

METHOD AND APPARATUS FOR APPLYING A LAYER OF RESIN UNIFORMLY
AND REGULARLY ON A SUBSTRATE

The present invention relates to a method, and to apparatus for implementing the method, enabling a thin film layer of a liquid to be spread over and deposited on the surface of a substrate, in particular by means of a centrifuge effect.

- 5 A particular application of the invention lies in the context of depositing an extremely thin layer of photosensitive resin on the surface of a substrate of any material, and in particular of a semiconductor metal such as silicon.
- 10 Particularly in the context of making integrated circuits, which requires successive layers or stages to be made, each including a conductive array, it is known that each stage is made by depositing a layer of photosensitive resin on a substrate which is then exposed through an appropriate mask,
- 15 followed by fixing, enabling the network that corresponds to the stage under consideration to be made.

The fabrication of ultra-miniaturized integrated circuits requires photosensitive resin (referred to below as "resin") to be deposited thinner and thinner so as to make it

20 possible to obtain extremely fine definition for each stage.

The technique commonly used for obtaining a thin film of resin consists in taking the resin in the liquid state in solution in a solvent and in depositing it on the receiving substrate which is generally a circular or quadrangular

25 wafer.

The wafer is initially deposited on and secured to a turntable; the turntable is immediately set into rotation, thereby causing the liquid constituted by the solution of resin and solvent to be spread under the effect of centrifugal force into a layer that is extremely thin and uniform on the surface of the substrate.

The extreme volatility of the solvent makes it necessary to perform the rotation at high acceleration so that proper spreading is obtained before evaporation of the solvent changes the viscosity of the mixture of solvent plus resin too much.

Initial deposition of the resin in solution may be performed while the wafer is stationary; however it is also possible to deposit the resin in solution in an initial step during which the substrate is already in rotation at low speed, thereby facilitating initial dispersion movement over the entire surface; subsequent fast rotation with high acceleration serves to eliminate excess resin from the surface of the substrate, with the excess resin then being sprayed outwards and being collected on the walls of a bowl inside which the turntable is mounted.

The search for films of ever decreasing thickness on substrates of ever increasing size leads to the implementation of ever finer techniques acting respectively on the nature of the resin in solution, and in particular its concentration, on the properties of the solvent, and in particular its volatility, and also on operating conditions, and in particular speed of rotation, intensity of acceleration, etc. For the record, mention is made of the essential precautions associated with very high purity and with stability of the environment, in particular the elimination of all dust particles which, if deposited, would

give rise to distortion that is unacceptable at the required scale of miniaturization.

It is nevertheless clear that the more the size of the substrate is increased while simultaneously decreasing the thickness of the deposited resin film, in particular for the purpose of obtaining film thicknesses of less than 1 micron, the greater the difficulties, and operating conditions become more and more difficult to implement and to control to ensure not only that a resin film is obtained that is of small thickness, but also and this is essential, that a resin film is obtained which is constant and uniform in thickness.

It is necessary for the film to be completely regular in its thickness over the entire surface of the substrate.

Independently of the nature (viscosity, associated with concentration) of the resin solution, attempts may be made to reduce thickness by acting on the acceleration and on the speed of rotation; thus, accelerations are used that can cause the speed of rotation to be raised to 10,000 revolutions per minute in one second.

However, experience shows that problems are then encountered associated with interference between the static air or volume of gas situated over the substrate, and both the rotating substrate and the liquid film it carries and that is in the process of becoming fixed.

The accelerations used in this way do not allow a speed gradient to be established in the displacement of the air (or the layer of gas) situated above the substrate, and interferences between the liquid surface being rotated and in the process of stabilizing and hardening on the one hand, and the static or semi-static air on the other hand gives

rise to surface distortions in the form of waves or wrinkles that can be detected optically, in particular.

5 Above all, the technique as described above becomes completely unsuitable when it is desired to spread resin over substrates that are quadrangular in shape, e.g. for the purpose of subsequent use in the manufacture of flat screens.

10 When a substrate that is quadrangular, and in particular square, is caused to rotate, each corner constitutes a leading edge penetrating into the air and consequently giving rise to turbulence which interferes strongly with the flow and distribution of the liquid film on the surface of the substrate.

15 As a result, the fabrication of wafers or substrates that are square and that carry a film of photosensitive resin is consequently accompanied in each corner by a zone showing traces of the turbulence encountered by the liquid while it was being spread out, and this gives rise, in particular, to thickness non-uniformities in the resin film in the form, in
20 particular, of spiral segments marking the corners of the substrate.

As a result, it seems impossible at present, with existing techniques, to make square wafers or substrates carrying a film of resin in the form of a thin layer of uniform
25 thickness, while using the rotary and centrifuging techniques described above.

The invention solves this problem and makes it possible to avoid interference between the rotating substrate carrying the resin that is being spread out and the volume of gas in
30 which it is located. The invention also solves the difficulties associated with an increase in the area that is

covered by the film of resin by providing better control of solvent evaporation.

5 The invention thus makes it possible to obtain substrates that are quadrangular as easily as substrates that are circular, including a thin film of resin of perfectly regular and uniform thickness that may be less than one micron.

10 The method and the apparatus of the invention also make it possible to keep the option of modulating and adapting the thickness by selectively choosing the resin in its solvent.

15 To this end, according to the invention, the method of coating a substrate, in particular made of semiconductor material such as silicon, or of an inorganic material such as glass, with a layer of resin, e.g. photosensitive resin, for the purpose of fabricating components, in particular electronic or optical components, in which method, a measured quantity of resin in solution is deposited on the substrate which is in position on a circular turntable, the resin being spread out in a thin layer by rapid and accelerated rotation of the turntable while simultaneous evaporation of the solvent leaves a layer of resin of desired thickness on the substrate, is characterized in that a concentric cover is superposed over the circular turntable making contact with said circular turntable, thereby defining a gaseous volume that encloses the substrate, and in that said cover is caused to be set into rotation together with the turntable so that the said gaseous volume is entrained in rotation synchronously with the turntable and the cover.

30 In this way, the surface of the rotating substrate carrying the resin in solution in the solvent that is in the process

of evaporating is protected from any interference with the ambient gaseous atmosphere.

It will be observed that the documents "Patent abstracts of Japan, Vol. 11, No. 259 (C-441) (2706), August 21, 1987, of JP-A-62 61 670" discloses a method of coating a substrate with a layer of covering agent, in which method a measured quantity of said agent is deposited on the substrate which is in position on a circular turntable, the agent is then spread out in a thin layer by causing the turntable to rotate rapidly. That known method shows that a flat concentric cover is superposed over the circular turntable to co-operate with the circular turntable to define a volume of gas that is peripherally open such that in operation, air is sucked in centrally and is ejected through the open periphery of the gaseous volume between the turntable and the flat cover.

In addition, the document "Patent abstracts of Japan, Vol. 9, No. 230 (E-343) (1953), September 17, 1985, of JP-A-60 84 816" describes apparatus for making a thin resin coating on a substrate uniform by means of a wing that reduces the influence of air resistance.

The present invention also provides apparatus for implementing the method of the invention for coating a substrate, in particular a substrate of semiconductor material such as silicon, or of inorganic material such as glass, with a layer of resin, in particular a photosensitive resin, for the purpose of fabricating components, in particular electronic or optical components, said apparatus including a source of resin in solution suitable for depositing a measured quantity of resin on the surface of the substrate, and a substrate-receiving turntable provided with means for securing said substrate on the turntable so that rotation of the turntable causes the resin to be spread

out in a thin layer on the surface of the substrate. The apparatus is characterized in that it includes a partitioning cover in contact with said turntable enabling said substrate to be enclosed in the gaseous space situated above the turntable, the cover being suitable for being set into rotation synchronously with the turntable so as to entrain the layer of gaseous atmosphere situated above the substrate in rotary motion that is synchronous with the substrate.

10 Preferably, said partitioning cover is in the form of an upside-down saucer, resting via its edges on the turntable beyond the edges of the substrate.

15 The cover may be removably mounted so as to enable the substrate to put into place and optionally the resin to be initially deposited, and the cover is mounted on an axis of rotation suitable for taking up a position that is in alignment with and above the axis of rotation of the turntable, thereby enabling the turntable and the cover to be set into rotation that is harmonized, synchronous, and concentric, with the cover being entrained by the turntable.

20 According to yet another characteristic, the cover is rotatably mounted on a transverse arm suitable for extending diametrically over the turntable, and the arm supporting the cover is movable between a withdrawn position allowing access to the turntable for installing or removing the substrate and optionally for initial deposit of the resin, and an engaged position in which the cover is brought into contact with and rests on the turntable.

30 According to another characteristic, the arm carries the cover via an axis of rotation formed by a bearing whose center is left open to allow the duct for feeding the resin

in solution to pass through and terminate at one or more discharge nozzles above the turntable.

5 In a particular embodiment, the edge of the cover bears on the substrate-receiving turntable without sealing, thereby allowing excess resin in solution that has come from the substrate to pass through and escape under centrifugal force.

10 According to yet another characteristic, the arm carrying the cover is mounted on a lateral hinge, and is angularly displaceable in a plane that is vertical and diametral relative to the turntable in such a manner as to be capable of being displaced between a withdrawn position and an engaged position in which it overlies a diameter of the turntable and holds the cover in a rest position on said
15 turntable.

The arm may include locking means enabling it to be held stationary both in its active position and its inactive position.

20 According to yet another characteristic, the cover held on the substrate-receiving turntable by the arm is caused to bear thereagainst by means of a spring rated to a value that allows the cover to bear in such a manner as to enable the resin in solution to flow between the turntable below and the cover above during the centrifuging step.

25 Other characteristics and advantages of the invention appear from the following description which is given with reference to a particular embodiment given by way of example and shown in the accompanying drawings.

Figures 1 and 2 are a diagrammatic horizontal section view through a centrifuge turntable made in accordance with the invention.

5 In Figures 1 and 2, the turntable 1 is shown mounted on a vertical shaft 2 driven from below by a motor device (not shown).

On the turntable 1, there is placed the substrate 3 which is constituted in this case by a substrate that may be square or circular in shape.

10 The substrate 3 is held in position on the turntable 1, in particular during the step of establishing rotation with rapid acceleration, by a suction device connected to another vacuum source (not shown) and passing through the central portion of the supporting turntable 1.

15 A stationary assembly is held around this rotary apparatus, and is constituted by a lower bowl 4 and by an upper deflector 5.

20 The lower bowl 4 is mounted on the stand 6 and in its central portion it includes a hole through which the shaft 2 passes.

The upper deflector 5 is mounted stationary on the stand 6 and 7 that is above the turntable 1 and the peripheral bowl 4.

25 The arm 7 is hinged at 8 and it can thus be moved about the axis 8 in a diametral vertical plane relative to the turntable 1.

The arm 7 can thus be moved from a withdrawn position in which it is substantially vertical above the axis 8, and an

engaged position in which it extends over the turntable, and as shown in the figure.

5 In Figure 2, the ducts 9 and 9' pass through the central portion of the arm, which ducts serve to deliver the resin in solution in an appropriate volatile solvent and open out into the lower nozzle 10 that is itself over the receiving wafer 3.

10 In accordance with the invention, the arm 7 carries a ring bearing 11 whose central portion is open so as to allow the ducts 9 and 9' to pass therethrough, and the cover 12 is rotatably mounted on said bearing.

15 In Figures 1 and 2, the cover, which is in the form of an upside-down saucer, has its edges 12' resting on the top wall of the turntable 1, while its central portion is rotatably mounted on the bearing 11.

The axis of rotation of the cover 11 is in accurate alignment with the axis of rotation of the turntable 1.

As a result, when the turntable is set into rotation, that motion is naturally communicated to the cover 12.

20 The arm 7 may be locked on the assembly constituted by the stand 6 and the side uprights 6a and 6b.

The pressure of the cover 12 against the turntable 1 beneath it is rated so as to avoid any sealing contact between the edges 12' of the cover and the turntable 1.

25 The operation of the assembly as described is readily understood.

In Figure 2, the nozzle 10 initially deposits an appropriate quantity of resin in its volatile solvent on the substrate 3 which may be driven at that time in slow rotation so as to allow initial spreading of the resin in its solvent on the surface of the substrate.

Thereafter, the speed of rotation of the turntable 1 is increased, thereby causing the resin in its solvent to be shifted outwards centrifugally.

Simultaneously, the extremely volatile solvent is partially confined between the turntable 1 and the cover 12.

However, the simultaneous and uniform rotation of the assembly constituted by the turntable 1 and its cover 12 simultaneously entrains the confined inside atmosphere between the cover 12 and the turntable 1 in rotation so that the gaseous atmosphere situated over the substrate is entrained in rotation simultaneously or substantially simultaneously with the substrate, thereby avoiding interference, turbulence, and any risk of distortion in the distribution over the surface of the substrate of the liquid film constituted by the resin in solution.

This happens likewise in the event that the substrate is square in shape.

Under such circumstances, the angular portions formed by the corners of the substrate are no longer caused to penetrate violently and at accelerated speed into the gaseous atmosphere which is itself entrained in rotation substantially simultaneously because it is enclosed and confined between the turntable and the cover, so the atmosphere is subjected to the same acceleration as the substrate and the liquid film which constitutes the interface between the substrate and the gaseous atmosphere.

However, sealed contact between the edges of the cover and the turntable is avoided so that excess resin in suspension in the liquid state and flung violently outwards can slip and flow between the turntable and the cover so as to escape from the chamber constituted by the inside space defined between the turntable and the cover; this avoids any excess solution and in particular any excess solvent running the risk of poisoning the atmosphere inside the chamber by causing it to become supersaturated in solvent which would run the risk of causing the surface of the resin film to be deformed by the solvent at the end of the operation.

Provision may also be made for the ring-shaped space surrounding the central pipes 9, 9' and the bearing 11 can be enclosed or open depending on circumstances, and in particular depending on the viscosity (and thus the concentration) of the solution, and consequently depending on the vapor pressure of the solvent that is given off during fabrication of the film.

Radial baffles may also be provided disposed on the inside wall of the cover 12 so as to subdivide the inside space of the chamber 14 into a plurality of mutually partitioned sectors, each sector corresponding to a partial atmosphere over the substrate, and each sector entraining its own atmosphere in motion over the substrate, thereby even more thoroughly avoiding any distortion and any speed gradient between the film that is being spread out and that is drying on the substrate and the corresponding atmosphere over it.

Tests and experiments performed by the Applicant have made it possible to fabricate films in this way that are perfectly regular and of a thickness that may go down to a figure of less than 0.5 microns, corresponding to definition which is particularly precise and fine in the fabrication of

integrated circuits, thus making a particularly high degree of miniaturization possible.

CLAIMS

1. Method to coat a substrate, especially one made of a semi-conductive material, such as silicon, or one made of a mineral material, such as glass, with a photosensitive resin coating, for example, with a view to producing in particular
5 optical or electronic components, wherein a dissolved resin dose is deposited on the substrate in position on a circular rotary plate, the resin being immediately spread as a thin layer by the fast and accelerated rotation of the plate at the same time as evaporation of the solvent allows the resin
10 coating of the desired thickness to be present on the substrate,

characterized in that a concentric cover (12) in contact with said circular plate and defining thereby a gaseous volume encompassing the substrate (3) is superimposed on the
15 circular plate (1) and in that this cover is made to rotate with the plate so that said gaseous volume is driven in rotation synchronous with the plate and the cover.

2. Device to implement the method according to claim 1 and intended to coat a substrate, especially one made of a
20 semi-conductive material, such as silicon, or one made of a mineral material, such as glass, with in particular a photosensitive resin coating with a view to producing in particular optical or electronic components, said device comprising a dissolved resin source (9,9') and being
25 suitable for depositing a resin dose on the surface of the substrate and a plate (1) receiving the substrate (3) and provided with means for rendering said substrate stationary on the plate so that the rotation of the plate (1) provokes the spreading of the resin as a thin coat over the surface
30 of the substrate,

characterized in that it comprises a partitioning cover in contact with said plate allowing said substrate to be contained inside the gaseous space located above the plate



and being suitable for being rotated synchronous with the plate so as to drive the gaseous atmosphere layer located above the substrate in a rotary movement synchronous with the latter.

5 3. Device according to claim 2,
characterized in that said partitioning cover (12) is formed from an inverted bowl resting via its edges on the plate (1) above the edges of the substrate (3).

4. Device according to either claim 2 or 3,
10 characterized in that the cover (12) is movable-mounted so as to allow for placing of the substrate and subsequently the initial depositing of the resin (3), this cover being mounted on a spin axis (11) suitable for coming into a collinear position with respect to the spin axis of the
15 lower plate (1), thus allowing for the matched synchronous and concentric rotation between the plate and the cover, said cover being driven by the plate.

5. Device according to either claim 3 or 4,
characterized in that the cover (12) is rotary-mounted on a
20 transversal arm (7) suitable for diametrically overhanging the rotary plate (1), this arm supporting the cover being able to be moved between an inactive position, allowing for access to the plate with a view to the depositing or removal of the substrate and possibly the initial resin deposit, and
25 an active position in which the cover is brought into contact and rests on the plate.

6. Device according to claim 5,
characterized in that the arm (7) bears the cover (12) by means of a spin axis formed by a rolling bearing (11) whose
30 center is left free so as to allow for the passage of the dissolved resin admission pipe (9,9') and ending at one or more discharging nozzles overhanging the plate.



7. Device according to any one of claims 3 to 6,
characterized in that the support of the edge of the cover
(12) on the receiving plate (1) is embodied without
imperviousness, thus allowing for the passage and
5 accordingly the escape due to the centrifugal force of the
excess dissolved resin from the substrate.

8. Device according to any one of claims 5 to 7,
characterized in that the arm (7) bearing the cover (12) is
articulated laterally mounted and is able to be moved
10 angularly within a vertical plane and diametrical to the
rotary plate (1) so as to be able to be moved between an
inactive position and an active position where it
diametrically overhangs the plate by keeping the cover in
the rest position on said plate.

15 9. Device according to any one of claim 5 to 8,
characterized in that the arm (7) comprises locking means
enabling said arm to be rendered stationary in the active
position, as well as in the inactive position.

10. Device according to any one of claims 3 to 9,
20 characterized in that the support of the cover (12) kept on
the receiving plate (1) by the arm (7) is obtained by means
of a spring calibrated to a value allowing for a support of
the cover so that it allows the dissolved resin to flow
between the lower plate and the upper cover during the
25 centrifuging phase.

