PURPOSE OF THE INVENTION

Embodiments of the invention therefore seek to propose a method of manufacturing a hybrid structure and find a solution to the disadvantages of the former art. Embodiments of the invention seek to propose a method for applying a required heat treatment without damaging the hybrid structure.

BRIEF DESCRIPTION OF THE INVENTION

An aspect of the invention provides a method of manufacturing a hybrid structure comprising an effective layer of piezoelectric material that has an effective thickness disposed on a support substrate with a support thickness and a coefficient of thermal expansion less than that of the effective layer. The method comprises:

a) A step of providing a bonded structure comprising a donor substrate of piezoelectric material and the support substrate, the bonded structure having a bonding interface between these two substrates;

b) A first step of thinning the donor substrate to form a thinned layer, having an intermediate thickness, disposed on the support substrate; the assembly forming a thinned structure;

c) A heat treatment step of the thinned structure at an annealing temperature;

d) A second thinning step, after step c), of the thinned layer to form the effective layer;

the method being remarkable in that it comprises, prior to step b), a step a') of determining a range of intermediate thicknesses avoiding a degradation of the thinned structure (6') during the step c), the range being defined by a threshold

thickness and a maximum thickness, and the intermediate thickness of the thinned layer being chosen in this range. The threshold thickness and the maximum thickness are determined respectively from a first sensitivity model and a second sensitivity model. The first sensitivity model is associated with a relaxation of the thinned layer in compression on the support substrate and the second sensitivity model is associated with rupture of the support substrate, constrained in extension by the thinned structure during the heat treatment.

The manufacturing method according to the invention thus makes it possible to apply a heat treatment to an annealing temperature required to consolidate the bonding interface or to cure all or part of defects present in the thinned layer (which will become the effective layer), to a thinned structure for which the range of compatible thicknesses of the thinned layer has been previously determined. The said heat treatment is generally not applicable to the final hybrid structure, that is with the effective layer to its effective thickness, without generating damage to the effective layer, especially when unglued areas (bonding defects or pre-existing engraved patterns on the assembled faces of the substrates) are found at the bonding interface

according to advantageous features of the invention, taken alone or in combination:

- • The threshold thickness is determined from a first sensitivity model whose input parameters include the support thickness, the thermal expansion coefficients of the donor substrate and of the support substrate, the annealing temperature and a maximum size of unglued areas found at the bonding interface of the bonded structure;

- The maximum thickness is determined from a second sensitivity model whose input parameters include the support thickness (of the support substrate 1), the thermal expansion coefficients of the donor substrate 2 and the support substrate 1 and the required annealing temperature in step c) heat treatment.
- The manufacturing process comprises, after step a') and prior to step b), a step a'') of recycling the bonded structure, when the determining step a') establishes the

upper threshold thickness at maximum thickness or maximum thickness lower than the effective thickness;

- Recycling step a'' comprises a separation at the bonding interface of the bonded structure;
- Recycling step a'') comprises the reuse of the donor and support substrates resulting from the separation for a new step a) of providing a bonded structure;
- The second thinning step d) may further comprise a step of thinning the support substrate;
- The effective layer is composed of a material chosen from: lithium tantalate ($LiTaO_3$), lithium niobate ($LiNbO_3$), aluminium nitride (AlN), zinc oxide (ZnO);
- The support substrate is composed of a material chosen from the group: silicon, III-V semiconductors, silicon carbide, glass, sapphire;
- The support substrate comprises one or more surface layers.

There is also disclosed a hybrid structure comprising an effective layer of piezoelectric material with an effective thickness of less than 50 microns assembled to a support substrate having a coefficient of thermal expansion less than that of the effective layer, the hybrid structure being characterized in that a bonding interface between the effective layer and the support substrate has a bonding energy greater than 1000 mJ/m2 and at least one non-bonded zone whose size is between 1 and 1000 microns.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantages of the invention will emerge from the detailed description of the invention which follows in the References to the accompanying drawings in which:

CLAIMS

1. A method of manufacturing a hybrid structure (60) having a effective layer (20) of piezoelectric material with a effective thickness disposed on a support substrate (1) that has a support thickness and a coefficient of thermal expansion less than that of the effective layer (20), the method comprises:

a) A step of providing a bonded structure (6) comprising a donor substrate (2) of piezoelectric material and the support substrate (1), the bonded structure (6) having a bonding interface (5) between these two substrates;

b) A first step of thinning the donor substrate (2) to form a thinned layer (2'), having an intermediate thickness, disposed on the support substrate (1); the whole forms a thinned structure (6');

c) A heat treatment step of the thinned structure 6' at an annealing temperature;

d) A second thinning step, after step c), of the thinned layer (2') to form the effective layer (20);

the method being characterized in that it comprises, prior to step b), a step a') of determining a range of intermediate thicknesses avoiding a degradation of the thinned structure (6') during the step c), the range being defined by a threshold thickness and a maximum thickness, and the intermediate thickness of the thinned layer (2') having being chosen in this range;
wherein the threshold thickness and the maximum thickness are determined respectively from a first sensitivity model and a second sensitivity model,

wherein the first sensitivity model is associated with a relaxation of the thinned layer in compression on the support substrate and the second sensitivity model is associated with rupture of the support substrate, constrained in extension by the thinned structure during the heat treatment.

2. A method of manufacturing a hybrid structure (60) according to the preceding claim, wherein the first sensitivity model has input parameters including the support thickness, the thermal expansion coefficients of the donor substrate (2) and the

support substrate (1), the annealing temperature and a maximum size of unglued areas found at the bonding interface (5) of the bonded structure (6).

3. A method of manufacturing a hybrid structure (60) according to one of the preceding claims, wherein the second sensitivity model has input parameters including the support thickness, the coefficients of thermal expansion of the donor substrate (2) and the support substrate (1) and the annealing temperature.

4. A method of manufacturing a hybrid structure (60) according to one of the preceding claims, comprising after step a') and prior to step b), a step a'') of recycling the bonded structure (6), when the determining step a') establishes the threshold thickness higher than the maximum thickness or the maximum thickness less than the effective thickness.

5. A method of manufacturing a hybrid structure (60) according to the preceding claim, wherein the step a'') of recycling comprises a detachment at the bonding interface (5) of the bonded structure (6).

6. A method of manufacturing a hybrid structure (60) according to the preceding claim, wherein the step a") of recycling comprises the reuse of the donor substrate (2) and the support substrate (1) from the detachment for a new stage a) to provide a bonded structure (6).

7. A method of manufacturing a hybrid structure (60) according to one of the preceding claims, wherein the second thinning step d) may further comprise a step of thinning the support substrate (1).

8. A method of manufacturing a hybrid structure (60) according to one of the preceding claims, wherein the effective layer (20) is composed of a material selected from the group: lithium tantalate ($LiTaO_3$), lithium niobate ($LiNbO_3$), aluminium nitride (AlN), zinc oxide (ZnO).

9. A method of manufacturing a hybrid structure (60) according to one of the preceding claims, wherein the support substrate (1) is composed of a material selected from the group: silicon, III-V semiconductor, silicon carbide, glass, sapphire.

10. A method of manufacturing a hybrid structure (60) according to the preceding claim, wherein the support substrate (1) comprises one or more surface layers.