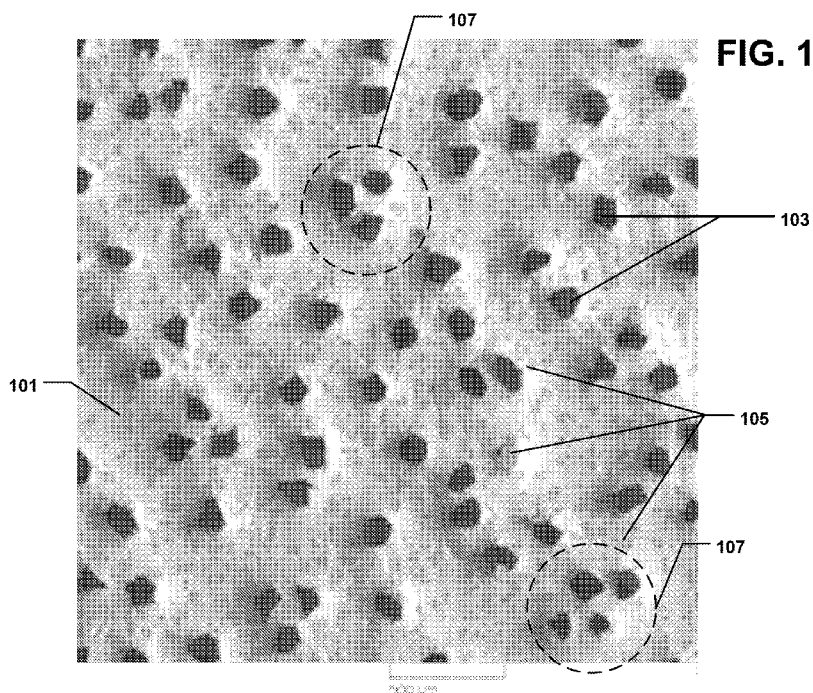




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[Continued on next page]

- (54) **Title:** CHEMICAL MECHANICAL PLANARIZATION (CMP) PAD CONDITIONER AND METHOD OF MAKING



(57) **Abstract:** A method of forming a chemical mechanical planarization (CMP) pad conditioner includes placing abrasive grains on a major surface of a substrate, forming a binding composition at an exterior surface of the abrasive grains, and depositing a bonding layer over the surface of the substrate and a portion of the abrasive grains to secure the abrasive grains to the major surface of the substrate.

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CHEMICAL MECHANICAL PLANARIZATION (CMP) PAD CONDITIONER AND METHOD OF MAKING

TECHNICAL FIELD

5 The following application is directed to an abrasive tool, and more particularly to an abrasive tool for use as a chemical mechanical planarization pad conditioner.

BACKGROUND ART

10 In the fabrication of electronic devices, multiple layers of various types of material are deposited including for example conducting, semiconducting, and dielectric materials. Successive deposition or growth and removal of various layers results in a non-planar upper surface. A wafer surface that is not sufficiently planar will result in structures that are poorly defined, with the circuits being nonfunctional or exhibiting less than optimum performance. Chemical mechanical planarization (CMP) is a common technique used to planarize or polish workpieces such as semiconductor
15 wafers.

20 During a typical CMP process, a workpiece is placed in contact with a polishing pad and a polishing slurry is provided on the pad to aid in the planarization process. The polishing slurry can include abrasive particles that may interact with the workpiece in an abrasive manner to remove materials, and may also act in a chemical manner to improve the removal of certain portions of the workpiece. The polishing pad is typically much larger than the workpiece, and is generally a polymer material that can include certain features, such as micro-texture suitable for holding the slurry on the surface of the pad.

25 During such polishing operations, a pad conditioner is typically employed to move over the surface of the polishing pad to clean the polishing pad and properly condition the surface to hold slurry. Polishing pad conditioning is important to maintaining a desirable polishing surface for consistent polishing performance, since the surface of

the polishing pad wears down over time, resulting in smoothing of micro-texture of the pad. Still, the conditioning operation faces certain obstacles, including the presence of polishing debris which can clog the components, chemical corrosion, conditioner geometry irregularity, conditioner over-use, and grain pull-out, which can interfere with conditioning operations and damage the sensitive electronic components being polished.

Accordingly, the industry continues to demand improved CMP pad conditioners and methods of forming thereof.

DISCLOSURE OF THE INVENTION

According to one aspect, a method of forming a chemical mechanical planarization (CMP) pad conditioner includes placing abrasive grains on a major surface of a substrate, forming a binding composition at an exterior surface of the abrasive grains, and depositing a bonding layer over the surface of the substrate and a portion of the abrasive grains to secure the abrasive grains to the major surface of the substrate.

In another aspect, a chemical mechanical planarization (CMP) pad conditioner includes a substrate and abrasive grains contained within a bonding layer overlying the substrate, wherein the abrasive grains comprise an average grit size of less than about 90 microns. The CMP pad conditioner comprises an upper surface having an average surface roughness (Ra) of not greater than about 15 microns.

In yet another embodiment, a chemical mechanical planarization (CMP) pad conditioner has a substrate and abrasive grains contained within a bonding layer overlying the substrate. The exterior surfaces of the abrasive grains have a binding composition comprising a carbide, and the abrasive grains have exposed tips, wherein a majority of the exposed tips are essentially free of a conductive carbon film.

According to another aspect, a chemical mechanical planarization (CMP) pad conditioner includes a substrate and abrasive grains contained within a bonding layer overlying the substrate. A binding composition including a carbide is present at a

surface of the abrasive grains. The CMP pad conditioner has an upper surface having an average surface roughness (Ra) of not greater than about 15 microns.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be better understood, and its numerous features and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. 1 includes a top view image of a portion of a conventional CMP pad conditioner.

FIG. 2 includes a top view image of a portion of a CMP pad conditioner in accordance with an embodiment.

FIG. 3 includes a magnified top view image of a portion of the CMP pad conditioner of FIG. 1.

FIG. 4 includes a magnified top view image of a portion of the CMP pad conditioner of FIG. 2.

The use of the same reference symbols in different drawings indicates similar or identical items.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The following generally directed to single-layered abrasive articles, and more particularly abrasive articles having abrasive grains secured within a bonding layer including a metal material. Notably, the abrasive articles of the embodiments herein may be particularly useful as chemical mechanical planarization (CMP) pad conditioners, which are commonly used in the electronics industry for conditioning of CMP pads.

In accordance with an embodiment, a method of forming a CMP pad conditioner can include placing abrasive grains on a major surface of a substrate. Generally, the

substrate can have a size and shape suitable for holding the abrasive grains. In particular, the substrate is intended to provide a surface to which the abrasive grains can be secured.

In accordance with one embodiment, the substrate can be made of a metal or metal alloy material. Some suitable metals can include a transition metal element, such as Fe, Ti, V, Cr, Mn, Co, Ni, W, Zr, Ta, Cu, Zn, and a combination thereof. Certain substrates can be made of steel. In particular instances, the substrate can be made of a material having at least 2% chromium, wherein a particular content of chromium can facilitate certain aspects of the forming process. In other embodiments, the substrate can have a greater content of chromium, such as at least about 5%, at least about 8%, or even at least about 10% chromium. In particular instances, the substrate is formed of a material having a chromium content within a range between about 2% and about 30%, such as between about 2% and 25%, and more particularly, between about 10% and 20%. Particularly suitable metals can include 430 stainless steel, 304 stainless steel, and 440 stainless steel.

Prior to placing the abrasive grains on the substrate, the major surface of the substrate may be prepared with a composition intended to temporarily hold the position of the abrasive grains. For example, in accordance with one embodiment, an adhesive can be placed on the major surface of the substrate prior to placing the abrasive grains on the substrate. The adhesive can be applied in the form of a tape, layer, or film. The adhesive can be deposited using various techniques, including but not limited to, printing, spraying, screening, applying as a tape, casting, blading, and a combination thereof. The adhesive can be applied to the major surface of the substrate in a manner to have a suitable thickness to temporarily secure the abrasive grains in their position with respect to the major surface of the substrate.

In accordance with an embodiment, the adhesive can include an organic material. Suitable organic materials can include polymers, such as polyamides, polyimides, polyesters, acrylates, polyvinyls, resins, epoxies, and a combination thereof. In accordance with one particular embodiment, the adhesive can be a water-based

adhesive containing a majority content (by weight %) of water. According to one particular embodiment, the adhesive can include a pressure sensitive adhesive (e.g., K4-2-4) commercially available from Vitta Corporation.

5 Placement of the abrasive grains on the major surface of the substrate can include a screening process, wherein a form having openings (i.e., a screen) is placed over the substrate and abrasive grains are deposited on the screen. The abrasive grains are placed and adhered to the abrasive layer at the locations where the screen has openings. In particular, the combination of the forming process and placement process can facilitate the formation of CMP pad conditioners utilizing very fine
10 abrasive grit sizes (e.g., less than 90 microns).

The abrasive grains may be placed on the major surface of the substrate to form a particular pattern. For example, the abrasive grains may be placed within the bonding layer in a random arrangement having no short range or long range order.

Alternatively, the placement of the abrasive grains may be completed in a manner
15 such that the grains have a pattern, and even arranged in a pattern having long range order, such as an array (e.g., face centered cubic pattern, cubic pattern, hexagonal pattern, rhombic pattern, spiral pattern, random pattern, and combinations of such patterns). In particular instances, the abrasive grains may be placed at particular locations within the bonding layer such that they are arranged in a self-avoiding
20 random distribution (i.e., a SARDTM pattern).

The abrasive grains may be particularly hard materials, such that the abrasive grains can have a Vickers hardness of at least about 1500 kg/mm². In particular instances, the abrasive grains can include materials such as oxides, borides, nitrides, carbides, carbon-based structures (including man-made carbon-based materials such as
25 fullerenes), and a combination thereof.

In accordance with one embodiment, the abrasive grains can include a superabrasive material. Suitable superabrasive materials can include cubic boron nitride, diamond, and a combination thereof. In particular instances, the abrasive grains can consist

essentially of cubic boron nitride. Still, in other examples, the abrasive grains can consist essentially of diamond.

In accordance with one embodiment, the abrasive grains utilized for the CMP pad conditioner can have an average grit size of not greater than about 300 microns. In other instances, the abrasive grains can have an average grit size that is less, such as not greater than 250 microns, not greater than 200 microns, not greater than 150 microns, or even not greater than about 100 microns. Certain CMP pad conditions may utilize abrasive grains having an average grit size that is significantly smaller than the abrasive grains utilized in conventional CMP pad conditioners. For example, the abrasive grit size can be not greater than about 90 microns, not greater than about 85 microns, not greater than about 80 microns, or even not greater than about 75 microns. In particular instances, the CMP pad conditioner can utilize abrasive grains having an average grit size within a range between about 1 micron and about 90 microns, such as between about 1 micron and about 85 microns or even between about 1 micron and 80 microns.

After placing the abrasive grains on the major surface of the substrate, the method of forming the CMP pad conditioner can continue by forming a binding composition (i.e., a primary binding composition) at an exterior surface of the abrasive grains. The binding composition can also be formed at an interface of the abrasive grains and the substrate to form a bond between the abrasive grains and the surface of the substrate. The binding composition can have sufficient strength to secure the position of each of the abrasive grains relative to the surface of the substrate, and thus facilitating maintaining of the original positioning of the abrasive grains on the major surface of the substrate throughout the forming process. Notably, such a process is distinct from other, conventional processes that can lead to shifting of the original positions of the abrasive grains.

In accordance with one embodiment, the process of forming a binding composition can include heating the preform, which includes the substrate, adhesive, and abrasive grains. The heating process can cause a chemical reaction between components of

the substrate and the abrasive grains, resulting in the formation of the binding composition at the interface of the abrasive grains and the substrate. In accordance with one embodiment, the heating process can be conducted at a heating temperature of at least about 500°C. In other embodiments, the heating temperature may be greater, such as at least about 600°C, 700°C, or even 800°C. Particular processes can utilize a heating temperature within a range between about 700°C and about 1200°C, more particularly between about 800°C and 1100°C.

The heating process can be conducted for a particular heating duration, wherein the preform is held at the heating temperature. The heating duration can be at least about 5 minutes, at least about 10 minutes, or even at least about 15 minutes. Certain embodiments can utilize a heating duration within a range between about 5 minutes and about 90 minutes, such as between about 5 minutes and 60 minutes, or even between about 10 minutes and about 40 minutes.

During the formation of the binding composition the preform may be placed within a chamber having an inert atmosphere. In particular, the atmosphere may be controlled, such that an inert gas can be provided within the chamber. For example, an inert gas may be flowed over the surface of the substrate and abrasive grains during the formation process to avoid oxidation of the abrasive grains and/or substrate surface. In other instances, the atmosphere within the chamber can be controlled such that it may be a reduced pressure atmosphere.

According to one process, the chamber containing the preform can have a pressure less than the ambient atmosphere, such that the formation process may be conducted in an atmosphere having a reduced oxygen partial pressure. For example, the pressure within the chamber during formation of the binding composition can be not greater than about 10^{-1} Torr, such as not greater than about 10^{-2} Torr, not greater than about 10^{-3} Torr, or even not greater than about 10^{-4} Torr. Particular embodiments may utilize a pressure within the chamber within a range between about 10^{-2} Torr and about 10^{-6} Torr.

During the formation process, and particularly during a heating process, the adhesive on the major surface of the substrate can be altered. For example, heating may be conducted at a temperature and in an atmosphere sufficient to volatilize components of the adhesive material from the surface of the substrate. It will be appreciated that
5 volatilization includes changing certain chemical components of the adhesive material to a gaseous phase.

Furthermore, the atmosphere of the chamber holding the preform during formation can have a gas flowing through at a sufficient rate to purge the atmosphere of volatilized species. For example, gas can be flowed at a rate of at least about 5
10 ml/min, such as at least about 50 ml/min, at least about 100 ml/min, and particularly within a range between about 5 ml/min and about 500 ml/min.

In accordance with an embodiment, the binding composition can include a metal material. In particular instances, the binding composition can include at least one transition metal element. More particularly, the binding composition may include a
15 compound including a carbide, boride, nitride. In certain instances, the binding composition can include chromium carbide, which can be a reaction product formed by a chemical reaction between chromium contained within the substrate and carbon present within the abrasive grains. In accordance with one particular embodiment, the binding composition consists essentially of chromium carbide.

After forming a binding composition at the exterior surface of the abrasive grains, the
20 process can continue by conducting an optional cleaning process. In accordance with an embodiment, the cleaning process can be conducted to remove residue, such as organics and other materials from the major surface of the substrate and the abrasive grains. The cleaning operation may include a plasma cleaning process, wherein the
25 surface of the substrate and abrasive grains are bombarded with high energy particles. In accordance with one embodiment, the plasma material selected for the plasma cleaning process can include a gaseous material, including for example, oxygen, hydrogen, and a combination thereof.

In a particular instance, the cleaning process can remove a certain content of a conductive film formed on the surfaces of the abrasive grains. During certain forming processes, in formulations utilizing abrasive grains of diamond, a conductive carbon film may be formed on the surfaces of the abrasive grains, particularly in the context of diamond abrasive grains. Existence of conductive carbon film on the tips of the abrasive grains may limit the performance of the finally-formed CMP pad conditioner and may further act as a contaminant during operation of the conditioner in the industry of sensitive electronics.

According to embodiments herein, the CMP pad conditioner can be formed such that the majority (i.e., greater than about 50%) of the abrasive grains have exposed tips that are essentially free of a conductive carbon film. For example, at least 80% of the total number of abrasive grains can have exposed tips that are essentially free of a conductive carbon film. In other instances, at least 95%, or even at least about 99% of the abrasive grains have exposed tips that are essentially free of a conductive carbon film. It will be appreciated that conductive carbon may be identified by certain imaging techniques (e.g., light microscope or scanning electron microscope), and may be present as a polycrystalline form of carbon.

The method of forming the CMP pad conditioner can continue by depositing a bonding layer over the surface of the substrate and a portion of the abrasive grains to the major surface of the substrate. The bonding layer can form a lasting bond and facilitate permanently securing the abrasive grains to the major surface of the substrate. In accordance with one embodiment, the bonding layer can include a metal or metal alloy material. In certain instances, the bonding layer can be formed to include at least one transition metal element. More particularly, the bonding layer can be formed of a metal, such as, Ni, Cr, Au, Ag, Pt, Pd, Rh, W, Ti, V, Co, Cu, Zn, Mo, and a combination thereof. One particular CMP pad conditioner includes a bonding layer having an alloy of nickel and tungsten.

In accordance with one embodiment, the bonding layer can be formed of a series of films overlying each other. The bonding layer can include multiple films and more

particularly, a series of metal films bonded to each other. For example, the bonding layer can be formed of a series of films, wherein each of the successive films can have a composition that is different than the composition of an immediately adjacent or abutting film. For example, differences in composition between successive films can include a difference of at least 2% of an elemental component between the two films. For example, an underlying film may comprise 99% nickel, and an immediately adjacent and overlying film can have an amount of nickel that is 97% or less and be considered a film of a different composition.

The process of depositing the bonding layer can include a plating process. In particular, the plating process may be an electroplating process and can include submersion of the substrate having the abrasive grains and the binding composition in an electroplating environment (i.e., electroplating tank).

Deposition of the bonding layer can be conducted in a manner to control the thickness of the bonding layer. For example, the bonding layer can be formed to have an average thickness that is at least 30% of the average grit size of the abrasive grains. In other instances, the bonding layer can have an average thickness that is at least 40%, such as at least 50% or even at least about 60% of the average grit size of the abrasive grains. In particular instances, the bonding layer can have average thickness within a range between about 30% and 90%, such as between about 50% and 80%, or even more particularly between about 55% and 70% of the average grit size of the abrasive grains.

After depositing the bonding layer over the surface of the substrate and portion of the abrasive grains, the process may continue with an optional treatment including forming a second binding composition. Such treatment can include heating of the assembly after depositing the binding layer to form a secondary binding composition at an interface of the abrasive grains and the bonding layer. Such a treatment can include heating to a temperature sufficient to create the secondary binding composition, wherein the secondary binding composition can be a reaction product between a chemical component of at least 2 of the bonding layer, abrasive grains, and

the primary binding composition. For example, a secondary binding composition can include a carbide composition or a nitride composition formed at the interface of the abrasive grains of the bonding layer. More particularly, the secondary binding composition can include a tungsten carbide material. It will be appreciated that
5 formulation of a tungsten carbide material as a secondary binding composition can be facilitated by use of tungsten within the bonding layer and abrasive grains made of diamond. Other suitable materials that can be formed as the secondary binding composition can include chromium carbide, titanium carbide, titanium nitride, and the like.

10 FIG 1. includes a top view image of a portion of a conventional CMP pad conditioner. As illustrated, the conventional CMP pad conditioner can include abrasive grains 103 secured within a brazed material 101. The brazed material can include a metal having a significantly rough surface between the abrasive grains. Furthermore, the brazed material 101 may include crystallites 105 dispersed
15 throughout the volume of the material, which are chromium carbide crystals that may cause regions of localized stress within the brazed material 101.

FIG. 2 includes a top view image of a portion of CMP pad conditioner formed in accordance with an embodiment. As illustrated, the CMP pad conditioner includes abrasive grains 203 secured within a bonding layer 201. The bonding layer 201
20 exhibits limited carbide crystals. In fact, the bonding layer 201 can be formed such that it has not greater than 5 vol% of the carbide crystals of the total bonding layer 201. In other instances, the bonding layer 201 can have not greater than about 3 vol%, not greater than 2 vol% carbide crystals for the total volume of the bonding layer 201. Certain CMP pad conditioners 201 can be essentially free of carbide
25 crystals within the bonding layer 201.

As evidence by the image of FIG. 2, the CMP pad conditioner comprises a bonding layer 201 having a particular surface profile. Notably, control of processes disclosed in the embodiments herein facilitates the formation of a CMP pad conditioner that has controlled exposure of grains and more uniform height of the bonding layer 201, such

that the uniformity of the surface profile is enhanced as compared to conventionally formed CMP pad conditioners. As such, the consistency in the protrusion of the abrasive grains 203 above the surface of the bonding layer 201 is better controlled and more uniform from abrasive grain to abrasive grain. This is evidenced by the surface roughness of the upper surface of the CMP pad conditioner. Measurement of the average surface roughness of the upper surface includes measurement of the exterior surface of the bonding layer 201 and the abrasive grains 203 contained within the bonding layer 201. For example, the CMP pad conditioner can have an upper surface having an average surface roughness (R_a) that is not greater than about 15 microns. The average surface roughness (R_a) is the arithmetic mean of the departures (V) of the points on the profile from a mean line over the sample area (3 mm x 3 mm). Samples were examined using a Zygo 3D Surface Profilometer (white light chromatic aberration technique). The parameters were normalized in the ISO 4287 standard and/or the EUR 15178 EN report.

In accordance with other embodiments, the CMP pad conditioner can have an upper surface having an average surface roughness (R_a) not greater than about 12 microns, such as not greater than about 10 microns, not greater than about 8 microns, not greater than about 6 microns, or even not greater than about 4 microns. In particular embodiments, the upper surface of the CMP pad conditioner can have a average surface roughness (R_a) within a range between about 0.1 microns and about 15 microns, such as between about 0.1 microns and 10 microns, and more particularly, between about 0.1 microns and about 8 microns.

Furthermore, the CMP pad conditioner can have an upper surface having a surface roughness (R_z) that is not greater than about 100 microns as measured using the Zygo 3D Surface Profilometer. The surface roughness (R_z) is the average difference between the five highest peaks and five deepest valleys within the sampling area (3 mm x 3 mm), the heights being measured from a line parallel to the mean line and not crossing the profile. Certain CMP pad conditioners can have an upper surface including a surface roughness (R_z) of not greater than about 90 microns, such as not greater than about 80 microns, not greater than about 70 microns, not greater than

about 60 microns, or even not greater than about 50 microns. In accordance with one embodiment, the CMP pad conditioner can have an upper surface having a surface roughness (R_z) that is within a range between about 1 micron and about 100 microns, such as between about 1 micron and about 70 microns, or more particularly within a range between about 1 micron and about 50 microns.

The CMP pad conditioner of embodiments herein can further include an upper surface having a surface roughness (R_{rms}) that is not greater than about 20 microns as measured using the Zygo 3D Surface Profilometer. The surface roughness (R_{rms}) is defined as the average root mean square deviation (Y) of the profile from a mean line within the sampling area (3 mm x 3 mm). In fact, the CMP pad conditioner can have a surface roughness (R_{rms}) that is not greater than about 15 microns, such as not greater than about 12 microns, or even not greater than about 10 microns. In particular instances, the bonding layer 201 can have a surface roughness (R_{rms}) within a range between about 0.1 microns, and about 20 microns, such as between about 0.1 microns and 15 microns, or even between about 0.1 microns and 10 microns.

Moreover, the CMP pad conditioners of embodiments herein can have an improved bonding layer thickness variation. For example, the bonding layer thickness may vary from an average thickness, as measured as a standard deviation from a measured average of at least about 10 points along the full width of the bonding layer across the substrate, of not greater than about 50%. In other instances, the bonding layer thickness variation can be not greater than about 40%, not greater than about 30%, not greater than about 20%, or even not greater than about 10%.

Furthermore, as illustrated in FIG. 1, conventional brazed CMP pad conditioners may have abrasive grain groupings 107 across the surface of the substrate. Abrasive grain groupings 107 are typically formed due to the high temperature processing, wherein the bond material may become liquid at high temperatures facilitating flow of the brazed material and further facilitating movement of the abrasive grains 103 relative to each other and the surface of the substrate. Abrasive grain groupings 107 can limit the conditioning performance of the CMP condition. Abrasive grain groupings 107

represent groupings of three or more abrasive grains having a significant and identifiable shift in the positioning from an original intended position such that the average spacing between abrasive grains within the grouping is at least 30% less than the average spacing between abrasive grains across the surface of the CMP conditioner. The average spacing of abrasive grains is measured as the average distance between one abrasive grain and the nearest abrasive grains surrounding the abrasive grain. The average spacing is based upon a sampling of at least 25 random abrasive grains across the surface of the CMP conditioner.

By contrast, the CMP pad conditioner of FIG. 2 demonstrates limited abrasive grain groupings. In fact, in a comparison of a particular area of the CMP pad conditioners of 1 cm², the CMP pad conditioner of FIG. 2, exhibits at least 5% less abrasive grain groupings than the conventional CMP pad conditioner of FIG. 1. The forming process of embodiments herein facilitates maintaining the original position, and thus the original spacing, between abrasive grains and limiting abrasive grain groupings.

FIG. 3 includes a magnified image of a portion of FIG. 1. As illustrated, the abrasive grains 103 as illustrated in the magnified SEM image have dark exposed tips extending above the bonding layer 101. By contrast, turning to FIG. 4, a magnified SEM image of a portion of the CMP pad conditioner of FIG. 2 is provided. Notably, the majority of the abrasive grains 203 of FIG. 4 are illustrated as having bright or shiny exposed tips extending above the bonding layer 201. The bright nature of the exposed tips of the abrasive grains 203 is evidence that the exposed tips are essentially free of a conductive carbon film. The darker color of the exposed tips of the abrasive grains of FIG. 3, demonstrate that the abrasive grains 103 have a significant amount of conductive carbon on the exposed tips.

EXAMPLE 1

A 430 stainless steel substrate having approximately 16% chromium is coated with pressure sensitive adhesive material K4-2-4 commercially available from Vitta Corporation. The adhesive material is in the form of a tape that can be applied to a major surface of the substrate. After, applying the adhesive, abrasive grains of

diamond having an average grit size of 151 microns are placed on the adhesive using a screening process.

After the abrasive grains are sufficiently set in the adhesive to form a conditioner preform, the preform is placed in a chamber and heated to 1020°C for 20 minutes.

5 During heating, the pressure of the atmosphere was reduced to approximately 10^{-5} Torr. The heating forms a binding layer of chromium carbide at the surface of the abrasive grains and at an interface between the substrate and abrasive grains and also volatilizes organics and water from the adhesive layer.

10 After heating the preform, a plasma cleaning process is completed using oxygen plasma to remove residual organics and clean the abrasive grains. The preform is then placed in an electroplating tank to form a bonding layer of nickel. The bonding layer had an average thickness of approximately 140 microns.

15 The surface geometry was measured using a Zygo 3D Surface Profilometer according to the description within the embodiments herein. The sample area of the measurements was 3 mm x 3 mm. The results of average surface roughness (R_a), surface roughness (R_z), surface roughness (R_{rms}), and average peak to valley measurements, are provided below in Table 1 for the sample of Example 1 and a comparative, conventional CMP conditioner illustrated in FIGs 1 and 3.

Table 1

Surface Roughness	Example 1	Comparative Sample
R_a (microns)	1.8	20.1
R_z (microns)	34	176
R_{rms} (microns)	2.6	25
Average Peak Valley (microns)	67	192

20 As demonstrated above, the CMP pad conditioner of Example 1 has improved surface geometry features over the comparative sample in all categories. In fact, in certain instances, Example 1 demonstrates a difference of certain surface features that are nearly a factor of 10 improved over the comparative sample.

The CMP pad conditioner and methods of forming disclosed herein represent a departure from the state of the art. In particular, the method of forming the CMP pad conditioner according to embodiments herein facilitates securing of abrasive grains in their original position and maintaining the original position of the abrasive grains throughout the forming process. Moreover, the forming process facilitates formation of a binding composition at the interface of the abrasive grains and the substrate and further facilitates formation of a bonding layer having a controlled thickness variation for improved control of abrasive grain exposure across the surface of the CMP pad conditioner. Furthermore, the CMP pad conditioner of the embodiments herein include a combination of features including improved control of spacing between abrasive grains, limited existence of conductive carbon films on the exposed tips of the abrasive grains, control of bonding layer thickness and variations in thickness, as well as surface roughness and existence of carbide crystals within the bonding layer.

In the foregoing, reference to specific embodiments and the connections of certain components is illustrative. It will be appreciated that reference to components as being coupled or connected is intended to disclose either direct connection between said components or indirect connection through one or more intervening components to carry out the methods as discussed herein. As such, the above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the true scope of the present invention. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

The Abstract of the Disclosure is provided to comply with Patent Law and is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description of the Drawings, various features may be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more

features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter may be directed to less than all features of any of the disclosed embodiments. Thus, the following claims are incorporated into the Detailed Description of the Drawings, with each claim standing on its own as
5 defining separately claimed subject matter.

WHAT IS CLAIMED IS:

1. A chemical mechanical planarization (CMP) pad conditioner comprising:
a substrate; and
abrasive grains contained within a bonding layer overlying the substrate, wherein
the abrasive grains comprise an average grit size of less than about 90
5 microns; and
wherein the CMP pad conditioner comprises an upper surface having an average
surface roughness (Ra) of not greater than about 15 microns.

2. A chemical mechanical planarization (CMP) pad conditioner comprising:
a substrate; and
10 abrasive grains contained within a bonding layer overlying the substrate, wherein
a binding composition comprising a carbide is present at a surface of the
abrasive grains; and
wherein the CMP pad conditioner comprises an upper surface having an average
surface roughness (Ra) of not greater than about 15 microns.

15 3. The CMP pad conditioner of any one of claims 1 or 2, wherein the average
surface roughness (Ra) is within a range between about 0.1 microns and about 15
microns.

4. The CMP pad conditioner of any one of claims 1 or 2, wherein the upper
surface of the CMP pad conditioner comprises an average surface roughness (Rz) of not
20 greater than about 100 microns.

5. The CMP pad conditioner of any one of claims 1 or 2, wherein the average
surface roughness (Rz) within a range between about 1 micron and about 100 microns.

6. The CMP pad conditioner of any one of claims 1 or 2, wherein the upper surface of the CMP pad conditioner comprises an average surface roughness (Rrms) of not greater than about 20 microns.

7. The CMP pad conditioner of any one of claims 1 or 2, wherein the substrate
5 comprises a metal.

8. The CMP pad conditioner of any one of claims 1 or 2, wherein the substrate comprises steel.

9. The CMP pad conditioner of any one of claims 1 or 2, wherein the substrate comprises at least about 2% chromium.

10. The CMP pad conditioner of any one of claims 1 or 2, wherein the substrate
10 comprises chromium in an amount within a range between about 2% and about 30%.

11. The CMP pad conditioner of any one of claims 1 or 2, wherein the abrasive grains comprise a superabrasive material.

12. The CMP pad conditioner of any one of claims 1 or 2, wherein the abrasive
15 grains consist essentially of diamond.

13. The CMP pad conditioner of any one of claims 1 or 2, wherein the abrasive grains have an average grit size of not greater than about 85 microns.

14. The CMP pad conditioner of any one of claims 1 or 2, wherein the abrasive grains have an average grit size within a range between about 1 micron and about 90
20 microns.

15. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises a metal or metal alloy.

16. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises at least one transition metal element.

17. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises a metal selected from the group consisting of Ni, Cr, Au, Ag, Pt, Pd, Rh,
5 W, Ti, V, Co, Cu, Zn, Mo, and a combination thereof.

18. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises an alloy comprising Ni and W.

19. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises a series of films overlying each other.

10 20. The CMP pad conditioner of claim 19, wherein each of the films comprises a metal element.

21. The CMP pad conditioner of claim 19, wherein each of the films can have a composition that is different than a composition of an adjacent film.

15 22. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises not greater than about 5 vol% carbide crystals of the total volume of the bonding layer.

23. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer is essentially free of carbide crystals.

20 24. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer is essentially free of carbide crystals.

25. The CMP pad conditioner of any one of claims 1 or 2, wherein the carbide crystals have an average size of not greater than about 50 microns.

26. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding layer comprises an average thickness that is at least about 30% of the average grit size of the abrasive grains.

27. The CMP pad conditioner of any one of claims 1 or 2, wherein the bonding
5 layer comprises an average thickness that is within a range between about 30% and about 90% of the average grit size of the abrasive grains.

28. A chemical mechanical planarization (CMP) pad conditioner comprising:
a substrate; and
abrasive grains contained within a bonding layer overlying the substrate, wherein
10 an exterior surface of the abrasive grains comprise a binding composition comprising a carbide, and wherein abrasive grains have exposed tips and wherein a majority of the exposed tips are essentially free of a conductive carbon film.

29. The CMP pad conditioner of claim 28, wherein at least about 80% of the total
15 number of abrasive grains have exposed tips essentially free of a carbon film.

30. The CMP pad conditioner of claim 28, wherein an average surface roughness (Ra) of an upper surface of the CMP pad conditioner is not greater than about 15 microns.

31. The CMP pad conditioner of claim 28, wherein an average surface roughness
20 (Ra) of an upper surface of the CMP pad conditioner is within a range between about 0.1 microns and about 15 microns.

32. The CMP pad conditioner of claim 28, wherein the CMP pad conditioner comprises an upper surface having an average surface roughness (Rz) of not greater than about 100 microns.

33. The CMP pad conditioner of claim 28, wherein an average surface roughness (Rz) of an upper surface of the CMP pad conditioner is within a range between about 1 micron and about 100 microns.

34. The CMP pad conditioner of claim 28, wherein the CMP pad conditioner
5 comprises an upper surface having an average surface roughness (Rrms) of not greater than about 20 microns.

35. The CMP pad conditioner of claim 28, wherein an average surface roughness (Rrms) of an upper surface of the CMP pad conditioner is within a range between about 0.1 microns and about 20 microns.

10 36. The CMP pad conditioner of claim 28, wherein the substrate comprises at least about 2% chromium.

37. The CMP pad conditioner of claim 28, wherein the abrasive grains comprise a superabrasive material.

15 38. The CMP pad conditioner of claim 28, wherein the abrasive grains consist essentially of diamond.

39. The CMP pad conditioner of claim 28, wherein the bonding layer is essentially free of carbide crystals.

40. The CMP pad conditioner of claim 28, wherein the conductive carbon film is polycrystalline.

20 41. A method of forming a chemical mechanical planarization (CMP) pad conditioner comprising:
placing abrasive grains on a major surface of a substrate;
forming a binding composition at an exterior surface of the abrasive grains; and

depositing a bonding layer over the surface of the substrate and a portion of the abrasive grains to secure the abrasive grains to the major surface of the substrate.

42. The method of claim 41, further comprising placing an adhesive on a major surface of the substrate prior to placing the abrasive grains on the major surface of the substrate.

43. The method of claim 42, wherein the adhesive comprises an organic material.

44. The method of claim 42, wherein the abrasive grains are held in position by the adhesive.

45. The method of claim 41, wherein depositing includes a plating process.

46. The method of claim 45, wherein depositing includes electroplating.

47. The method of claim 41, wherein deposition includes electroplating a bonding layer including a metal selected from the group consisting of Ni, Cr, Au, Ag, Pt, Pd, Rh, W, Ti, V, Co, Cu, Zn, Mo, and a combination thereof.

48. The method of claim 41, further comprising cleaning the abrasive grains and surface of the substrate prior to depositing the bonding layer.

49. The method of claim 48, wherein cleaning includes a plasma cleaning process.

50. The method of claim 49, wherein cleaning includes a plasma material selected from the group consisting of oxygen, hydrogen, and a combination thereof.

51. The method of claim 48, wherein cleaning includes removal of a thin film of conductive carbon from a portion of the surfaces of the abrasive grains.

52. The method of claim 41, wherein forming includes heating the substrate and abrasive grains.

53. The method of claim 52, wherein heating volatilizes organic material from an adhesive.

5 54. The method of claim 52, wherein heating causes a chemical reaction and formation of the binding composition.

55. The method of claim 52, wherein heating is conducted in an inert atmosphere.

56. The method of claim 52, wherein heating is conducted at a heating temperature of at least about 500°C.

10 57. The method of claim 52, wherein heating is conducted at a heating temperature of within a range between about 700°C and about 1200°C.

58. The method of claim 41, wherein the binding composition is formed at an interface of the abrasive grains and the substrate.

59. The method of claim 41, wherein the binding composition comprises a metal.

15 60. The method of claim 59, wherein the binding composition comprises transition metal element.

61. The method of claim 41, wherein the binding composition comprises chromium carbide.

20 62. The method of claim 41, wherein the abrasive grains have an average grit size of not greater than about 300 microns.

63. The method of claim 41, wherein the abrasive grains have an average grit size within a range between about 1 micron and about 90 microns.

64. The method of claim 41, wherein the bonding layer is essentially free of chromium carbide crystals.

5 65. The method of claim 41, wherein the substrate comprises a metal or metal alloy.

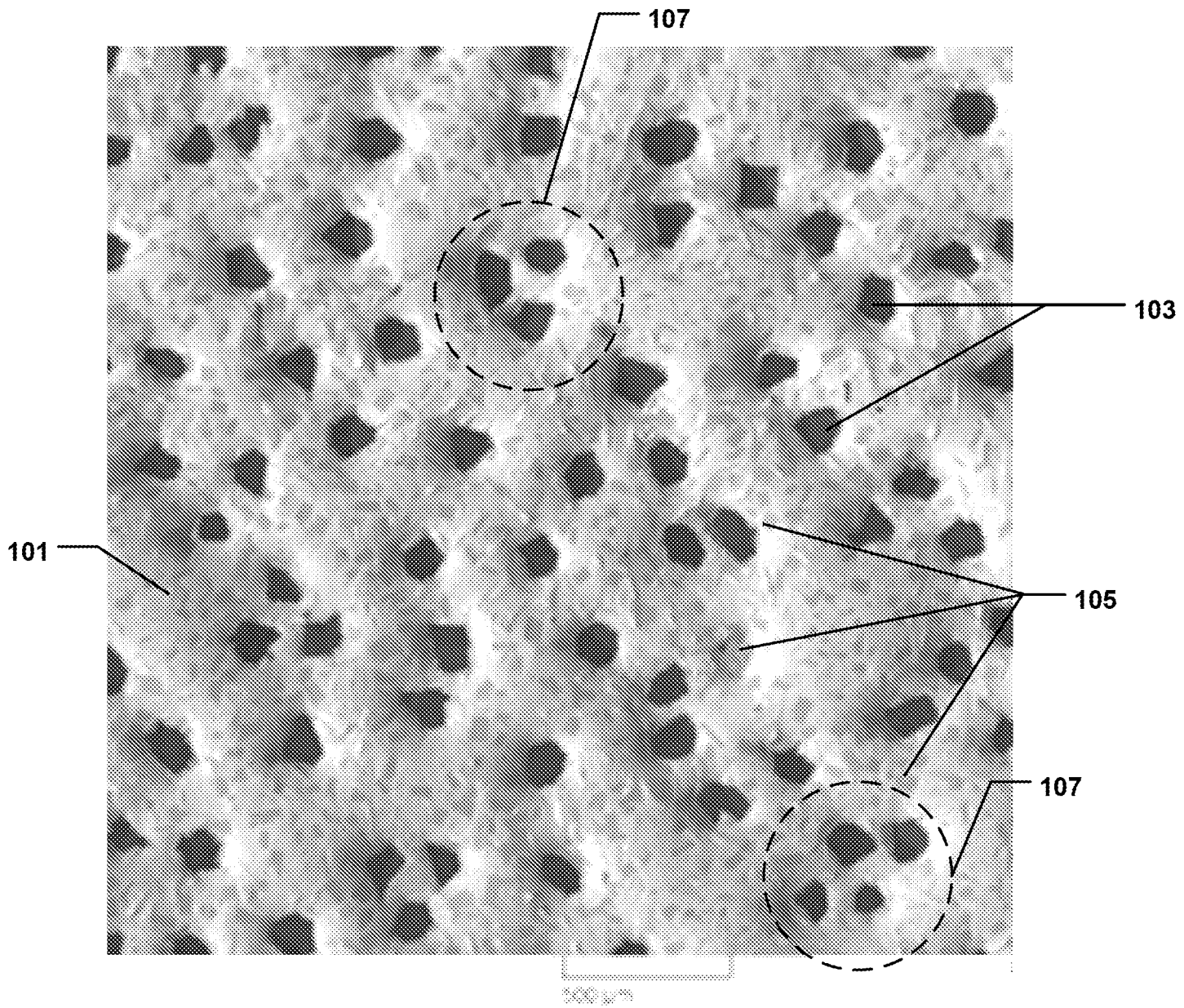
66. The method of claim 41, wherein the substrate comprises at least about 2% chromium.

10 67. The method of claim 41, wherein the substrate comprises chromium in an amount within a range between about 2% and about 30%.

68. The method of claim 41, further comprising treating the substrate after depositing the bonding layer to form a secondary binding composition at an interface of the abrasive grains and bonding layer.

15 69. The method of claim 68, wherein treating comprises heating to a temperature to create a secondary binding composition.

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**FIG. 1**

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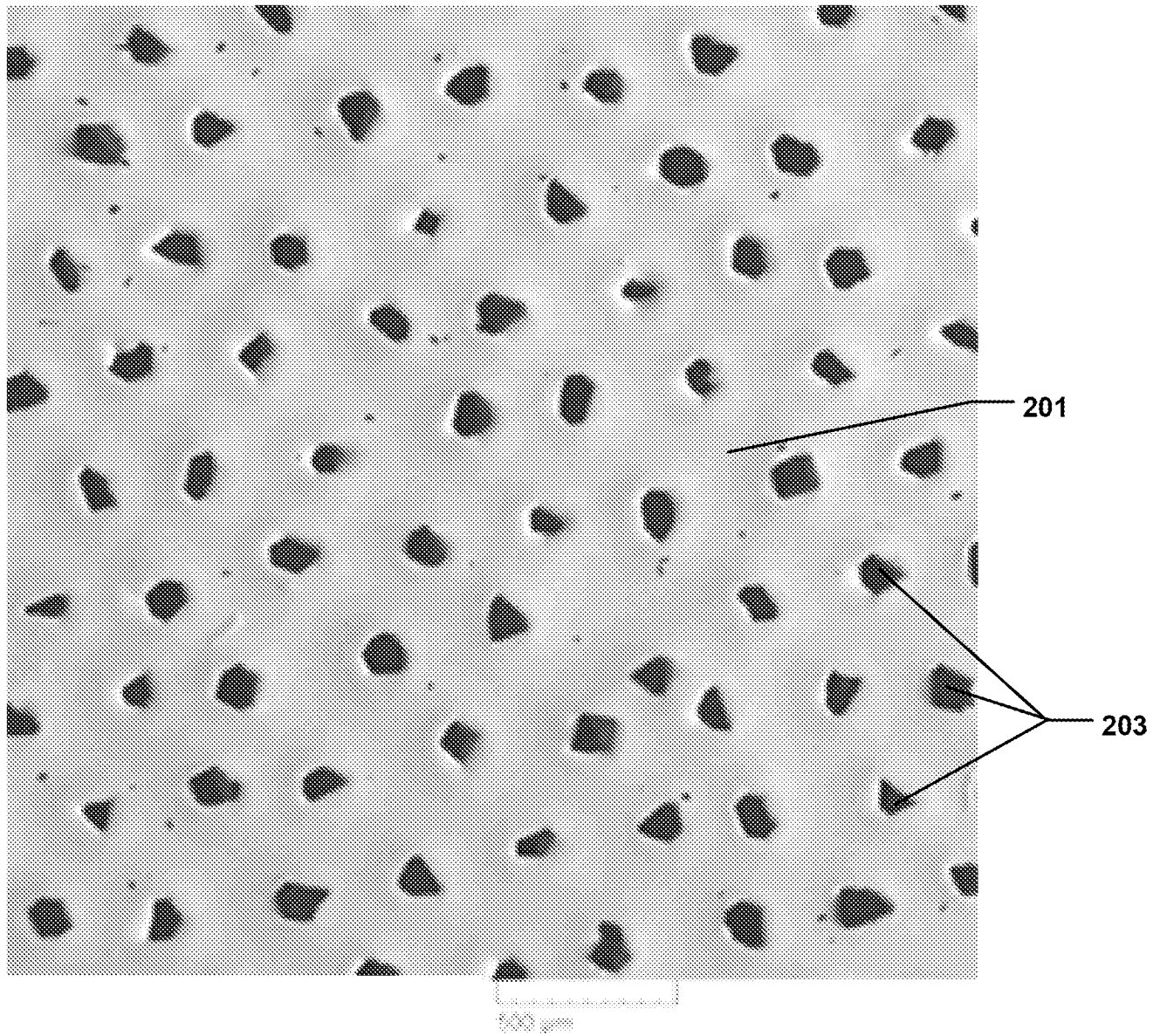


FIG. 2

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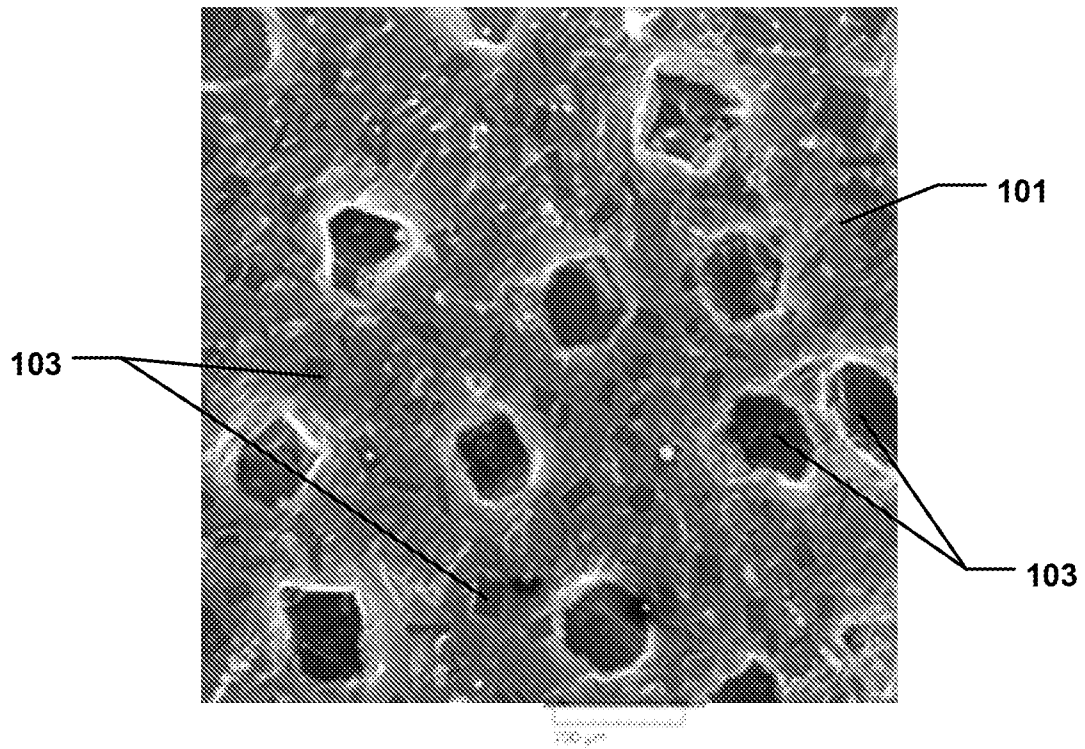


FIG. 3

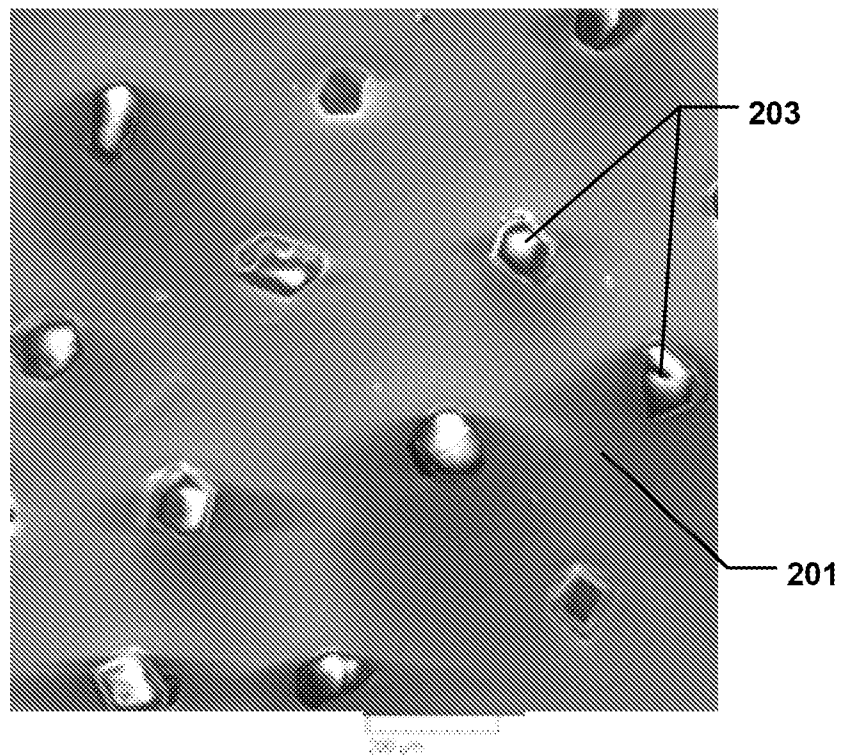


FIG. 4