

## Laser machining using a surfactant film

This invention relates to use of a surfactant film to reduce adhesion of laser machining debris to a workpiece being machined.

5        During laser machining of, for example, a wafer substrate, some material removed from a machining zone is deposited on a surface of the wafer substrate on which machining is being carried out, for example as debris at the edge of a laser cut. Material ejected from the machining zone during laser machining is in a molten or gaseous form and adheres to the  
10        surface of the wafer substrate upon cooling during, and subsequent to, machining. Such adherent debris may, for example, damage thermally-sensitive electronic circuitry on the surface of the wafer substrate as the debris cools upon contact with the surface and re-solidifies. Such re-solidified debris is difficult to remove from the surface of the wafer substrate  
15        using conventional wafer cleaning techniques due to its adherent nature.

It is an object of the present invention at least to ameliorate the aforesaid difficulties in the prior art.

According to a first aspect of the present invention there is provided a method of laser machining a workpiece including the steps of: dispensing a  
20        surfactant onto a surface of the workpiece to be laser machined to provide a surfactant film to reduce adhesion to the surface of debris produced during laser machining; and laser machining the workpiece from the surface.

Conveniently, the surfactant is dispensed in a pre-wash of the workpiece.

25        Preferably, the method includes a further step of at least partially drying the surfactant film before laser machining the workpiece.

Advantageously, the step of dispensing a surfactant comprises dispensing a surfactant onto surfaces of a plurality of workpieces in a batch process before the workpieces are laser machined.

Advantageously, the method includes a further step of removing the  
5 surfactant film, subsequent to laser machining, together with any debris from the laser machining deposited thereon.

Conveniently, the step of dispensing a surfactant comprises dispensing a surfactant which is soluble in a solvent in which the surface of the workpiece is insoluble and wherein the step of removing the surfactant film  
10 comprises dissolving the surfactant film in the solvent.

Advantageously, the solvent is water.

Advantageously, the step of laser machining the workpiece includes at least one of laser scribing, laser dicing and laser via drilling the workpiece.

Conveniently, the step of laser machining the workpiece comprises  
15 laser machining a multilayer workpiece.

Conveniently the multilayer workpiece comprises a semiconductor wafer and associated layers forming an active region of the wafer.

Conveniently, the step of dispensing the surfactant comprises spray depositing the surfactant film on the surface.

20 Alternatively, the step of dispensing the surfactant comprises knife-edge depositing the surfactant film on the surface.

Alternatively, the step of dispensing the surfactant comprises roller depositing the surfactant film on the surface.

Alternatively, the step of dispensing the surfactant comprises  
25 immersing the surface of the workpiece in a surfactant solution.

Conveniently, the step of dispensing the surfactant comprises dipping a batch of wafers to be machined into a surfactant solution.

Preferably, the step of dispensing the surfactant comprises dispensing an anionic, non-ionic or amphoteric surfactant.

- 5        Preferably, the step of dispensing the surfactant comprises coating the surface with a surfactant film having a sufficiently high degree of wetting to wet substantially all the surface.

Conveniently, the step of laser machining includes optimisation of machining parameters and such optimisation includes seeking to minimise  
10        adherence of debris to the surfactant film.

Conveniently, the step of removing the surfactant film comprises a spin-rinse-dry process.

- Advantageously, the step of laser machining comprises laser scribing the workpiece and the step of removing the surfactant film comprises at least  
15        partially removing the thin film of surfactant and any debris with a coolant used in a subsequent dicing step using a dicing saw.

Advantageously, the step of laser machining comprises providing a gas environment for the laser machining for reducing solid debris created in the laser machining step.

- 20        Conveniently, the step of dispensing the surfactant comprises coating the surface with a surfactant dissolved or suspended in a liquid carrier and evaporating the liquid carrier from the surface.

Advantageously, the step of dispensing the surfactant to form a thin film of surfactant comprises the step of acquiring an image of the film of  
25        surfactant on the workpiece and comparing the image with a reference image of a workpiece with an optimum thin film of surfactant and where the image is not sufficiently comparable with the reference image washing the

surfactant film form the workpiece and redispersing surfactant on the surface of the workpiece.

Advantageously, the step of comparing the image with a reference image includes comparing the image with at least one of a second reference  
5 image of a workpiece with an excess of surfactant on a surface and a third reference image of a workpiece with insufficient surfactant on a surface to determine whether the thin film of surfactant is excessive or insufficient respectively.

Advantageously the step of dispensing a surfactant onto a surface of  
10 the workpiece comprises a step of using a camera and associated hardware and software to align a wafer on an xy table with machine coordinates of a laser apparatus with which the wafer is to be machined, or with a laser of the laser apparatus, before the surfactant is dispensed on the wafer, such that the surfactant is dispensed on the wafer on the xy table after the wafer has  
15 been clamped in position thereon.

Conveniently the step of dispensing a surfactant comprises the steps of: removing a wafer from wafer carrier means; transporting the wafer to a surfactant dispensing station and coating the surface of the wafer with a surfactant film to form a coated wafer; and the step of laser machining  
20 comprises transporting the coated wafer to a laser machining station and laser machining the coated wafer to form a machined coated wafer such that debris from the laser machining is deposited on the surfactant film; and the step of removing the surfactant film comprises the steps of transporting the machined coated wafer to a surfactant removal station and removing the  
25 surfactant film and the debris deposited thereon to form an uncoated machined wafer.

According to a second aspect of the invention, there is provided a laser machining apparatus comprising surfactant dispensing means arranged for

coating a surface of a workpiece to be machined with a surfactant film to reduce adherence to the surface of debris produced during laser machining by the apparatus.

Preferably, the surfactant dispensing means comprises pre-washing  
5 means.

Preferably, the laser machining apparatus further comprises surfactant film removal means for removing the surfactant film from the surface together with any debris deposited thereon during laser machining thereof.

Conveniently, the surfactant film removal means comprises spin-rinse-  
10 dry means.

Advantageously, the surfactant film removal means comprises post-washing means.

Advantageously, the pre-washing means and the post-washing means are a same washing means.

15 Preferably, the laser machining apparatus is arranged for at least one of laser scribing, laser dicing and laser via drilling the workpiece.

Conveniently, the surfactant dispensing means comprises spray deposition means.

Alternatively, the surfactant dispensing means comprises knife-edge  
20 deposition means.

Alternatively, the surfactant dispensing means comprises roller deposition means.

Alternatively, the surfactant dispensing means comprises immersion means for batch dipping a plurality of workpieces.

Advantageously, the laser machining apparatus further comprises gas environment control means for producing a gas environment for laser machining arranged to reduce solid debris produced in laser machining.

Preferably, the laser machining apparatus further comprises drying  
5 means arranged at least partially to dry the surface subsequent to coating the surface.

Conveniently, the laser machining apparatus further comprises imaging means for obtaining an image of the surfactant film on the surface of the workpiece and image comparison means for comparing the image  
10 with a least one reference image for determining whether the thin film of the surfactant is sufficiently optimised for laser machining.

Conveniently the surfactant dispensing means comprises a surfactant dispensing station for coating a surface of a workpiece to be laser machined with the surfactant film for reducing adherence to the surface of debris  
15 produced during laser machining by producing a coated workpiece; the laser machining apparatus further comprises a laser machining station for machining the coated workpiece; and the surfactant removal means comprise a surfactant film removal station for removing the surfactant film subsequent to laser machining together with any debris from the laser  
20 machining deposited thereon; and the laser machining apparatus further comprises transport means for transporting the workpiece from the surfactant dispensing station to the laser machining station and from the laser machining station to the surfactant film coating removal station.

According to a third aspect of the invention there is provided a  
25 workpiece coated on at least one surface with a surfactant film arranged to reduce adherence to the at least one surface of debris produced during laser machining of the workpiece.

Preferably, the surfactant film is removable subsequent to laser machining without significantly damaging the at least one surface.

Preferably, the surfactant film is not more than 10 micron thick.

Conveniently, the surfactant film is an anionic, ionic or amphoteric  
5 surfactant film.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 (a) is a vertical cross-sectional view of a pre-washed substrate being laser machined according to a first aspect of the present invention;

10 Figure 1 (b) is a vertical cross-section of the substrate of Figure 1 after machining;

Figure 1 (c) is a vertical cross-section of the substrate of Figure 2 after removal of debris and a thin film of surfactant;

Figure 2 is a diagrammatic perspective drawing of a spray deposition  
15 technique suitable for use in the invention;

Figure 3 is a diagrammatic perspective drawing of a knife-edge deposition technique suitable for use in the invention;

Figure 4 is a diagrammatic perspective drawing of a roller deposition technique suitable for use in the invention;

20 Figure 5 is a diagrammatic perspective drawing of a laser machining apparatus according to a second aspect of the invention, illustrating removal of a wafer substrate from a cassette holder;

Figure 6 is a diagrammatic perspective drawing of the laser machining apparatus of Figure 5, illustrating roller washing of the wafer substrate in  
25 order to deposit a thin film surfactant coating;

Figure 7 is a diagrammatic perspective drawing of the laser machining apparatus of Figure 5, illustrating placing of the wafer substrate in a laser machining head;

Figure 8 is a diagrammatic perspective drawing of the laser machining apparatus of Figure 5, illustrating washing of a wafer substrate subsequent to laser machining to remove debris and the surfactant film; and

Figure 9 is a diagrammatic perspective drawing of the laser machining apparatus of Figure 5, illustrating replacing of the laser machined wafer substrate in the cassette holder subsequent to machining and cleaning.

In the Figures, like reference numerals represent like parts.

Referring to Figure 1(a), a thin film of surfactant 11, which preferably is water-soluble and an anionic, non-ionic or amphoteric thin film of surfactant with a high degree of surface watability, is coated on a wafer substrate 12 prior to laser machining with a laser beam 14 at a machining site 13 in the wafer substrate. Preferably, the thin film of surfactant is less than 10 microns thick. The thin film of surfactant 11 has a sufficiently high degree of watability to ensure that the film uniformly wets the wafer surface and remains on the wafer surface during machining. Preferably, the surfactant film is applied in a pre-wash of the wafer. Preferably the surface is at least partially dried after the thin film of surfactant has been applied and before laser machining. Alternatively, the wafer substrate is machined while the surface is still wet.

The wafers may be pre-deposited, for example hours or days before laser machining, and then fed into a laser machining apparatus in a normal manner. In addition, a full boat of wafers may be coated by a dipping process or alternative batch process in advance of insertion into the laser machining apparatus.

Laser beam parameters, such as wavelength, laser pulse energy, laser repetition rate and scanning velocity of the laser beam 14 over the wafer substrate 12, determine a nature of the debris 15 produced during laser machining. A combination of parameters, such as wavelength, laser pulse energy, laser repetition rate and scanning velocity of the laser beam 14 over the wafer substrate 12, are preferably chosen, subject to other constraints, to produce debris 15 that has low adherence to the thin film of surfactant upon re-solidification and is therefore more easily removed in a wash process. That is, the presence of the thin film of surfactant on the wafer surface after a pre-wash step reduces the surface adhesive properties thus permitting easier removal of the laser-machined debris. Referring to Figure 1(a), molten and gaseous material 15 is ejected from the laser machining site 13 during laser machining. Such material moves back toward the wafer surface both during and after laser machining and is deposited on the thin film of surfactant 11 as re-solidified material 151, as shown in Figure 1(b). However, the surfactant film reduces adherence of the debris to the workpiece, easing subsequent removal of debris from the workpiece. This differs from a known protective coating which physically prevents debris coming into contact with the surface of the wafer by acting as a barrier. In the case of the thin film of surfactant of the invention, the process of physically or chemically bonding debris or laser re-deposited material to the wafer is prevented. That is, if hot material lands on, for example, a bond pad the surfactant acts as an "anti-fluxing" agent. This may be understood as a reverse process to that of a solder flux in which a chemical is added to allow metal to bond better to a metal pad, for example, by chemically stimulating the bonding process at elevated temperature.

After laser machining, the wafer substrate 12 is washed using a conventional wash for semiconductor substrates, such as a spin-rinse-dry process with water, and both the thin film of surfactant 11 and re-solidified

debris 151 are removed from the wafer surface, leaving the surface clean and undamaged, as shown in Figure 1(c).

In one embodiment of this invention, laser machining is performed in an active gas environment or in a gas environment where photo-dissociation produces active radicals. Laser machining in an active gas environment can change the chemical nature of debris produced. In particular, a chemical reaction between the active gas and the debris 15 while in a molten state can result in removal of debris in gaseous form, with consequentially reduced deposition of solid debris 151 around the laser machining site 13.

Various known techniques are suitable for depositing the thin film of surfactant 11 on the wafer surface, such as spray deposition, knife edge deposition and roller application. Spray deposition is illustrated in Figure 2 which shows a nozzle 21, for emitting a jet of liquid surfactant, mounted above the wafer substrate 12. The wafer substrate 12 is rotated in the sense of arcuate arrow 22 and the nozzle 21 is translated in the plane of the wafer in direction of double arrow headed line 23 to ensure complete wafer coverage with the liquid surfactant. Figure 3 illustrates liquid surfactant dispensing through a linear dispensing head 31 via a linear knife edge type nozzle 311 that is at least a same length as a diameter of the wafer substrate 12. As before, rotation of the wafer in the sense of arcuate arrow 32 and translation of the dispensing head 31 in the direction of double arrow headed line 33 in the plane of the wafer permit complete coverage of the wafer with surfactant. Alternatively, as shown in Figure 4, a roller 41 may be used to dispense surfactant on the wafer substrate 12 by rotation in the sense of arcuate arrow 44 and translation over the wafer surface in the direction of double arrow headed line 43. Again, the wafer substrate 12 may be rotated in the sense of arcuate arrow 42.

A wafer may be placed on an XY table, the wafer aligned and the surfactant solution deposited on the wafer prior to machining, that is the deposition head or mechanism is used on the XY table after the wafer has been clamped in position.

5        Preferably the surface is at least partially dried subsequent to pre-washing and before laser machining since the thin film 11 is also efficient in reducing the adhesive properties of the substrate 12 when a primary solvent carrying the surfactant has evaporated or where the thin layer is formed by a phase change or congealing of a deposited surfactant solution. Alternatively,  
10        the surface may be laser machined with a wet surfactant film.

          Alternatively, the thin film of surfactant 11 may be deposited in a batch process. For example, the wafers are pre-deposited, for example hours or days before laser machining, and then fed into a laser machining apparatus in a normal manner. Alternatively, a full boat of wafers may be coated by a  
15        dipping process in advance of insertion into the laser machining apparatus.

A laser machining apparatus 50 for carrying out the steps of the method of the invention is illustrated schematically in Figures 5 to 9.

A cassette holder 51, for holding a stack of spaced-apart wafers 12, is located on a table or frame 52 at a first end 521 thereof. The cassette holder  
20        51 is generally cuboid with open opposed vertical ends transverse to a longitudinal axis of the table or frame 52, to provide access to wafers 12 stacked therein.

          Spaced generally vertically above, in use, the cassette holder 51 is a surfactant dispensing (pre-wash) station 53 having a roller 531 with an axle  
25        532 transverse to the longitudinal axis of the table or frame 52 and parallel to a plane defined by a surface of the table or frame 52. The roller 531 is

partially immersed in a bath 533 for containing surfactant solution to be deposited on a surface of the wafer substrate 12.

The apparatus preferably includes a drying station, not shown, possibly combined with the surfactant dispensing station, for drying the surface subsequent to pre-washing and before laser machining. An infrared lamp, an oven or a warm air jet are examples of suitable means of drying the surface.

As best seen in Figure 6, a laser machining head 54 is located offset from the table or frame 52 corresponding to a position on the table or frame 52 between the cassette holder 51 and a second end 522 of the table or frame 52 opposed to the first end 521. The laser machining head 54 has a vertical access end 541 open for loading wafers to be machined and unloading machined wafers, which is most proximate the table or frame 52 and parallel to the longitudinal axis thereof.

As best seen in Figures 6 and 7, a coating removal bath 55 is sunk in a well 551 in the table or frame 52 between the cassette holder 51 and the second end 522 of the table or frame 52 and proximate the access end 541 of the laser machining head 54. Alternatively, a same bath may be used for pre-washing to deposit the surfactant on the surface and for post-washing to remove the surfactant film and debris from the surface.

Referring again to figure 5, located at the second end 522 of the table or frame 52, proximate the well 551, is a robot 56 having a substantially horizontal, in use, platform 561, vertically movable with respect to the table or frame 52 above the well 551 on vertical, in use, guide rails 560 substantially perpendicular to the surface of the table or frame 52. An end effector carrier 562 is rotatably suspended from the platform 561 by a vertical axle 563 passing through the platform 561 for rotation of the end

effector carrier 562 with respect to the platform 561 and substantially parallel to the surface of the table or frame 52.

An end effector 564 is slideably mounted on the end effector carrier 562 for movement with respect to the end effector carrier 562 parallel to a longitudinal axis thereof between an extended position and a retracted position.

Figures 5 to 9 illustrate, in sequence, use of the laser machining apparatus to perform the process steps of a complete cycle of the method of the invention of pre-washing a substrate to form a thin film of surfactant on the substrate, laser machining the substrate and, preferably, removing the thin film surfactant from the substrate.

In use, the cassette holder 51 is loaded with wafer substrates 12 to be laser machined. The wafer substrates may optionally be mounted on respective tape frames 121. A selected wafer substrate 12 is removed from the wafer cassette holder 51, as shown in Figure 5, using the end-effector 564 attached to the robot 56, by locating the platform 561 at a suitable height above the surface of the table or frame 52 to extend the end effector 564, with a longitudinal axis of the end effector carrier 562 parallel to the longitudinal axis of the table or frame 52, towards the cassette holder 51 for the end effector 564 to engage the selected wafer substrate 12 in the cassette holder and by retracting the end effector 564 with the selected wafer substrate 12 held by the end effector 564. Alternatively, a slide mechanism may be used instead of the robot.

The wafer substrate 12, held by the end effector 564, is transported vertically away from the surface of the table or frame 52 by the robot to the pre-wash station 53. The end effector 564 is extended such that a lower, in use, surface of the wafer substrate 12 to be machined engages the roller 531, as shown in Figure 6. The roller 531 is rotated about the roller axle 532 as the

end effector 564 moves the wafer substrate 12 over the roller 531 to wash the lower surface of the wafer substrate 12 in a surfactant solution from the bath 533. Alternative dispensing tools such as a nozzle or knife edge dispenser may alternatively be used, optionally with the wafer being rotated with  
5 respect to the dispensing tool during pre-washing.

When pre-washed, the wafer substrate 12 is removed from the pre-wash station 53 by retracting the end effector 564 and lowering the platform 561 and end effector 564 towards the surface of the table or frame 52 to a suitable distance from the surface to position the wafer substrate 12 at a  
10 machining position in the laser machining head 54. As shown in figure 7, the end effector carrier is rotated through substantially 90° about the axle 563 thereof towards the laser machining head 54. The end effector 564 is extended to pass the pre-washed wafer substrate 12 through the laser machining head access 541 for laser machining of the pre-washed wafer  
15 substrate 12, from the lower, in use, pre-washed surface thereof. During laser machining, debris which would otherwise be deposited on the lower surface of the wafer substrate 12 is deposited on the thin film of surfactant.

As shown in Figure 8, after the laser machining operation is complete the wafer substrate 12 is removed from the laser machining head 54 by  
20 retracting the end effector 564 and rotating the end effector carrier 562 through substantially 90° in an opposite sense to that in which the carrier was rotated to load the substrate into the laser machining head and lowering the platform 561 in the direction of the surface of the table or frame 52 to immerse the machined substrate in the washing system 55. Both the  
25 surfactant layer and debris are removed during a wash cycle.

As shown in figure 9, the wafer substrate 12 is then removed from the washing system 55 by moving the platform 561 away from the surface of the table or frame 52 to a distance from the surface sufficient to re-insert the

machined and washed wafer substrate 12 into the cassette holder 51. The end effector 564 is extended to insert the wafer substrate 12 in the cassette holder 51 and the wafer substrate 12 released from the end effector 564 in the cassette holder 51.

- 5           Although a particular arrangement of apparatus has been described by way of example, it will be understood by the person skilled in the art that other arrangements of the component parts, and additional or fewer component parts, may be used.

10           In an alternative machine cycle, the wafer substrate 12 is returned to the wafer cassette holder 51 immediately after laser machining and remains therein until all wafers 12 in the cassette holder 51 have been sequentially pre-washed and laser machined. The entire batch of wafers in the cassette is then loaded into the washing system 55 and all wafers 12 are washed in one wash cycle, thus reducing machine cycling time for a wafer batch.

- 15           Where a same piece of hardware is used to prewash and dispense the surfactant and to wash the workpiece after laser machining, and where cycle time of machining is the same as or shorter than the dispensing or wash cycle time, throughput of the system may be improved through the use of a buffer. Specifically, wafers are sequentially passed through the dispense and  
20           dry step and fed into a buffer. The buffer is unloaded sequentially to feed wafers into the XY table where machining occurs and following machining the wafers are unloaded to the washer. Optimisation of the number of wafers in the buffer will depend on the number of wafers in a cassette as well as deposition and dry times, handling times, machining time and wash  
25           times. A correctly optimised buffer significantly increases throughput.

          In a further embodiment of the invention, the camera system used to perform wafer alignment is used to detect and confirm the presence of surfactant on the wafer before machining. This for example may be achieved

through use of an ideal or "golden" image of an ideal wafer. In further refinement, excess or insufficient surfactant may also be detected through comparison with images of workpieces with excess or insufficient surfactant. This method may be used as an inline control system to prevent machining  
5 of wafers which have, through operator error or machine fault, not received an amount of surfactant sufficiently close to an optimum amount.

In summary, the method of the present invention is to laser machine semiconductor substrates, for example, that have been pre-washed in a surfactant solution in order to reduce the adhesive properties of a surface of  
10 the substrate upon which laser machined debris will collect. This thin film of surfactant, and the debris deposited on the thin film of surfactant, are removed subsequent to laser machining of the substrate thus leaving the wafer surface free of debris and undamaged. This invention is applicable to, for example, laser dicing, laser scribing and laser via drilling in single  
15 substrate and multi-layer substrate materials consisting of layers such as plastic, dielectric, glass, metal and semiconductor materials.

The invention provides the advantages that the thin film of surfactant is easier to remove than known protective plastics films and the surfactant is compatible with known processing being similar to that used as a wettability  
20 agent in mechanical sawing of wafers. Thus, in a laser scribing process, where a dicing process or dicing saw is used in subsequent processing and the sawing process uses water as a coolant or lubricant, that water may also be used to remove the thin film of surfactant.

## CLAIMS

1. A method of laser machining a workpiece (12) including the steps of:
  - a. dispensing a surfactant onto a surface of the workpiece to be  
5 laser machined to provide a surfactant film (11) to reduce  
adhesion to the surface of debris produced during laser  
machining; and
  - b. laser machining the workpiece from the surface.
2. A method as claimed in claim 1, wherein the surfactant is applied  
10 in a pre-wash of the workpiece.
3. A method as claimed in claims 1 or 2, including a further step of at  
least partially drying the surfactant film (11) before laser  
machining the workpiece.
4. A method as claimed in any of the claims 1 to 3, wherein the step  
15 of dispensing a surfactant comprises dispensing a surfactant onto  
surfaces of a plurality of workpieces in a batch process before the  
workpieces are laser machined.
5. A method as claimed in any of the preceding claims, including a  
further step of removing the surfactant film (11), subsequent to  
20 laser machining, together with any debris (151) from the laser  
machining deposited thereon.
6. A method as claimed in any of the preceding claims, wherein the  
step of dispensing a surfactant comprises dispensing a surfactant  
which is soluble in a solvent in which the surface of the workpiece  
25 is insoluble and wherein the step of removing the surfactant film  
comprises dissolving the surfactant film in the solvent.

7. A method as claimed in claim 6, wherein the solvent is water.
8. A method as claimed in any of the preceding claims, wherein the step of laser machining the workpiece includes at least one of laser scribing, laser dicing and laser via drilling the workpiece.
- 5 9. A method as claimed in any of the preceding claims, wherein the step of laser machining the workpiece comprises laser machining a multilayer workpiece.
- 10 10. A method as claimed in claim 9, wherein the step of laser machining a multilayer workpiece comprises machining a semiconductor wafer and associated layers forming an active region of the wafer.
11. A method as claimed in any of the preceding claims, wherein the step of dispensing the surfactant comprises spray depositing the surfactant film on the surface.
- 15 12. A method as claimed in any of claims 1 to 10, wherein the step of dispensing the surfactant comprises knife-edge depositing the surfactant film on the surface.
13. A method as claimed in any of claims 1 to 10, wherein the step of dispensing the surfactant comprises roller depositing the surfactant film on the surface.
- 20 14. A method as claimed in any of the claims 1 to 10, wherein the step of dispensing the surfactant comprises immersing the surface of the workpiece in a surfactant solution.
- 15 25 15. A method as claimed in claim 14, wherein the step of dispensing the surfactant comprises dipping a batch of wafers to be machined into a surfactant solution.

16. A method as claimed in any of the preceding claims, wherein the step of dispensing the surfactant comprises dispensing an anionic, non-ionic or amphoteric surfactant.
- 5 17. A method as claimed in any of the preceding claims, wherein the step of dispensing the surfactant comprises coating the surface with a surfactant film having a sufficiently high degree of wetting to wet substantially all the surface.
- 10 18. A method as claimed in any of the preceding claims, wherein the step of laser machining includes optimisation of machining parameters and such optimisation includes seeking to minimise adherence of debris (15) to the surfactant film.
19. A method as claimed in claim 5, wherein the step of removing the surfactant film comprises a spin-rinse-dry process.
- 15 20. A method as claimed in claim 5, wherein the step of laser machining comprises laser scribing the workpiece and the step of removing the surfactant film comprises at least partially removing the thin film of surfactant and any debris with a coolant used in a subsequent dicing step using a dicing saw.
- 20 21. A method as claimed in any of the preceding claims, wherein the step of laser machining comprises providing a gas environment for the laser machining for reducing solid debris created in the laser machining step.
- 25 22. A method as claimed in any of the preceding claims, wherein the step of dispensing the surfactant comprises coating the surface with a surfactant dissolved or suspended in a liquid carrier and evaporating the liquid carrier from the surface.

23. A method as claimed in any of the preceding claims wherein the step of dispensing the surfactant to form a thin film of surfactant (11) comprises the step of acquiring an image of the film of surfactant on the workpiece and comparing the image with a reference image of a workpiece with an optimum thin film of surfactants and where the image is not sufficiently comparable with the reference image washing the workpiece and re-dispensing surfactant on the surface of the workpiece.
24. A method as claimed in claim 23 wherein the step of comparing the image with a reference image includes comparing the image with at least one of a second reference image of a workpiece with an excess of surfactant on a surface and a third reference image of a workpiece with insufficient surfactant on a surface.
25. A method as claimed in any of the preceding claims, wherein the step of dispensing a surfactant onto a surface of the workpiece comprises a step of using a camera and associated hardware and software to align a wafer on a xy table with machine coordinates of a laser apparatus with which the wafer is to be machined, or with a laser of the laser apparatus, before the surfactant is dispensed on the wafer, such that the surfactant is dispensed on the wafer on the xy table after the wafer has been clamped in position thereon.
26. A method as claimed in claim 5, comprising the steps of:
- a. removing a wafer (12) from wafer carrier means (51);
  - b. transporting the wafer to a surfactant dispensing station (53) and coating the surface of the wafer with a surfactant film (11) to form a coated wafer;

- c. transporting the coated wafer to a laser machining station (54) and laser machining the coated wafer to form a machined coated wafer such that debris (151) from the laser machining is deposited on the surfactant film; and
- 5 d. transporting the machined coated wafer to a surfactant removal station (55) and removing the surfactant film and the debris (151) deposited thereon to form an uncoated machined wafer.
- 10 27. A laser machining apparatus comprising surfactant-dispensing means arranged for coating a surface of a workpiece (12) to be machined with a surfactant film (11) to reduce adherence to the surface of debris (151) produced during laser machining by the apparatus.
- 15 28. A laser machining apparatus as claimed in claim 27, wherein the surfactant dispensing means comprises pre-washing means.
29. A laser machining apparatus as claimed in claim 27 or 28, further comprising surfactant film removal means (55) for removing the surfactant film (11) from the surface together with any debris (151) deposited thereon during laser machining thereof.
- 20 30. A laser machining apparatus as claimed in claim 29, wherein the surfactant film removal means comprises spin-rinse-dry means.
31. A laser machining apparatus as claimed in claim 29, wherein the surfactant film removal means comprises post-washing means.
- 25 32. A laser machining apparatus as claimed in claim 31, wherein the pre-washing means and the post-washing means are a same washing means.

33. A laser machining apparatus as claimed in any of claims 27 to 32, arranged for at least one of laser scribing, laser dicing and laser via drilling the workpiece.
34. A laser machining apparatus as claimed in any of claims 27 to 33,  
5 wherein the surfactant dispensing means comprises spray deposition means (21).
35. A laser machining apparatus as claimed in any of claims 27 to 33, wherein the surfactant dispensing means comprises knife-edge deposition means (31).
- 10 36. A laser machining apparatus as claimed in any of claims 27 to 33, wherein the surfactant dispensing means comprises roller deposition means (41).
37. A laser machining apparatus as claimed in any of claims 27 to 33, wherein the surfactant dispensing means comprises immersion  
15 means for batch dipping a plurality of workpieces.
38. A laser machining apparatus as claimed in any of claims 27 to 37, further comprising gas environment control means for producing a gas environment for laser machining arranged to reduce solid debris (15) produced in laser machining.
- 20 39. A laser machining apparatus as claimed in any of claims 27 to 38, further comprising drying means arranged at least partially to dry the surface subsequent to coating the surface.
40. A laser machining apparatus as claimed in any of claims 27 to 39, further comprising imaging means for obtaining an image of the  
25 surfactant film on the surface of the workpiece and image comparison means for comparing the image with a least one

reference image for determining whether the thin film of the surfactant is sufficiently optimised for laser machining.

41. A laser machining apparatus as claimed in claim 29, comprising: a surfactant dispensing station (53) for coating a surface of a workpiece (12) to be laser machined with the surfactant film (11) for reducing adherence to the surface of debris (15) produced during laser machining by producing a coated workpiece; a laser machining station (54) for machining the coated workpiece; a surfactant film removal station (55) for removing the surfactant film (11) subsequent to laser machining together with any debris (151) from the laser machining deposited thereon; and transport means (560, 561, 562, 563, 564) for transporting the workpiece from the surfactant dispensing station (53) to the laser machining station (54) and from the laser machining station (54) to the surfactant film coating removal station (55).
42. A workpiece (12) coated on at least one surface with a surfactant film (11) arranged to reduce adherence to the at least one surface of debris (15) produced during laser machining of the workpiece.
43. A workpiece as claimed in claim 42, wherein the surfactant film is removable subsequent to laser machining without significantly damaging the at least one surface.
44. A workpiece as claimed in claims 42 or 43, wherein the surfactant film is not more than 10 microns thick.
45. A workpiece as claimed in any of claims 42 to 44, wherein the surfactant film is an anionic, ionic or amphoteric film.