

Cleaning Process and Apparatus

Field of the Invention

- 5 The present invention relates to a scrubbing module for cleaning substrates and methods thereof, including but not limited to disc-shaped substrates of varying materials, such as to glass, aluminium and silicon.

Background of the Invention

10

The computer, electronics and entertainment industries use many disc-shaped substrates for the manufacture of electronic circuits. These substrates typically comprise silicon wafers, aluminium, plastics, glass, ceramic and composite materials. For convenience, the materials referred to in this specification will
15 discuss aluminium or glass. This is not to be construed, however, as a limitation on the application of the invention.

The substrates undergo numerous processes in manufacturing, including repeated application and removal of conductive, non-conductive and semi-
20 conductive materials of magnetic, optical and magneto-optical materials.

During manufacturing, the substrates must be buffed, polished, etched and cleaned repeatedly. As the trend in substrate design inclines towards miniaturisation, the level of cleanliness required during the manufacturing
25 process of substrates also increases. In particular, complicated multi-layer circuits require extremely clean substrates to be fabricated on. Otherwise, defects will arise thereby leading to a decreased yield, an increased production time and an inferior product quality.

30 One known design of a cleaning module for cleaning aluminium discs comprises a cleaning station having two brush cylinders arranged adjacent to each other. The two brush cylinders form two central longitudinal axes that are

parallel to each other. One or more aluminium discs are then arranged between the two central longitudinal axes of the brush cylinders, so that the opposite sides of the disks can be cleaned when the brush cylinders rotate about their respective longitudinal axes.

5

A first disadvantage of the known cleaning module is that it may not satisfy the increased level of cleanliness as required for modern applications (for example, miniaturised integrated circuits). This is because the area of contact between each side of each disk with the respective brush cylinders is not maximised, which may inevitably lead to substrate defects as described above.

10

A second disadvantage of the known cleaning module is that it cleans a limited number of substrates within a given period. This is because the number of aluminium discs being cleaned simultaneously by the two brush cylinders is restricted by the diameter of the aluminium discs. Further, the contact between the brush and disc is merely a line contact. Accordingly, the brush must move downward for the entire diameter of the disc in order to ensure full contact between the disc and brush. As a result, the residence time of the disc in the cleaning station is significant.

15
20

In addition, the known cleaning module generally has more than one cleaning station. A third disadvantage of the known cleaning module is that the aluminium discs are progressively transferred from one cleaning station to another cleaning station individually. Accordingly, this results in "idle time" during transfers between different cleaning stations and during loading and unloading of the disks.

25

The present invention therefore proposes a cleaning module to overcome at least some of the disadvantages of the known cleaning module.

30 **Summary of the Invention**

A first aspect of the invention relates to a cleaning module for cleaning one or more substrates, comprising one or more brushes operable to move along a

radial path in relation to the substrate. For example, the cleaning module may be more useful more, but not limited to, cleaning aluminium discs.

5 Preferably, the brush may be adjacent to a side of the substrate so that when the brush moves towards the centre of the substrate, a scrubbing portion of the brush overlaps a corresponding portion of the substrate to contact each other.

10 In a preferred embodiment, the cleaning module may further comprise a substrate rotation device to rotate the substrate when the substrate is in contact with the scrubbing portion of the brush. The substrate rotation device may comprise a rotatable shaft coupled to the periphery of the at least one substrate. This may permit the surface area of the substrate being cleaned by the scrubbing portion of the brush to be maximised.

15 Preferably, the brush may also be rotatable to maximise the area of the scrubbing portion of the brush for cleaning the substrate. In this embodiment, the brush provides an "area" contact, as compared to the line contact of the longitudinal prior art brushes. This may provide longer actual contact time per unit area, than that of the longitudinal brush for the same residence time of the disc within the cleaning station.

20 Preferably, both the brush and the substrate may be operable to rotate in a same direction, so that the opposing frictional force between the brush and the substrate may more efficiently clean the latter.

25 Designing the radius of rotation of the brush to be greater than or equal to the radius of the substrate may permit the portion of the substrate being cleaned by the scrubbing portion brush to be optimised.

30 In addition, the cleaning module may also comprise one or more peripheral brushes for cleaning an outer edge of the substrate, and/or one or more inner brushes for cleaning an edge of an orifice in the substrate. This may ensure a

higher level of cleanliness of the substrate. This may be useful for applications involving the miniaturisation of integrated circuits.

5 A second aspect of the invention relates to a method of positioning one or more brushes during the cleaning of one or more substrates, comprising the step of moving the brush along a radial path in relation to the substrate. The method is more particularly, but not exclusively, for cleaning aluminium discs.

10 A third aspect of the invention relates to a method of cleaning one or more substrates, comprising the steps of moving one or more brushes along a radial path in relation to the substrate and overlapping a scrubbing portion of the brush with a corresponding portion of the substrate.

15 By rotating the substrate when the scrubbing portion of the brush overlaps with the corresponding portion of the substrate, the surface area of the substrate being cleaned by the scrubbing portion of the brush may be optimised.

20 Preferably, the method of cleaning the substrate may further comprise the step of rotating the brush to maximise the area of the scrubbing portion of the brush for cleaning the substrate.

25 Preferably, the brush and the substrate rotate in a same direction, so that the opposing frictional force between the scrubbing portion of the brush and the substrate cleans the latter.

In addition, the method of cleaning the substrate may further comprise the step of moving one or more peripheral brushes adjacent to an edge of the substrate, and/or the step of moving one or more inner brushes adjacent to an edge of an orifice in the substrate, to meet a higher level of substrate cleanliness as may
30 be required.

Brief description of the drawings

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention. Other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to be understood as
5 superseding the generality of the preceding description of the invention.

Figure 1 illustrates a cleaning module prior to a substrate-cleaning process;

Figure 2 illustrates an example of a robotic lifter in the cleaning module of Figure 1;

10 Figure 3 illustrates a process-jig tray in the cleaning module of Figure 1;

Figure 4 illustrates a first cleaning station of the cleaning module of Figure 1;

Figure 5 illustrates a closed-up view of one of the substrates being cleaned at the first cleaning station of Figure 4;

Figure 6 illustrates a second cleaning station of the cleaning module of Figure 1;

15 Figure 7 illustrates a closed-up view of one of the substrates being cleaned at the second cleaning station of Figure 6;

Figure 8 illustrates a third cleaning station of the cleaning module of Figure 1;

Figure 9 illustrates the cleaning module after the substrate-cleaning process;

20 Figure 10 illustrates a side-view of the cleaning station in a different configuration;

Figure 11 illustrates the cleaning module comprising the cleaning station of Figure 10;

Figures 12A and 12B are plan views of discs demonstrating the substrate-cleaning process according to two embodiments of the present invention.

25

Detailed Description of the Preferred Embodiment

Figures 1 illustrates a cleaning module 101 for cleaning one or more substrates according to one embodiment. In this case, the cleaning module 101 is divided
30 into three sections: a loading section 103; a cleaning section 105; and an unloading section 107.

The loading section 103 comprises three substrate carriers or magazines in the form of feed-jig trays 109, each for holding a stack of twenty disc-shaped substrates 110. These substrates 110 may have undergone various upstream processes (e.g. ultrasonic washings) before being transferred to the trays 109 for cleaning according to the invention.

Prior to the substrate-cleaning process, the substrates 110 at evenly-spaced positions in a particular tray 109 are transferred to a process-jig tray 113 in the cleaning station 103 by a robotic lifter. The cleaning section 103 comprises three cleaning stations 401, 601, 801 which will be described later. For simplicity, details of the cleaning stations are shown in the figures only in relation to the process-jig tray 113.

Figure 2 provides an example of the robotic lifter 201 arranged above the tray 109 holding 25 substrates 110. The robotic lifter 201 comprises five lifting arms 203 arranged in parallel. In addition, the respective distances between the adjacent lifting arms 203 are identical, and can be any multiples of the total number of each substrate 110. The robotic lifter 201 can lift all the $(1+kn)^{th}$ substrates simultaneously from the tray 109 to the process-jig tray 113 – the variable “k” being the multiple of the total number of substrates and the variable “n” being any integer = {0, 1, 2, 3, ...}. For this particular embodiment, as illustrated in Figure 2, “k” has a value of 5. Thus, the lifting arms 203 will lift the 1st, 6th, 11th, 16th and 21st substrates 110 simultaneously from the tray 109 to the process-jig tray 113 during the start of the cleaning process.

When the lifting arms 203 are aligned with the substrates 110 in the tray 109, they simultaneously engage the peripheral edges of the $(1+kn)^{th}$ substrates below the horizontal diametric axis of the substrates so as to transfer these selected substrates from the tray 109 to the process-jig tray 113 as shown in Figure 3.

The process-jig tray 113 comprises a substrate rotation device in the form of a motor-driven shaft 205 arranged at the periphery of the substrates 110 such

that the shaft 205 contacts the circumferential of the substrates 110. The motor-driven shaft 205 is coupled to a motor 207, so that the shaft 205 rotates about a longitudinal axis that is parallel to that of the process-jig tray 113. Thus, as the shaft 205 rotates in a clockwise or anti-clockwise direction, the substrates 110 in the process-jig tray 113 will rotate accordingly in an opposing direction in relation to that of the shaft 205.

Referring again to Figure 1, the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, 15th, 17th and 19th substrates 110 from the left end of the tray 109 are transferred by a robotic lifter similar to the robotic lifter 201 to the process-jig tray 113 in the cleaning section 105 during the start of the cleaning cycle. In other embodiments having a different number of substrates or robotic lifters having different “k” values, the substrates to be lifted from the tray 109 to the process-jig tray 113 are identified by the expression $(1+kn)$, $n = \{0, 1, 2, 3...\}$ and “k” being a multiple of the substrate thickness, as explained earlier.

Figures 4 to 9 show the process for each station. For clarity, the stations are considered individually, with the figures showing one tray 113 at a time. In a preferred embodiment, there will be trays in each station, with the cleaning process for each station conducted simultaneously. In general, the trays 113 move to each station, with the simultaneous process performed, the trays then move along a conveyor, with a new tray introduced into the first station 401, and at the far end, the tray 113 emptied and removed from the conveyor. Empty trays 113 can then be reintroduced at the beginning of the process for receiving new discs, either by replacement by an operator, or through a separate conveyor automating the process further. The following describes the process in greater detail.

The process-jig tray 113 is arranged on a conveyor (not shown), so that it can move across opposite ends of the cleaning section 105. Figure 4 illustrates the arrangement of the process-jig tray 113 as it moves into a first cleaning station 401. In the first cleaning station 401, each disc-shaped brush 403 is designed to

clean one side of a particular substrate 110. Thus, a row of twenty brushes 403 is required to clean both sides of all the 10 substrates 110 supported by the process-jig tray 113. In this embodiment, the brushes 403 are presented as distinct pairs of brushes corresponding to each substrate, the brushes in each
5 said pair sufficiently spaced from each other to receive the corresponding substrate 110.

As the process-jig tray 113 moves into the first cleaning station 401, the row of brushes 403 are lowered to overlap a proportion of the disc, which is in this
10 embodiment less than half of the surface area of each substrate 110. As the brushes 403 overlap with the substrates 110, they are brought into contact with each other.

Figure 5 illustrates a close-up view of one of the substrates 110 being cleaned
15 by a pair of brushes 403 – one on each side of the substrate 110. As the brushes 403 move along a radial path in relation to the substrate 110, a scrubbing portion 501 of each brush overlaps with the substrate 110 to contact a corresponding portion of the substrate 110.

20 The substrate 110 is made to rotate in a clockwise direction by operating the motor 207 to rotate the motor-driven shaft 205 in the opposing anti-clockwise direction, so that the substrate 110 is scrubbed by the scrubbing portions of the brushes 403. Likewise, the brushes 403 are also coupled to a motor (not shown) so that they rotate in the same clockwise direction as the substrate rotation. As
25 a result, the opposing frictional forces between the scrubbing portion of the brushes 403 and the substrate 110 clean the latter.

Advantageously, the radius of rotation of the brushes 403 is the same as, or preferably, greater than the radius of the substrate 110 so that the substrate
30 110 is thoroughly cleaned by the brushes 403 due to the opposing frictional contact between the scrubbing portions 501 of the brushes 403 and the

respective sides of the substrate 110. The radius of rotation of the brushes 403 may generally be around 5mm longer than the radius of the substrate 110.

Accordingly, the surface of the substrate 110 being cleaned by the brushes 403 within a given time may be larger than the surface of the substrate being
5 cleaned by the prior art, since embodiments of the invention negate circular effects during the cleaning process, which will be described with reference to Figures 12A and 12B..

In this embodiment, the cleaning cycle lasts between 5 to 20 seconds, after
10 which the row of brushes 403 is raised to the original position.

After the substrates 110 are cleaned at the first cleaning station, the process-jig tray 113 then moves along the cleaning section 105 towards a second cleaning station 601.

15 The second cleaning station 601 comprises a row of ten peripheral brushes 603. As the process-jig tray 113 moves into the second cleaning station 601, the row of peripheral brushes 603 is lowered so that they contact the circumferential edge of the substrates 110. In addition, the second cleaning station 601 further
20 comprises a row of ten inner brushes 605 for cleaning the edges of the orifices within each substrate 110.

Figure 7 illustrates a close-up view of one of the substrates 110 being cleaned by both the peripheral brush 603 and the inner brush 605. As both the
25 peripheral brush 603 and the inner brush 605 come into contact with the circumferential edge of the substrate 110 and the edge of the orifice of the substrate 110 respectively, the substrate 110 rotates in a clockwise direction. Thus, both the outer edge of the substrate 110 and the internal edge are cleaned by the opposing frictional contact between the substrate 110 and the
30 brushes 603, 605.

Advantageously, the inner brush 605 is coupled to a motor (not shown) so that it rotates in the opposing anti-clockwise direction in relation to the substrate rotation. This makes the cleaning time of the substrate 110 shorter. Thus, the outer peripheral brush 603 is also advantageously made to rotate in the same clockwise direction as the substrate rotation. Thus, the opposing frictional forces between the brushes 603, 605 and substrate clean the latter.

After cleaning of the substrate 110 at the second cleaning station 601 is completed, the process-jig tray 109 then proceeds to a third cleaning station 801 shown in Figure 8. As the process-jig tray 113 moves into the third cleaning station 801, a row of twenty brushes 803 are lowered to overlap with about half the respective surface areas of the substrates 110. It can be seen that the third cleaning station 401 is identical to the first cleaning station, and thus no further elaboration is required.

It should be appreciated that as the substrates 110 are sequentially cleaned in three cleaning stations, the level of cleanliness of the substrates 110 is improved. Further, in view of the modularity of the cleaning stations 401, 601, 801, the duration of each cleaning cycle at the cleaning stations 401, 601, 801 can be adjusted independently of one another.

When the substrate-cleaning at the third cleaning station 801 is completed, the process-jig tray 109 again moves along the cleaning section 105 to the opposite end of the cleaning section 105. Another feed-jig tray 901 is arranged in the unloading section 107 adjacent to that opposite end of the cleaning section 105. The substrates 110 on the process-jig tray 109 in the cleaning section 105 are then lifted to the tray 901 in the unloading section 107 of the cleaning module 101 by means of another robotic lifter operates in an identical or similar fashion as the robotic lifter 201 of Figure 2.

After the substrates 110 are transferred to the tray 901, they may then undergo various downstream processes (e.g. ultrasonic rinse) as required.

The robotic lifter of the cleaning module 101 then moves back to the tray 109 in the loading section 103, whilst the lifting arms are moved by the distance of one substrate thickness (or one substrate space), so that the next series of
5 substrates 110 corresponding to the 2nd, 4th, 6th, 8th, 10th, 12th, 14th, 16th, 18th and 20th substrates 110 from the left end of the tray 109 can be transferred to the process-jig tray 113. The same cleaning process as described above then continues again.

10 Thus, a plurality of substrates 110 is transferred together from one cleaning station to the next cleaning station as the process-jig tray 113 moves across the cleaning section 105. This is in contrast with the prior art, where the substrates are generally transferred individually. Thus, it should be appreciated that the cleaning module 110 minimises the "idle time" caused by the loading and
15 unloading of individual substrate for cleaning.

Although the three cleaning stations 401, 601, 801 in the cleaning module 101 are disclosed to be modular or distinct, it should however be appreciated that they can be combined to form an integral cleaning station. For simplicity, only a
20 side-view of such an integral cleaning station (labelled as 1001) is shown in Figure 10.

The integral cleaning station 1001 comprises ten elongate members (one of which is labelled as 1002) arranged in parallel to one another and in
25 perpendicular to the direction of motion of the process-jig tray 113.

The elongate member 1002 comprises three arms 1003, 1005, 1007 extending from an elongate portion, and the same set of brushes 403; 603, 605; 803 respectively as described earlier. Thus, it can be seen that the integral cleaning station 1001 combines the three cleaning stations 401, 601, 801. Accordingly,
30 in this embodiment, the elongate member 1002 can effect simultaneous cleaning at all stations.

As the process-jig tray 113 moves into the integral cleaning station 1001, the integral cleaning station 1001 is lowered, so that the substrates 110 on the process-jig tray 113 are cleaned by either set of the brushes 403; 603, 605; 803. A further arm (not shown) may be provided to support the disc during the
5 cleaning process. The support arm is most advantageous for the second cleaning station to ensure the application of the peripheral brush 603 may tend to destabilize the disc during cleaning, and so push it out of alignment. By providing the support, the disc may be held in place.

10 Further, the support arm may provide additional drive to rotate the disc. In so doing, contact between the support arm and the disc may be with a roller, with said roller providing all or part of the required torque in order to drive the rotation of said disc.

15 In view of the integral cleaning station 1001, it should be appreciated that there could be one or more process-jig trays moving in parallel in the cleaning section 105. This is because the arms 1003, 1005, 1007 can be designed to align with the substrates 110 in the one or more process-jig trays, so that the substrates 110 can be cleaned simultaneously by all sets of the brushes 401; 601, 605;
20 803.

Figure 11 illustrates the cleaning module 110 having the integral cleaning station 1001. For simplicity, the integral cleaning station 1001 and robotic lifters are not drawn in Figure 11. In this case, the cleaning module 110 comprises
25 three process-jig trays 113a-c. In contrast to the process jig 113 moving on the conveyor from one cleaning station to the next in the cleaning section 105, the process jigs 113a-c are fixed in position in the cleaning section 105. This is because the substrates 110 are progressively transferred between the adjacent trays along the cleaning module 101 by specialised robotic lifters.

It should be appreciated that such a design of the cleaning module 101 may be suitable if it is desirable to increase the number of substrates 110 being cleaned during the substrate-cleaning process.

- 5 It is also envisaged that the substrate rotation device may be in the form of a motor-driven shaft that is operable to secure to the walls of the central cavities of the substrates 110. However, the substrates 110 may have to be lifted from the process-jig tray 113 so that the substrates 110 can be rotated along with the motor-driven shaft to which they are secured.

10

In addition, it is further envisaged the brushes 403, 803 may also be made to completely overlap the sides of the substrates 110. Thus, as the brushes 403, 803 or the substrates 110 rotate, or when the brushes 403, 803 and the substrates 110 both rotate in opposing directions, so that the opposing frictional
15 forces between the brushes 403, 803 and the substrates 110 clean the latter.

Figures 12A and 12B show the effect of differing scrubbing patterns based on the radius of rotation of the brush relative to the diameter of the disc.

- 20 In Figure 12A there is shown the case where the radius of rotation 1110 is significantly less than the diameter of the disc 1105 being scrubbed. Whilst extreme this illustration indicates the deposition of dirt 1115 around the periphery of the scrubbing radius 1110. Because of the much smaller radius, the dirt remains wholly, or at least in part, on the face 1120 of the disc 1105,
25 thus negating the benefits of the scrubbing process.

By contrast, Figure 12B shows the effect of having the radius 1210 much larger than the diameter of the disc 1205. Here, the dirt 1220, 1230 is deposited on the internal diameter, or orifice 1215 of the disc, as well as the peripheral edge
30 1225. By applying a scrubbing process to the orifice 1215 and the peripheral edge 1230, the dirt 1220, 1230 is removed from the disc 1205 in a two step process.

In reality, the radius of rotation of the brush will vary, providing differing benefits. Whilst the illustration shows certain benefits of a larger radius, this is not to be considered a limitation of the invention, as the efficiency of the process,
5 irrespective of the radius of rotation, remains superior to that of the prior art.

Thus, although the invention has been described using a preferred embodiment, many variations are possible within the scope of the claims, as will be clear to the skilled reader, without departing from the scope of the invention as claimed.
10

Claims

1. A cleaning module for cleaning at least one substrate, the module comprising at least one brush operable to move along a radial path in relation to the at least one substrate and a substrate rotation device to rotate the at least one substrate, wherein the substrate rotation device comprises a rotatable shaft engaged with the periphery of the at least one substrate and wherein the at least one substrate and the at least one brush are operable to rotate in a same direction..
2. The cleaning module according to claim 1, wherein a scrubbing portion of the at least one brush overlaps a corresponding portion of the at least one substrate as the at least one brush moves along the radial path.
3. The cleaning module according to any one of the preceding claims, wherein the at least one brush is rotatable.
4. The cleaning module according to any one of claims 1 to 3, wherein the radius of rotation of the at least one brush is greater than or equal to the radius of the at least one substrate.
5. The cleaning module according to any one of the preceding claims, further comprising at least one peripheral brush for cleaning an outer edge of the at least one substrate.
6. The cleaning module according to any one of the preceding claims, further comprising an inner brush for cleaning an edge of an orifice in the at least one substrate.
7. A cleaning module for cleaning a plurality of substrates, the module comprising:
a tray for supporting said substrates in a pre-determined spaced relation;

a plurality of brushes located at a first station, each brush corresponding to one of said plurality of substrates;

a second plurality of said brushes located at a second station, and;

a conveyor for moving the tray from the first station to the second station,
5 wherein each brush is operable to move along a radial path in relation to the respective substrate brush corresponding to one of said plurality of substrates.

8. The module according to claim 7, wherein the first tray supports the substrates such that planes defined by the substrates are parallel.

10

9. The module according to claim 7, further comprising a plurality of peripheral brushes, for cleaning an outer edge, and a plurality of inner brushes, for cleaning an edge of an orifice, of each substrate;
the plurality of peripheral and inner brushes located at a third station
15 intermediate the first and second station;
wherein said conveyor is further adapted to move the tray from the first station to the third station and then to the second station.

10. A method of cleaning at least one substrate, the method comprising the steps of:

20

moving at least one brush along a radial path in relation to the at least one substrate and overlapping a scrubbing portion of the at least one brush with a corresponding portion of the at least one substrate;

rotating the at least one substrate with a substrate rotation device that
25 comprises a rotatable shaft engaged with the periphery of the at least one substrate; and

rotating the at least one brush, wherein

the at least one substrate and the at least one brush rotate in a same direction.

30

11. The method according to claim 10, further comprising the step of moving at least one peripheral brush adjacent to an edge of the at least one substrate.

12. The method according to claim 10 or 11, further comprising the step of moving at least one inner brush adjacent to an edge of an orifice in the at least one substrate.