Method for Coating Cavities of a Semiconductor Substrate

Specification

This invention relates to a method for coating cavities, at least partially running through a semiconductor substrate, with a coating material ~~according to Claim 1~~ as well as a method for removing a coating from cavities of a semiconductor substrate ~~according to Claim 7~~.

In the semiconductor industry, the trend toward three-dimensional structures has been evident for several years now. Although a start was made with stacks of varying functional units more than ten years ago, the connections between these structures could only be produced in an expensive manner using outer wiring. This wiring (English: wires) was performed by wire bonders. The wiring is costly, susceptible to flaws and accordingly takes up a great deal of space.

For some years now, therefore, work has been underway on technologies in which the wiring of the varying functional units is carried out vertically by a substrate or by a chip. These passages are called vias. Vias in silicon are called TSVs (English: through silicon vias), and vias in polymer are called TPVs (English: through polymer vias).

viscosity in general increases again to a very high value, having a negative effect on the cleaning, by a dropping of the temperature between the debonding process and the cleaning process. In the case of debonding processes, which are performed at room temperature, the temporary bonding adhesive never reaches a low viscosity value.

In general, in order to be able to clean the vias, the product substrates must be put in a chemical bath after the debonding and be exposed in particular to ultrasound. Both treatment steps lay claim to the product substrate, in particular take time, and thus increase costs.

~~The object~~Embodiments of this invention ~~is to indicate~~ disclose a method with which the processing of semiconductor substrates with cavities, in particular vias, is optimized.

~~This object is achieved with the features of Claim 1. Advantageous further developments of the invention are indicated in the subclaims.~~

According to a first aspect of the present invention, there is provided a method for temporary coating of cavities, which are at least partially running through a semiconductor substrate and provided for a permanent coating and/or equipping, with a temporarily applied coating material before processing steps for processing at least one surface of the semiconductor substrate, wherein the coating material is formed from a high-adhesive part, which adheres to the surface of the cavities, and a low-adhesive part, which points into the interior of the cavities and thus comes into contact with contaminants.

All combinations that consist of at least two features indicated in the specification, in the claims and/or the drawings also fall within the scope of the invention. In the indicated ranges of values, values as boundary values that lie within

the above-mentioned limits are also to be regarded as disclosed and can be claimed in any combination.

On the one hand, embodiments of the invention relates to a method for temporary coating of a surface of cavities that at least partially, and preferably primarily (more than up to half the thickness of the semiconductor substrate), run through a semiconductor substrate. Cavities are in particular vias, preferably boreholes, clearance holes, contact holes in general, but any type of recess with respect to the surface of the substrate. Vias are produced in particular in order to coat or fill them permanently with an electric material, in particular a metal, in most cases copper, so that a conductive connection between the two semiconductor substrates is produced. Cavities are also used in

particular for equipping with or for receiving functional components, preferably LEDs or MEMs.

The object of the temporary coating consists in particular in a simple, fast and primarily economical removal of foreign substances, which can penetrate the cavities/vias during one or more process steps. It is therefore essential to embodiments of the invention to perform the coating before the processing of at least one surface of the semiconductor substrate and thus before a contamination.

Such a processing step is in particular the coating of at least one of the surfaces of the semiconductor substrate, preferably with a bonding adhesive. The following processing steps are alternative according to embodiments of the invention or conceivable cumulative to the above-mentioned:

- Mechanical surface processing processes
    - Grinding
    - Polishing
- Treatment with liquids
    - Etching
    - Washing
- Coatings
    - Gas phase depositions, such as PVD, CVD, PECVD
    - Molecular beam depositions
    - Electrochemical depositions
    - Sputtering
    - Application of polymers
        - Temporary adhesives

- Enameling with photoresist, so-called resist

~~The~~Embodiments of the invention thus describes in particular a method to coat the cavities/vias before a process step, which could contaminate the cavities/vias, with a material that has a low adhesion to other materials, and can preferably be easily removed. In addition, the coating according to embodiments of the invention prevents or hampers at least the deposition and the adhesion of contaminants to the surface of the cavities.

According to ~~a separate aspect~~another embodiment of the invention, ~~the invention relates to~~ there is provided a method for removing a coating from cavities/vias of a semiconductor substrate, whereby the coating is applied in particular according to a previously-described method. The removal is done in particular according to the above-mentioned processing steps, whereby with the removal, in particular also some contaminants are removed, preferably extracted from the cavities/vias. In particular, immediately after the removal, the permanent coating/ equipping of the vias/cavities is carried out.

The coating consists in particular of a material that can be removed more easily than contaminants produced by the processing steps. In special cases, the coating and/or the contaminants are removed more than 1x, preferably more than 10x, more preferably more than 50x, most preferably more than 100x, and with utmost preference more than 1000x as quickly as the removal of the contamination without the coating according to embodiments of the invention would take place. In particular, the cleaning step of the contaminants and the removal of the temporary coating according to embodiments of the invention can take place separately from one another. This is primarily advantageous when several process steps lie between the production of the coating according to embodiments of the invention and its final removal, which steps contaminate the cavities/vias. In a quite especially

preferred embodiment, however, contaminants and temporary coating are simultaneously removed.

Another embodiment of ~~aspect according to~~ the invention is the preferred removal of contaminants from the cavities/vias at the lowest possible temperatures and in particular in a chemically neutral and/or non-basic and/or non-acidic and/or non-toxic environment.

The temperature for removing contaminants from the cavities/vias is in particular less than 500°C, preferably less than 300°C, most preferably less than 100°C, and even more preferably room temperature.

In combination, the embodiments of invention describe~~s~~ in particular a method to coat the surface of cavities/vias of the semiconductor substrate in order to be able to more quickly remove a contamination of the cavities/vias that possibly took place after several processing steps. The cavities/vias are not filled with the coating in particular, but rather preferably only a coating that is thin with respect to the diameter of the cavities/vias is applied. On the condition of an in particular radially symmetrical VIA, the ratio between the coating thickness and the radius of the VIA is less than 0.5, preferably less than 0.1, more preferably less than 0.01, most preferably less than 0.001, and with utmost preference less than 0.0001. The coating thickness is in particular less than 1 μm, more preferably less than 100 nm, most preferably less than 10 nm, with utmost preference less than 1 nm, and all the more preferably the coating thickness consists of only a single monolayer of the coating material.

The embodiment according to the invention is suitable in principle for all types of cavities. Hereinafter in the patent specification, a special type of cavity, the via, is described as representative of all types of cavities. To one skilled in this field, it is

clear that the method according to embodiments of the invention, however, is not only limited to vias, but rather can be used for any type of cavity. The use in the case of vias represents the preferred embodiment ~~according to~~of the invention.

One ~~aspect according to~~ embodiment of the invention consists in using a coating material that preferably has the following properties. The coating material is suitable in particular for the coating of the surface of the semiconductor substrate that is to be coated, is preferably as economical as possible and stable at least until the cavities/vias are cleaned. Stability is defined according to embodiments of the invention as the adhesion between the surface of the cavities/vias being as high as possible. The adhesion is preferably defined by the energy per unit of surface area, which is necessary to separate from one another two surfaces that are connected to one another. In this case, the energy is indicated in J/m^2. The energy per unit of surface area is in particular greater than 0.00001 J/m^2, preferably greater than 0.0001 J/m^2, more preferably greater than 0.001 J/m^2, most preferably greater than 0.01 J/m^2, with utmost preference greater than 0.1 J/m^2, and even more preferably greater than 2.5 J/m^2. In addition, stability is defined as the coating during additional process steps not changing with respect to the physical and/or chemical properties thereof. In addition, the coating material preferably has a property of low adhesion to other materials, in particular contaminants from processing steps between the temporary coating and the permanent coating/ equipping, but at least to all materials that can contaminate the cavities/vias during additional process steps. In particular, these include the following materials:

- Organic materials, in particular
  - Polymers, preferably
    - Thermoplasts, preferably

According to an advantageous embodiment of this invention, the coating material with a coating thickness b that is less than or equal to half the mean diameter D of the cavities is applied at least on an inner periphery and a base of the cavities. The coating is applied as homogeneously as possible, whereby the coating thickness d can be considered to be a mean coating thickness. The cavities are preferably cylindrical cavities, whereby the mean diameter of the cylinder can be considered to be diameter D, whereby bevels or roundings that are present in particular at a transition to the base of the cavities can be ignored. In the case of the complete filling of the cavities/vias, the material is used as a protective barrier in order to prevent absolutely any penetration of contaminants. This embodiment ~~according to~~ of the invention is only technically and economically useful if the thus used coating material can also be removed extremely quickly and primarily unproblematically again from the cavity/via, since the coating material otherwise itself represents a contaminant.

The coating material can be applied in particular first over the entire surface, and excess coating material can be extracted by rotation of the substrate, so that a homogeneous coating remains. Especially preferably, the coating material is applied by the method that is mentioned in the publication US 8,586,132 B2. This method is suitable in particular for coating vias.

It is especially preferred when the coating material in the case of the coating is applied in addition to intermediate surfaces of the semiconductor substrate running between the cavities. Thus, not only the cavities are protected, which can be advantageous in particular in the case of specific, subsequent processing or treatment steps.

After, between or before some treatment or processing steps downstream from the coating, it is conceivable according to embodiments of the invention to remove the coating material at the intermediate surfaces after the coating, in particular completely, without removing coating material applied in the cavities. In this way, the intermediate surfaces of the semiconductor substrate that are optionally to be processed are open for processing, while the inner periphery and the base of the cavities are protected by the coating material. The removal of the coating material is in this case carried out physically and/or chemically. A physical removal would be in particular a polishing and/or grinding process. The contaminants produced in this way would in this case penetrate the cavities/vias, but the latter would be protected by the coating according to embodiments of the invention. In a subsequent cleaning process, a quick and efficient cleaning could be performed. A chemical removal would be carried out in particular by a wet-chemical process.

The most important thing in this respect would be to ensure that the liquid did not penetrate into the cavities/vias, since otherwise the coating material in the cavities/vias would also be destroyed. The penetration of the liquid could be prevented in particular by a quickly-rotating substrate, preferably by spin-etching. The use of highly viscous etching means, whose high viscosity and high surface tension do not allow the liquid to penetrate into the cavities/vias, would also be conceivable.

~~In~~A further ~~development~~embodiment of this invention~~, it is provided according to an advantageous embodiment~~ is to remove the coating material at the intermediate surfaces by centrifuging, in particular by a spin-etching process, in particular in connection with the application of a solvent for dissolving the coating material, at least partially, preferably completely. In the case of a partial removal of the coating material at the

intermediate surfaces arranged in particular in a plane, preferably only a circular wall section of the surface of the semiconductor substrate is cleared of the coating material.

In this way, an edge section can be exposed to an adhesive material in order to attach the semiconductor substrate only in this edge section to another substrate. In the case of complete removal of the solvent at the intermediate surfaces, a flat surface that is cleared of the coating material remains, which surface is open with respect to the additional processing steps.

Another, ~~in particular independent aspect~~ embodiment of the invention is the cleaning of a substrate that is coated with an above-described method and processed with processing steps. Particularly during the processing steps, there is an intake of contaminants, in particular adhesive (for example bonding adhesive), which above all can penetrate in the cavities. The coating according to embodiments of the invention greatly simplifies and accelerates the cleaning. An especially preferred removal of the contamination from the cavities/vias is done, however, preferably with ultrasound action, while the substrate is located in a solvent.

One ~~aspect~~embodiment according to the invention consists in the fact that an optionally used ultrasound can clear the cavities/vias of the contaminants in an extremely short time, in contrast to the state of the art, based on the extremely low adhesion between the coating and the contaminant. The cleaning process according to embodiments of the invention is even more efficient when the substrate, according to an advantageous embodiment of the invention, is rotated in the solvent during the exposure to ultrasound. In an even more preferred embodiment, the cavities/vias are oriented in the gravitational direction during the ultrasound exposure in the solvent bath and the rotating movement, so that

in addition, the force of weight acts on the contaminants if the latter have a higher density than the solvent.

Because of the extremely low adhesion between contaminants and coating, a removal of the contaminants also with the help of gases is conceivable according to an advantageous embodiment of the invention. In this case, the gases are injected into the substrate under a specific angle of incidence. The gases preferably penetrate into the cavities/vias and convey the contaminants to the substrate surface. The angle of incidence of the gas flow is in particular less than/equal to 90°, preferably less than 70°, even more preferably less than 50°, most preferably less than 30°, and all the more preferably less than 10°. In a quite especially preferred embodiment, the gas is injected parallel to the substrate surface and produces an underpressure above the cavities/vias. Gases that can be used according to embodiments of the invention are in particular

- Air and/or
- Inert gases, in particular
    - Argon and/or
    - Helium and/or
    - Nitrogen and/or
    - Carbon dioxide and/or
    - Ammonia and/or
- Reactive gases, in particular
    - Hydrogen and/or
    - Oxygen and/or
    - Carbon monoxide.

In an even more preferred embodiment, the substrate, in particular in the case of an almost parallel gas flow relative to the substrate, is rotated during the exposure to the gas relative to the gas flow. With a gas flow that is almost normal relative to the substrate, the substrate during exposure to the gas is preferably moved in a translatory manner relative to the gas flow. A combination of rotary and translatory movement of the substrate relative to the gas flow is also conceivable.

In particular in connection to the cleaning or at the same time with the cleaning, a removal of the coating from the cavities/vias of the semiconductor substrate is carried out according to another~~, in particular independent, aspect~~ embodiment of the invention, whereby the coating is applied and designed as previously described.

In an especially preferred manner, the removal is carried out by introducing one or preferably multiple coated substrates into a solvent bath that is filled with a solvent for dissolving the coating material. In particular, the semiconductor substrate does not need to be rotated around its own axis in this case. Exposure to ultrasound and/or rotation of the substrate around an axis while it is lying in a solvent bath can accelerate the removal of the coating material.