Method for Applying a Bonding Layer

Specification

The invention relates to a method for bonding a substrate as well as a substrate.

In the state of the art, countless methods to connect various materials to one another exist. In the semiconductor industry, in recent years, primarily the bonding technology to connect two substrates temporarily or permanently to one another has gained acceptance. Very often, the bonding process takes place between semiconductor(s) and/or metal structures on the substrate. The best-known metal bonding technology of recent times is copper bonding. Substrates are the carriers for functional assemblies such as microchips, memory chips, or MEMS assemblies. In recent years, increasingly attempts were made to produce a connection between assemblies arranged on various substrates in order to avoid a wire-bonding process between the assemblies that is labor-intensive, costly, and susceptible to flaws. In addition, the direct bonding variant has the enormous advantage of elevated assembly density. The assemblies must no longer be positioned beside one another and connected via wires, but rather are stacked on one another and connected vertically to one another by various technologies. In most cases, the vertical connections are produced by contact points. The contact points of different substrates must be identical to one another and are oriented to one another before the actual bonding process.

Another little-used process is aluminum bonding. In this process, aluminized points on the surface of a substrate are to be bonded with a material lying on a second substrate. In this case, this can be aluminum or a suitable, different material. One drawback of aluminum is its extreme oxygen affinity. Even with copper, the oxygen affinity is high, so that copper oxides must be regularly removed before a bonding process. With aluminum, the oxygen affinity is higher by a multiple. Aluminum still

forms relatively thick, passivating aluminum oxide layers, which are difficult to remove. In contrast to copper, aluminum is therefore little used for bonding connections, since at this time, because of the very stable oxide layers, no reliable bonding result can be achieved at a reasonable cost. Nevertheless, aluminum is widely used in the semiconductor area to produce metal connections on the chip surface in the lateral direction. Here, aluminum is distinguished in that it has significantly slower diffusion behavior in silicon than, for example, copper or gold. Metal diffused into silicon would impair the characteristics of transistors or make the latter completely unfunctional. Based on this advantageous diffusion behavior, paired with low costs and relatively good electrical conductivity, aluminum has been established over many years as the material that is mainly used for producing electrical connections laterally on the semiconductor chips. Recently, in chips of the newest generation, aluminum is increasingly being replaced by copper because of its better electrical conductivity; however, aluminum still enjoys great importance, primarily in the production of chips on 200 mm substrates with somewhat older production technology. It is specifically these production surrounding areas/plants that in recent times have found enhanced use for the production of MEMS (micro-electro-mechanical systems) components. The production of these MEMS components in turn frequently requires bonding processes, so that the need for a reliable aluminum bonding process increases. Outside of the semiconductor industry, aluminum is also a structural material that is in demand, since it is light, inexpensive, and primarily hardenable. In the semiconductor industry, based on the above-mentioned reasons, it has been attempted for some time to develop processes that make aluminum usable as structural material and in particular material for bonding connections.

The greatest problem when using oxygen-affine materials such as copper and aluminum is the avoidance of oxidation on bonding surfaces and/or the complete removal of oxide from bonding surfaces before a bonding process. Extremely oxygen-affine

materials such as aluminum produce, moreover, oxides that are strong and difficult to reduce. Plants for oxide removal are expensive, labor-intensive and under certain circumstances dangerous (toxic substances).

Embodiments of this invention disclose a method as well as a substrate provided with a bonding layer, with which an oxidizable material (such as in particular aluminum) can be used for bonding.

According to a first aspect of the present invention, there is provided a method for bonding a first substrate with a second substrate, said method comprising: applying an oxidizable basic material as a basic layer on a bonding side of the first substrate; at least partially covering the basic layer with a protective layer having a thickness of less than 100 nm, the protective layer being comprised of a protective material; and bonding the first and second substrates, the bonding comprising at least partially dissolving the protective material in the basic material, the bonding being performed at a temperature that is less than a eutectic temperature of a eutectic system of the basic material and the protective material.

According to a second aspect of the present invention, there is provided substrates bonded using the above method.

Advantageous further developments of the invention are indicated in the subclaims. All combinations of at least two of the features indicated in the specification, the claims and/or the figures also fall within the scope of the invention. In the indicated ranges of values, values that lie within the above-mentioned limits are also to be disclosed as boundary values and can be claimed in any combination.

Embodiments of this invention provide a bonding layer, consisting of a basic layer and a protective layer, in particular as a diffusion pair, on the substrate,

Claims

1. A method for bonding a first substrate with a second substrate, said method comprising:

applying an oxidizable basic material as a basic layer on a bonding side of the first substrate;

at least partially covering the basic layer with a protective layer having a thickness of less than 100 nm, the protective layer being comprised of a protective material; and

bonding the first and second substrates, the bonding comprising at least partially dissolving the protective material in the basic material, the bonding being performed at a temperature that is less than a eutectic temperature of a eutectic system of the basic material and the protective material.

2. The method according to claim 1, wherein the basic material is oxygen-affine and is comprised of aluminum and/or copper.

3. The method according to one of the preceding claims, wherein the step of applying the basic material as the basic layer and/or covering of the basic layer with the protective layer is/are carried out by deposition.

4. The method according to one of the preceding claims, wherein the protective layer is applied such that the basic layer is sealed at least predominantly relative to the atmosphere.

5. The method according to one of the preceding claims, wherein the protective layer is applied such that the basic layer is sealed completely relative to the atmosphere.

6. The method according to one of the preceding claims, wherein the protective layer is treated before the step of bonding, said protective layer is treated with one or more of the following processes:

(a) chemical oxide removal;

(b) physical oxide removal; and

(c) ion-assisted chemical etching.

7. The method according to claim 6, wherein said chemical oxide removal process includes a gaseous reducing agent and/or a liquid reducing agent.

8. The method according to claim 6, wherein said physical oxide removal process is done with plasma.

9. The method according to claim 6, wherein said ion-assisted chemical etching process includes fast ion bombardment, grinding and/or polishing.

10. The method according to one of the preceding claims, wherein one or more of the following materials are selected as the basic material and/or the protective material:

(a) metals;

(b) alkali metals;

(c) alkaline-earth metals;

(d) alloys; and

(e) semiconductors, provided with corresponding doping.

11. The method according to claim 10, wherein said metals are selected from the group consisting of: Cu, Ag, Au, Al, Fe, Ni, Co, Pt, W, Cr, Pb, Ti, Te, Sn, Zn, and Ga.

12. The method according to claim 10, wherein said alkali metals are selected from the group consisting of: Li, Na, K, Rb, and Cs.

13. The method according to claim 10, wherein said alkaline earth metals are selected from the group consisting of: Mg, Ca, Sr, and Ba.

14. The method according to claim 10, wherein said semiconductors are selected from the group consisting of: element semiconductors and compound conductors.

15. The method according to claim 14, wherein said element semiconductors are selected from the group consisting of: Si, Ge, Se, Te, B, and Sn.

16. The method according to claim 14, wherein said compound semiconductors are selected from the group consisting of: GaAs, GaN, InP, InxGal-xN, InSb, InAs, GaSb, AlN, InN, GaP, BeTe, ZnO, CuInGaSe2, ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, Hg(1-x)Cd(x)Te, BeSe, HgS, AlxGal-xAs, GaS, GaSe, GaTe, InS, InSe, InTe, CuInSe2, CuInS2, CuInGaS2, SiC, and SiGe.

17. The method according to one of the preceding claims, wherein the basic material is Al and the protective material is selected from the group consisting of Ge, Ga, Zn, and Mg.

18. The method according to one of the preceding claims, wherein the basic material is Al and the protective material is Ge.

19. The method according to one of the preceding claims, wherein the bonding of the first and second substrates further comprises bringing the bonding side of the first substrate into contact with the second substrate.

20. The method according to one of the preceding claims, wherein the bonding of the first and second substrates comprises bringing the protective layer into contact with the second substrate.

21. Substrates bonded using the method according to one of the preceding claims.