strength between the thin glass sheet and the carrier should be adequate to maintain lamination through the entire device fabrication process but still allow the glass sheet and carrier to be separated, without breaking, after device fabrication and extraction processes.

SUMMARY

[0006] In light of the above, there is a need for a thin sheet and substrate article that can withstand the rigors of high temperature processing, yet allow the entire area of the thin sheet to be removed (either all at once, or in sections), without breaking, from the substrate. The substrate may then be used for processing another thin sheet. The present specification describes methods to control the adhesion between the substrate and the thin sheet to create a temporary bond sufficiently strong to survive high temperature processing but weak enough to permit debonding of the sheet from the substrate, without breaking at least the sheet and, preferably without breaking either the sheet or the substrate. Such controlled bonding can be utilized to create an article having a re-usable substrate, or alternately an article having patterned areas of controlled bonding and covalent bonding between a substrate and a sheet. More specifically, the present disclosure provides a substrate, sheet or both comprising a residual material disposed thereon that may be provided by washing the substrate or sheet with a detergent, prior to bonding, to control both room-temperature van der Waals, and/or hydrogen, bonding and high temperature covalent bonding between the thin sheet and carrier. Even more specifically, the room-temperature bonding may be controlled so as to be sufficient to hold the thin sheet and carrier together during vacuum processing, wet processing, and/or ultrasonic cleaning processing. And at the same time, the high temperature covalent bonding may be controlled so as to prevent a permanent bond between the thin sheet and substrate during high temperature processing such that the thin sheet can be separated from the substrate without breaking the thinner of the substrate and the thin sheet into two or more pieces, as well as maintain a sufficient bond to prevent delamination of the thin sheet and the substrate during high temperature processing. In some examples, when two pieces of glass are permanently bonded to one another, they act as a monolith.

[0007] It is to be understood that various features disclosed in this specification and in the drawings can be used in any and all combinations. By way of non-limiting example, the various features may be combined with one another as set forth in the following examples.

[0008] In a first example, there is a glass article comprising:

a substrate having a substrate bonding surface;

a sheet having a sheet bonding surface;

a surfactant disposed between the substrate bonding surface and the sheet bonding surface;

the sheet bonding surface being non-permanently bonded to the substrate bonding surface such that the sheet may be separated from the substrate without breaking the sheet into two or more pieces, wherein the separation bonding energy between the sheet bonding surface and the substrate bonding surface is less than 800 mJ/m^2 (milli-Joules per square meter) after the glass article is subjected to an aging period of 30 days at 60° C and then to a baking period of 2 hours at 300° C in air.

[0008a] In one aspect, there is a glass article comprising:

a glass substrate comprising a substrate bonding surface;

a glass sheet comprising a sheet bonding surface; and

a surfactant disposed between the substrate bonding surface and the sheet bonding surface, the sheet bonding surface being non-permanently bonded to the substrate bonding surface such that the sheet may be separated from the substrate without breaking the sheet into two or more pieces, and such that the separation bonding energy between the sheet bonding surface and the substrate bonding surface is less than 800 mJ/m^2 after the glass article is subjected to an aging period of 30 days at 60° C and then to a baking period of 2 hours at 300° C in air, wherein the surfactant comprises a compound selected from the group consisting of diethanolamide, coconut diethanolamide, polyethylene glycols, 4-nonylphenyl-polyethylene glycol, bisphenol A ethoxylate, octoxynol-9, oxtylphenol ethoxylate and mixtures thereof.

[0009] In an example, the separation bonding energy between the sheet bonding surface and the substrate bonding surface is equal to or less than about 600mJ/m^2.

[0010] In another example, the separation bonding energy between the sheet bonding surface and the substrate bonding surface is equal to or less than 400 mJ/m^2.

[0011] In another example, the sheet is a glass sheet having a thickness equal to or less than 300 microns.

[0012] In another example, a thickness of the substrate is greater than or equal to the thickness of the sheet.

[0013] In another example, the substrate is a glass substrate.

[0014] In another example, the substrate bonding surface after drying and prior to the substrate being bonded with the sheet comprises an atomic ratio of oxygen to silicon in the range of 2.5 to 3.5, an atomic ratio of silicon to carbon in the range of 4 to 5 and an atomic ratio of oxygen to carbon in the range of 12 to 14.

[0015] The first example may be provided alone or in combination with any one or more of the examples of the first example discussed above.

[0016] In a second example, there is provided a glass article of example 1, the glass article further comprising residue from a Standard Clean 1 cleaning process disposed between the substrate bonding surface and the sheet bonding surface prior to bonding the sheet bonding surface to the substrate bonding surface.

[0017] In an example, the substrate bonding surface prior to the substrate being bonded with the sheet comprises an atomic ratio of oxygen to silicon in the range of 2.5 to 3.5, an atomic ratio of silicon to carbon in the range of 4 to 5 and an atomic ratio of oxygen to carbon in the range of 12 to 14.

[0018] In another example, the article further comprises a detergent residue disposed between the substrate bonding surface and the sheet bonding surface, wherein the

detergent residue can contain a compound selected from the group consisting of diethanolamide, polyethylene glycols, 4-nonylphenyl-polyethylene glycol, bisphenol A ethoxylate, octoxynol-9, oxtylphenol ethoxylate and mixtures thereof.

[0019] In another example, the surfactant can be selected from the group consisting of diethanolamide, polyethylene glycols, 4-nonylphenyl-polyethylene glycol, bisphenol A ethoxylate, octoxynol-9, oxtylphenol ethoxylate and mixtures thereof.

[0020] The second example may be provided alone or in combination with any one or more of the examples of the second example discussed above.

[0021] In a third example, there is a glass article comprising:

a substrate having a substrate bonding surface;

a sheet having a sheet bonding surface;

a surfactant disposed between the substrate bonding surface and the sheet bonding surface;

the sheet bonding surface being non-permanently bonded to the substrate bonding surface such that the sheet may be separated from the substrate without breaking the sheet into two or more pieces, wherein the separation bonding energy between the sheet bonding surface and the substrate bonding surface is less than 400 mJ/m^2 (milli-Joules per square meter) after holding the glass article in an oven at a temperature of 500° C for 10 minutes in an air atmosphere.

[0022] In an example, the as-deposited surface energy of a surfactant bonding surface formed by the surfactant being disposed on the substrate is between about 65 mJ/m^2 and 74 mJ/m^2.

[0023] In another example, the surfactant being a compound selected from the group consisting of diethanolamide, coconut diethanolamide, polyethylene glycols, 4-nonylphenyl-polyethylene glycol, and mixtures thereof.

[0024] In another example, the separation bonding energy between the sheet bonding surface and the substrate bonding surface is equal to or less than 350 mJ/m^2 after holding the glass article in an oven at a temperature of 300° C to 500° C for 10 minutes in an air atmosphere.

[0025] In another example, the separation bonding energy between the sheet bonding surface and the substrate bonding surface is equal to or less than 250 mJ/m^2 after holding the glass article in an oven at a temperature of in the range of 200° C to 300° C for period of time in the range of 20 minutes to 2.5 hours in an air atmosphere, wherein the glass article can be subjected to a pre-treatment step prior to holding the glass article in the oven,

the pre-treatment step includes heating the glass article to a temperature in the range of 100° to 250° C and holding the article in this temperature range for a period of 10 to 30 minutes.

[0026] In another example, the change in percent bubble area of the surfactant is less than or equal to about 5 percent according to Outgassing Test #1 after holding the article in an oven at a temperature of 350 °C for 120 minutes in a nitrogen atmosphere.

[0027] In another example, the glass article further includes a residue from a Standard Clean 1 cleaning process disposed between the substrate bonding surface and the sheet bonding surface.

[0028] The third example may be provided alone or in combination with any one or more of the examples of the third example discussed above.

[0029] In a fourth example, a method of making a glass article is described comprising:

cleaning a bonding surface of a substrate and/or a sheet with a surfactant solution;

drying the bonding surface of the substrate and/or the bonding surface of the sheet and/or substrate and ;

non-permanently bonding the substrate bonding surface to the sheet bonding surface such that the sheet may be separated from the substrate without breaking the sheet into two or more pieces, and such that the separation bonding energy between the sheet bonding surface and the substrate bonding surface is less than about 800 mJ/m^2 after the glass article is subjected to an aging period of 30 days at 60° C and then a baking period of 2 hours at 300° C in air.

[0030] In an example, the substrate bonding surface and the sheet bonding surface are in contact with a surfactant solution.

[0031] In an example, the surfactant solution is a detergent containing a surfactant.

[0032] In another example, the cleaning comprises cleaning the substrate bonding surface with a surfactant solution and the sheet bonding surface with a Standard Clean 1 process prior to bonding the substrate bonding surface to the sheet bonding surface.

[0033] In another example, the sheet is a glass sheet comprising a thickness equal to or less than about 300 micrometers.

[0034] In another example, the substrate comprises a thickness greater than the thickness of the sheet.

[0035] In another example, the substrate is a glass substrate.

[0036] In another example, the substrate bonding surface after the drying and prior to bonding the substrate with the sheet comprises an atomic ratio of oxygen to silicon in the range of 2.5 to 3.5, an atomic ratio of silicon to carbon in the range of 4 to 5 and an atomic ratio of oxygen to carbon in the range of 12 to 14.

[0037] In another example, the drying comprises drying the bonding surface of the substrate and the bonding surface of the sheet for a period of at least about 15 minutes at a temperature equal to or greater than about 85° C.

[0038] In another example, the drying comprises drying the bonding surface of the substrate and the bonding surface of the sheet for a period of at least about 15 minutes at a temperature of at least about 110° C.

[0039] In another example, the drying comprises convectively drying the bonding surface of the substrate and the bonding surface of the sheet.

[0040] In another example, the drying comprises drying, in a convective oven, the bonding surface of the substrate and the bonding surface of the sheet.

[0041] In another example, the drying comprises drying the bonding surface of the substrate and the bonding surface of the sheet for a period of at least about 30 minutes at a temperature equal to or greater than about 85° C.

[0042] In another example, the drying comprises convectively drying the bonding surface of the substrate and the bonding surface of the sheet.

[0043] The fourth example may be provided alone or in combination with any one or more of the examples of the fourth example discussed above.

[0044] The accompanying drawings are included to provide a further understanding of the principles described herein, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more examples, and together with the description serve to explain, by way of example, principles and operation of those examples.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] The above description and other features, aspects and advantages are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0046] **FIG. 1** is a schematic side view of an article having a substrate bonded to a sheet with detergent residue therebetween.

[0047] **FIG. 2** is an exploded and partially cut-away view of the article in **FIG. 1**.

What is claimed is:

1. A glass article comprising:

a glass substrate comprising a substrate bonding surface;

a glass sheet comprising a sheet bonding surface; and

a surfactant disposed between the substrate bonding surface and the sheet bonding surface, the sheet bonding surface being non-permanently bonded to the substrate bonding surface such that the sheet may be separated from the substrate without breaking the sheet into two or more pieces, and such that the separation bonding energy between the sheet bonding surface and the substrate bonding surface is less than 800 mJ/m^2 after the glass article is subjected to an aging period of 30 days at 60° C and then to a baking period of 2 hours at 300° C in air, wherein the surfactant comprises a compound selected from the group consisting of diethanolamide, coconut diethanolamide, polyethylene glycols, 4-nonylphenyl-polyethylene glycol, bisphenol A ethoxylate, octoxynol-9, oxtylphenol ethoxylate and mixtures thereof.

2. The glass article of claim 1, wherein the separation bonding energy between the sheet bonding surface and the substrate bonding surface is equal to or less than 600 mJ/m^2.

3. The glass article of claim 1 or claim 2, further comprising residue from a Standard Clean 1 cleaning process disposed between the substrate bonding surface and the sheet bonding surface, wherein the substrate bonding surface comprises an atomic ratio of oxygen to silicon in the range of 2.5 to 3.5, an atomic ratio of silicon to carbon in the range of 4 to 5 and an atomic ratio of oxygen to carbon in the range of 12 to 14, wherein the atomic ratios between silicon, oxygen and carbon are measured from the substrate bonding surface of the substrate as dried and prior to the substrate being bonded with the sheet.