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(54) **CHEMICAL-MECHANICAL POLISHING MACHINE FOR POLISHING A WAFER OF MATERIAL, AND AN ABRASIVE DELIVERY DEVICE FITTED TO SUCH A MACHINE**

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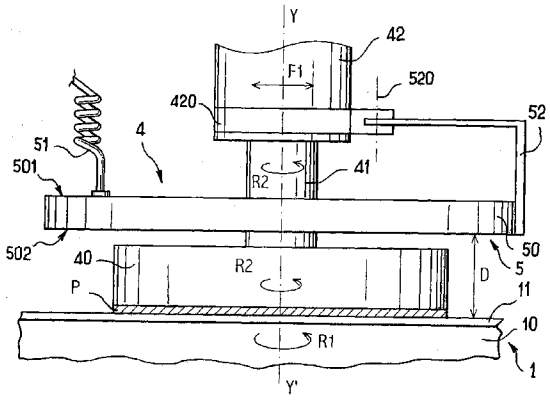
(57) **ABSTRACT**

The invention provides a chemical-mechanical polishing machine for polishing a wafer of a material, the machine comprising a rotary polishing turntable, a polishing head comprising a non-rotary portion and a rotary portion, and means for delivering an abrasive to the surface of the polishing turntable. The machine is remarkable in the means for distributing the abrasive comprise a hollow abrasive delivery ring fitted with abrasive feed means, with a plurality of abrasive delivery orifices distributed over its bottom face, and fixing means enabling it to be secured to the non-rotary portion of the polishing head, the ring being disposed around the rotary portion in a plane that is substantially parallel to the plane of the polishing turntable, but that is spaced apart therefrom. The invention is applicable to polishing wafers of semiconductor material.



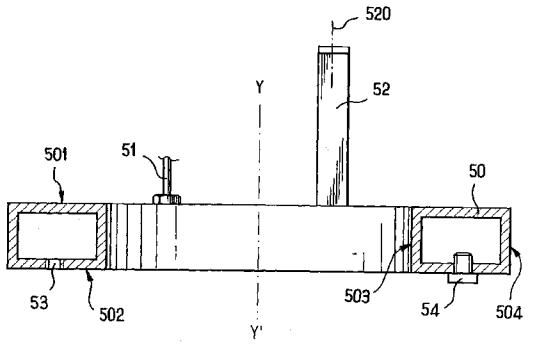


FIG.1

PRIOR ART

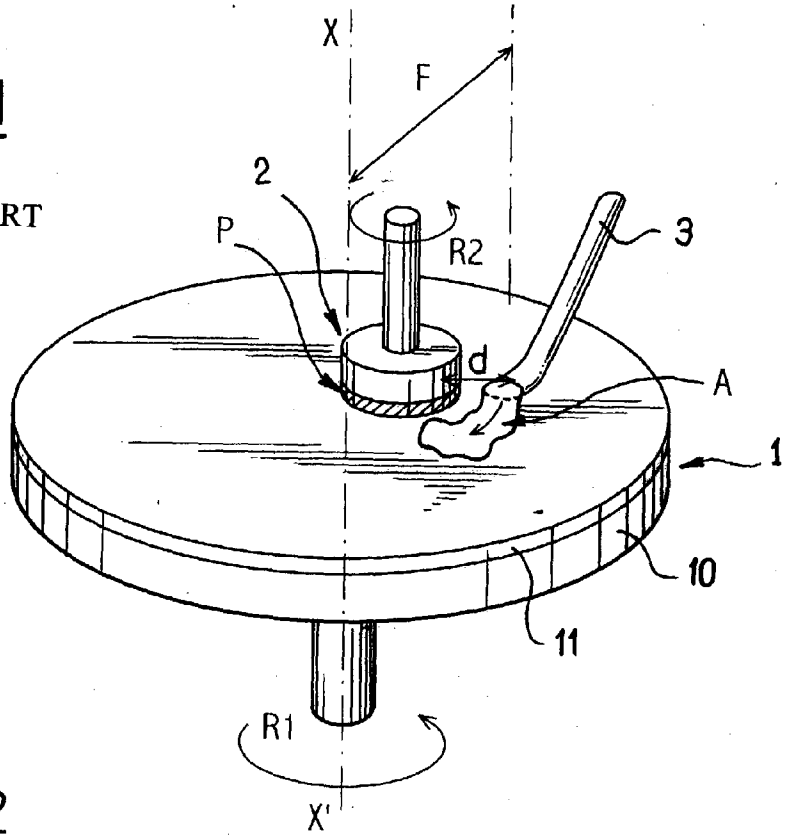


FIG.2

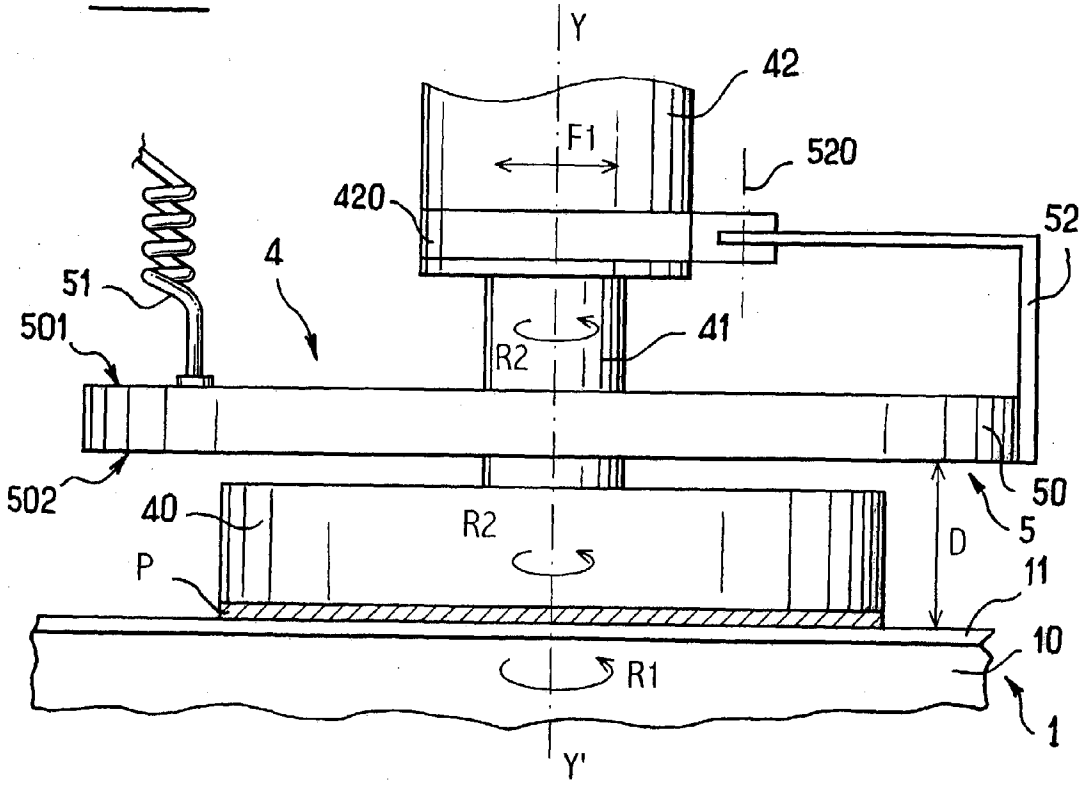


FIG.3

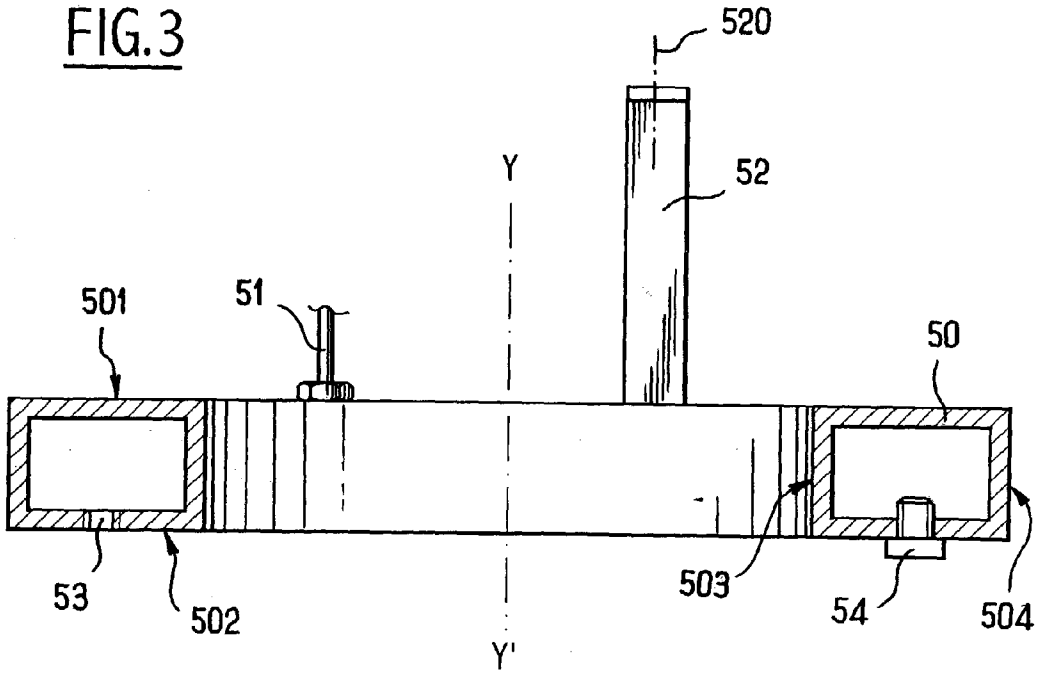
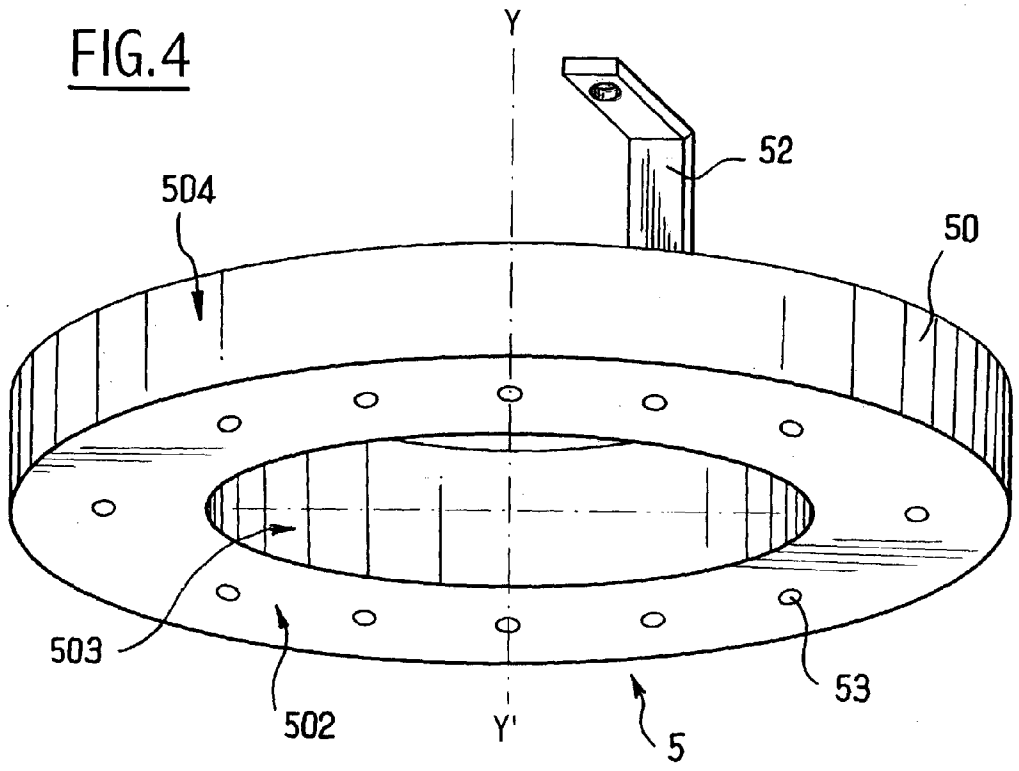


FIG.4



CHEMICAL-MECHANICAL POLISHING MACHINE FOR POLISHING A WAFER OF MATERIAL, AND AN ABRASIVE DELIVERY DEVICE FITTED TO SUCH A MACHINE

FIELD OF INVENTION

[0001] The present invention relates to a chemical-mechanical polishing machine for polishing a wafer of material for use in fabricating substrates in optics, optoelectronics, or electronics, in particular a wafer of semiconductor material. The invention also relates to a device for delivering abrasive that is fitted to such a machine.

BACKGROUND OF THE INVENTION

[0002] The above-mentioned wafers are used in fabricating integrated circuits. During such fabrication, techniques are used whereby layers coming from a first wafer constituting a source substrate are transferred and bonded directly onto a second wafer constituting a support. Such direct bonding techniques have very high requirements in terms of absence of roughness and flatness of the surfaces that are to be put into contact, and they require the surfaces of the wafers to be perfectly polished.

[0003] Furthermore, in some layer transfer methods, for example the method known under the name SMART CUT®, multiple layers are transferred from a wafer, and the surface of the wafer is reconditioned before each new operation of removing a layer. This reconditioning step is also performed by polishing.

[0004] In both the above-specified circumstances, polishing is performed by means of a chemical-mechanical polishing machine.

[0005] Such a machine is known to the skilled person and, as shown diagrammatically in **FIG. 1**, generally comprises: a polishing turntable **1**; a polishing head **2**; and one or more fixed members **3** for dispensing an abrasive A that is in the form of a paste or a liquid. By way of example, the abrasive may be colloidal silica.

[0006] The polishing turntable **1** comprises a disk **10** rotated about a vertical axis X-X', this rotary movement being, symbolized by arrow R1.

[0007] The disk **10** is covered in a polishing cloth **11**.

[0008] The polishing head **2** is also rotary (arrow R2), and it generally turns in the same direction as the turntable **1**. It also has oscillating or reciprocating motion imparted thereto as symbolized by arrow F. This oscillating motion generally takes place along a radius of the turntable **1** in such a manner as to move the polishing head **2** in a plane parallel to that of the turntable **1**.

[0009] The polishing head **2** has fixing means (not shown in the figure) for fixing thereto a wafer P for polishing.

[0010] In general, these fixing means comprise an insert (or diaphragm) of disk-shape made of a material having a high coefficient of adhesion, the insert being surrounded by a retaining ring secured to the polishing head **2**. The insert holds the wafer P for polishing via one of its faces, referred to as its "rear" face, and the retaining ring holds it via its edges.

[0011] These fixing means enable the wafer P to be rotated together with the polishing head **2**. The retaining ring prevents the wafer P from moving in translation and prevents it from being entrained by the linear speed produced by rotation of the turntable **1**.

[0012] In addition, the polishing head **2** enables the front face of the wafer P to be pressed against the polishing cloth **11** on the turntable **1**.

[0013] The front face of the wafer P is thus polished because of the relative movement between the polishing head **2** and the turntable **1**, i.e., by mechanical action, and it is also polished because of the presence of the chemical substance constituted by the abrasive A, hence the term "chemical-mechanical" polishing to designate the action of the machine.

[0014] The fact that the polishing head **2** has oscillating motion F imparted thereto while the polishing turntable **1** rotates, serves to ensure that the polishing cloth **1** is worn uniformly over its entire surface area.

[0015] This oscillation of the polishing head **2** also varies the distance d between the head and the abrasive dispenser member **3** which occupies a fixed point located substantially in the middle of a radius of the turntable **1**. This is a source of non-reproducibility in the polishing method.

[0016] In addition, when the distance d is large, i.e., when the polishing head **2** is maximally offset from the dispensing point **3** because it is located either in the center or at the edge of the turntable **1**, the abrasive A is observed to disperse, leading to significant loss of abrasive.

[0017] U.S. Pat. No. 6,398,906 discloses a chemical-mechanical polishing machine for a wafer similar to that described above.

[0018] In that machine, the polishing head is surround by a retaining ring whose face in contact with the polishing turntable presents an annular groove of upside-down U-shape. That groove in combination with the facing surface of the polishing turntable forms a "pocket" for an abrasive mixture, which mixture is fed into the U-shaped groove from an external supply via a tube. The abrasive mixture is distributed over the polishing turntable and slides between the turntable and the face of the wafer that is to be polished.

[0019] Nevertheless, that polishing machine presents numerous drawbacks.

[0020] First, since the retaining ring is rotated together with the polishing head, the tube feeding abrasive to the inside of the ring tends to become wound around the head which greatly impedes operation thereof.

[0021] In addition, the retaining ring is a wear part since it is in direct contact with the cloth covering the polishing turntable, and it therefore needs to be replaced regularly. Unfortunately, machining the U-shaped groove makes its structure rather complex. As a result, the retaining ring becomes more expensive to manufacture and replacing it also increases the overall cost of operating the polishing machine.

[0022] Finally, the abrasive is delivered via a U-shaped groove over the entire periphery of the retaining ring and there are no means for limiting its delivery at certain localized points.

[0023] U.S. Pat. No. 6,030,487 also discloses a chemical-mechanical polishing head for polishing a wafer, which head is provided with an additional device enabling both an abrasive mixture and a fluid for renovating the surface of a facing polishing turntable to be delivered simultaneously.

[0024] Such an additional device comprises four legs, each pierced by one or more channels enabling the above-mentioned fluid to be brought to a skirt element occupying one-fourth of a circle, and likewise pierced by a plurality of delivery orifices and channels.

[0025] That additional abrasive delivery device presents the drawback of being secured to the rotary polishing head, and as a result it too rotates, and the abrasive is delivered irregularly or is sprayed towards the outside of the wafer. A portion of the abrasive is thus not used for polishing, which is highly disadvantageous from an economic point of view.

[0026] Finally, U.S. Pat. No. 6,409,579 discloses a device for delivering an abrasive mixture used in a wafer polishing machine. That device comprises a wafer support of annular shape presenting a plurality of vertical abrasive delivery channels that open out in its plane bottom face.

[0027] That device suffers from the drawback that the channels are machined directly in the wafer support, even though it constitutes a wear part which must be replaced regularly in order to maintain the performance of the polishing machine. That wafer support of structure that is more complex than a conventional support is therefore more expensive, as is replacing it.

[0028] The present invention now remedies the above-mentioned drawbacks of the prior art and-provides-an improved polishing machine for this purpose.

SUMMARY OF THE INVENTION

[0029] The invention relates to a machine for polishing a wafer for use in fabricating substrates comprising a rotatable turntable; a polishing head for holding a wafer and being movable relative to the turntable, the polishing head comprising a non-rotary portion and a rotary portion for rotating the wafer while maintaining a surface of the wafer in contact with the turntable; and means for delivering an abrasive to the surface of the turntable. Advantageously, the polishing head is movable with reciprocating motion in a plane parallel to that of the turntable.

[0030] Preferably, the means for delivering the abrasive comprises a tubular ring connected to a supply of abrasive, with the ring having a plurality of abrasive delivery orifices and being secured to the non-rotary portion of the polishing head. The ring may be made of thermoplastic resin and include between about six and twenty delivery orifices. In a preferred arrangement, the ring is disposed around the rotary portion of the polishing head in a plane that is substantially parallel to the plane of the turntable but is spaced apart therefrom, with the delivery orifices opening out so as to face the turntable. The abrasive delivery orifices are spaced equidistantly from the wafer periphery for optimum delivery of the abrasive to the turntable e.g., under pressure or by gravity. The ring may also have plugs for closing the abrasive delivery orifices.

[0031] The machine may also include means for pressing the wafer into the polishing head, such as an actuator for applying pressure to the polishing head or a diaphragm for applying pressure to the wafer.

[0032] The invention also relates to a device for delivering an abrasive to the surface of a turntable of a polishing machine for polishing a wafer, comprising a non-rotatable tubular ring having means for receiving an abrasive from a supply, the ring having a plurality of abrasive delivery orifices distributed over a bottom surface of the ring, wherein the ring is to be secured to a non-rotatable portion of the polishing machine.

[0033] As above, the ring may be made of thermoplastic resin and include about six and twenty delivery orifices. The ring is preferably disposed in a plane that is substantially parallel to that of the turntable but is spaced apart therefrom, with the delivery orifices opening out so as to face the turntable.

[0034] Another embodiment of the invention relates to a method for polishing a wafer, which comprises positioning a wafer in contact with a polishing head while feeding an abrasive onto the polishing head from a non-rotatable tubular ring having orifices for delivering the abrasive, and rotating the wafer against the polishing head to polish the wafer. Advantageously, the polishing head is movable with reciprocating motion in a plane parallel to that of the wafer. Also, the ring may be made of thermoplastic resin, includes between about six and twenty abrasive delivery orifices, and is disposed in a plane that is substantially parallel to the wafer but is spaced apart therefrom, with the abrasive delivery orifices opening out so as to face the wafer. The abrasive delivery orifices can be spaced equidistantly from the wafer periphery and the abrasive is delivered to the turntable under pressure or by gravity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] Other characteristics and advantages of the invention appear on reading the following description of a preferred embodiment of the invention given by way of non-limiting example. The description refers to the accompanying drawings, in which:

[0036] **FIG. 1** is a diagrammatic perspective view of a prior art chemical-mechanical polishing machine;

[0037] **FIG. 2** is a fragmentary side view of the chemical-mechanical polishing machine of the invention;

[0038] **FIG. 3** is a view on a larger scale showing the abrasive delivery ring of the invention shown in section on a vertical diametral plane; and

[0039] **FIG. 4** is a perspective view from beneath of the abrasive delivery ring of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0040] The invention specifically provides a chemical-mechanical polishing machine for polishing a wafer of a material, in particular a semiconductor material, for use in fabricating substrates for optics, optoelectronics, or electronics, the machine comprising:

[0041] a polishing turntable driven in rotation;

[0042] a polishing head movable relative to the polishing turntable and comprising a non-rotary portion and a rotary

portion having fixing means for fixing to the wafer to be polished, the rotary portion enabling the wafer to be rotated while maintaining one of its faces in contact with the polishing turntable; and

[0043] means for delivering an abrasive to the surface of the polishing turntable.

[0044] According to the invention, the means for delivering abrasive comprise a tube looped to form a "abrasive delivery" ring connected to a supply of abrasive and provided with a plurality of abrasive delivery orifices, the abrasive delivery ring having fixing means enabling it to be secured to the non-rotary portion of the polishing head while being disposed around the rotary portion in a plane that is substantially parallel to the plane of the polishing turntable-but that is spaced apart therefrom, the-delivery orifices opening out so as to face the polishing turntable.

[0045] According to advantageous and non-limiting characteristics of the invention, taken singly or in combination:

[0046] the polishing head has reciprocating motion imparted thereto in a plane parallel to the plane of the polishing turntable;

[0047] all of the abrasive delivery orifices are equidistant from the edge of the wafer to be polished; and

[0048] the abrasive delivery orifices are suitable for being closed by plugs.

[0049] The invention also provides a device for delivering abrasive to the surface of the polishing turntable **1** of a chemical-mechanical polishing machine for polishing a wafer P.

[0050] This device is remarkable in that it comprises a tube looped to form a "abrasive delivery" ring, the ring being provided with means for feeding abrasive from a supply, with a plurality of abrasive delivery orifices distributed over its bottom face, and with fixing means enabling it to be secured to a non-rotary portion of the polishing head fitted to the chemical-mechanical polishing machine.

[0051] With reference to **FIG. 2**, it can be seen that a "chemical-mechanical" polishing machine of the invention comprises a polishing turntable **1** identical to that described above for the state of the art as shown in **FIG. 1**, and having component parts which are therefore given the same reference numerals.

[0052] The polishing head **4** comprises a rigid portion **40** that is generally in the form of a disk that is rotated by a motor (not shown in the figures) via a drive shaft **41**. Rotation takes place about a vertical axis Y-Y'.

[0053] The rotary portion **40** is provided with fixing means for fixing a wafer P that is to be polished, the fixing means enabling the wafer to be rotated. By way of example, these means are a retaining ring and an insert similar to those described above for the polishing head known in the state of the art. Other fixing means known to the skilled person could also be used.

[0054] The polishing head **4** also comprises means (not shown in the figures) enabling the face of the wafer P that is to be polished to be pressed more or less strongly against the polishing turntable **1** or more precisely against the polishing cloth **11** covering it. Generally, the pressure is applied either directly to the polishing head by means of an actuator, or else to the wafer by means of a diaphragm, like a balloon.

[0055] The shaft **41** is mounted inside a sleeve **42**, itself connected to members for supporting and driving the polishing head **4**, which members are not shown in the figures.

[0056] The sleeve **42** is not free to rotate and is capable of moving only with the oscillating, or reciprocating motion represented by arrow F **1**. Advantageously, this motion takes place along a radius of the polishing turntable **1**. The shaft **41** and the sleeve **42** are advantageously coaxial.

[0057] This type of polishing head is known to the skilled person and is not described in greater detail.

[0058] In the invention, the polishing head **4** is fitted with abrasive delivery means **5**.

[0059] These means **5** comprise a tube **50** that is curved to form a loop so that in plan view its general shape is that of a ring, referred to below as the "abrasive delivery ring".

[0060] With reference to **FIG. 3**, it can be seen that this ring **50** presents an axis of revolution Y-Y' that coincides with the axis Y-Y' of the polishing head **4** once the ring has been fixed to the non-rotary sleeve **42**.

[0061] The ring **50** is preferably rectangular in section on a vertical section plane containing the axis Y-Y'.

[0062] As a result it presents a top face **501**, and a bottom face **502**, which faces are both plane, and an inner face **503** and an outer face **504**, which faces are both cylindrical.

[0063] Advantageously, the delivery ring **50** is made of a thermoplastic resin of the fluoropolymer type (e.g. of perfluoro-alkoxyresin PFA).

[0064] As can be seen more clearly in **FIG. 2**, the ring **50** is connected to an abrasive feed source (not shown) via abrasive feed means **51** such as a tube. The tube **51** is fixed to the top face **501** of the ring **50** and opens out through an orifice (not shown) formed in the face **501**.

[0065] The abrasive is delivered under pressure, or alternatively flows under gravity, depending on its viscosity.

[0066] Furthermore, the delivery ring **50** has a fixing bracket **52**, which may be welded to its outside face **504**. This fixing bracket **52** is fixed to a collar **420** mounted at the base of the sleeve **42** on the polishing head **4** by any appropriate fixing means, such as a screw. Only the fixing axis is shown in **FIG. 2**, where it is referenced **520**.

[0067] In addition, as can be seen in **FIGS. 3 and 4**, the delivery ring **50** has a series of orifices **53** in its bottom face **502**, which orifices are referred to as "abrasive delivery orifices" and they are uniformly distributed.

[0068] While there may be any number of orifices, there would typically be about six to twenty orifices. By way of example, there can be twelve orifices **53** angularly distributed at **30°** intervals.

[0069] All of these orifices **53** are preferably equidistant from the axis Y-Y' and thus from the polishing head **4** and from the circular edge of the wafer P for polishing which is fixed thereto. They open out facing the cloth **11** on the polishing turntable **1** when the ring **50** is mounted on the sleeve **42** of the polishing head **4**.

[0070] These delivery orifices **53** are capable of being closed by plugs **54**. By way of example, these plugs **54** can be screwed into the orifices **53**, in which case they are provided with suitable tapping.

[0071] Thus, it is possible to select the number of delivery orifices **53** which are open and how they are distributed in space. It is thus possible to deliver varying quantities of abrasive, for example as a function of the kind of material that constitutes the wafer P for polishing.

[0072] The delivery ring **50** is fixed to the sleeve **42** in such a manner that its plane bottom face **502** lies in a plane parallel or substantially parallel to that of the polishing turntable **1**, but that lies above it. In other words, and as shown in **FIG. 2**, the bottom face **502** of the delivery ring **50** lies at a distance D from the cloth **11** on the polishing turntable **1**, which distance D may lie in the range, for example, 5 centimeters (cm) to 10 cm. The delivery ring **50** is thus not in contact with the polishing cloth **11**, and as a result it does not wear.

[0073] The operation of the chemical-mechanical polishing machine of the invention is described below with reference to FIGS. **2** to **4**.

[0074] The wafer P for polishing is fixed to the rotary portion **40** of the polishing head **4**. This portion **40** is rotated as is the polishing turntable **1**. Simultaneously, liquid abrasive is fed via the tube **51** to the inside of the ring **50** in which it spreads out uniformly and from which it flows via the delivery orifices **53** onto the polishing cloth **11**.

[0075] The device of the invention makes it possible to increase the stability with which material is removed from the wafer P. The polishing method is thus more uniform, reproducible, and leads to a reduction in the consumption of abrasive.

[0076] Distributing the abrasive uniformly also makes it possible to reduce friction between the polishing head **4** and the cloth **11**, and thus limits wear of the cloth.

[0077] The abrasive delivery ring **50** of the invention is simple in structure and thus inexpensive to manufacture. It is removable and can be mounted selectively on an existing polishing head without it being necessary to modify its structure.

[0078] It is to be understood that the invention is not to be limited to the exact configuration as illustrated and described herein. Accordingly, all expedient modifications readily attainable by one of ordinary skill in the art from the disclosure set forth herein, or by routine experimentation therefrom, are deemed to be within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A machine for polishing a wafer for use in fabricating substrates comprising:

a rotatable turntable;

a polishing head for holding a wafer and being movable relative to the turntable, the polishing head comprising a non-rotary portion and a rotary portion for rotating the wafer while maintaining a surface of the wafer in contact with the turntable; and

means for delivering an abrasive to the surface of the turntable.

2. The machine of claim 1, wherein the polishing head is movable with reciprocating motion in a plane parallel to that of the turntable.

3. The machine of claim 1, wherein the means for delivering the abrasive comprises a tubular ring connected to a supply of abrasive, with the ring having a plurality of abrasive delivery orifices and being secured to the non-rotary portion of the polishing head.

4. The machine of claim 3, wherein the ring is made of thermoplastic resin and includes between about six and twenty delivery orifices.

5. The machine of claim 3 wherein the ring is disposed around the rotary portion of the polishing head in a plane that is substantially parallel to the plane of the turntable but is spaced apart therefrom, with the delivery orifices opening out so as to face the turntable.

6. The machine of claim 5, where in the abrasive delivery orifices are spaced equidistantly from the wafer periphery.

7. The machine of claim 5, further comprising plugs for closing the abrasive delivery orifices.

8. The machine of claim 5, wherein the abrasive is delivered to the turntable under pressure or by gravity.

9. The machine of claim 1, further comprising means for pressing the wafer into the polishing head.

10. The machine of claim 9, wherein the means for pressing the wafer comprises an actuator for applying pressure to the polishing head.

11. The machine of claim 9, wherein the means for pressing the wafer comprises a diaphragm for applying pressure to the wafer.

12. A device for delivering an abrasive to the surface of a turntable of a polishing machine for polishing a wafer, comprising a non-rotatable tubular ring having means for receiving an abrasive from a supply, the ring having a plurality of abrasive delivery orifices distributed over a bottom surface of the ring, wherein the ring is to be secured to a non-rotatable portion of the polishing machine.

13. The device of claim 12, wherein the ring is made of thermoplastic resin and includes between about six and twenty delivery orifices.

14. The device of claim 12, wherein the ring is disposed in a plane that is substantially parallel to that of the turntable but is spaced apart therefrom, with the delivery orifices opening out so as to face the turntable.

15. The device of claim 12, further comprising plugs for closing the abrasive delivery orifices.

16. A method for polishing a wafer, which comprises positioning a wafer in contact with a polishing head while feeding an abrasive onto the polishing head from a non-rotatable tubular ring having orifices for delivering the abrasive, and rotating the wafer against the polishing head to polish the wafer.

17. The method of claim 16, wherein the polishing head is movable with reciprocating motion in a plane parallel to that of the wafer.

18. The method of claim 16, wherein the ring is made of thermoplastic resin, includes between about six and twenty abrasive delivery orifices, and is disposed in a plane that is substantially parallel to the wafer but is spaced apart therefrom, with the abrasive delivery orifices opening out so as to face the wafer.

19. The method of claim 16, wherein the abrasive delivery orifices are spaced equidistantly from the wafer periphery and the abrasive is delivered to the turntable under pressure or by gravity.

20. The method of claim 16, which further comprises providing plugs for closing the abrasive delivery orifices.

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