US 20210317558A1

(19) United States
(12) Patent Application Publication
Kalfhaus et al.
(10) Pub. No.: US 2021/0317558 A1
(43) Pub. Date: Oct. 14, 2021

(54) **METHOD FOR COATING A COMPONENT AND COATED COMPONENT**

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(21) Appl. No.: **17/267,729**

(22) PCT Filed: **Aug. 19, 2019**

(86) PCT No.: **PCT/EP2019/072137**

§ 371 (c)(1),
(2) Date: **Feb. 10, 2021**

(30) **Foreign Application Priority Data**

Sep. 11, 2018 (DE) 10 2018 215 389.2

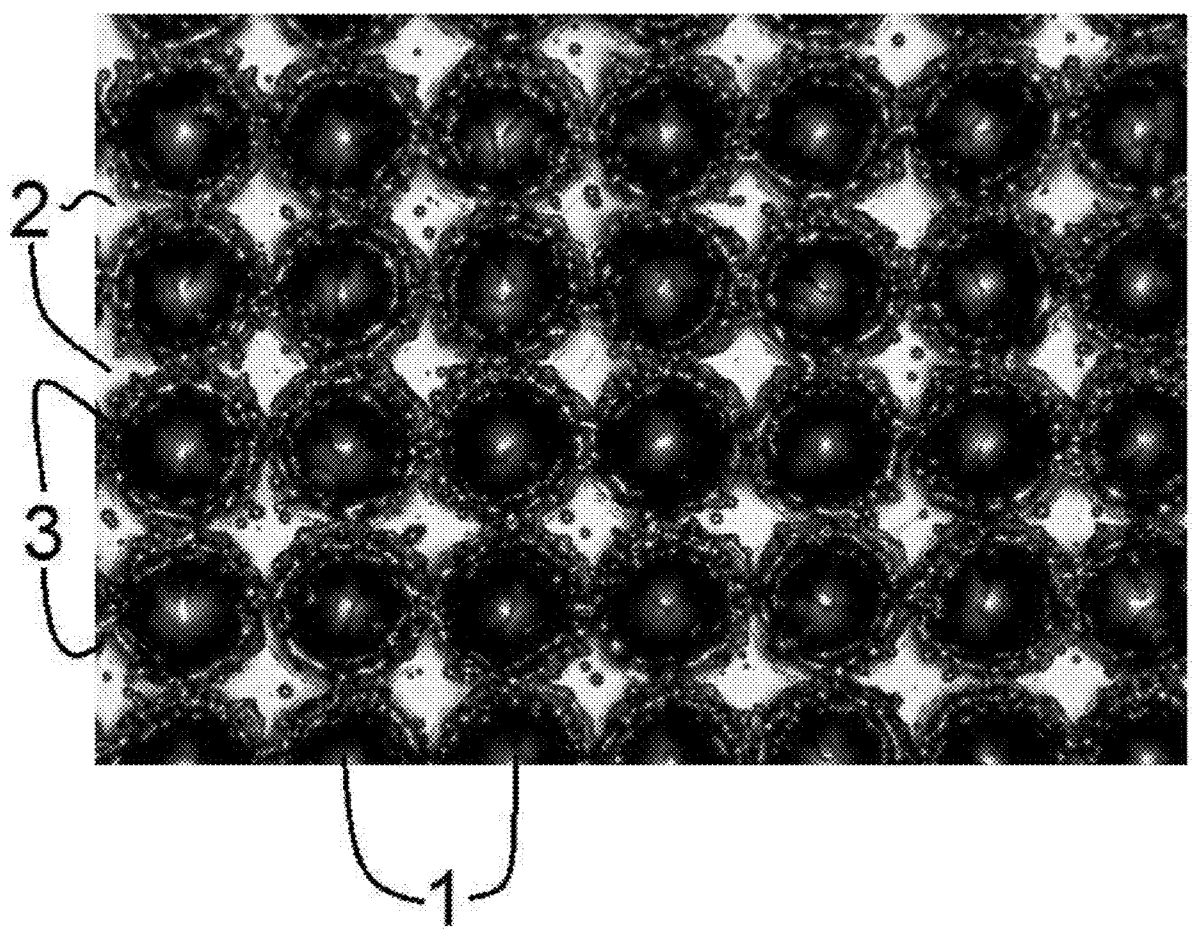
Publication Classification

(51) **Int. Cl.**
C23C 4/02 (2006.01)
C23C 4/129 (2006.01)
C23C 24/04 (2006.01)

(52) **U.S. Cl.**
CPC ***C23C 4/02*** (2013.01); ***C23C 24/04*** (2013.01); ***C23C 4/129*** (2016.01)

(57) **ABSTRACT**

A surface to be coated of a component is roughened by a laser. The roughened surface is coated by cold spraying. A component may be produced according to the method, which is coated with a layer.



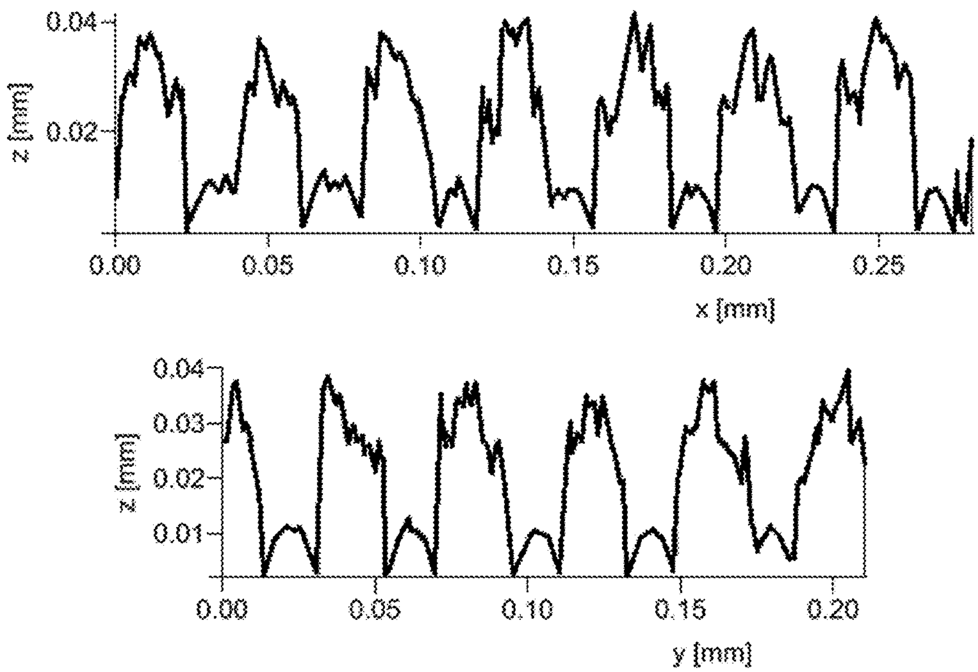

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FIG. 1

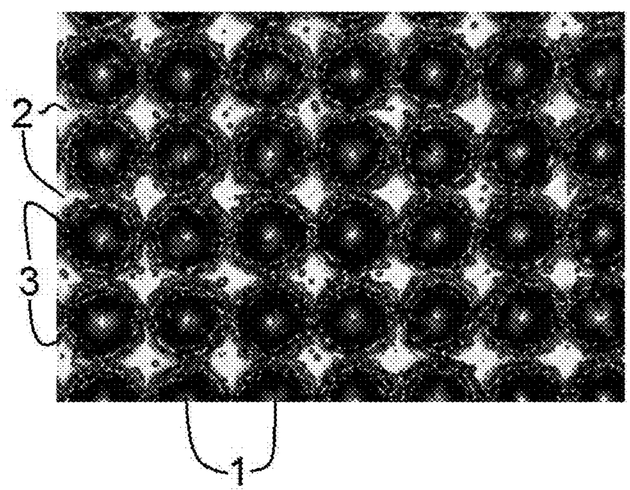

FIG. 2

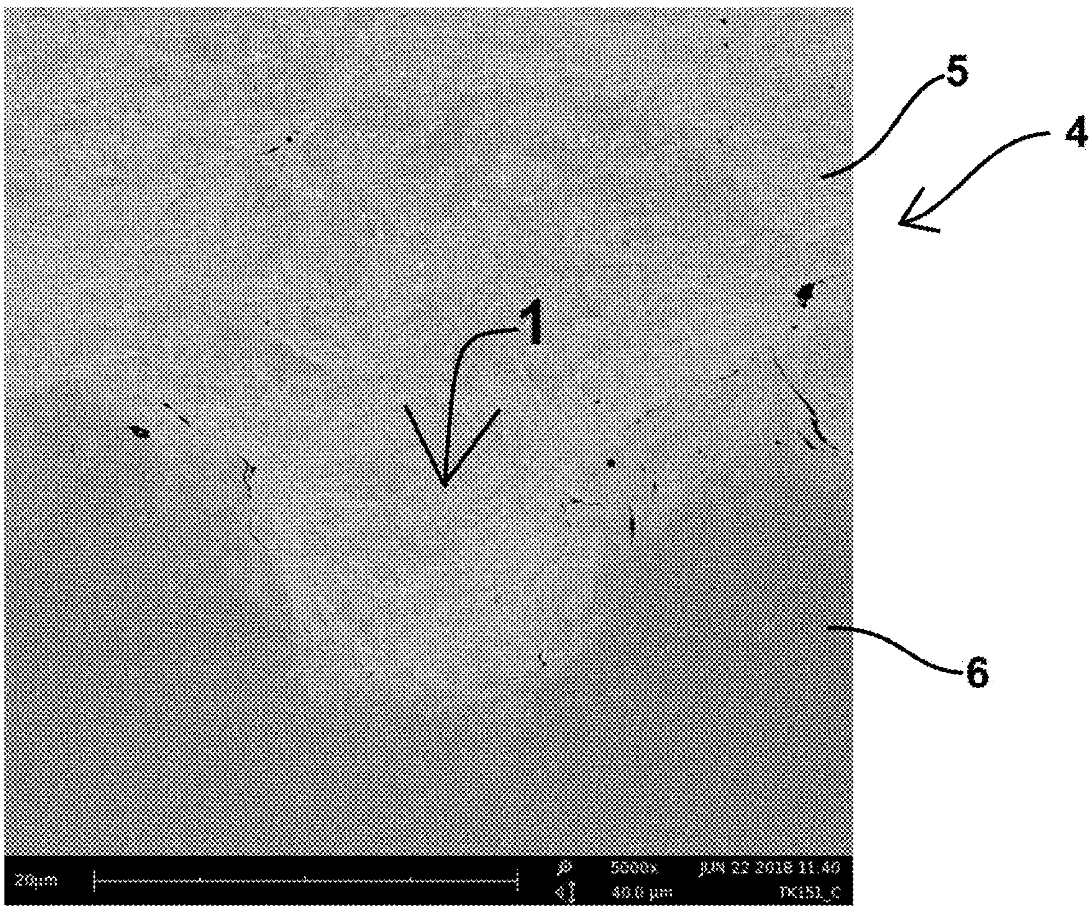

FIG. 3

METHOD FOR COATING A COMPONENT AND COATED COMPONENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a national stage entry under 35 USC § 371 of PCT International Application Number PCT/EP2019/072137, filed Aug. 19, 2019, and claims priority to

[0002] German Publication No. 10 2018 215 389, filed Sep. 11, 2018, the entire disclosures of each of which is expressly incorporated by reference herein.

FIELD OF THE DISCLOSURE

[0003] The present disclosure relates to a method for coating a component. The present disclosure further relates to a component coated in accordance with the method.

BACKGROUND

[0004] Some components may be coated by cold spraying. A surface of the component may be roughened by sand-blasting in order to improve the adhesion between a substrate consisting of steel and the coating material to be applied. Tilted structural elements may be provided on a surface in order to be able to coat regions of a component that are difficult to access satisfactorily by cold spraying.

[0005] In cold spraying (cold gas spraying), a surface of a component is coated by depositing a coating material in powder form. A heated gas such as nitrogen or helium is accelerated to very high velocities, for example by expansion in a de Laval nozzle, in the direction of the surface to be coated. The velocities are above the speed of sound and amount to 500 to 1000 m/s, for example. The powdered coating material is injected into the accelerated gas jet. This causes the powdered coating material to impact the surface to be coated at such a high velocity that the particles of the powder plastically deform on impact and as a result adhere to the surface to be coated. In contrast to thermal coating processes such as plasma spraying, arc spraying, flame spraying, the particles of the powder are not melted.

[0006] By the impact of a powder particle on the surface to be coated a shear stress is generated, which plastically deforms the material of a powder particle. The resulting shear stress leads to an adiabatic shear instability, which brings surface areas of a powder particle to temperatures close to the melting point of the coating material and thus softens them, thus bonding causing powder particles and component to each other. A good adhesion between a substrate and the coating material in cold spraying therefore requires that sufficient shear instabilities are generated by the impact.

[0007] The roughness of a surface to be coated may influence an adiabatic shear instability upon impact.

SUMMARY

[0008] One aspect of the present disclosure includes a method for coating a component, in which a surface to be coated of the component is roughened by a laser and the roughened surface is coated by a thermal spraying process with high energy, such as cold spraying. In some embodiments, roughening is done in a crater-shaped manner. The component can be coated with metals, polymers, ceramics, composite materials and nanocrystalline powder by cold spraying. In order to achieve sufficient adiabatic shear instabilities on impact and thus good adhesion, sufficiently smooth surfaces may be used.

[0009] The present disclosure is explained in more detail below with using examples and figures.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0010] FIG. **1** shows two sectional views of a surface generated according to the present disclosure;

[0011] FIG. **2** is a top view of surface to be coated of a component;

[0012] FIG. **3** is a transverse section of a component coated according to the present disclosure.

DETAILED DESCRIPTION

[0013] According to one embodiment of the present disclosure, a surface to be coated of a component is ground and/or polished, i.e. smoothed, before it is roughened by means of a laser. In this embodiment, ground and/or polished surface areas may remain even after processing by a laser in order to favorably influence adiabatic shear instabilities and thereby achieve further improved adhesion properties.

[0014] Grinding may be performed with a grinding machine and polishing can be performed with a polishing machine. Polishing may be performed using a polishing paste or a suspension, each with polishing grains included therein.

[0015] In one embodiment of the present disclosure, the surface to be coated of the component is exposed by laser at predetermined locations in such a way that crater-shaped depressions are produced at the exposed locations and other areas of the surface to be coated remain in the previous state even after the production of crater-shaped depressions, i.e. in particular in a ground and/or polished and thus smoothed state. In this way, the ratio between crater-shaped depressions and areas not roughened by laser can be optimized in order to achieve particularly good adhesion properties.

[0016] In one embodiment of the present disclosure, the surface to be coated of the component is repeatedly exposed by laser in pulses at the predetermined locations in such a way that crater-shaped depressions are formed at the exposed locations, in particular to achieve crater depths of at least 10 μm or 20 μm, or to achieve crater depths of at least 30 μm, in order to further improve the adhesion properties. It has been found that too great depths again worsen adhesion properties. Therefore, the depth of a crater-shaped depression may be limited to 60 μm, or to 50 μm, in some embodiments.

[0017] In order for a crater-shaped depression to contribute particularly well to stable adhesion, the diameter of the crater-shaped depression at the upper edge corresponds approximately to the depth of the crater-shaped depression. Thus, if a crater-shaped depression at the upper edge has a diameter of about 40 μm, for example, then a depth of about 40 μm is included. In some embodiments, the depth does not deviate more than 20% from the diameter. Thus, if the diameter is 40 μm, the depth should be at least 32 μm and no more than 48 μm to further improve adhesion properties. In one embodiment, the crater-shaped depressions have a diameter of 30 μm to 50 μm at the upper edge and a depth of 30 μm to 50 μm.

[0018] Time intervals are provided between the individual light pulses in such a way that material melted by laser light can first solidify again before the predetermined location is again exposed. Crater-shaped depressions can thus be optimized in a further improved manner. The adhesion between the component and the coating can thus be further improved.

[0019] Each predetermined location is exposed by the light of the laser at least 3 times, at least 5 times, and/or not more than 25 times, and/or not more than 15 times, in order to produce crater-shaped depressions in an optimized manner, in order to thus achieve particularly good adhesion properties.

[0020] In one embodiment of the present disclosure, the crater-shaped depressions have circular diameters. By this embodiment it is achieved that areas of the surface to be coated remain between crater-shaped depressions that have not been exposed by the laser and therefore have not been roughened.

[0021] In one embodiment of the present disclosure, the upper edge of the crater-shaped depressions protrudes in a bead-like manner with respect to areas of the surface to be coated that have not been exposed to the light of the laser. In some embodiments, the upper edge protrudes by at least 5 μm, or by at least 10 μm, and/or by not more than 20 μm with respect to areas of the surface to be coated that have not been exposed to the light of the laser.

[0022] In one embodiment of the present disclosure, the component is located in a gas atmosphere of noble gas, such as argon or of nitrogen, during its processing. In one embodiment, the component is then in a space through which, for example, a noble gas or nitrogen is passed, or which is gas-tight and into which noble gas or nitrogen has previously been introduced. Alternatively or additionally, a protective gas jacket is created which surrounds the laser beam during exposure. A protective gas jacket can be created by means of nozzles arranged around the light of the laser in such a way that the light beam of the laser impinging on the component is enveloped by the gas emerging from the nozzles. The adhesion between the component and the coating can be further improved in this way.

[0023] In one embodiment of the present disclosure, the coating material corresponds to the material of the surface to be coated. If the material of a component has been damaged by external influences, such damage can be repaired in a particularly stable and reliable manner by a coating according to the present disclosure with the same material.

[0024] In one embodiment of the present disclosure, beads of crater-shaped depressions adjoin each other and/or overlap or intersect. The diameter of each crater-shaped depression then corresponds approximately to the distance between two centers of two adjacent crater-shaped depressions.

[0025] In one embodiment of the present disclosure, the predetermined locations and thus the crater-shaped depressions are arranged according to a repeating pattern and thus in a planned manner. This can be, for example, a checkerboard pattern. In the case of a checkerboard pattern, the predetermined locations and thus the crater-shaped depressions are arranged one behind the other and side by side along a straight line, respectively. In this embodiment, the craters are therefore not randomly distributed.

[0026] In one embodiment of the present disclosure, the gas is heated to temperatures of 500° C. to 1200° C. during cold spraying to thus improve adhesion properties. The component to be coated may not be heated beyond this. In this way, thermally induced physical and/or chemical changes to the surface to be coated are avoided. Nitrogen can be used as the gas.

[0027] In one embodiment of the present disclosure, the laser beam impinges on the surface of the component at a right angle to create crater-shaped depressions. However, it is also possible to provide an angle different from 90° in order to roughen the surface of the component suitably by laser light.

[0028] FIG. **1** shows two sectional views of the surface to be coated generated according to the present disclosure, according to the aforementioned first part of the substrates, which were determined using a laser microscope. Shown is on the one hand a sectional view of exposed locations in xz direction and on the other hand in yz direction. The two sectional views illustrate that a crater-shaped depression with a diameter of about 0.4 μm was created at an exposed location. The depth was just under 0.4 μm.

[0029] The centers of the essentially circular crater-shaped depressions were regularly spaced 40 μm apart on the polished surface of the component according to a checkerboard pattern.

[0030] FIG. **2** shows an image of the laser microscope on the surface of a component to be coated, i.e. a substrate. This image shows a top view of the distribution of the crater-shaped depressions **1** according to a checkerboard pattern created by multiple exposures. Between obliquely opposite round crater-shaped depressions **1** there are unexposed, polished areas **2**. The edges of the craters have on the edge side a solidification pattern **3** due to the individual exposure, which protrude upwards, i.e. in the z-direction, by up to approx. 15 μm relative to the unexposed, polished areas. The bead-like solidification patterns **3** form upper edges of the crater-shaped depressions **1**. Upper edges **3** of the craters overlap or at least adjoin each other. The depth of the crater-shaped depressions **1** in relation to the polished base surface is about 20 μm. A total depth of about 35 μm has thus been created.

[0031] By means of a laser profilometer, roughnesses of surfaces of substrates processed according to the present disclosure and roughnesses of surfaces to be coated of the other substrates were determined for comparison purposes. For substrates processed according to the present disclosure, i.e. components with a surface according to FIGS. **1** and **2**, an average roughness R_a (μm)=7.15 and a maximum surface roughness R_{max} (μm)=48.85 were determined. For components with a surface roughened by sandblasting, a mean roughness R_a (μm)=2.31 and a maximum surface roughness R_{max} (μm)=19.12 were determined. For components with a polished surface, a mean roughness R_a (μm)=0.02 and a maximum surface roughness R_{max} (μm)=0.44 were determined.

[0032] Three substrates each consisting of the IN738 alloy were coated with IN738 powder having an average diameter of 7.89 μm in the commercially available equipment "CGT-Oerlikon Metco Kinetics 8000" using a water-cooled D-24 De-Laval nozzle, wherein the first three substrates comprised surfaces to be coated treated according to the present disclosure, the second three substrates comprised surfaces to be coated treated by sandblasting, and the third three substrates comprised polished surfaces to be coated. A pressure of 40 bar nitrogen, a gas temperature of 950° C. and a coating distance of 60 mm were selected as coating parameters. The layer thicknesses produced in this way were approx. 400 μm.

[0033] These coated substrates were glued between two cylinders for adhesion peel tests, so that the substrate was glued to one of the cylinders and the produced coating to the other cylinder. In the case of the substrates with the polished surfaces to be coated and with the sandblasted surfaces to be coated, the coating detached from the substrate. In the case of the surfaces to be coated treated according to the present disclosure, one cylinder always detached from the coated substrate. It was thus found that in the case of the surfaces to be coated treated according to the present disclosure, a significantly better adhesion between the coating and the substrate was achieved.

[0034] FIG. **3** shows a transverse section of a component **4** coated according to the present disclosure with a layer **5** on the substrate **6** in the region of a crater-shaped depression **1** after the adhesion peel tests have been performed. FIG. **3** illustrates that the crater-shaped depressions **1** have been completely filled by the cold spraying and that the adhesion peel tests performed could not change this. No cracks have formed either.

[0035] The present disclosure is not limited to the exemplary embodiment. For example, it is also possible to prepare the surface of a component alternatively or additionally in other ways compared to grinding and polishing, for example by sandblasting or shot peening, in order to subsequently roughen it by means of a laser. Good adhesion properties can also be achieved in this way, especially in comparison with surface preparation that comprises only sandblasting for subsequent coating. To achieve good adhesion properties, another thermal coating process can be used instead of cold spraying, in which the coating material is brought to a high velocity in order to coat. For example, HVAF (High Velocity Air-Fuel) can be provided instead of cold spraying to achieve good results. However, the mentioned alternatives relating to sandblasting, shot peening or HVAF are less preferable. Thus, the task of the present disclosure can also be solved by a method for coating a component, in which a surface to be coated of the component is roughened by a laser and the roughened surface is coated by a thermal spraying process with high kinetic energy such as cold spraying or HVAF.

[0036] Compared to literature values, the maximum achievable layer thickness could be tripled by the present disclosure.

[0037] It is one task of the present disclosure to further develop the coating of a component. The task may be solved by the present disclosure, including as described in the claims.

[0038] The inventors have found that a combination of the two measures “roughening by laser” and “coating by cold spraying” lead to a stable adhesion between the component and the coating layer. It has been found that roughening by means of a laser does not adversely modify the material of the surface of the component physically or chemically in such a way as to reduce adhesion between component and layer. Roughening by means of a laser is therefore advantageous over roughening by sandblasting. It has also been found that cold spraying does not adversely modify the physical and chemical properties of the surface either, so that a very good adhesion between the component and the coating can be achieved by a combination of the two measures.

[0039] A large number of tests were performed in which substrates consisting of alloy IN738 were used as components and these were coated with a powdered alloy IN738 by cold spraying.

[0040] Substrates consisting of the alloy IN738, i.e. components, were first ground and then polished with a 1 μm diamond suspension, i.e. with diamond grains having an average diameter of 1 μm, on a soft cloth. After cleaning with ethanol in an ultrasonic bath, a first portion of the substrates was brought to a laser processing system commercially available under the name “Laser Marking Trumpf 5020.” This comprises an Nd-YAg laser with a laser light wavelength of 1064 nm. The focus of the laser was set to 100 μm below the substrate surface to be coated. Argon was used as the atmosphere during exposure to the laser to avoid detrimental oxidation. In pulsed mode, at full power, corresponding to a peak power of 15 kW, the substrate surface to be coated was ablated at a frequency of 35 kHz and a pulse length of 120 ns. Crater-shaped depressions with a diameter of 40 μm were thus created on the surface to be coated. Craters were made one behind the other and side by side, i.e., checkerboard-like, with a spacing of 40 μm. Each individual location where a crater was to be created was exposed to the light of the laser a total of 12 times. However, a single location was not exposed immediately again, following an exposure. Instead, each of the locations was exposed for a first time and then, in the same order, for a second time and so on, until all locations had been exposed twelve times in this way. Each individual location was therefore allowed to cool down and solidify again after an exposure before being exposed again. Unwanted oxidation of the surface could thus be avoided in an improved manner.

[0041] For comparison tests, a second part of the substrates was not further processed. The surface to be coated thus remained in the state smoothed by grinding and polishing.

[0042] For comparison tests, the surfaces to be coated of substrates consisting of the alloy IN738 were also roughened by sandblasting. These surfaces to be coated had also been previously ground and polished.

1. A method for coating a surface of a component comprising steps of:

roughening the surface of the component by a laser in a crater-shaped manner and coating the roughened surface of the component by a thermal spraying process with high kinetic energy.

2. The method of claim **1**, wherein the surface to be coated is ground and/or polished before roughening.

3. The method of claim **1**, wherein the surface to be coated of the component is repeatedly exposed by laser in pulses at predetermined locations in such a way that crater-shaped depressions are formed at the predetermined locations.

4. The method of claim **3**, wherein time intervals are provided between the pulses in such a way that material melted by light of the laser can first solidify again before the predetermined location is again exposed by the light of the laser.

5. The method of claim **3**, wherein each predetermined location is exposed at least 3 times and not more than 25 times by light of the laser.

6. The method of claim **3**, wherein, by laser roughening, crater-shaped depressions with a depth of at least 10 μm and not more than 60 μm are produced.

7. The method of claim **6**, wherein, by laser roughening, crater-shaped depressions are produced in which the diameter of each crater-shaped depression at the upper edge thereof corresponds to about the depth of the crater-shaped depression.

8. The method of claim **7**, wherein the crater-shaped depressions have a diameter of 30 μm to 50 μm at the upper edge and a depth of 30 μm to 50 μm.

9. The method of claim **1**, wherein the component is located in a gas atmosphere of noble gas, including one of argon and nitrogen, during at least one of the roughening and the coating.

10. The method of claim **1**, wherein the roughened surface is coated by cold spraying or HVAF.

11. The method of claim **1**, wherein the coated surface includes crater-shaped depressions having circular diameters and having a depth of at least 20 μm and not more than 60 μm.

12. The method of claim **11**, wherein an upper edge of each crater-shaped depression protrudes in a bead-like manner with respect to adjacent polished areas of the coated surface.

13. The method of claim **12**, wherein upper edge of each crater-shaped depression protrudes in a bead-like manner with respect to adjacent polished areas of the coated surface by at least 10 μm.

14. The method of claim **1**, wherein the coated surface includes crater-shaped depressions having circular diameters and having a depth of not more than 60 μm.

15. The method of claim **3**, wherein each predetermined location is exposed not more than 25 times by light of the laser.

16. The method of claim **3**, wherein, by laser roughening, crater-shaped depressions with a depth of not more than 60 μm are produced.

17. The method of claim **1**, wherein the step of roughening the surface of the component includes impinging the surface with a laser beam of the laser as a right angle to the surface.

18. The method of claim **9**, wherein the gas is heated to a temperature within a range of about 500 degrees Celsius to about 1200 degrees Celsius.

19. The method of claim **3**, wherein the predetermined locations form a repeating pattern on the surface of the component.

20. The method of claim **1**, wherein the coated surface includes crater-shaped depressions having circular diameters and having a depth of not more than 20 percent of the circular diameter.

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