

Method and Device for Permanent Bonding of Wafers

This invention relates to a method for bonding of a first contact area of a first substrate to a second contact area of a second substrate and a corresponding device.

The objective in permanent or irreversible bonding of substrates is to produce an interconnection which is as strong and especially as irreversible as possible, therefore a high bond force, between the two contact areas of the substrates. There are various approaches and production methods for this purpose in the prior art.

The known production methods and the approaches which have been followed to date often lead to results which cannot be reproduced or can be poorly reproduced and which can hardly be applied in particular to altered conditions. In particular, production methods which are used at present often use high temperatures, especially $> 400^{\circ}\text{C}$, in order to ensure reproducible results.

Technical problems such as high energy consumption and a possible destruction of structures which are present on the substrates result from the high temperatures of partially far above 300°C which have been necessary to date for a high bond force.

Other demands consist in the following:

- front-end-of-line compatibility.

This is defined as the compatibility of the process during the production of the electrically active components. The bonding process must therefore be designed such that active components such as transistors, which are already present on the structure wafers, are neither adversely affected nor damaged during the processing. Compatibility criteria include mainly the purity of certain chemical elements (mainly in CMOS structures) and mechanical loadability, mainly by thermal stresses.

- low contamination.
- no application of force.
- temperature as low as possible, especially for materials with different coefficients of thermal expansion.

The reduction of the bond force leads to more careful treatment of the structure wafer and thus to a reduction of the failure probability by direct mechanical loading.

Embodiments of this invention provide a method and a device for careful production of a permanent bond with a bond force which is as high as possible at a temperature which is at the same time as low as possible.

According to a first aspect of the present invention, there is provided a method for bonding of a first contact area of a first substrate to a second contact area of a second substrate, the second substrate having at least one reaction layer, with the following sequence: receiving the substrates into a plasma chamber or into a substrate chamber which is connected to a plasma chamber, the plasma chamber having at least two generators which can be operated with different frequencies, especially are operated with different frequencies for producing the plasma, formation of a reservoir in a reservoir formation layer on the first contact area by applying a plasma which has been produced in the plasma chamber to the first contact area, at least partial filling of the reservoir with a first educt or a first group of educts, making contact of the first contact area with the second contact area for formation of a pre-bond interconnection, formation of a permanent bond between the first and second contact area at least partially strengthened by the reaction of the first educt with a second educt which is contained in a reaction layer of the second substrate.

According to a second aspect of the present invention, there is provided a method for bonding of a first contact area of a first substrate to a second contact area of a second substrate, the second substrate having a least one reaction layer, with the following sequence: receiving the substrates into an inductively coupled plasma chamber, formation of a reservoir in a reservoir formation layer on the first contact area by exposing the first contact area to a plasma which has been produced by means of inductive coupling of the coil, a first frequency different from a second frequency of a second generator being applied on a first generator during plasma production, at least partial filling of the reservoir with a first educt or a first group of educts, making contact of the first contact area with the second contact area for forming a pre-bond interconnection, formation of a permanent bond between the first and second contact area at least partially strengthened by the reaction of the first educt with a second educt which is contained in a reaction layer of the second substrate.

According to a third aspect of the present invention, there is provided a device for bonding of a first contact area of a first substrate to a second contact area of a second substrate, the second

substrate having a least one reaction layer with the following features: a bonding chamber, a first electrode and a second electrode which is located opposite, receiving means for receiving the substrates between the first electrode and the second electrode, reservoir formation means for forming a reservoir in a reservoir formation layer on the first contact area by exposing the first contact area to a plasma which has been produced by means of capacitive coupling of the electrodes, and a first frequency which is different from a second frequency of the second electrode can be applied on the first electrode during the plasma production, means for making contact of the first contact area with the second contact area for forming a pre-bond interconnection.

According to a fourth aspect of the present invention, there is provided a device for bonding of a first contact area of a first substrate to a second contact area of a second substrate, the second substrate having a least one reaction layer with the following features: a bonding chamber, a coil, receiving means for accommodating the substrates, reservoir formation means for forming a reservoir in a reservoir formation layer on the first contact area by exposing the first contact area to a plasma which has been produced by means of inductive coupling of a first and a second generator, and a first frequency which is different from a second frequency of the second generator can be applied on the first generator during the plasma production, means for making contact of the first contact area with the second contact area for forming a pre-bond interconnection.

All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the framework of the invention. At the given value ranges, values within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination.

The basic idea of embodiments of this invention is, using a capacitively coupled plasma or an inductively coupled plasma or a plasma from a remote plasma apparatus, to produce a plasma using which a reservoir for holding a first educt in one substrate is formed, which educt after making contact or producing a temporary bond between the substrates reacts with a second educt which is present in the other substrate, and which thus forms an irreversible or permanent bond between the substrates. Before or after forming the reservoir in a reservoir formation layer on the first contact area,