of claims 3-7, wherein the apparatus is configured for movement in a working direction, and wherein the working point is in a vertical plane perpendicular to the working direction and separating the air injection point and the inlet (21).

9. The surface preparation apparatus according to any of claims 3-8, wherein the air supply is configured to displace the plume towards the inlet (21) by the injected air.

10. The surface preparation apparatus according to any of claims 2-9, comprising a plume sensor configured to determine a plume orientation signal representing an orientation of the plume, and wherein the air supply is controlled based on the plume orientation signal.

11. The surface preparation apparatus according to claim 10, wherein the plume sensor comprises a vision system with a camera and software configured for recognition of the plume and the orientation of the plume.

12. The surface preparation apparatus according to claim 11, wherein the software includes an artificial intelligence network trained based on a plurality of orientations of plumes and corresponding measurements, where the measurements are indicative of a content of soot.

13. The surface preparation apparatus according to any of the preceding claims, comprising at least one sensor (30, 31) configured to provide a measured value of a process parameter in the incineration chamber (3) and a controller (29) configured to provide a control setting for at least one of the energizer, the ventilation tract, and the air supply based on the measured value.

14. The surface preparation apparatus according to claim 13, wherein the excess matter contains organic matter burning at a lower temperature and inorganic matter burning at a higher temperature, and wherein the controller is configured to provide the control setting for at least one of the energizer, the ventilation tract, and the air supply to obtain a temperature which is between the lower temperature and the higher temperature.

15. The surface preparation apparatus according to claims 13 or 14, wherein the measured value indicates a temperature or a content of an organic compound in the excess matter, content of oxygen, carbon dioxide, or carbon oxide in the fumes or in the incineration chamber.

16. The surface preparation apparatus according to claim 15, wherein the controller is configured to control the air supply to increase oxygen injected into the incineration chamber when the measured value indicates content of the organic compound above a first threshold or indicates content of oxygen below a second threshold.

17. The surface preparation apparatus according to any of claims 13-16, wherein the controller comprises a CPU and a data storage, the data storage comprising at least one process data set, each process data set comprising at least one type of coating or contaminant to be removed from the surface and a corresponding reference parameter, the reference parameter being comparable with the measured value, and the controller being configured to provide the control settings based on a comparison between the reference parameter and the measured value.

18. The surface preparation apparatus according to claim 17, wherein the reference parameter comprises a desired temperature range and corresponding control settings for at least one of the energizer, the ventilation tract, and the air supply.

19. The surface preparation apparatus according to claim 17 or 18, wherein the controller is configured to carry out an iterative operation cycle comprising multiple cycles each comprising:

- submitting control settings to at least one of the energizer, the ventilation tract, and the air supply,

- obtaining a measured value from the sensor,

- amending the control setting based on a comparison between the measured value and a reference parameter, and

-controlling at least one of the energizer, the ventilation tract, and the air supply based on the control settings.

20. The surface preparation apparatus according to any of claims 13-19, wherein the sensor comprises at least one of:

- a vision system configured to detect a deviation between an image and a reference image,

- an oxygen, CO2, CO, or NOx sensor probe, and

- a temperature sensor probe.

21. The surface preparation apparatus according to claims 13 and 20, wherein the sensor is configured to determine the organic compound based on colour of the dust.

22. The surface preparation apparatus according to any of the preceding claims, comprising an outlet sensor configured to analyse the extracted air and to detect potential organic matter therein.

23. The surface preparation apparatus according to any of claims 2-22, wherein the laser-based energizer is configured with a laser input for receiving laser energy from a laser source placed outside the incineration chamber.

24. The surface preparation apparatus according to claim 23, comprising a support module located outside the incineration chamber and movable as a separate unit, the support module comprising the laser source.

25. The surface preparation apparatus according to any of the preceding claims, wherein the air supply comprises a blower arranged to blow air from ambient space into the incineration chamber.

26. The surface preparation apparatus according to any of the preceding claims, comprising a motion structure (6) configured to move the housing (2) in a direction of movement over a surface of the coated structure (27).

27. The surface preparation apparatus according to claim 26, wherein the motion structure is configured for movement over the surface after it is cleaned.

28. The surface preparation apparatus according to claim 26 or 27, wherein air supply is located after the inlet to the ventilation tract in the direction of movement.

29. The surface preparation apparatus according to any of the preceding claims, wherein energizer is configured to direct the energy beam against the surface such that the working point is between the air supply and the inlet to the ventilation tract.

30. A method of purifying excess matter from a cleaning a surface, the method comprising

- pointing a laser towards the surface until the excess matter is heated and released in a plume from the surface,

- applying a stream of air comprising oxygen to the plume until at least a part of organic matter in the excess matter is burned.

31. The method according to claim 30, further comprising removing at least the inorganic matter by suction.

32. The method according to claim 30 or 31, wherein the stream of air is allowed to displace the orientation of the plume.

33. The method according to any of claims 30-32, wherein air and excess matter is removed at a suction point, and where the stream of air is directed towards the suction point.

34. The method according to any of claims 30-33, wherein the stream of air is mainly laminar.

35. The method according to any of claims 30-34, wherein the stream of air is preheated before reaching the plume.

36. The method according to any of claims 30-35, further comprising controlling the temperature of the heated excess matter in a range between a low temperature at which organic matter in the excess matter burns and a high temperature at which inorganic matter in the excess matter burns.

37. The method according to any of claims 30-36, wherein the laser is moved over the surface in a direction of movement, and wherein the stream of air is applied in the direction of movement.

38. The method according to 30 and 37, wherein the inorganic matter is removed in the direction of movement.

39. A method of manufacturing a coating composition, said method comprising
    a) collecting recycled inorganic matter from a coating composition, and;
    b) dispersing the collected inorganic matter in a binder matrix to form said coating composition.

40. The method according to claim 39, wherein the recycling is performed by the method according to any of claims 30-38.

41. The method according to claim 39 or 40, wherein the collected inorganic matter, at the point of collection or at a later stage, is subjected to one of the following steps; filtering, milling, heat treatment or washing, before being dispersed in the binder matrix.

42. The method according to any one of claims 39 - 41, wherein the binder matrix comprises a curable polymer selected from the group consisting of epoxy, polyurethane, polysiloxane, vinyl, acrylic, alkyd, and silicone polymers, or mixtures or blends thereof.

43. The method according to any one of claims 39-42, wherein the binder matrix comprises an epoxy-based binder system comprising:

one or more epoxy resins selected from bisphenol A, bisphenol F and Novolac; and

one or more curing agents selected from Mannich Bases, polyamidoamines, polyoxyalkylene amines, alkylene amines, aralkylamines, polyamines, and adducts and derivatives thereof.

44. The method according to any one of claims 39-43, wherein the inorganic matter is present in up to 90 % by dry weight of the total coating composition, such as up to 80%, up to 70 %, up to 60 %, up to 50 %, up to 40 %, up to 30 %, up to 20 % or up to 10 % by dry weight of the total coating composition.

45. The method according to any one of claims 39-44, wherein the inorganic matter comprises a material selected from the group consisting of magnesium silicate, aluminium silicate, potassium silicate, titanium dioxide, and iron oxide, or a mixture thereof.

46. The method according to any one of claims 39-45, wherein the inorganic matter comprises or consists of inorganic particles, preferably inorganic particles of aluminium silicate or magnesium silicate, having an essentially spherical shape.

47. The method according to claim 46, wherein inorganic particles have an average diameter of less than 40 µm.

48. A coating composition obtained by the method according to any one of claims 39-47.

49. A coating composition comprising a binder matrix and inorganic matter, wherein the inorganic matter comprises or consists of inorganic particles, preferably inorganic particles of aluminium silicate or magnesium silicate, having an essentially spherical shape.

50. The coating composition according to claim 48 or claim 49, wherein the binder matrix is as defined in claim 42 or 43, and/or wherein the inorganic matter is as defined in any one of claims 45-47.

51. The coating composition according to any one of claims 48 - 50, wherein the inorganic matter is present in up to 90% percent by dry weight of the total coating composition.

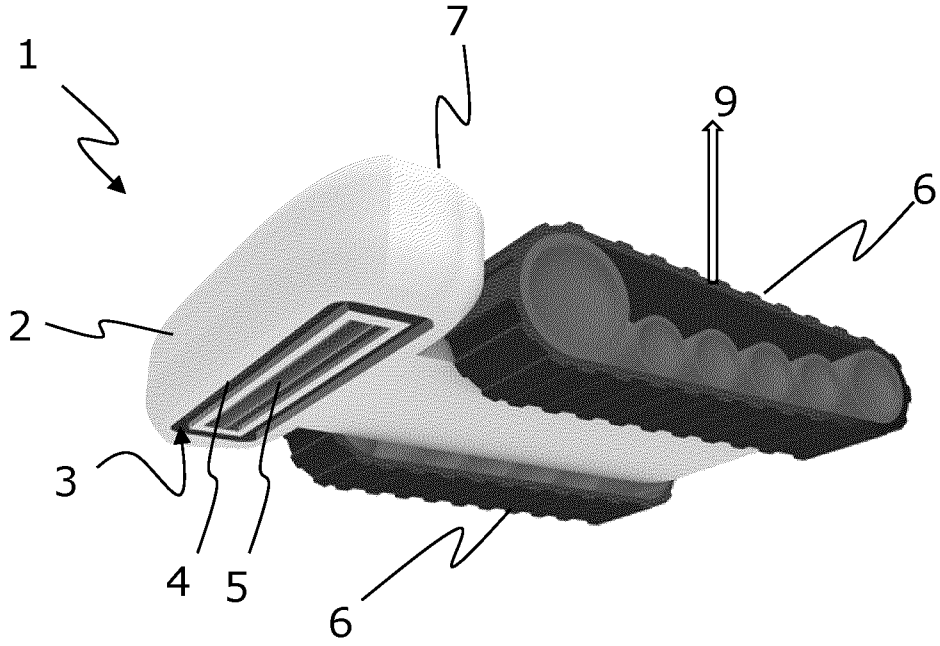

Fig. 1

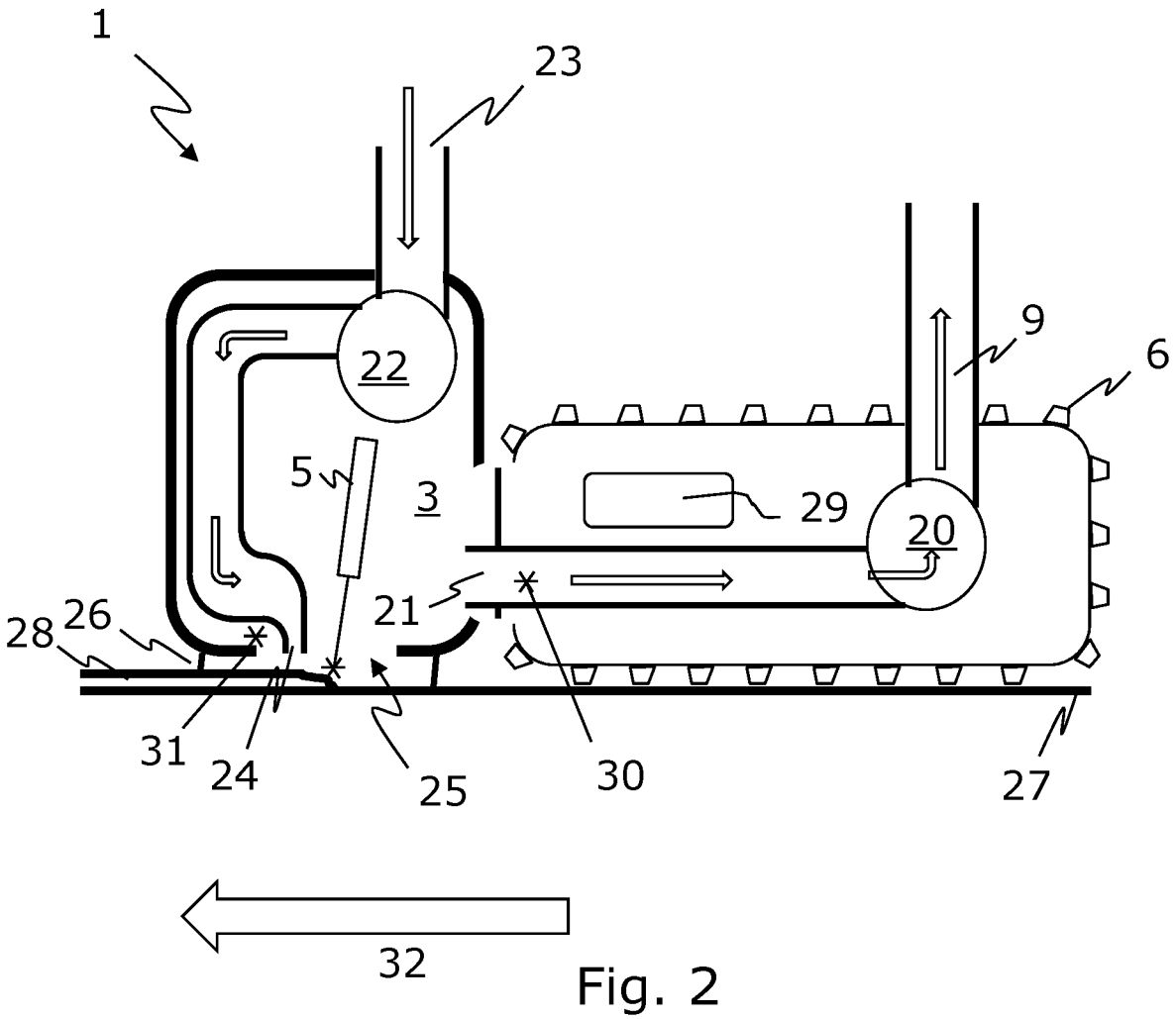

Fig. 2

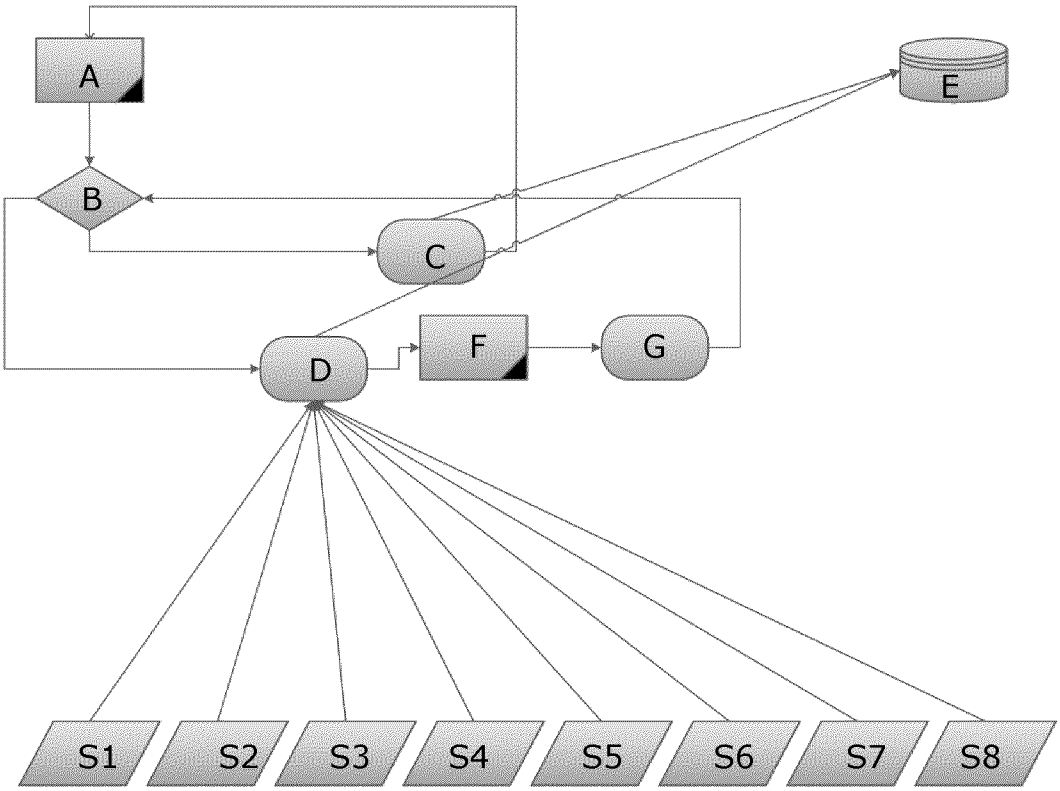
A
E
B
C
D
F
G
S1
S2
S3
S4
S5
S6
S7
S8

Fig. 3

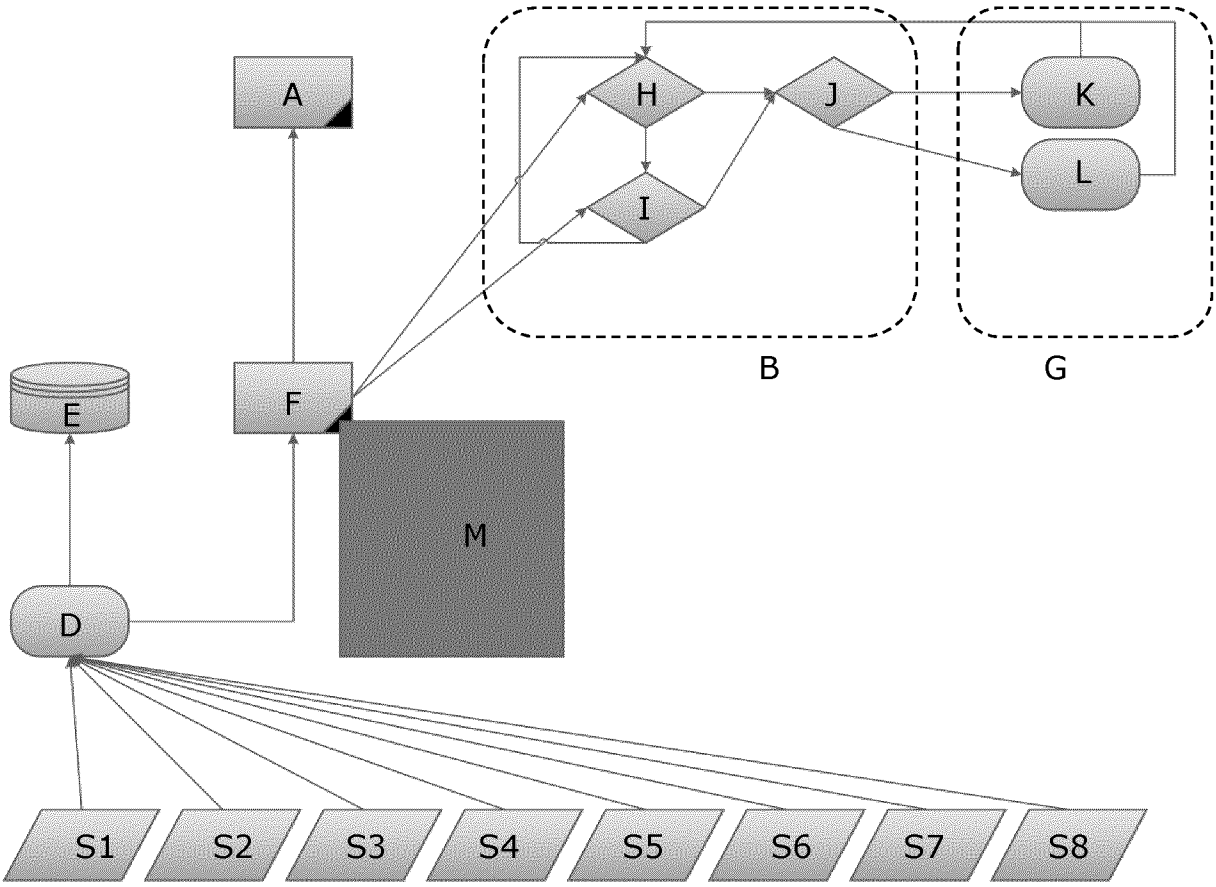
A
H
J
K
L
I
B
G
E
F
M
D
S1
S2
S3
S4
S5
S6
S7
S8

Fig. 4

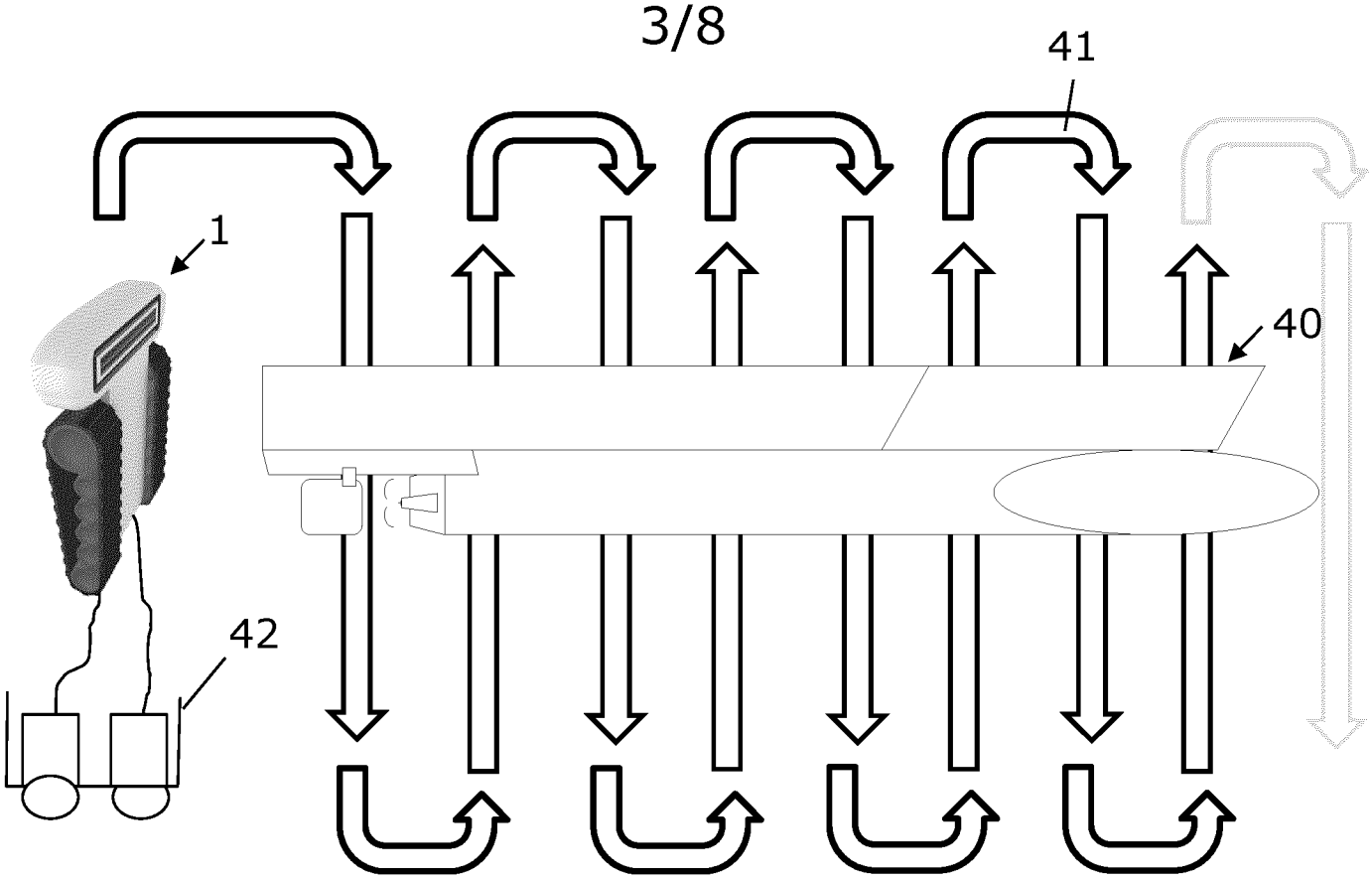

Fig. 5

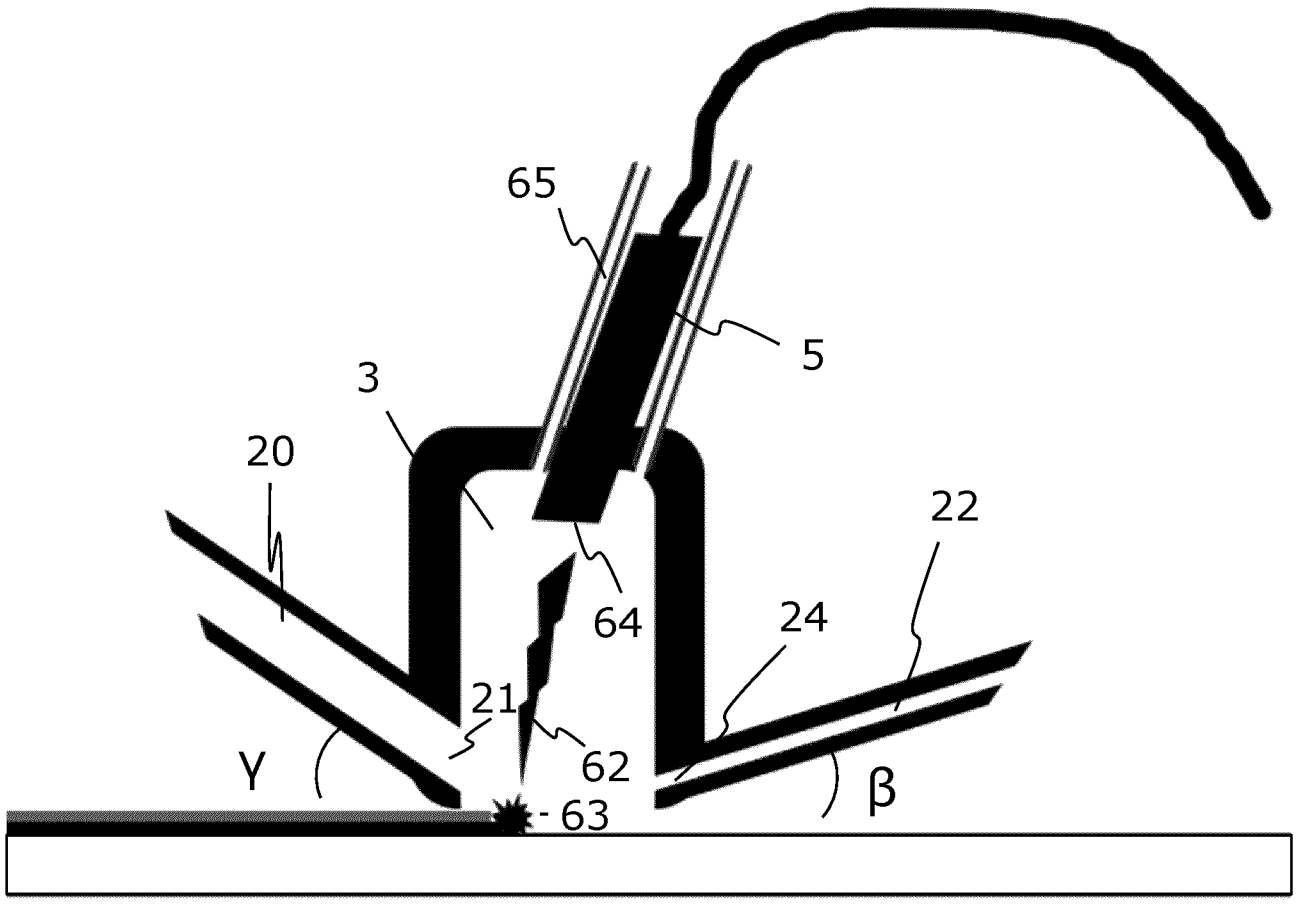

Fig. 6

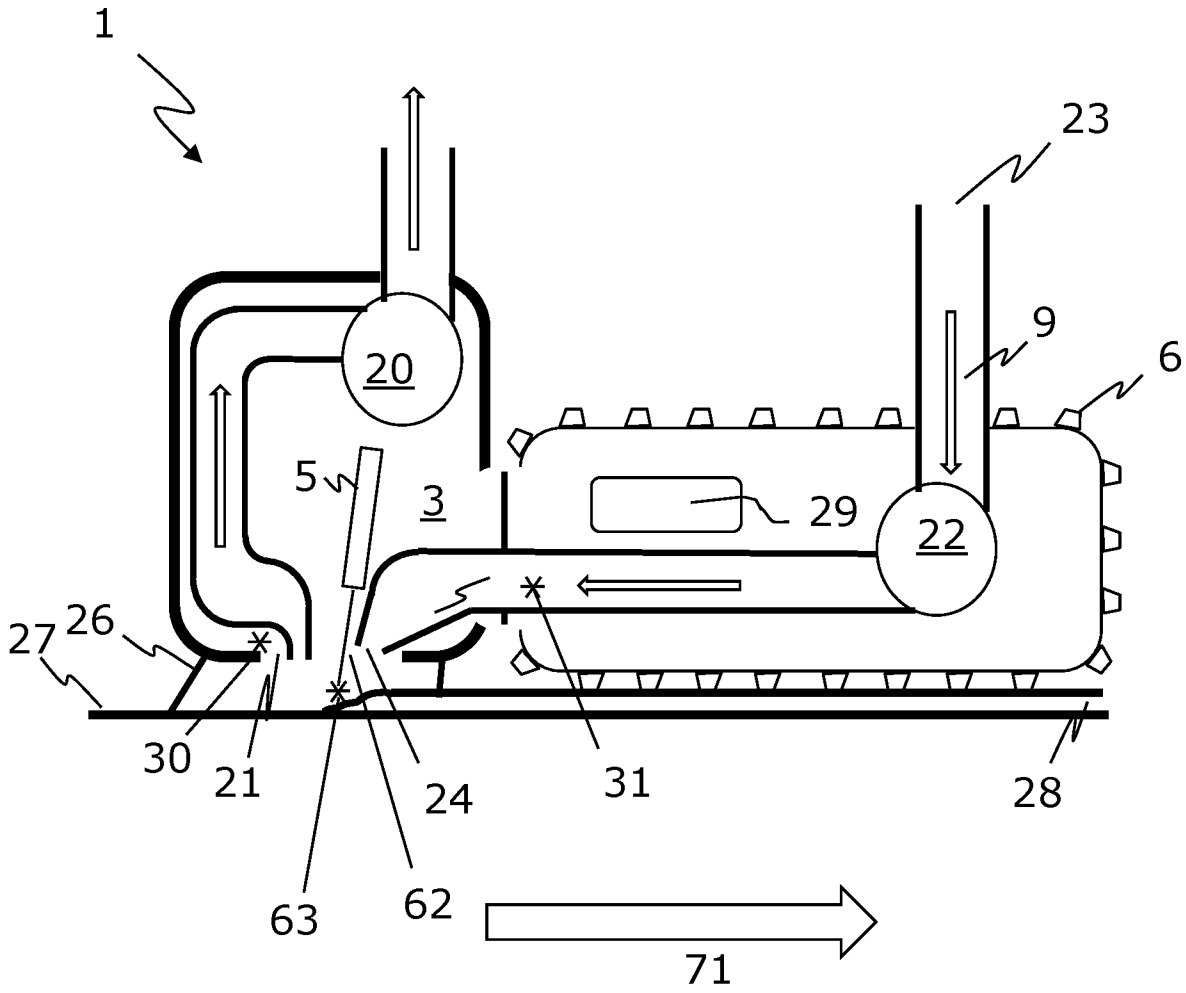

Fig. 7

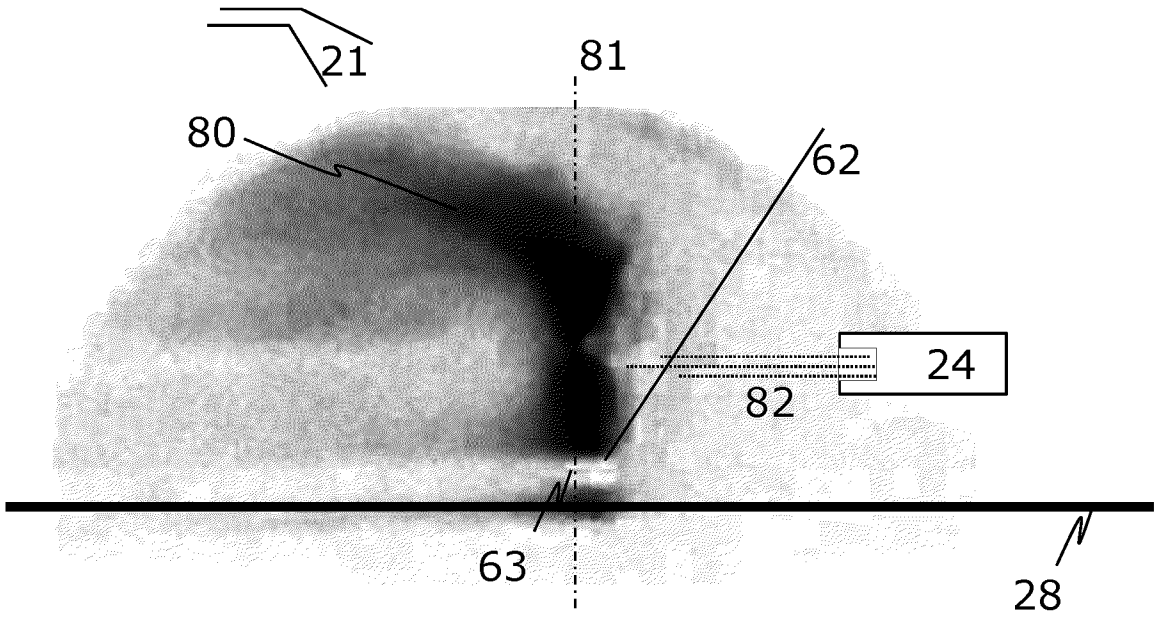

Fig. 8

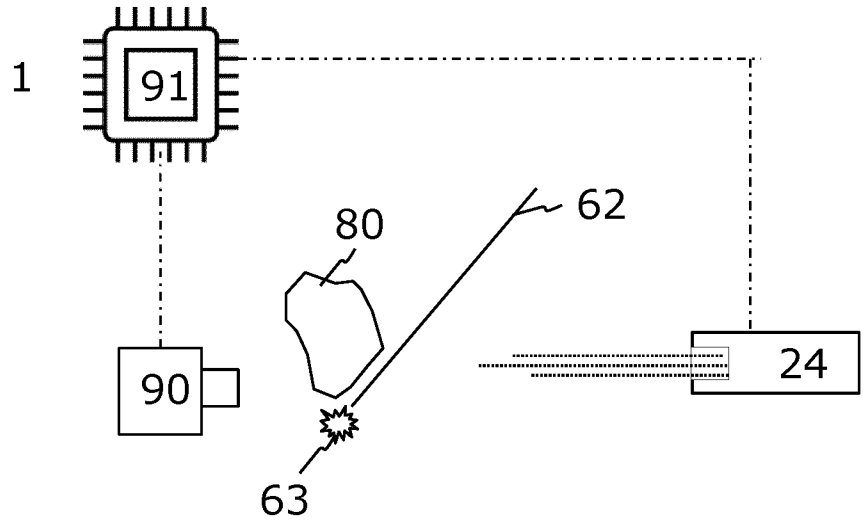

Fig. 9

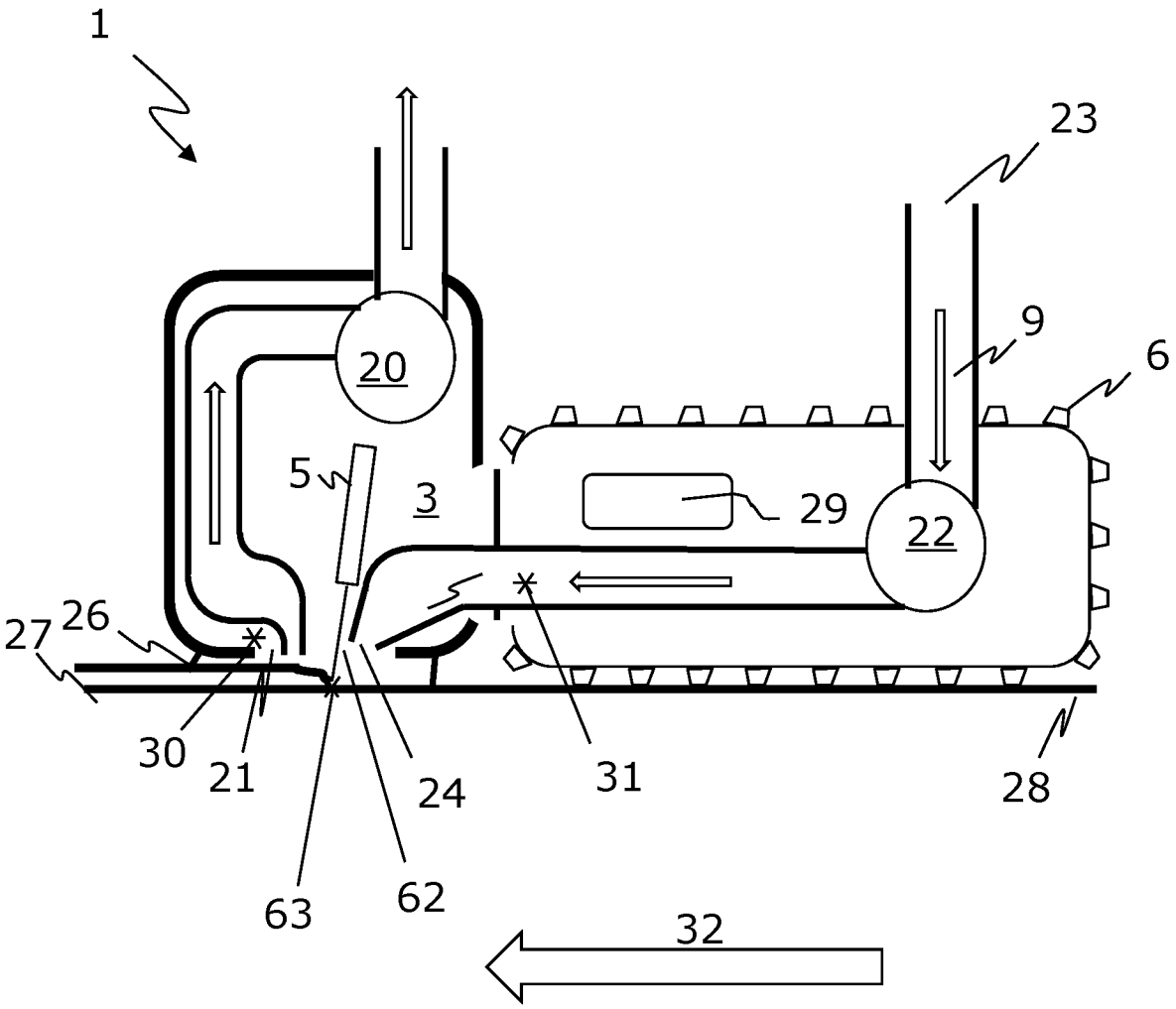

Fig. 10

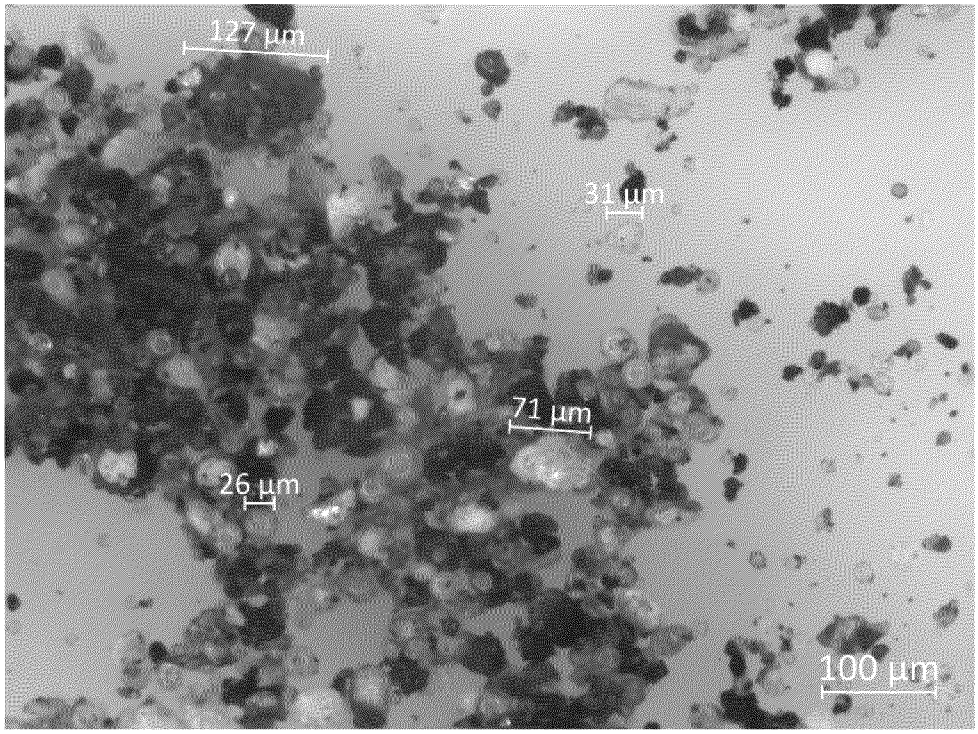

Fig. 11

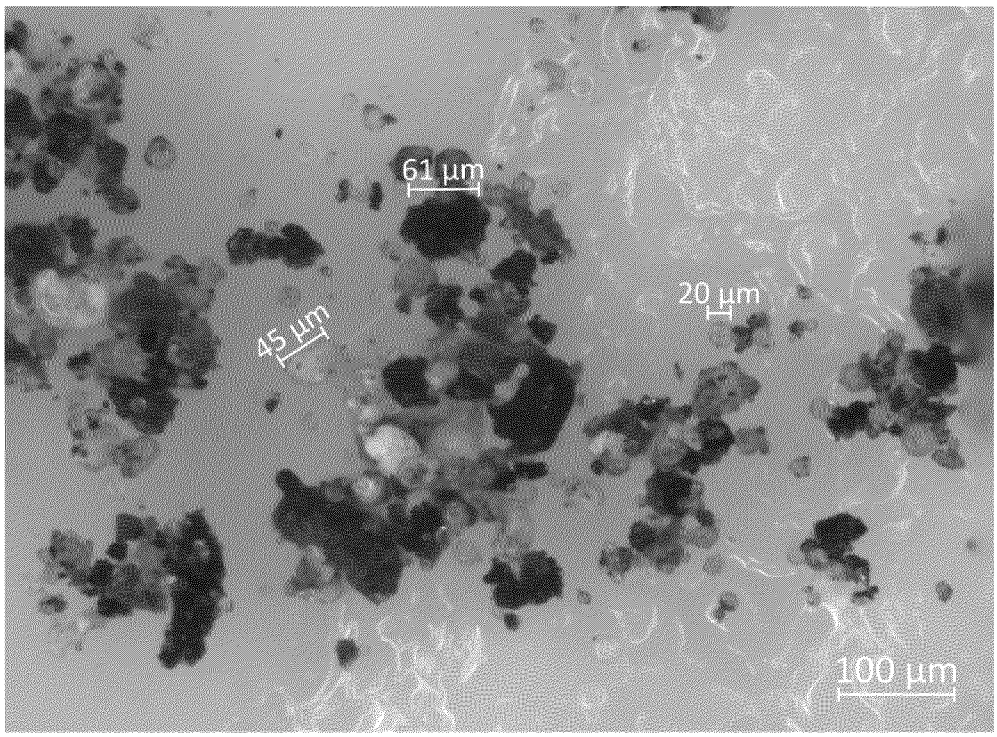

Fig. 12

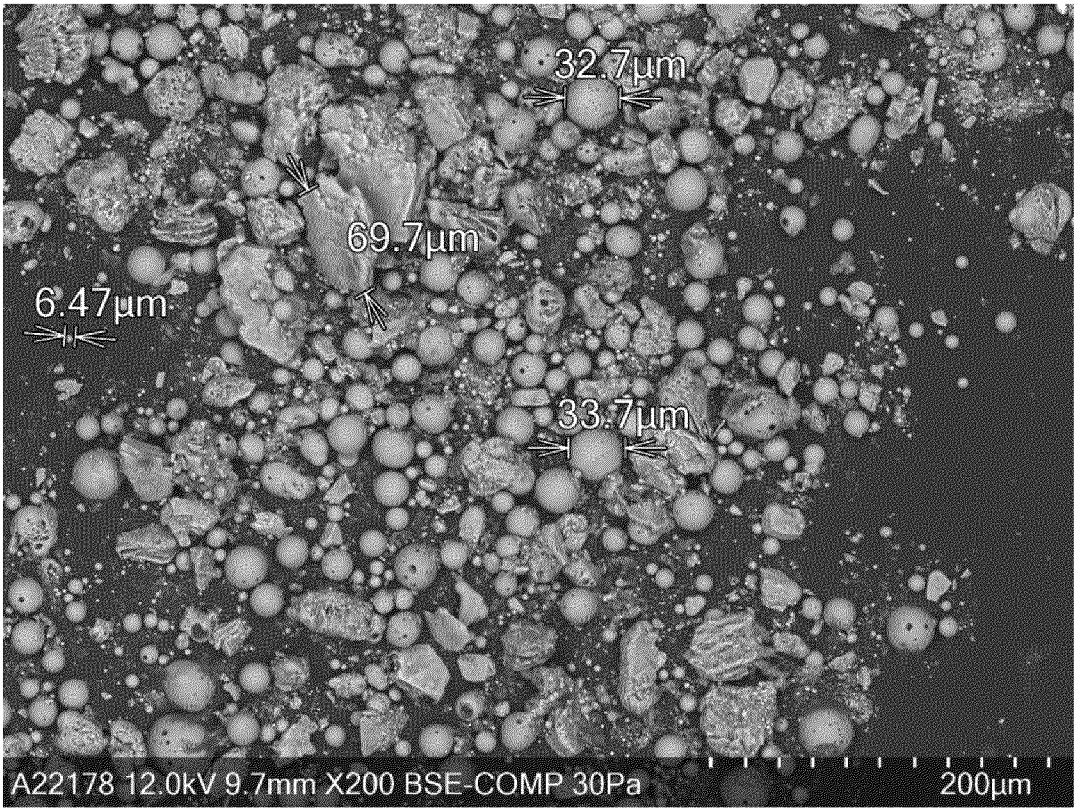
32.7µm
69.7µm
6.47µm
33.7µm
A22178 12.0kV 9.7mm X200 BSE-COMP 30Pa
200µm

Fig. 13

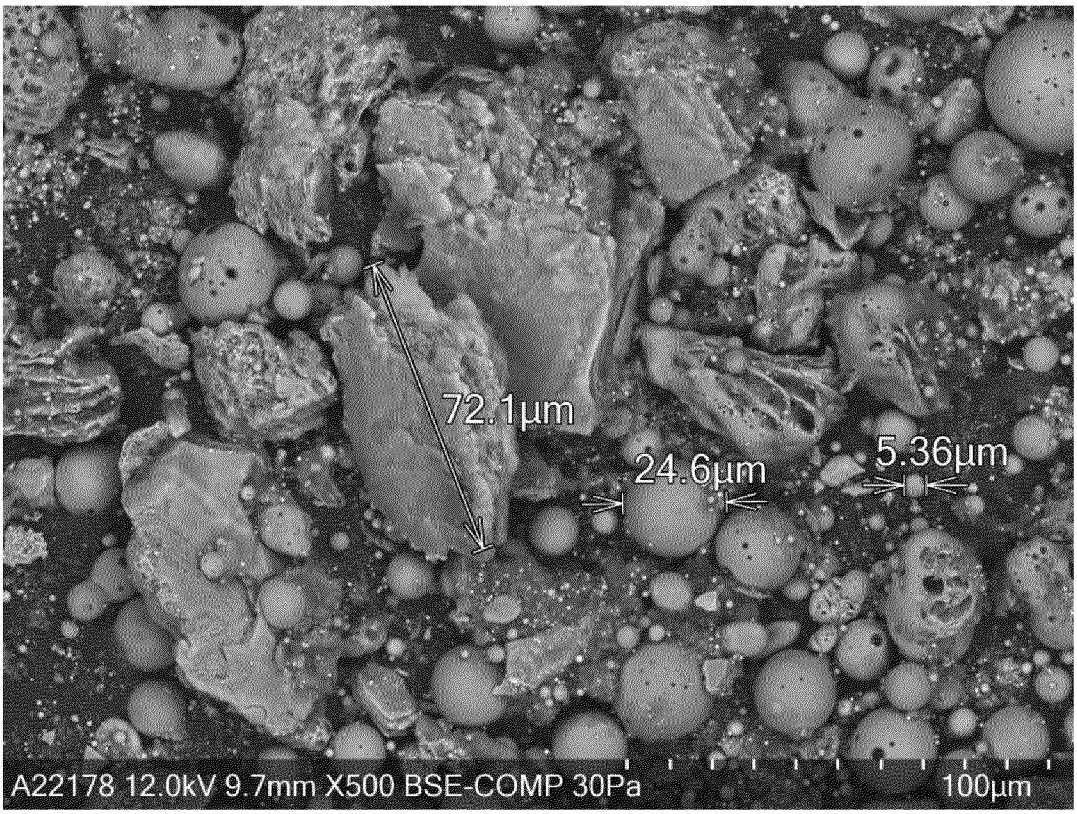
72.1µm
24.6µm
5.36µm
A22178 12.0kV 9.7mm X500 BSE-COMP 30Pa
100µm

Fig. 14

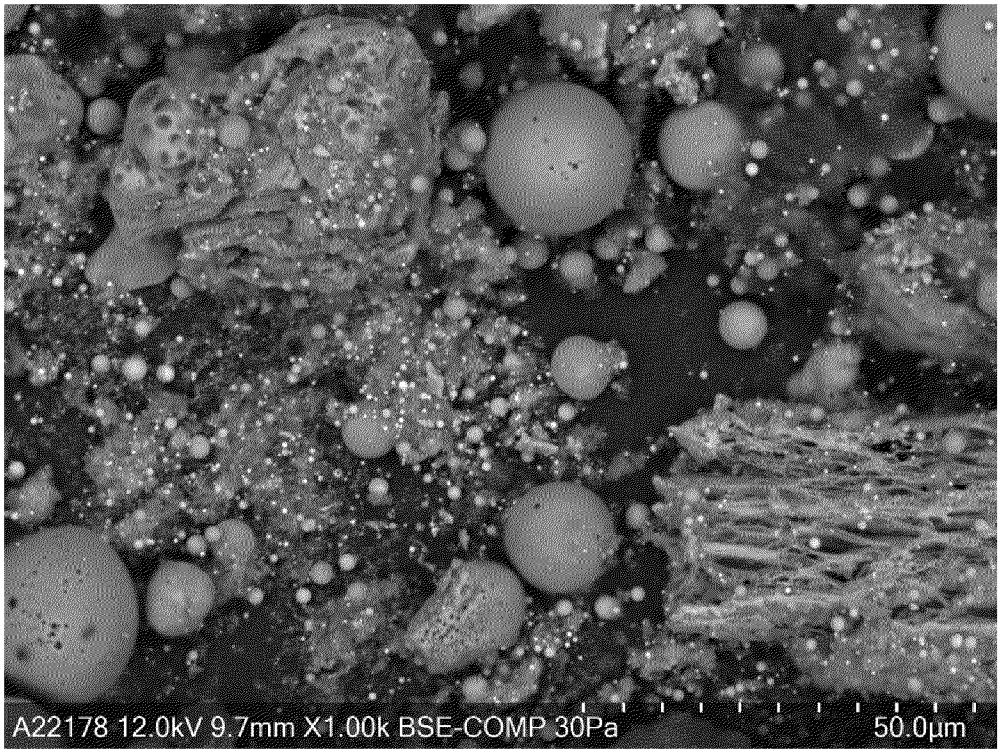
A22178 12.0kV 9.7mm X1.00k BSE-COMP 30Pa
50.0µm

Fig. 15

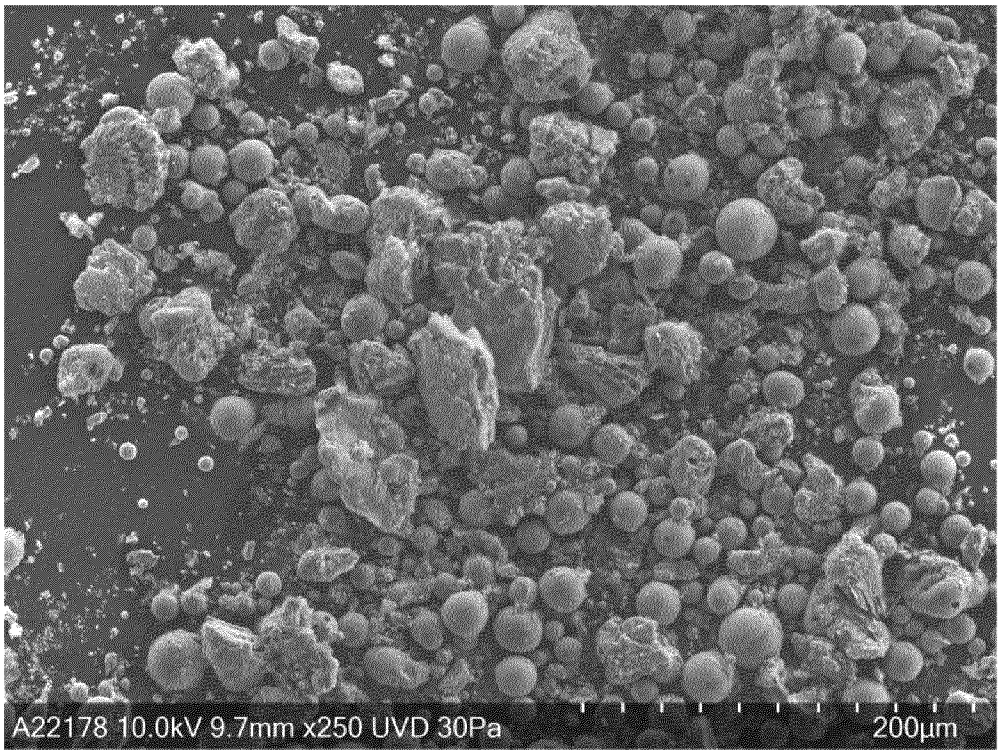
A22178 10.0kV 9.7mm x250 UVD 30Pa
200µm

Fig. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2024/055055

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
1-38

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/055055

A. CLASSIFICATION OF SUBJECT MATTER
INV. B08B7/00 B08B15/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B08B B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 882 487 A (LI LIN [GB] ET AL) 16 March 1999 (1999-03-16) abstract column 1, line 5 - column 2, line 27 column 2, line 48 - column 3, line 6 claims figures	1-9, 22-38 10-21

Y A	US 2014/230558 A1 (GRAFTON-REED CLIVE [GB] ET AL) 21 August 2014 (2014-08-21) the whole document	10-21 1,2,8, 23,24, 26,27, 30,36-38

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2024	26/07/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	van der Zee, Willem

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/055055

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 123 803 A (GENUT MENACHEM [IL] ET AL) 26 September 2000 (2000-09-26) abstract column 1, line 5 - line 25 column 2, line 20 - line 40 column 3, line 3 - line 27 column 4, line 12 - line 33 column 5, line 30 - column 6, line 10 claims figures -----	1-7,9, 23-25, 29-38
A	US 6 144 010 A (TSUNEMI AKIRA [JP] ET AL) 7 November 2000 (2000-11-07) abstract column 1, line 13 - line 16 column 1, line 33 - line 65 column 2, line 18 - column 3, line 4 column 3, line 55 - column 5, line 28 claims figures -----	1-6, 8-21, 23-34, 37,38
A	KR 2013 0056517 A (KIM JIN GAB [KR]) 30 May 2013 (2013-05-30) figures -----	1,22,30

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/055055

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP 2000500285 A	11-01-2000
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		JP H1128900 A	02-02-1999
		US 6144010 A	07-11-2000
		US 6384370 B1	07-05-2002
KR 20130056517 A	30-05-2013	NONE	

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-38

   Apparatus and method for removing coating or contaminants from a surface

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2. claims: 39-51

   Method of manufacturing a coating composition, and coating composition

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