temperature covalent bonding between the thin sheet and carrier. Even more specifically, the present disclosure describes methods of depositing a coating layer that serves to bond a thin sheet to a carrier, methods for preparing the coating layer for bonding, and bonding the coating layer to both the thin sheet and the carrier. These methods produce bonding between the components such that the bonding energy is not too high, which might render the components inseparable after electronic device processing, and such that the bonding energy is not too low, which might lead to compromised bonding quality thus leading to possible de-bonding or fluid ingress between the thin sheet and carrier during electronic device processing. These methods also produce a glass article that exhibits low outgassing and survives high temperature processing for example, LTPS TFT processing as well additional processing steps, for example wet cleaning and dry etching. In alternative embodiments, the coating layers may be used to create various controlled bonding areas (wherein the carrier and thin sheet remain sufficiently bonded through various processes, including vacuum processing, wet processing, and/or ultrasonic cleaning processing), together with covalent bonding regions to provide for further processing options, for example, maintaining hermeticity between the carrier and sheet even after dicing the article into smaller pieces for additional device processing.

[0009] In a first aspect, there is an article comprising:

a first sheet comprising a first sheet bonding surface;

a second sheet comprising a second sheet bonding surface; and

a coating layer comprising a first coating layer bonding surface and a second coating layer bonding surface, the coating layer comprising a plasma-polymerized organosiloxane compound;

the first coating layer bonding surface being bonded with the first sheet bonding surface, and the second coating layer bonding surface being bonded with the second sheet bonding surface.

[0010] In an example, the coating layer comprises poly(diphenylsiloxane).

[0011] In another example, the first coating layer bonding surface has a surface energy between 40 and 75 mJ/m^2.

[0012] In another example, the coating layer has a thickness of less than 100 nm.

[0013] In another example, the coating layer is a single layer.

[0014] In another example, the first sheet has a thickness less than 200 μm.

[0015] In another example, the first coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0016] In another example, the first coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 700 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, wherein prior to after subjecting the article to a temperature of 600 °C, the first coating layer bonding surface was annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0017] In another example, the first coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, wherein prior to after subjecting the article to a temperature of 600 °C, the first coating layer bonding surface was annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0018] In another example, the change in percent blister area is less than 10 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, after the first coating layer bonding surface has been annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0019] In another example, the change in percent blister area is less than 5 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, after the first coating layer bonding surface has been annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0020] In another example, the first sheet is a glass sheet.

[0021] In another example, the second sheet is a glass sheet.

[0022] In another example, the first sheet is a glass sheet and the second sheet is a glass sheet.

[0023] There is provided an article as defined herein, the plasma-polymerized organosiloxane compound formed by depositing a monomer on at least one of the first sheet bonding surface and the second sheet bonding surface.

[0024] In an example, the monomer is deposited on at least one of the first sheet bonding surface and the second sheet bonding surface using low-pressure plasma chemical vapor deposition (CVD) or atmospheric pressure plasma CVD.

[0025] There is provided an article as defined herein, the monomer comprising a compound of formula $(R^1)_mSi(X^1)_n$, wherein each R^1 is independently aryl, alkyl, alkenyl alkynyl, or a combination thereof; m is 1, 2 or 3; each X^1 is independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof; and n is 1, 2 or 3.

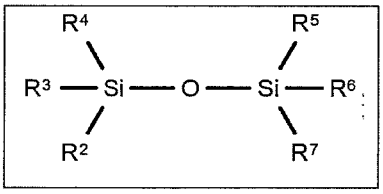
[0026] In an example, R^1 is aryl.

[0027] In another example, X^1 is alkoxy.

[0028] In another example, R^1 is aryl and X^1 is alkoxy.

[0029] In another example, the monomer is phenyltrimethoxysilane, phenyltriethoxysilane, phenyltribromosilane, phenyltrichlorosilane, dimethoxydiphenylsilane, diethoxydiphenylsilane, dibromodiphenylsilane, dichlorodiphenylsilane, bis(dimethylamino)diphenylsilane, bis(diethylamino)diphenylsilane, phenylsilane, or diphenylsilane.

[0030] There is provided an article as defined herein, the monomer comprising a disiloxane compound having the structure below, wherein each of R^2-R^7 is independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



[0031] In an example, the monomer is hexamethyldisiloxane.

[0032] There is provided an article as defined herein, the coating layer is comprised of a bottom coating layer and a top coating layer, the bottom coating layer being between the top coating layer and the second sheet.

[0033] In an example, the bottom coating layer has a thickness between 10 and 80 nm and the top coating layer has a thickness between 10 and 50 nm.

[0034] In a second aspect, there is a method of making an article comprising:

forming a coating layer comprising a plasma-polymerized organosiloxane compound on a bonding surface of a second sheet by depositing a monomer on the bonding surface of

the second sheet using plasma CVD, the coating layer comprising a coating layer bonding surface; and

bonding the coating layer bonding surface to a bonding surface of a first sheet.

[0035] In an example, the monomer is deposited on the bonding surface of the second sheet using low pressure plasma CVD or atmospheric pressure plasma CVD.

[0036] In an example, the coating layer comprises poly(diphenylsiloxane).

[0037] In another example, the coating layer has a thickness less than 100 nm.

[0038] In another example, the coating layer is a single layer.

[0039] In another example, the first sheet has a thickness less than 200 μm.

[0040] In another example, the coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0041] In another example, the first sheet is a glass sheet.

[0042] In another example, the second sheet is a glass sheet.

[0043] In another example, the first sheet is a glass sheet and the second sheet is a glass sheet.

[0044] There is provided the method as defined herein, further comprising increasing the surface energy of the coating layer bonding surface before the bonding surface of the first sheet is bonded to the coating layer bonding surface.

[0045] In an example, the surface energy of the coating layer bonding surface is increased by exposing the bonding surface to oxygen, nitrogen, or a combination thereof.

[0046] In another example, the surface energy of the coating layer bonding surface is increased to between 40 and 75 mJ/m^2.

[0047] There is provided the method as defined herein, the monomer comprising a compound of formula $(R^1)_mSi(X^1)_n$, wherein each R^1 is independently aryl, alkyl, alkenyl, alkynyl, or a combination thereof; m is 1, 2 or 3; each X^1 is independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof; and n is 1, 2 or 3.

[0048] In an example, R^1 is aryl.

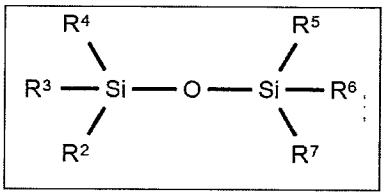
[0049] In another example, X^1 is alkoxy.

[0050] In another example, R^1 is aryl and X^1 is alkoxy.

[0051] In another example, the monomer is phenyltrimethoxysilane, phenyltriethoxysilane, phenyltribromosilane, phenyltrichlorosilane, dimethoxydiphenylsilane, diethoxydiphenylsilane, dibromodiphenylsilane, dichlorodiphenylsilane,

bis(dimethylamino)diphenylsilane, bis(diethylamino)diphenylsilane, phenylsilane, or diphenylsilane.

[0052] There is provided the method as defined herein, the monomer comprising a disiloxane compound having the structure below, wherein each of R^2-R^7 is independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



[0053] In an example, the monomer is hexamethyldisiloxane.

[0054] There is provided the method as defined herein, the coating layer being comprised of a bottom coating layer and a top coating layer, the bottom coating layer being between the top coating layer and the second sheet.

[0055] In another example, the bottom coating layer has a thickness between 10 and 80 nm and the top coating layer has a thickness between 10 and 50 nm.

[0056] There is provided the method as defined herein, further comprising subjecting the coating layer to thermal annealing before the first sheet and the coating layer are bonded.

[0057] In an example, the coating layer is subjected to thermal annealing in a nitrogen atmosphere.

[0058] In another example, the coating layer is subjected to thermal annealing at a temperature of at least 300 °C.

[0059] In another example, the coating layer is subjected to thermal annealing at a temperature of at least 400 °C.

[0060] In another example, the coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 700 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0061] In another example, the coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0062] In another example, the change in percent blister area is less than 10 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0063] In another example, the change in percent blister area is less than 5 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0064] In a third aspect, there is an article comprising:

a first sheet comprising a first sheet bonding surface;

a second sheet comprising a second sheet bonding surface; and

a coating layer comprising a first coating layer bonding surface and a second coating layer bonding surface, the coating layer comprising poly(diphenylsiloxane);

the first coating layer bonding surface being bonded with the first sheet bonding surface, and the second coating layer bonding surface being bonded with the second sheet bonding surface.

[0065] In an example, the first coating layer bonding surface has a surface energy between 40 and 75 mJ/m^2.

[0066] In another example, the coating layer has thickness of less than 100 nm.

[0067] In another example, the coating layer is a single layer formed by depositing the monomer.

[0068] In another example, the first sheet having a thickness less than 200 μm.

[0069] In another example, the first coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 700 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, wherein prior to after subjecting the article to a temperature of 600 °C, the first coating layer bonding surface was annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0070] In another example, the first coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, wherein prior to after subjecting the article to a temperature of 600 °C, the first coating layer bonding surface was annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0071] In another example, the change in percent blister area is less than 10 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, after the first coating layer bonding surface has been annealed at a temperature

of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0072] In another example, the change in percent blister area being less than 5 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere, after the first coating layer bonding surface has been annealed at a temperature of 400 °C in a nitrogen atmosphere prior to the first coating layer bonding surface being bonded to the first sheet bonding surface.

[0073] In another example, the first sheet is a glass sheet.

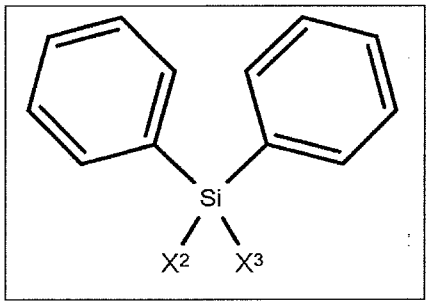
[0074] In another example, the second sheet is a glass sheet.

[0075] In another example, the first sheet is a glass sheet and the second sheet is a glass sheet.

[0076] There is provided an article as defined herein, the poly(diphenylsiloxane) coating layer formed by depositing a monomer on at least one of the first sheet bonding surface and the second sheet bonding surface.

[0077] In an example, the monomer is deposited on at least one of the first sheet bonding surface and the second sheet bonding surface using low-pressure plasma CVD, or atmospheric pressure plasma CVD.

[0078] In another example, the monomer comprises a diphenylsilane compound having the structure below, wherein X^2 and X^3 are independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



[0079] There is provided an article as defined herein, the coating layer being comprised of a bottom coating layer and a top coating layer, the bottom coating layer being between the top coating layer and the second sheet.

[0080] In another example, the bottom coating layer has a thickness between 10 and 80 nm and the top coating layer has a thickness between 10 and 50 nm.

[0081] In a fourth aspect, there is a method of making an article comprising:

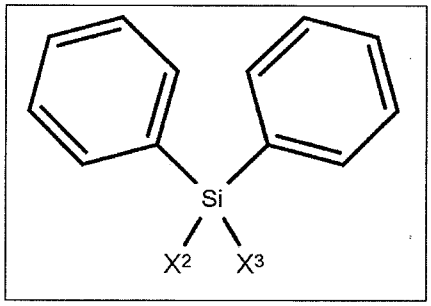
forming a coating layer comprising poly(diphenylsiloxane) on a bonding surface of a

second sheet by depositing a monomer on the bonding surface of the second sheet, the coating layer comprising a coating layer bonding surface; and

bonding the coating layer bonding surface to a bonding surface of a first sheet.

[0082] In an example, the monomer is deposited on the bonding surface of the second sheet using low pressure plasma CVD, or atmospheric pressure plasma CVD.

[0083] In another example, the monomer comprises a diphenylsilane compound having the structure below, wherein X^2 and X^3 are independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



[0084] In another example, the coating layer has a thickness less than 100 nm.

[0085] In another example, the coating layer being a single layer.

[0086] In another example, the first sheet has a thickness less than 200 μm.

[0087] In another example, the first sheet is a glass sheet.

[0088] In another example, the second sheet is a glass sheet.

[0089] In another example, the first sheet is a glass sheet and the second sheet is a glass sheet.

[0090] There is provided the method as defined herein, the coating layer being comprised of a bottom coating layer and a top coating layer, the bottom coating layer being between the top coating layer and the second sheet.

[0091] In another example, the bottom coating layer has a thickness between 10 and 80 nm and the top coating layer has a thickness between 10 and 50 nm.

[0092] There is provided the method as defined herein, further comprising subjecting the coating layer to thermal annealing before the first sheet and the coating layer are bonded.

[0093] In an example, the coating layer is subjected to thermal annealing in a nitrogen atmosphere.

[0094] In another example, the coating layer is subjected to thermal annealing at a temperature of at least 300 °C.

[0095] In another example, the coating layer is subjected to thermal annealing at a temperature of at least 400 °C.

[0096] In another example, the coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 700 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0097] In another example, the coating layer bonding surface is bonded with the first sheet bonding surface with a bond energy of less than 600 mJ/m^2 after subjecting the article to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0098] In another example, the change in percent blister area is less than 10 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0099] In another example, the change in percent blister area is less than 5 when the article is subjected to a temperature of 600 °C for 10 minutes in a nitrogen atmosphere.

[0100] Any one of the above aspects may be provided alone or in combination with any one or more of the examples of that aspect discussed above; i.e. the first aspect may be provided alone or in combination with any one or more of the examples of the first aspect discussed above; and the second aspect may be provided alone or in combination with any one or more of the examples of the second aspect discussed above; and so-forth.

[0101] The accompanying drawings are included to provide a further understanding of principles of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain, by way of example, principles and operation thereof. 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 specification, above, as aspects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0102] The above and other features, aspects and advantages of the embodiments disclosed in the present specification are better understood when the following detailed description thereof is read with reference to the accompanying drawings, in which:

[0103] **FIG. 1** is a schematic side view of an article having a carrier bonded to a thin sheet with a coating layer therebetween.

[0104] **FIG. 2** is an exploded and partially cut-away view of the article in FIG. 1.

[0105] **FIG. 3** is a graph of the thickness of plasma-polymerized phenylsilicone and diphenylsilicone coating layers as deposited and upon being subjected to processing.

What is claimed is:

1. An article comprising:

a first sheet comprising a first sheet bonding surface;

a second sheet comprising a second sheet bonding surface; and

a coating layer comprising a first coating layer bonding surface and a second coating layer bonding surface, the coating layer comprising a plasma-polymerized organosiloxane compound;

the first coating layer bonding surface is bonded with the first sheet bonding surface, and the second coating layer bonding surface is bonded with the second sheet bonding surface.

2. The article of claim 1, the coating layer comprising poly(diphenylsiloxane).

3. A method of making an article comprising:

forming a coating layer comprising a plasma-polymerized organosiloxane compound on a bonding surface of a second sheet by depositing a monomer on the bonding surface of the second sheet using plasma CVD, the coating layer comprising a coating layer bonding surface; and

bonding the coating layer bonding surface to a bonding surface of a first sheet.

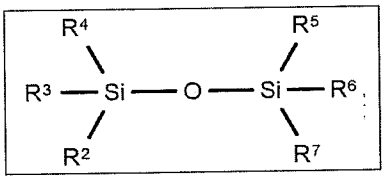
4. The method of claim 3, further comprising exposing the bonding surface to oxygen, nitrogen, or a combination thereof , to increase the surface energy of the coating layer bonding surface before the bonding surface of the first sheet is bonded to the coating layer bonding surface, the surface energy of the coating layer bonding surface being increased to between 40 and 75 mJ/m^2.

5. The method of claim 3 or 4, the monomer comprising a compound of formula $(R^1)_mSi(X^1)_n$, wherein each R^1 is independently an aryl, alkyl, alkenyl, alkynyl, or a combination thereof; m is 1, 2 or 3; each X^1 is independently, hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof; and n is 1, 2 or 3.

6. The method of claim 5, R^1 being aryl and/or X^1 being alkoxy.

7. The method of claim 5, wherein the monomer comprises at least one monomer selected from the group consisting of phenyltrimethoxysilane, phenyltriethoxysilane, phenyltribromosilane, phenyltrichlorosilane, dimethoxydiphenylsilane, diethoxydiphenylsilane, dibromodiphenylsilane, dichlorodiphenylsilane, bis(dimethylamino)diphenylsilane, bis(diethylamino)diphenylsilane, phenylsilane, and diphenylsilane.

8. The method of claim 3 or 4, the monomer comprising a disiloxane compound having the structure below, wherein each of R^2-R^7 is independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



9. The method of claim 8, wherein the monomer is hexamethyldisiloxane.

10. The method of any one of claims 3-9, the coating layer comprising poly(diphenylsiloxane).

11. The method of any one of claims 3-10, further comprising subjecting the coating layer to thermal annealing, at a temperature of at least 300 °C in a nitrogen atmosphere, before the first sheet and the coating layer are bonded.

12. An article comprising:

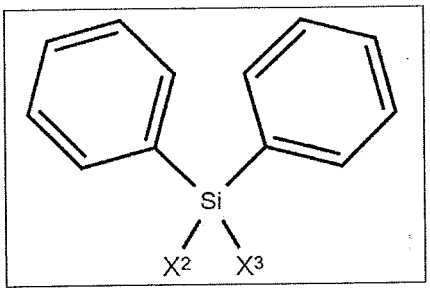
a first sheet comprising a first sheet bonding surface;

a second sheet comprising a second sheet bonding surface; and

a coating layer comprising a first coating layer bonding surface and a second coating layer bonding surface, the coating layer comprising poly(diphenylsiloxane);

the first coating layer bonding surface is bonded with the first sheet bonding surface, and the second coating layer bonding surface is bonded with the second sheet bonding surface.

13. The article of claim 12, the poly(diphenylsiloxane) coating layer formed by depositing a monomer on at least one of the first sheet bonding surface and the second sheet bonding surface, wherein the monomer is deposited on at least one of the first sheet bonding surface and the second sheet bonding surface, the monomer comprising a diphenylsilane compound having the structure below, wherein X^2 and X^3 are independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.

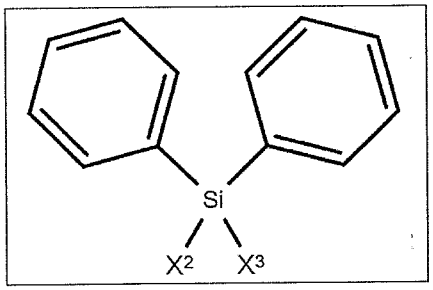


14. A method of making an article comprising:

forming a coating layer comprising poly(diphenylsiloxane) on a bonding surface of a second sheet by depositing a monomer on the bonding surface of the second sheet, the coating layer comprising a coating layer bonding surface; and

bonding the coating layer bonding surface to a bonding surface of a first sheet.

15. The method of claim 14, the monomer comprising a diphenylsilane compound having the structure below, wherein X^2 and X^3 are independently hydrogen, halogen, hydroxy, alkoxy, amino, aryl, alkyl, alkenyl, alkynyl, or a combination thereof.



16. The method of claim 14 or claim 15, further comprising subjecting the coating layer to thermal annealing, at a temperature of at least 300 °C in a nitrogen atmosphere, before the first sheet and the coating layer are bonded, comprising subjecting the coating layer to thermal annealing.