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 aspects:

[0018] According to a first aspect, there is provided an article, comprising:

a carrier with a carrier bonding surface;

a sheet with at least one via therein, the sheet further comprising a sheet bonding surface;

a surface modification layer, wherein the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer and

b) aromatic silane;

the carrier bonding surface being bonded with the sheet bonding surface with the surface modification layer therebetween, wherein the surface modification layer is of such a character that at least one of:

(i) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 500°C at a rate of 9.2 °C per minute, held at a temperature of 500°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature; and

(ii) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 400°C at a rate of 9.2 °C per minute, held at a temperature of 400°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, there is no outgassing from the surface modification layer according to test #2, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature.

[0019] According to a second aspect, there is provided a method of making an interposer, comprising:

obtaining a carrier with a carrier bonding surface;

obtaining a sheet with at least one via therein, the sheet further comprising a sheet bonding surface, wherein at least one of the carrier bonding surface and the sheet bonding surface comprises a surface modification layer thereon, wherein the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer and

b) aromatic silane;

bonding the carrier to the sheet with the bonding surfaces and the surface modification layer to form an article;

subjecting the article to front-end-of-line (FEOL) processing at a temperature of ≥ 500°C, wherein after FEOL processing the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity;

removing the sheet from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces.

[0019a] Herein disclosed is an article, comprising:

a carrier with a carrier bonding surface;

a sheet with at least one via therein, the sheet further comprising a sheet bonding surface;

a surface modification layer;

the carrier bonding surface being bonded with the sheet bonding surface with the surface modification layer therebetween, wherein the surface modification layer is of such a character that after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 400°C at a rate of 9.2 °C per minute, held at a temperature of 400°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, there is no outgassing from the surface modification layer according to test #2, and

the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature.

[0020] The sheet may comprise silicon, quartz, sapphire, ceramic, or glass.

[0021] The sheet thickness may be ≤ 200 microns.

[0022] Herein disclosed is an article, comprising:

a carrier with a carrier bonding surface;

a wafer sheet comprising a thickness ≤ 200 microns, the sheet further comprising a sheet bonding surface, the sheet comprising silicon, quartz, or sapphire;

a surface modification layer;

the carrier bonding surface being bonded with the sheet bonding surface with the surface modification layer therebetween, wherein the surface modification layer is of such a character that at least one of:

(i) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 500°C at a rate of 9.2 °C per minute, held at a temperature of 500°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature; and

(ii) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 400°C at a rate of 9.2 °C per minute, held at a temperature of 400°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, there is no outgassing from the surface modification layer according to test #2, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature.

[0023] Herein disclosed is an article, comprising:

a carrier with a carrier bonding surface;

a wafer sheet comprising a thickness ≤ 200 microns, the sheet further comprising a sheet bonding surface, the sheet comprising silicon, quartz, or sapphire;

a surface modification layer;

the carrier bonding surface being bonded with the sheet bonding surface with the surface modification layer therebetween, wherein the surface modification layer is of such a character that after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 400°C at a rate of 9.2 °C per minute, held at a temperature of 400°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and

sheet do not separate from one another if one is held and the other subjected to the force of gravity, there is no outgassing from the surface modification layer according to test #2, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature.

[0024] As mentioned in the above aspects, the sheet comprises at least one via therein.

[0025] The at least one via may have a diameter of ≤ 150 microns.

[0026] The at least one via may comprise electrically conductive material therein.

[0027] The sheet may comprise a device surface opposite the sheet bonding surface, the device surface comprising an array of devices selected from the group consisting of: integrated circuits; MEMS; CPU; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride.

[0028] The sheet may comprise a device surface opposite the sheet bonding surface, the device surface comprising at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; interconnection routings; interconnect lines; insulating oxide layers; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

[0029] The heating may be performed in Nitrogen.

[0030] There may be no outgassing from the surface modification layer during the heating, wherein outgassing from the surface modification layer is defined as at least one of:

(a) wherein the change in surface energy of the cover is ≥ 15 mJ/m^2 at a test-limit temperature of 600°C according to outgassing test #1; and

(b) wherein the change in % bubble area is ≥ 5 at a test limit temperature of 600°C according to outgassing test #2.

[0031] As mentioned in the above aspects, the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer; and

b) an aromatic silane.

[0032] Thickness of the surface modification layer may be from 0.1 to 100 nm.

[0033] The carrier may comprise glass.

[0034] The bonding surface of at least one of the carrier and the sheet may comprise an area of ≥ 100 square cm.

[0035] Herein disclosed is a method of making an interposer, comprising:

obtaining a carrier with a carrier bonding surface;

obtaining a sheet with at least one via therein, the sheet further comprising a sheet bonding surface, wherein at least one of the carrier bonding surface and the sheet bonding surface comprises a surface modification layer thereon;

bonding the carrier to the sheet with the bonding surfaces and the surface modification layer to form an article;

subjecting the article to front-end-of-line (FEOL) processing, wherein after FEOL processing the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity;

removing the sheet from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces.

[0036] The sheet may comprise silicon, quartz, sapphire, ceramic, or glass.

[0037] The sheet thickness may be ≤ 200 microns.

[0038] Herein disclosed is a method of processing a silicon wafer sheet, comprising:

obtaining a carrier with a carrier bonding surface;

obtaining a wafer sheet with a thickness ≤ 200 microns, the sheet comprising silicon, quartz, or sapphire, the sheet further comprising a sheet bonding surface, wherein at least one of the carrier bonding surface and the sheet bonding surface comprises a surface modification layer thereon;

bonding the carrier to the sheet with the bonding surfaces and the surface modification layer to form an article;

subjecting the article to front-end-of-line (FEOL) processing, wherein after FEOL processing the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity;

removing the sheet from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces.

[0039] As mentioned in the above aspects, the sheet comprises at least one via therein.

[0040] The FEOL processing may comprise at least one of:

(i) processing-chamber temperatures of from 500°C to 700°C; and

(ii) at least one of: DRIE (dry reactive ion etch); PVD; CVD TiN; PECVD SiO2; Electrolytic Cu Plating; Cu Annealing; Metrology; Cu CMP; Cu (H2O2 + H2SO4) + Ti (DHF) Wet Etch; Sputter Adhesion Layer; Sputter Seed Layer; Lithography (Photoresist, expose, strip, etch Cu).

[0041] The FEOL processing may comprise at least one of: DRIE (dry reactive ion etch); PVD; CVD TiN; PECVD SiO2; Electrolytic Cu Plating; Cu Annealing; Metrology; Cu CMP; Cu (H2O2 + H2SO4) + Ti (DHF) Wet Etch; Sputter Adhesion Layer; Sputter Seed Layer; Lithography (Photoresist, expose, strip, etch Cu).

[0042] The at least one via may have a diameter of ≤ 150 microns.

[0043] The at least one via may comprise electrically conductive material therein.

[0044] The sheet may comprise a device surface opposite the sheet bonding surface, the device surface comprising at least one of:

(i) an array of devices selected from the group consisting of: integrated circuits; MEMS; CPU; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride; and

(ii) at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; interconnection routings; interconnect lines; insulating oxide layers; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

[0045] The sheet may comprise a device surface opposite the sheet bonding surface, the device surface comprising at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; interconnection routings; interconnect lines; insulating oxide layers; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

[0046] The heating may be performed in Nitrogen.

[0047] There may be no outgassing from the surface modification layer during the heating, wherein outgassing from the surface modification layer is defined as at least one of:

(a) wherein the change in surface energy of the cover is ≥ 15 mJ/m^2 at a test-limit temperature of 600°C according to outgassing test #1; and

(b) wherein the change in % bubble area is ≥ 5 at a test limit temperature of 600°C according to outgassing test #2.

[0048] As mentioned in the above aspects, the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer; and

b) an aromatic silane.

[0049] The thickness of the surface modification layer may be from 0.1 to 100 nm.

[0050] The carrier may comprise glass.

[0051] The bonding surface of at least one of the carrier and the sheet may comprise an area of ≥ 100 square cm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0052] FIG. 1 is FIG. 1 is a schematic side view of an article having carrier bonded to a thin sheet with a surface modification layer therebetween.

[0053] FIG. 2 is an exploded and partially cut-away view of the article in FIG. 1.

What is Claimed is:

1. An article, comprising:

a carrier with a carrier bonding surface;

a sheet with at least one via therein, the sheet further comprising a sheet bonding surface;

a surface modification layer, wherein the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer and

b) aromatic silane;;

the carrier bonding surface being bonded with the sheet bonding surface with the surface modification layer therebetween, wherein the surface modification layer is of such a character that at least one of:

(i) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 500°C at a rate of 9.2 °C per minute, held at a temperature of 500°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature; and

(ii) after subjecting the article to a temperature cycle by heating in an chamber cycled from room temperature to 400°C at a rate of 9.2 °C per minute, held at a temperature of 400°C for 10 minutes, and then cooled at furnace rate to 300 °C, and then removing the article from the chamber and allowing the article to cool to room temperature, the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity, there is no outgassing from the surface modification layer according to test #2, and the sheet may be separated from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces when separation is performed at room temperature.

2. The article of claim 1, wherein the sheet comprises silicon, quartz, sapphire, ceramic, or glass.

3. An article of claim 2, wherein the sheet is a wafer sheet comprising a thickness ≤ 200 microns.

4. The article of claim 1 or claim 2, the at least one via has a diameter of ≤ 150 microns and comprises electrically conductive material therein.

5. The article of any one of claims 1-4, the sheet comprising a device surface opposite the sheet bonding surface, the device surface comprising an array of devices selected from the group consisting of: integrated circuits; MEMS; CPU; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride.

6. The article of any one of claims 1-5, wherein there is no outgassing from the surface modification layer during the heating, wherein outgassing from the surface modification layer is defined as at least one of:

(a) wherein the change in surface energy of the cover is $\geq$ 15 mJ/m^2 at a test-limit temperature of 600°C according to outgassing test #1; and

(b) wherein the change in % bubble area is ≥ 5 at a test limit temperature of 600°C according to outgassing test #2.

7. The article of any one of claims 1-6, the surface modification layer comprising a thickness ≤ 100 nm.

8. The article of any one of claims 1-7, the surface modification layer comprises a phenyl silane and is one of: phenyltriethoxysilane; diphenyldiethoxysilane; and 4-pentafluorophenyltriethoxysilane.

9. The article of any one of claims 1-7, the surface modification layer comprises a phenyl silane, and contains a chlorophenyl, fluorophenyl or silyl group.

10. The article of any one of claims 1-7, the surface modification layer comprises a plasma polymerized fluoropolymer and is one of: plasma polymerized polytetrafluroethylene; and a plasma polymerized fluoropolymer surface modification layer deposited from a CF_4-C_4F_8 mixture having ≤ 40% C_4F_8.

11. A method of making an interposer, comprising:

obtaining a carrier with a carrier bonding surface;

obtaining a sheet with at least one via therein, the sheet further comprising a sheet bonding surface, wherein at least one of the carrier bonding surface and the sheet bonding surface comprises a surface modification layer thereon, wherein the surface modification layer comprises one of:

a) a plasma polymerized fluoropolymer and

b) aromatic silane;

bonding the carrier to the sheet with the bonding surfaces and the surface modification layer to form an article;

subjecting the article to front-end-of-line (FEOL) processing at a temperature of ≥ 500°C, wherein after FEOL processing the carrier and sheet do not separate from one another if one is held and the other subjected to the force of gravity;

removing the sheet from the carrier without breaking the thinner one of the carrier and the sheet into two or more pieces.

12. The method of claim 11, the sheet comprises silicon, quartz, sapphire, ceramic, or glass.

13. A method of claim 12, wherein the sheet is a silicon wafer sheet comprising a thickness $\leq$ 200 microns.

14. The method of any one of claims 11-13, wherein the FEOL processing comprises at least one of:

(i) processing-chamber temperatures of from 500°C to 700°C; and

(ii) at least one of: DRIE (dry reactive ion etch); PVD; CVD TiN; PECVD SiO2; Electrolytic Cu Plating; Cu Annealing; Metrology; Cu CMP; Cu (H2O2 + H2SO4) + Ti (DHF) Wet Etch; Sputter Adhesion Layer; Sputter Seed Layer; Lithography (Photoresist, expose, strip, etch Cu).

15. The method of any one of claims 11, 12, or 14, the at least one via has a diameter of ≤ 150 microns and comprises electrically conductive material therein.

16. The method of any one of claims 11-15, the sheet comprising a device surface opposite the sheet bonding surface, the device surface comprising at least one of:

(i) an array of devices selected from the group consisting of: integrated circuits; MEMS; CPU; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride; and

(ii) at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; interconnection routings; interconnect lines; insulating oxide layers; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

17. The method of any one of claims 11-16, wherein there is no outgassing from the surface modification layer during the heating, wherein outgassing from the surface modification layer is defined as at least one of:

(a) wherein the change in surface energy of the cover is ≥ 15 mJ/m^2 at a test-limit temperature of 600°C according to outgassing test #1; and

(b) wherein the change in % bubble area is ≥ 5 at a test limit temperature of 600°C according to outgassing test #2.

18. The method of any one of claims 11-16, wherein the surface modification layer comprises a thickness ≤ 100 nm.

19. The method of any one of claims 11-18, wherein the surface modification layer comprises a phenyl silane and is one of: phenyltriethoxysilane; diphenyldiethoxysilane; and 4-pentafluorophenyltriethoxysilane

20. The method of any one of claims 11-18, wherein the surface modification layer comprises a phenyl silane, and contains a chlorophenyl, fluorophenyl or silyl group.

21. The method of any one of claims 11-18, wherein the surface modification layer comprises a plasma polymerized fluoropolymer and is one of: plasma polymerized polytetrafluroethylene; and a plasma polymerized fluoropolymer surface modification layer deposited from a CF4-C4F8 mixture having $\leq$ 40% C4F8.