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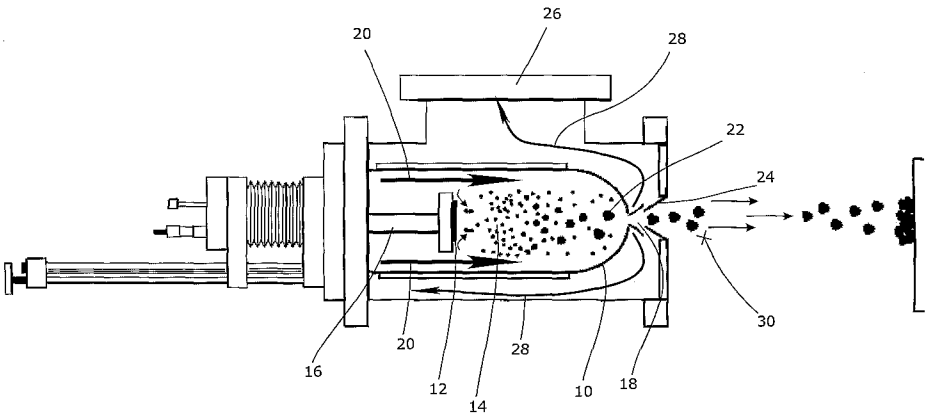
(54) Title: ANTIBACTERIAL SURFACE COATINGS



(57) Abstract: A method of depositing an antibacterial layer of material on a substrate, comprises the steps of generating a cloud of charged nanoparticles of an antibacterial material, and electrostatically accelerating the nanoparticles toward the substrate. Such a step of electrostatic acceleration allows a relatively fine degree of control to be exerted over the energy with which the nanoparticles impact the surface. This can thus be adjusted so as to give them sufficient energy to deform on impact and this create an adherent film, but not to deform so seriously that their nanoparticulate character is lost. Suitable materials include silver and copper. A nanoparticulate thin film coating is also described, comprising a plurality of at least partially merged nanoparticles. Each such nanoparticle can, in preferred films, define a local protruberance having a ratio of lateral versus perpendicular dimensions greater than 1.2:1. Thus, the nanoparticles forming the film show demonstrable deformation arising from their impact on arrival at the film surface. Further, an apparatus for treatment of surgical tools comprises a means for generating a plasma around the tool, a means for generating a cloud of charged nanoparticles of an antibacterial material, and a means for electrostatically accelerating the nanoparticles toward the tool.

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Antibacterial Surface Coatings

FIELD OF THE INVENTION

The present invention relates to the deposition of antibacterial surface coatings, and proposes the use of nanoparticle films to do so. It seeks to provide a means of generating adherent nanoparticle films by accelerated ionic cluster impact.

BACKGROUND ART

Nanoparticles are typically regarded as being those in which one (or preferably two) dimensions are less than 1μm at most. In practice, most nanoparticles have a dimension below 100nm.

Nanoparticle films are recognised as offering novel and useful properties as compared to surface coatings of the bulk material. In general, this relates to their high surface area, resulting from the structure of the film surface as a collection of partially fused nanoparticles. As observed via an atomic force microscope, the nanoparticles remain identifiable hence giving rise to a surface that undulates at the atomic scale, and which therefore has a very large surface area.

Such properties can be advantageously employed to provide active anti-bacterial coatings on surgical tools, workbenches, razor blades, kitchen

workbenches and the like, by depositing a coating of nanoparticles of a suitably antibacterial element such as Silver or Copper. The problem lies in the production of a coating that is reliably adherent to the substrate and which retains the nanoparticle properties.

Nanoparticles are formed by a range of processes. Some such processes are chemical in nature. Another process, typically referred to as 'gas condensation', involves the production of an atomic vapour (through one or more of a variety of means) in a relatively high pressure environment. The atoms lose energy through collisions with the background gas (usually an inert or noble gas such as argon or helium) and subsequently combine with other atoms to form nanoparticles.

Both such processes produce a powder. This does not (generally) adhere to a substrate in a reliable manner. Existing powder processing techniques such as sintering simply cause the nanoparticles to lose their identity and revert to bulk material. Alternatively, the nanoparticles can be suspended in an adherent binder such as a resin, but this masks the nanoparticle nature of the powder and does not offer a high surface area.

SUMMARY OF THE INVENTION

The present invention therefore describes a method of depositing an antibacterial layer of material on a substrate, comprising the steps of generating a cloud of charged nanoparticles of an antibacterial material, and electrostatically accelerating the nanoparticles toward the substrate. Such a step of electrostatic acceleration allows a relatively fine degree of control to be exerted over the energy with which the nanoparticles impact the surface. This can thus be adjusted so as to give them sufficient energy to deform on impact and this create an adherent film, but not to deform so seriously that their nanoparticulate character is lost.

A suitable method of forming the nanoparticles is by magnetron sputtering followed by condensation. This naturally leaves the particles with a charge that can be employed to accelerate them. The condensation step can be terminated

by reducing the ambient pressure around the nanoparticles, for example by transporting them to a region of lower pressure such as by entraining them in a gas flow.

Nanoparticles produced by other methods can be given an electrostatic charge by one of a range of known means after their production.

The present invention also relates to a nanoparticulate thin film coating comprising a plurality of at least partially merged nanoparticles, such as a film produced by the above-described method. Each such nanoparticle can, in preferred films, define a local protruberance having a ratio of lateral versus perpendicular dimensions greater than 1.2:1. This ratio can be measured via an atomic force microscope, for example. Thus, the nanoparticles forming the film show demonstrable deformation arising from their impact on arrival at the film surface.

The antibacterial material can be silver or copper, or an alloy thereof, or another material with like antibacterial properties. This coating is useful as for surgical tools, dentistry, workbenches, razor blades, and kitchen surfaces and the like.

The present invention also provides an apparatus for treatment of surgical tools, comprising a means for generating a plasma around the tool, a means for generating a cloud of charged nanoparticles of an antibacterial material, and a means for electrostatically accelerating the nanoparticles toward the tool.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the present invention will now be described by way of example, with reference to the accompanying figures in which;

Figure 1 shows a schematic view of the deposition of nanoparticles according to the present invention;

Figure 2 shows a view from above of a film produced by the present invention; and

Figure 3 shows a perspective view of a film produced by the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

As discussed above, the nanoparticles are formed by a process called 'gas condensation' in which an atomic vapour is generated (through a one of a variety of means) in a high pressure environment, which causes the atoms to lose energy through collisions with the background gas (usually an inert or noble gas such as argon or helium) and subsequently combine with other atoms to form nanoparticles.

According to the present invention, this method of generation is further refined by providing a controlled drift between the point of vapour generation and the exit of the high-pressure condensation region. Once the combined gas/nanoparticle stream exits the condensation zone, the nanoparticle growth generally terminates. Thus, the technique can be labelled 'terminated gas condensation'. The effect of this is to subject each nanoparticle to a strict vapour density and pressure path, and thereby ensures that the size of the nanoparticles on reaching the exit of the condensation zone are broadly similar leading to a narrow size distribution.

Figure 1 shows the apparatus and method in schematic form. A chamber 10 contains a magnetron sputtering source 12 to generate the vapour 14, mounted on a linearly translatable substrate 16. The interior of the chamber 10 contains an inert gas at a relatively high pressure of a hundred millitorr or more, say up to 5 torr.

The inert gas is fed into the chamber 10 from a point behind the magnetron 12 and extracted from an exit aperture 18 directly ahead of the magnetron 12. This creates a gas flow through the chamber as indicated by arrows 20 and establishes a drift of the vapour 14. During its transit to the exit aperture 18, the vapour condenses to form a nanoparticle cloud 22.

Alternatively, any method capable of creating an atomic vapour can be used, such as evaporative techniques (e.g. thermal evaporation, MBE) or chemical techniques (e.g. CVD).

On exiting the condensation zone defined by the chamber 10, the beam is subject to a large pressure differential and undergoes supersonic expansion. This expanded beam then impinges upon a second aperture 24, which allows the central portion of the beam to pass through, while the background gas and smaller nanoparticles do not pass through. The background gas is then collected by a pumping port 26 for re-circulation or disposal, as indicated by arrows 28. This provides a further refinement of the beam as the smaller particles are 'filtered' out.

By using magnetron sputtering, a high fraction of the nanoparticles produced are negatively charged. This allows the particles to be accelerated electrostatically across a vacuum 30 to a substrate or object, and thus gain kinetic energy. This can be achieved by raising the substrate or object to a suitably high potential. Non-conductive substrates can be placed behind a conductive mask having an appropriately shaped aperture in the line of sight of the particle beam.

The kinetic energy acquired in flight is lost on impact by way of deformation of the particles. The degree of deformation naturally depends on the energy imparted to the particles in flight. At very high energies, the nanoparticle structure may be lost and the resultant film will be essentially bulk material. At very low energies, the process will be akin to condensation and the film may be insufficiently adherent. Between these extremes, there is scope for deformation of the particles that is mild enough for the surface of the film to retain nanoparticulate properties but for the interface with the substrate to be adherent.

To obtain an antibacterial coating, we employ a magnetron source of a suitably antibacterial material such as silver or copper. These materials create an inherently hostile surface for bacteria

Where the particles are generated by methods other than sputtering, they can be ionised via any suitable method and then accelerated in like fashion.

In one example, a mixture of Helium and Argon gas are introduced into a condensation cavity to generate a pressure between 0.01 and 0.5 torr, depending on the coating conditions. A negative voltage, typically between 200V and 1000V is introduced to a silver target, held in the magnetron sputtering device contained within the condensation cavity. This voltage induces a discharge which acts to sputter silver atoms from the surface of the target. The high pressure gaseous environment causes the silver atoms to lose energy through collisions and eventually to combine with other silver atoms to form particles. Negatively and positively charged particles are formed in the discharge around the magnetron, but only the negatively charged particles can escape the electric field generated by the negative voltage on the target. These negatively charged particles grow as they drift towards the exit of the condensation zone in a controlled manner.

As they leave the exit the pressure differential between the condensation zone and the expansion region causes the beam to expand rapidly. The central portion of this expanding beam is filtered to capture mostly heavy nanoparticles. The charged silver nanoparticles emerge into a coating chamber. The items to be coated, such as surgical scalpels, for example, are held at a high positive voltage (typically 1000V). This creates a field gradient between the exit of the condensation zone and the object, which accelerates the charged silver nanoparticles to the object and results in an impact which partially deforms the particles to form an adherent film.

An example of such a film formed from copper nanoparticles is shown in figures 2 and 3, images produced by an atomic force microscope. Both figures show that the film consists of multiple protrusions on a nanometre scale, and that individual particles have, to an extent, merged to form a continuous film.

An antibacterial film produced in this way can be used in a variety of contexts, such as for surgical tools, workbenches, razor blades, kitchen workbenches and the like.

The technique can also be applied as an industrial coating tool, or as a combined sterilisation and silver-nanoparticle coating tool. In a surgical context, the removal of prions from surgical tools is a difficult task and calls for the generation of a plasma around the tool. Such a step is compatible with the above-described process and thus could be combined to form an apparatus for treatment of surgical tools, comprising a means for generating a plasma around the tool, a means for generating a cloud of charged nanoparticles, and a means for electrostatically accelerating the nanoparticles toward the tool.

It will of course be understood that many variations may be made to the above-described embodiment without departing from the scope of the present invention.

CLAIMS

1. A method of depositing an antibacterial layer of material on a substrate, comprising the steps of generating a cloud of charged nanoparticles of an antibacterial material, and electrostatically accelerating the nanoparticles toward the substrate.

2. A method according to claim 1 in which the antibacterial material is at least one of silver and copper or an alloy thereof.

3. A method according to claim 1 or claim 2 in which the nanoparticles are produced by magnetron sputtering followed by condensation.

4. A method according to claim 3 in which the condensation step is terminated by reducing the ambient pressure around the nanoparticles.

5. A method according to claim 4 in which termination of the condensation step is achieved by transporting the nanoparticles to a region of lower pressure.

6. A method according to claim 5 in which the nanoparticles are transported by being entrained in a gas flow.

7. A method according to claim 1 in which an electrostatic charge is applied to the nanoparticles after their production.

8. An antibacterial nanoparticulate thin film coating produced by the method of any one of claims 1 to 7.

9. An antibacterial nanoparticulate thin film coating have a surface comprising a plurality of at least partially merged nanoparticles of an antibacterial material.

10. An antibacterial nanoparticulate thin film coating according to claim 9 in which the antibacterial material is at least one of silver and copper or an alloy thereof.

11. A nanoparticulate thin film coating according to claim 9 or claim 10 in which each nanoparticle defines a local protruberance having a ratio of lateral versus perpendicular dimensions greater than 1.2:1.

12. A nanoparticulate thin film coating according to claim 11 in which the ratio is as measured via an atomic force microscope.

13. A nanoparticulate thin film coating according to any one of claims 9 to 12 in which the nanoparticles forming the film show demonstrable deformation arising from their impact on arrival at the film surface.

14. A nanoparticulate thin film coating according to any one of claims 9 to 13 in which the coating is on a surface of one of a surgical tool, a workbench, a razor blade, and a kitchen workbench.

15. Apparatus for treatment of surgical tools, comprising a means for generating a plasma around the tool, a means for generating a cloud of charged nanoparticles of an antibacterial material, and a means for electrostatically accelerating the nanoparticles toward the tool.

16. Apparatus according to claim 15 in which the antibacterial material is at least one of silver and copper or an alloy thereof.

17. A method of depositing a layer of material on a substrate substantially as herein described with reference to and/or as illustrated in the accompanying figures.

18. An antibacterial nanoparticulate thin film coating substantially as herein described with reference to and/or as illustrated in the accompanying figures.

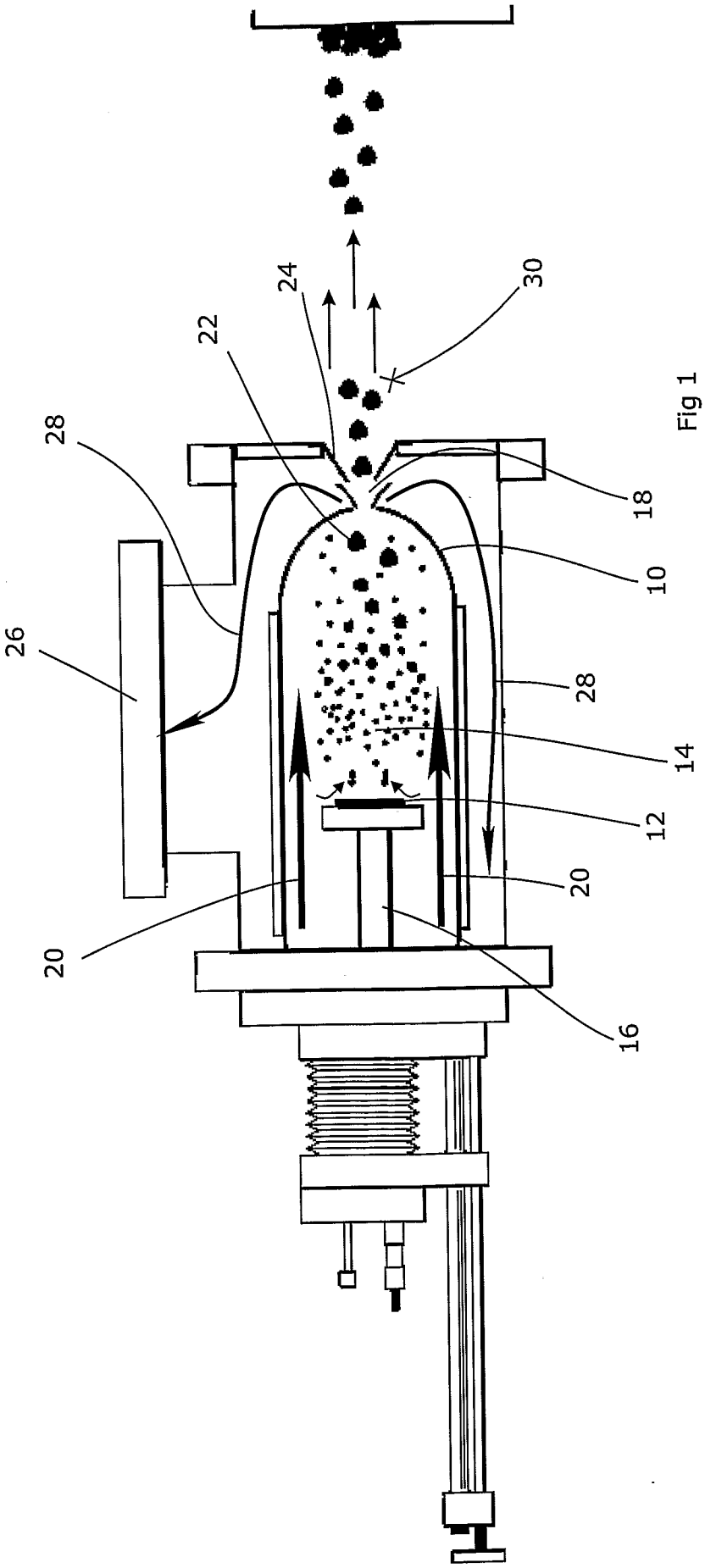
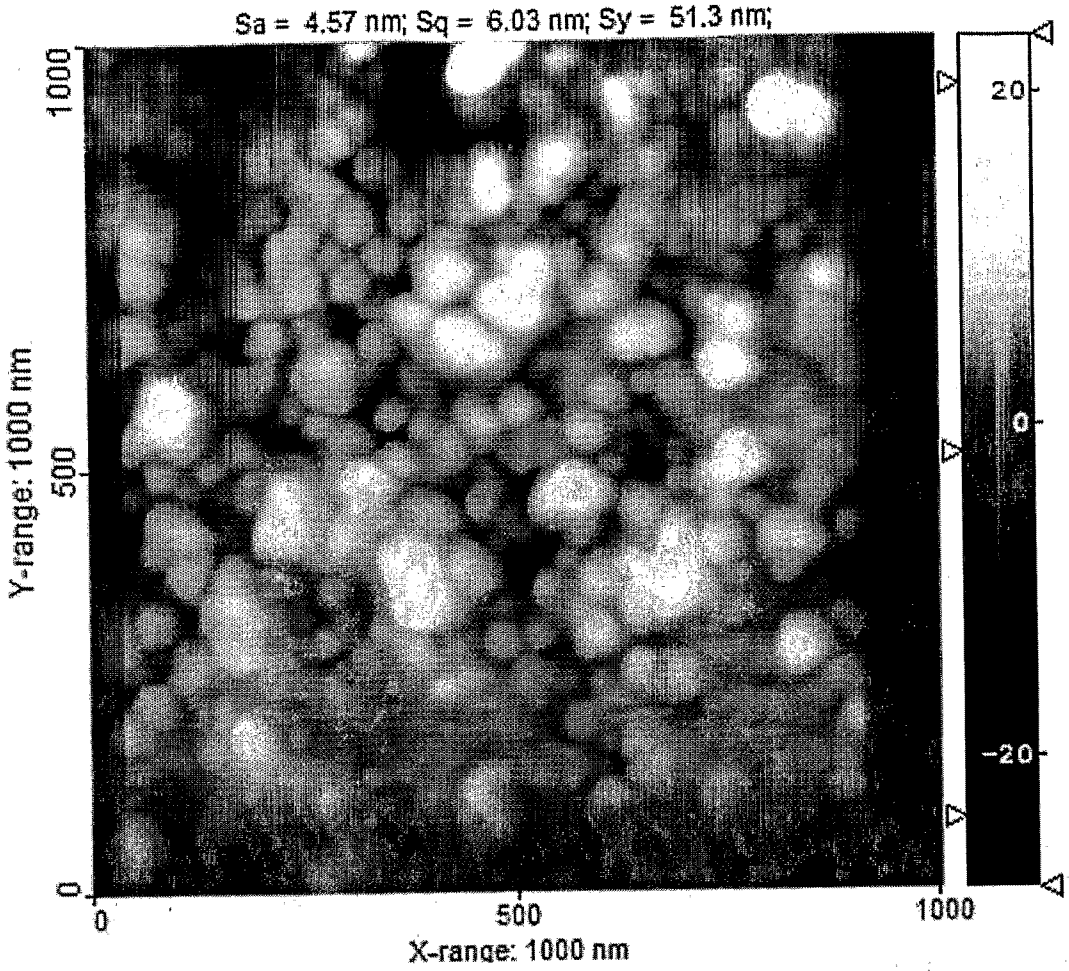


Fig 1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500
1000
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20
0
-20

Fig 2

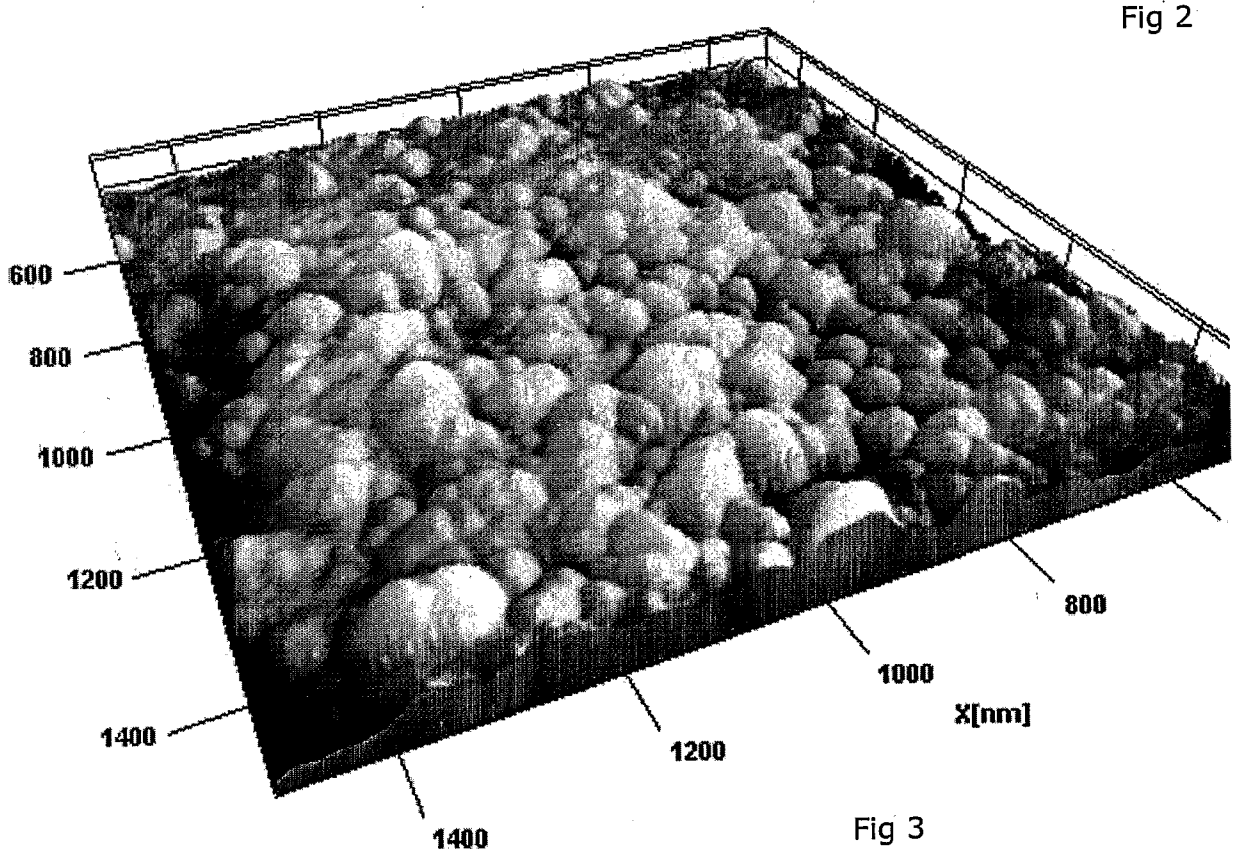
600
800
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Fig 3