

exposed surface of the pad contains open cells, which can be used during the CMP process to trap abrasive slurry consisting of the spent polishing slurry and material removed from the wafer. In each subsequent pad-conditioning step, the pad conditioner removes the outer layer of cells containing the embedded materials and minimizes removal of layers below the outer layer. Over-texturing of the polishing pad results in a shortened life, while under-texturing results in insufficient material removal rate and lack of wafer uniformity during the CMP step.

One type of CMP pad conditioner is a four-inch disc with fixed diamond abrasives. The diamond coated disc is rotated and pressed onto the polishing pad surface to cut and remove the top layer. The diamonds are typically set in an epoxy or a metal matrix material. However diamonds from these pad conditioners can become dislodged which can lead to yield loss due to scratching of the wafer during the polishing operation.

There is a continuing need for CMP pad dressers that reduce or eliminate abrasive particles becoming dislodged and CMP pad dressers that have varying surface heights for dressing CMP polishing pads.

SUMMARY

In a first aspect, there is provided a chemical mechanical polishing pad conditioner, comprising: a substrate including a front surface having a plurality of protrusions integral therewith, said plurality of protrusions extending in a frontal direction that is substantially normal to said front surface, each of said plurality of protrusions including a distal extremity, said plurality of protrusions including: a subset of said plurality of protrusions having said distal extremities that are within a variance of a registration plane, said registration plane being substantially parallel to said front surface, the protrusions of said subset of said plurality of protrusions being located on said registration plane in a fixed and predetermined relationship relative to each other; and a coating of polycrystalline diamond that covers at least said distal extremities of said subset of said plurality of protrusions, wherein said substrate has a porosity of at least 10 %.

5 In a second aspect, there is provided a chemical mechanical polishing pad conditioner, comprising: a substrate including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of the
10 respective registration axes defining a predetermined location on said front surface of said substrate, said plurality of protrusions including: a first subset of protrusions identified by said predetermined locations on said front surface, said predetermined locations of said first subset of protrusions defining a first predetermined pattern, said first subset of protrusions having a first average height; and a second subset of protrusions identified by
15 said predetermined locations on said front surface, said predetermined locations of said second subset of protrusions defining a second predetermined pattern, said second subset of protrusions having a second average height, said second average height being less than said first average height, at least a portion of said second subset of protrusions being interspersed amongst at least a portion of said first subset of protrusions, wherein a
20 fraction of said second subset of protrusions have respective heights that are greater than the respective height of at least one of said first subset of protrusions, wherein said substrate has a porosity of at least 10 %.

25 In a third aspect, there is provided a pad conditioner comprising a substrate with a matrixical arrangement of raised cutting regions, each of the cutting regions having
30 irregularly shaped peaks with respect to adjacent cutting regions, wherein the substrate, including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of said plurality of protrusions including a distal extremity located on a mesa of the respective protrusion, said mesa defined as being
35 within a predetermined distance from said distal extremity of the respective protrusion in a direction opposite said frontal direction, each of the respective registration axes defining a predetermined location on said front surface of said substrate, each of said plurality of protrusions defining a cross-section at the base of said mesa, said cross-section defining a centroid, wherein, for at least a portion of said plurality of protrusions, said centroid of
40 each of said cross-sections is offset from said respective registration axis.

In various embodiments of the invention, a pad conditioner machined from a substrate to have a desired distribution of feature heights and mesa roughness characteristics is provided. The pad conditioner is free of superabrasive particles such as diamond particles adhered to the substrate, eliminating the problem of particles being dislodged from a pad conditioner. Instead, the protrusions on the shaped ceramic act as geometric features that provide force concentrations on the pad surface. The cutting performance and longevity of these features is greatly enhanced by a polycrystalline CVD diamond coating that is grown over the surface protrusions. Versions of the present invention include a pad conditioner and methods of making the pad conditioner.

In one embodiment, the machining process capitalizes on the characteristics of a porous substrate material to provide the distribution and roughness characteristics. Because the features are machined from a substrate, the need to bond particles to a substrate is eliminated.

In one embodiment, the features are arranged in a predetermined pattern. The pattern can be matrixical, that is, uniformly distributed in a repeating, matrix pattern. The

AMENDED CLAIMS
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1. A chemical mechanical polishing pad conditioner, comprising:
 - a substrate including a front surface having a plurality of protrusions integral therewith, said plurality of protrusions extending in a frontal direction that is substantially normal to said front surface, each of said plurality of protrusions including a distal extremity, said plurality of protrusions including:
 - a subset of said plurality of protrusions having said distal extremities that are within a variance of a registration plane, said registration plane being substantially parallel to said front surface, the protrusions of said subset of said plurality of protrusions being located on said registration plane in a fixed and predetermined relationship relative to each other; and
 - a coating of polycrystalline diamond that covers at least said distal extremities of said subset of said plurality of protrusions,
 - wherein said substrate has a porosity of at least 10 %.
2. The pad conditioner of claim 1, wherein said substrate includes pore dimensions greater than 20 μm .
3. The pad conditioner of claim 1 or 2, wherein each of said distal extremities is located on a mesa of a respective protrusion of said subset of said plurality of protrusions, said mesa defined as being within a predetermined distance from said distal extremity of the respective protrusion in a direction opposite said frontal direction.
4. The pad conditioner of claim 3 wherein said predetermined distance from said distal extremity is between about 0.3 μm and 20 μm .
5. The pad conditioner of claim 3 or 4, wherein said coating of polycrystalline diamond on said distal extremities of said protrusions has a root-mean-square roughness across said mesa, and wherein said predetermined distance from said distal extremity is about three to five times said root-mean-square roughness.
6. The pad conditioner of claim 5, wherein said root-mean-square roughness of said polycrystalline diamond across said mesa is between 0.5 μm and 10 μm .

7. The pad conditioner of any of claims 3-6, wherein said mesa is defined as a fixed percentage of a prominence height of said respective protrusion.
8. The pad conditioner of claim 7, wherein said fixed percentage is within a range of 5% to 50%.
9. The pad conditioner of any of claims 1 - 8, wherein said variance is in the range of 5 μm to 50 μm .
10. The pad conditioner of claim 9, wherein said variance is in the range of 10 μm to 25 μm .
11. The pad conditioner of any of claims 1 - 9, wherein said substrate is comprised of silicon carbide.
12. A chemical mechanical polishing pad conditioner, comprising:
 - a substrate including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of the respective registration axes defining a predetermined location on said front surface of said substrate, said plurality of protrusions including:
 - a first subset of protrusions identified by said predetermined locations on said front surface, said predetermined locations of said first subset of protrusions defining a first predetermined pattern, said first subset of protrusions having a first average height; and
 - a second subset of protrusions identified by said predetermined locations on said front surface, said predetermined locations of said second subset of protrusions defining a second predetermined pattern, said second subset of protrusions having a second average height, said second average height being less than said first average height, at least a portion of said second subset of protrusions being interspersed amongst at least a portion of said first subset of protrusions,
 - wherein a fraction of said second subset of protrusions have respective heights that are greater than the respective height of at least one of said first subset of protrusions.
13. The chemical mechanical polishing pad conditioner of claim 12 wherein at least one of said first predetermined pattern and said second predetermined pattern is matrixical

14. The chemical mechanical polishing pad conditioner of claim 12 or 13 wherein said fraction of said second subset of protrusions having respective heights greater than the respective heights of at least one of said first subset of protrusions is greater than 20%.

15. (Original) The chemical mechanical polishing pad conditioner of claims 12, 13 or 14, wherein said first average height, said second average height and said respective heights are prominence heights.

16. The chemical mechanical polishing pad conditioner of claim 15, wherein said first average height is greater than 100 μm and said second average height is less than 100 μm .

17. The chemical mechanical polishing pad conditioner of claim 15, wherein said first average height is greater than 40 μm and said second average height is less than 40 μm .

18. The chemical mechanical polishing pad conditioner of any of claims 12-17, wherein a difference between said first average height and said second average height is in a range of 10 μm to 80 μm .

19. A chemical mechanical polishing pad conditioner, comprising:

a substrate including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, said plurality of protrusions including:

a first subset of protrusions, each having a first base dimension that is substantially similar, said first subset of protrusions defining a first pattern and defining a first statistical distribution having a first average height and a first standard deviation; and

a second subset of protrusions, each having a second base dimension that is substantially similar, said second subset of protrusions defining a second pattern and defining a second statistical distribution having a second average height and a second standard deviation, said first statistical distribution and said second statistical distribution combining to define a bimodal distribution,

wherein said first base dimension is greater than said second base dimension and at least a portion of said second subset of protrusions are interspersed amongst at least a portion of said first subset of protrusions.

20. The chemical mechanical polishing pad conditioner of claim 19 wherein at least one of said first predetermined pattern and said second predetermined pattern is matrixical
21. The chemical mechanical polishing pad conditioner of claim 19 or 20 wherein second average height is less than said first average height.
22. The chemical mechanical polishing pad conditioner of claims 19, 20 or 21 wherein said first and second base dimensions are measured at a distance of about 5 μm to about 10 μm in said frontal direction from a lowest encircling contour line of each respective protrusion.
23. The chemical mechanical polishing pad conditioner of claims 19, 20 or 21 wherein said first and second base dimensions are measured at a distance of about 5% to about 20% of a respective height of a protrusion in said frontal direction from a lowest encircling contour line of the respective protrusion.
24. The chemical mechanical polishing pad conditioner of any of claims 19 - 23, wherein a fraction of said second subset of protrusions have respective heights that are greater than the respective height of at least one of said first subset of protrusions.
25. The chemical mechanical polishing pad conditioner of any of claims 19 - 24, wherein said first base dimension and said second base dimension is a diameter.
26. A chemical mechanical polishing pad conditioner, comprising:
- a substrate including a front surface having a plurality of protrusions integral therewith, said plurality of protrusions extending in a frontal direction that is substantially normal to said front surface, each of said plurality of protrusions including a distal extremity, said plurality of protrusions including:
 - a first subset of protrusions having said distal extremities that are within a first variance centered about a first registration plane, said first registration plane being substantially parallel to said front surface, the protrusions of said first subset of protrusions being located on said substrate in a predetermined relationship relative to each other; and
 - a second subset of protrusions having said distal extremities that are within a second variance centered about a second registration plane, said second registration plane

being substantially parallel to said front surface, the protrusions of said second subset of protrusions being located on said substrate in a fixed and predetermined relationship relative to each other, at least a portion of said second subset of protrusions being interspersed amongst at least a portion of said first subset of protrusions,

each of said second subset of protrusions having a root-mean-square surface roughness that is greater than 3 μm .

27. The pad conditioner of claim 26, wherein at least one of said first variance and said second variance is in a range of 10 μm to 60 μm .

28. The pad conditioner of claim 26 or 27, wherein the protrusions of said first subset of said plurality of protrusions pass through said second registration plane of said second subset of said plurality of protrusions at locations that are predetermined relative to said second subset of said plurality of protrusions.

29. (Original) The pad conditioner of claims 26, 27 or 28, wherein said first subset of said plurality of protrusions are uniformly distributed with respect to each other

30. The pad conditioner of any of claims 26-29, wherein said first registration plane is nominally offset from said second registration plane in said frontal direction by an offset distance that is greater than one of said first variance and said second variance.

31. The pad conditioner of claim 30, wherein said offset distance is at least two times greater than one of said first variance and said second variance.

32. The pad conditioner of claim 30, wherein said offset distance is 10 μm or greater.

33. The pad conditioner of any of claims 26-32, further comprising a coating of polycrystalline diamond that covers at least one of said distal extremities of said first subset or of said second subset of said plurality of protrusions.

34. The pad conditioner of claim 33, wherein said coating of polycrystalline diamond is between 2 μm and 30 μm thickness.

35. The pad conditioner of claim 33 or 34, wherein said coating of polycrystalline diamond has a root-mean-square roughness greater than 3 μm .

36. The pad conditioner of claim 35, wherein said root-mean-square roughness is less than 10 μm .
37. The pad conditioner of any of claims 26-36, wherein said predetermined relationship of the protrusions of said first subset of said plurality of protrusions establish a repeating pattern.
38. The pad conditioner of claim 37, wherein said repeating pattern is matrixical.
39. The pad conditioner of any of claims 26-38, wherein said substrate is a porous material having a porosity greater than 10 %.
40. The pad conditioner of any of claims 26-39, wherein said substrate is a porous material including pore dimensions greater than 20 μm .
41. A pad conditioner comprising a substrate with a matrixical arrangement of raised mesas, each of the mesas having a highest peak of the mesa with an elevation and wherein elevations of highest peaks of adjacent mesas have different elevations.
42. A pad conditioner comprising a substrate with a matrixical arrangements of raised mesas, each of the mesas having peaks of varying elevations and shapes with respect to adjacent mesas.
43. A pad conditioner comprising a substrate with a matrixical arrangement of raised cutting regions, each of the cutting regions having an irregularly positioned highest peak with respect to adjacent cutting regions in the matrixical arrangement.
44. A conditioner comprising a substrate with a matrixical arrangement of raised cutting regions, each of the cutting regions having irregularly shaped peaks with respect to adjacent cutting regions.
45. A conditioner comprising a substrate with a matrixical arrangements of raised cutting regions, each of the cutting regions having a highest peak of the mesa with an elevation and wherein elevations of highest peaks of adjacent cutting regions have different elevations.
46. A conditioner comprising a substrate with a matrixical arrangements of raised cutting regions, each of the cutting regions having a peak of a different elevation and a different shape compared to the elevation and shape of the respective peaks of adjacent cutting regions in the matrixical arrangement.

47. A pad conditioner comprising a substrate with a matrixical arrangement of raised mesas, each of the mesas having an irregularly positioned highest peak with respect to adjacent mesas.

48. A pad conditioner having an arrangement of raised cutting regions generally arranged in a non random repeating pattern, the raised cutting regions being irregularly shaped with respect to one another.

49. The pad conditioner of any one of claims 41 through 48 wherein the pad conditioner has a circular shape comprises silicon carbide.

50. The pad conditioner of any one of claims 41 through 49 wherein the silicon carbide has a porosity of at least about 10 per cent, the pad conditioner

51. A pad conditioner, comprising:

a substrate including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of said plurality of protrusions including a distal extremity located on a mesa of the respective protrusion, said mesa defined as being within a predetermined distance from said distal extremity of the respective protrusion in a direction opposite said frontal direction, each of the respective registration axes defining a predetermined location on said front surface of said substrate, each of said plurality of protrusions defining a cross-section at the base of said mesa, said cross-section defining a centroid,

wherein, for at least a portion of said plurality of protrusions, said centroid of each of said cross-sections is offset from said respective registration axis.

52. The pad conditioner of claim 51, wherein each of said cross-sections defines a respective major dimension, and wherein, for said portion of said plurality of protrusions, said centroid of said cross-section is offset from said respective registration axis by a distance that is at least 5% of said major dimension.

53. The pad conditioner of any of claims 51 or 52, wherein said mesa is defined as a fixed percentage of a prominence height of said respective protrusion, said fixed percentage ranging from 5% to 10% of said prominence height.

54. The pad conditioner of claims 51, 52, or 53 further comprising:

a first subset of protrusions that defines a first pattern; and

a second subset of protrusions that defines a second pattern,

wherein at least a portion of the protrusions from said second subset of protrusions are interspersed amongst at least a portion of the protrusions from said first subset of protrusions.

CLAIMS:

1. A chemical mechanical polishing pad conditioner, comprising:
 - a substrate including a front surface having a plurality of protrusions integral therewith, said plurality of protrusions extending in a frontal direction that is substantially normal to said front surface, each of said plurality of protrusions including a distal extremity, said plurality of protrusions including:
 - a subset of said plurality of protrusions having said distal extremities that are within a variance of a registration plane, said registration plane being substantially parallel to said front surface, the protrusions of said subset of said plurality of protrusions being located on said registration plane in a fixed and predetermined relationship relative to each other; and
 - a coating of polycrystalline diamond that covers at least said distal extremities of said subset of said plurality of protrusions,
 - wherein said substrate has a porosity of at least 10 %.
2. The pad conditioner of claim 1, wherein said substrate includes pore dimensions greater than 20 μm .
3. The pad conditioner of claim 1, wherein each of said distal extremities is located on a mesa of a respective protrusion of said subset of said plurality of protrusions, said mesa defined as being within a predetermined distance from said

distal extremity of the respective protrusion in a direction opposite said frontal direction.

4. The pad conditioner of claim 3 wherein said predetermined distance from said distal extremity is between about 0.3 μm and 20 μm .

5. The pad conditioner of claim 3, wherein said coating of polycrystalline diamond on said distal extremities of said protrusions has a root-mean-square roughness across said mesa, and wherein said predetermined distance from said distal extremity is about three to five times said root-mean-square roughness.

6. The pad conditioner of claim 5, wherein said root-mean-square roughness of said polycrystalline diamond across said mesa is between 0.5 μm and 10 μm .

7. The pad conditioner of claim 3, wherein said mesa is defined as a fixed percentage of a prominence height of said respective protrusion.

8. The pad conditioner of claim 7, wherein said fixed percentage is within a range of 5% to 50%.

9. The pad conditioner of claim 1, wherein said variance is in the range of 5 μm to 50 μm .

10. The pad conditioner of claim 9, wherein said variance is in the range of 10 μm to 25 μm .

11. The pad conditioner of claim 3, wherein said substrate is comprised of silicon carbide.
12. The chemical mechanical polishing pad conditioner of claim 1, wherein said porosity is less than 60%.
13. A chemical mechanical polishing pad conditioner, comprising:
 - a substrate including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of the respective registration axes defining a predetermined location on said front surface of said substrate, said plurality of protrusions including:
 - a first subset of protrusions identified by said predetermined locations on said front surface, said predetermined locations of said first subset of protrusions defining a first predetermined pattern, said first subset of protrusions having a first average height; and
 - a second subset of protrusions identified by said predetermined locations on said front surface, said predetermined locations of said second subset of protrusions defining a second predetermined pattern, said second subset of protrusions having a second average height, said second average height being less than said first average height, at least a portion of said second subset of protrusions being interspersed amongst at least a portion of said first subset of protrusions,

wherein a fraction of said second subset of protrusions have respective heights that are greater than the respective height of at least one of said first subset of protrusions,

wherein said substrate has a porosity of at least 10 %.

14. The chemical mechanical polishing pad conditioner of claim 13 wherein at least one of said first predetermined pattern and said second predetermined pattern is matrixical.

15. The chemical mechanical polishing pad conditioner of claim 14 wherein said fraction of said second subset of protrusions having respective heights greater than the respective heights of at least one of said first subset of protrusions is greater than 20%.

16. The chemical mechanical polishing pad conditioner of claim 13, wherein said first average height, said second average height and said respective heights are prominence heights, and wherein said first average height is greater than 100 μm and said second average height is less than 100 μm .

17. The chemical mechanical polishing pad conditioner of claim 13, wherein said first average height, said second average height and said respective heights are prominence heights, and wherein said first average height is greater than 40 μm and said second average height is less than 40 μm .

18. The chemical mechanical polishing pad conditioner of claim 13, wherein said porosity is less than 60%.

19. A pad conditioner comprising a substrate with a matrixical arrangement of raised cutting regions, each of the cutting regions having irregularly shaped peaks with respect to adjacent cutting regions,

wherein the substrate, including a front surface having a plurality of protrusions integral therewith, each of said plurality of protrusions extending in a frontal direction about a respective registration axis normal to said front surface, each of said plurality of protrusions including a distal extremity located on a mesa of the respective protrusion, said mesa defined as being within a predetermined distance from said distal extremity of the respective protrusion in a direction opposite said frontal direction, each of the respective registration axes defining a predetermined location on said front surface of said substrate, each of said plurality of protrusions defining a cross-section at the base of said mesa, said cross-section defining a centroid,

wherein, for at least a portion of said plurality of protrusions, said centroid of each of said cross-sections is offset from said respective registration axis.

20. The conditioner of claim 19, wherein each of the cutting regions having a peak of a different elevation compared to the elevation of the respective peaks of adjacent cutting regions in the matrixical arrangement.

21. The pad conditioner of claim 19, wherein each of said cross-sections defines a respective major dimension, and wherein, for said portion of said plurality of protrusions, said centroid of said cross-section is offset from said respective registration axis by a distance that is at least 5% of said major dimension.

22. The pad conditioner of claim 19, wherein said mesa is defined as a fixed percentage of a prominence height of said respective protrusion, said fixed percentage ranging from 5% to 10% of said prominence height.

23. The pad conditioner of claim 19 further comprising:
a first subset of protrusions that defines a first pattern; and
a second subset of protrusions that defines a second pattern,
wherein at least a portion of the protrusions from said second subset of
protrusions are interspersed amongst at least a portion of the
protrusions from said first subset of protrusions.