Method and substrate system for the separation of carrier substrates

The present invention relates to a method, a device and substrate system for separating carrier substrates from further layers. The carrier substrate can be separated in different processes for the processing of substrates, for example in the debonding or in the transfer of substrates.

In the semiconductor industry, it is increasingly important to develop methods and devices, with the aid of which on the one hand a high degree of adhesion can be produced between surfaces, and on the other hand the adhesion can be prevented again if required. Such methods and devices for the processing of substrates are used chiefly for two different techniques, the layer transfer and the bonding or debonding of substrates.

In the case of the layer transfer, in particular inorganic, mainly very thin layers in themselves not mechanically stable are transferred between self-supporting substrates. The inorganic layers are produced for example on special growth substrates, but then must be transferred onto another substrate, in particular a product substrate, in order to be able to meet their functional properties there. In the rarest cases, the growth substrate and the product substrate are identical.

In the prior art, so-called release layers or separating layers are used in order to carry out a locally targeted separation of the useful layer from the carrier substrate. Until today, organic polymer layers are used as bonding layers, which expensively make an additional cleaning step necessary in the transfer of the useful substrate and increase the contamination.

In the bonding and debonding of substrates, two substrates are first joined together, in order that one of the two substrates, which usually does not have sufficient intrinsic stability for the process on account of a smaller thickness

or lower strength, can be processed supported by the second substrate. The processed substrate is called the product substrate, the supporting substrate being called the carrier substrate. Polymers are predominantly used to produce a so-called temporary bond, i.e. a bond which can be released without destruction. For this purpose, at least one polymer is deposited on a substrate by a process, in particular a centrifugal coating process. The carrier substrate is chiefly coated with the polymer (separating layer) and the carrier substrate is bonded to the product substrate. After the bonding of the product substrate to the carrier substrate, the product substrate is further processed in order to be separated from the carrier substrate again in a subsequent process step. There are different methods in the prior art for the separation of the carrier substrate.

In the early years, the carrier substrate was usually coated all over with the polymer. A very good adhesion between the carrier substrate and the product substrate thus arose. If the product substrate has elevations, for example solder bumps, dies or chips, they can be embedded in the polymer, as long as the polymer layer functioning as a separating layer has a suitable layer thickness. The drawback with this method is encountered in the release of the carrier substrate from the product substrate. For the separation, the polymer layer has to be acted upon over the whole area, so that the complete separation proves to be more complex, amongst other things with a plurality of processing steps. The adhesive force of the adhesive layer can be reduced so far with a chemical, which reaches the adhesive layer laterally or through the carrier substrate, that a mechanical separation is enabled. The action of the chemical on the adhesive layer preferably takes place at raised temperatures.

With the separation of a polymer layer over the full area, there is also a higher energy requirement (e.g. heat, ultrasound) or solvent requirement during the removal of the adhesive materials and thus also higher costs. The

separation itself is controlled in this process preferably by release forces normal to the substrate surface.

An alternative development is the so-called “slide-off debonding”. In this method, a device is used which fixes the product substrate and the carrier substrate over the whole area within each case a substrate holder. The two substrate holders are then moved towards one another in parallel, so that the substrates are sheared off from one another via forces along the adhesive surface. For this purpose, it is necessary to heat the polymer layer lying in between. The polymer layer thus softens and loses its adhesive strength. The advantage of this method consists in the fact that solvents and ultrasound can be completely dispensed with. A drawback is that the debonding still has to be carried out at raised temperature.

Alternative methods for debonding dispense with the use of a raised temperature and only make use of a solvent, which attacks the polymer from the periphery of the two substrates. The action of the solvent can be accelerated by means of ultrasound. The dissolved polymer is preferably carried away from the substrate stack by a revolution of the solvent and preferably continuously removed from the solvent bath. It is also possible to inject the solvent solely laterally onto the polymer and to remove it by means of a solvent jet.

A further development of the solvent process is the so-called ZoneBond™ method, which is described in publication WO 2009094558A2. This is a method in which a carrier substrate has to be specially prepared. The carrier substrate consists of two different zones. The central zone, which occupies the largest area, is coated with the aid of an anti-sticking layer and exhibits a low degree of adhesion to any kind of polymer. The second zone surrounds the first zone in a circular manner usually as a closed ring and reaches up to the edge of the carrier substrate. The thickness of the circular ring amounts to only a few millimetres. This very small area is sufficient to fix the

polymer and therefore the product substrate bonded to the carrier substrate over the whole area. The interior is thereby fixed during the processing steps by the air pressure and the sealing of the sides. It is advantageous that, for the debonding, only the polymer from the second, more easily accessible zone has to be removed, in order to enable debonding of the carrier substrate from the product substrate.

A further development consisted in the use of photosensitive separating layers. These were usually deposited on a, in particular transparent, carrier substrate. The carrier substrate was then coated with a polymer layer and bonded to a product substrate. After the product substrate had finished being processed, by irradiating the separating layer through the carrier substrate, the latter could be released from the product substrate. Such processes are described for example in publications US20150035554A1, US20160133486 and US20160133495A1. A special embodiment of this method, in which the separating layer was not deposited on the carrier substrate, but on the product substrate, can be found in publication WO 2017076682 A1.

The mentioned processes can be combined with one another. For example, a change of orientation of the product substrate can also be carried out. Since the carrier substrates are flipped in this process, one also speaks of a carrier flip. For example, WO2011120537A1 shows a process, in which the product substrate is fixed on a first carrier by means of a polymer layer and then processed. After the processing, in particular back-thinning, the product substrate is very thin and for further use of the other substrate side is bonded on a second carrier substrate. The transfer of the product substrate takes place via two polymer layers. The first carrier substrate, after the fixing of the product substrate on the second carrier substrate, has to be separated from the product substrate.

All the mentioned processes are chiefly based on the fact that some part, but in particular a layer, is influenced such that the adhesion to other parts is

reduced, in particular completely eliminated. In other words, the adhesive properties of the separating layer are reduced.

The devices and methods described in the prior art thus describe a separation process, which provides organic layers, in particular polymer layers, as separating layers or combines organic bonding layers with inorganic separating layers. The use of polymers as bonding layers and/or separating layers, which temporarily join two substrates together, has a number of drawbacks. The polymers are long-chain molecules, whose main component is carbon. Organic materials are often a drawback and undesired in the semiconductor industry, since they can contaminate a clean room environment, in particular the devices in which the substrates are processed. Furthermore, the polymers have the drawback that they maintain their adhesive property only up to a relatively low temperature, which represents an advantage for the debonding, but is disadvantageous if the product substrate has to be processed on the carrier substrate at high temperatures. Apart from the low temperature resistance of organic layers, organic separating layers often have to be applied relatively thick in order to provide suitable adhesive properties.

Apart from the problems in debonding, there is also the problem in the prior art of transferring layers produced on substrates onto product substrates, since a separating layer is also used for this, in order to separate the produced substrate stack from the carrier substrate.

The different methods are also distinguished in that, on the one hand, strong adhesive forces are required during processing irrespective of the process temperature, and on the other hand the substrates have to be separated from one another after the processing with the least possible forces.

Embodiments of the present invention disclose a method for the separation of a carrier substrate and a substrate system for processing and transferring a

substrate, which at least partially removes, in particular completely removes, the drawbacks stated in the prior art. In particular, embodiments of the invention disclose an improved process and improved substrate system for the separation of substrates or the separation of layers on a substrate. It is furthermore a problem of the invention to specify an alternative method and an alternative substrate system, with the aid of which a substrate can be easily and cleanly processed, in particular released (engl.: debonded) or transferred. Furthermore, it is a problem of the present invention to specify a method and a substrate system, which operate low in contamination or enable such an operation. Furthermore, it is a problem of the present invention to specify a substrate system, from which in particular a carrier substrate can be separated or released in a particularly easy manner.

All combinations of at least two features stated in the description, in the claims and/or the drawings also fall within the scope of the invention. In the case of stated value ranges, values lying within the stated limits should also be deemed to be disclosed as limiting values and can be claimed in any combination.

According to a first aspect of the present invention, there is provided a method for the separation of carrier substrate from a product substrate with at least the following steps:

i) preparation of the carrier substrate and the product substrate with a separating layer arranged in between, wherein the separating layer fixes the product substrate on the carrier substrate,

ii) irradiation of the separating layer with laser beams of a laser unit and

iii) separation of the carrier substrate from the product substrate,

wherein the separating layer is inorganic.

The separating layer at the same time functions as a bonding layer or adhesive layer for the, in particular, temporary fixing of the carrier substrate on the product substrate. The product substrate can be a substrate stack, a

component or a single functional layer. In this regard, the method for the separation is basically also provided for the separation of any further substrate from the carrier substrate. The separating layer is particularly preferably arranged directly on the carrier substrate. In this way, a further bonding layer can advantageously be dispensed with. In addition, apart from the inorganic separating layer, preferably no further layers, in particular no organic layers, are required in the separation process. The degree of contamination is thus advantageously reduced.

In a further embodiment of the method, provision is made such that at least one further layer is arranged between the separating layer and the product substrate, and wherein the at least one further layer is inorganic.

In other words, a substrate system with at least the carrier substrate, the separating layer and a further layer can advantageously be processed with the method by a targeted laser treatment, such that the carrier substrate can be separated or released from the at least one further layer easily and with little contamination. In contrast with the prior art, a separating layer of carbon-free material is acted upon by means of a laser with laser beams, so that the adhesive properties of this inorganic separating layer are reduced, whilst the further layer is also inorganic. By means of the release of the carrier substrate by the action on the inorganic separating layer, a completely inorganic layer structure of the substrate system is possible. In various processes for the processing of substrates, in particular in the debonding and transferring of substrates, use of organic separating layers or bonding layers can thus advantageously be dispensed with.

The higher temperature resistance of inorganic materials enables a flexible design of the process. Furthermore, inorganic separating layers and bonding layers typically have a good thermal conductivity, so that a better dissipation of heat via the carrier substrate can take place.

Organic separating layers and organic bonding layers on a polymer base can disadvantageously also cause contamination in corresponding equipment and affect the quality unfavourably. With inorganic materials for the separating layer and the bonding layer, contamination of the equipment can thus be reduced.

The high adhesive properties of the inorganic separating layers and/or bonding layers also enable a thinner separating layer and thus overall a thinner layer structure in the substrate system to be processed. An improved planarity of the substrate system can thus be brought about and materials to be processed and thus contaminating can be spared. A further advantage of the method for separating carrier substrates consists in the lower energy input into the substrate system to be processed and a corresponding lower heat load, as a result of which in particular temperature-sensitive substrate systems can be processed.

The separating layer is formed from a carbon-free material and in particular is deposited previously on the carrier substrate. To this extent, the separating layer can also continue to serve at the same time as a bonding layer (temporary bonding) for the connection to the product substrate via the at least one further layer.

By a carrier substrate, any substrate is to be understood which is suitable for the application of the inorganic separating layer. The carrier substrate is preferably an inorganic substrate, particularly preferably a silicon wafer. Silicon wafers are particularly preferred.

The laser unit acts in a targeted manner and with matched parameters on the separating layer in different, preferably regularly spaced, areas. The inorganic layer preferably impermeable for the laser radiation of the laser unit absorbs the laser radiation, so that the adhesive properties and/or the stability of the separating layer are reduced locally. In particular, lateral

cracks in the separating layer arise on account of the high local energy concentration, so that the carrier substrate can easily be released from the at least one further layer or the product substrate. By means of the inorganic separating layer, the carrier substrate can then be separated in a targeted manner from the at least one further layer in the method for the separation. It is possible, even though not preferable, for an, in particular continuous, large-area laser irradiation to be conceivable. The laser beam does not move in this case relative to the substrate, but is widened in such a way that it strikes the substrate over the whole area. In particular, the irradiation time must be selected much longer in such a special embodiment.

In a preferred embodiment of the method, provision is made such that exclusively inorganic layers are arranged between the product substrate and the carrier substrate. The method can thus be carried out with particularly little contamination.

In a preferred embodiment of the method, provision is made such that laser beams emitted by the laser unit during the irradiation in step ii) first penetrate the carrier substrate and then strike the separating layer. In other words, the laser beams first pass through the carrier substrate and are then absorbed by the separating layer. The carrier substrate is thus at least partially transparent for the laser radiation. The laser unit can thus advantageously be arranged on the carrier side rear side and a separation can be carried out flexibly from the rear side, without special demands being made on the product substrate. In this connection, it should be pointed out that the, if applicable, at least one further layer at all events also absorbs the laser radiation so intensely that the product substrate is advantageously protected.

In a preferred embodiment of the method, provision is made such that the at least one further layer is a silicon oxide layer, which functions as a bonding

layer. This inorganic bonding layer permits a separation process low in contamination.

In a preferred embodiment of the method, provision is made such that the at least one further layer is produced from a first oxide layer and a second oxide layer, in particular by fusion bonding. This further layer consisting of two oxide layers is particularly well suited for straightforward and stable bonding.

In a preferred embodiment of the method, provision is made such that the separating layer is made of a metal or nitride, preferably of a TiN. An inorganic separating layer made of metal or nitride is particularly suitable, since the latter in particular also enables a stable bond. A separating layer based on a tin is particularly preferred.

In a preferred embodiment of the method, provision is made such that the laser beam has a wavelength between 0.1 µm and 500 µm, preferably between 0.2 µm and 100 µm, still more preferably between 0.3 µm and 50 µm, most preferably between 0.5 µm and 10 µm, with utmost preference between 1 µm and 2.5 µm. The separating layer can thus be irradiated particularly efficiently and in a targeted manner. The carrier substrate is preferably transparent for the laser beams.

In a preferred embodiment of the method, provision is made such that the pulse energy of the laser beams amounts to between 0.01 µJ and 128 µJ, preferably between 0.125 µJ and 64 µJ, still more preferably between 0.25 µJ and 32 µJ, most preferably between 0.5 µJ and 16 µJ, with utmost preference between 1 µJ and 8 µJ. It has been shown that damage to the product substrate can be prevented with these pulse energies.

In a preferred embodiment of the method, provision is made such that the laser area is less than 2000 μm^2, preferably less than 500 μm^2, still more

preferably less than 80 μm^2, most preferably less than 20 μm^2, with utmost preference less than 1 μm^2. The area of the separating layer on which the laser acts as advantageously small and local to reduce the adhesive properties of the separating layer and to destroy the latter.

In a preferred embodiment of the method, provision is made such that at least 0.1 µm, preferably at least 1 µm, more preferably at least 5 µm, still more preferably at least 10 µm, most preferably at least 50 µm lie between the areas in which the laser beam acts on the separating layer, so that the areas in which the laser beam acts do not overlap. In this way, a particularly easy and efficient separation is possible.

In a preferred embodiment of the method, provision is made such that the pulse duration of the laser beams amounts to between 10,000 ps and 1 ps, preferably between 1000 ps and 1 ps, still more preferably between 500 ps and 1 ps, most preferably between 100 ps and 1 ps, with utmost preference between 50 ps and 1 ps. This pulse duration permits a targeted action for the separation.

According to a second aspect of the present invention, there is provided a substrate system, in particular for the production of semiconductor components, at least including,

A) a carrier substrate,

B) a separating layer arranged on the carrier substrate and

C) a product substrate arranged on the separating layer,

wherein the carrier substrate can be separated from the product substrate by irradiation of the separating layer with a laser unit, wherein the separating layer is an inorganic layer and the separating layer fixes the product substrate on the carrier substrate.

In other words, the separating layer serves at the same time as a bonding layer. A simple and carbon-free structure is thus enabled.

In a preferred embodiment of the substrate system, provision is made such that at least one further layer is arranged between the separating layer and the product substrate and the product substrate is fixed on the carrier substrate by the at least one further layer, wherein the at least one further layer is inorganic.

A further functional layer with optimum properties for the given project is thus provided. In addition, the further layer is inorganic, so that the advantages of a carbon-free and inorganic stack continue to be present. If the further layer is a bonding layer, the adhesive properties between the carrier substrate/separating layer and the product substrate can advantageously be adjusted.

In a preferred embodiment of the substrate system, provision is made such that the at least one further layer is a bonding layer, wherein the bonding layer is produced at least from a first oxide layer and a second oxide layer, in particular by fusion bonding.

In a preferred embodiment of the substrate system, provision is made such that exclusively inorganic layers are arranged between the carrier substrate and the product substrate. The substrate system can thus be processed independently of the demands on the carbon-containing stacks. In addition, the contamination is reduced.