may be used as a carrier for a second flexible glass substrate upon which different electronic devices will be made in a lower temperature (as compared to the first) process. Further yet, in some instances, the carrier may be used to carry multiple flexible glass substrates, wherein electronic devices are formed in turn on each of the substrates through subsequent processes, wherein passing through the prior process may advantageously make the next substrate better suited to undergo the next process.

[0009] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from the description or recognized by practicing the various aspects as exemplified in the written description and the appended drawings. It is to be understood that both the foregoing general description and the following detailed description are merely exemplary of the various aspects, and are intended to provide an overview or framework to understanding the nature and character of the invention as it is claimed.

[0010] The accompanying drawings are included to provide a further understanding of principles of the invention, 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 of the invention. 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 aspects:

[0011] ~~According to a first aspect, there is provided~~Herein disclosed is a method of processing electronic devices comprising:

obtaining an article comprising a thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the article to a first processing cycle to form a first device on the thin glass sheet, wherein after the first processing cycle, the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the thin glass sheet from the carrier; and

subjecting the carrier to a second processing cycle to form a second device on the carrier.

[0011a] According to a first aspect, there is provided a method of processing electronic devices comprising:

obtaining an article comprising a thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the article to a first processing cycle to form a first device on the thin glass sheet, wherein after the first processing cycle, the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the thin glass sheet from the carrier; and

using the carrier as a substrate in a second processing cycle to form a second device on the carrier,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,
4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the

nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X - Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)(dx_i - \overline{dx})}{\sum_{i=1}^{72}(x_i - 132)^2} \quad \text{Eq. (1)}$$

$$Y - Direction\ Compaction = \frac{\sum_{i=1}^{72}(y_i - 132)(dy_i - \overline{dy})}{\sum_{i=1}^{72}(y_i - 132)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *i* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

[0012] ~~According to a second aspect, t~~There is provided the method of the first aspect ~~1~~, wherein the carrier is chemically strengthened prior to the second processing cycle, and further wherein the second device includes an anti-glare, anti-fingerprint, anti-smudge, or anti-microbial, film.

[0013] ~~According to a third aspect, there is provided~~Herein disclosed is a method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the first article to a first processing cycle to form a first device on the first thin glass sheet, wherein after the first processing cycle, the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the first thin glass sheet from the carrier;

coupling the carrier to a second thin glass sheet to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the second thin glass sheet, wherein after the second processing cycle the carrier QCOLED compaction value decreases ≤ 5%.

[0013a] According to a second aspect, there is provided a method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the first article to a first processing cycle to form a first device on the first thin glass sheet, the first processing cycle comprising a first maximum temperature held for a first amount of time, wherein after the first processing cycle the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the first thin glass sheet from the carrier;

coupling the carrier to a second thin glass sheet to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the second thin glass sheet, the second processing cycle comprising a second maximum temperature held for a second amount of time, wherein the second maximum temperature differs from the first maximum temperature and/or the second amount of time differs from the first amount of time, wherein after the second processing cycle the carrier QCOLED compaction value decreases ≤ 5%,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a

small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,

4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X - Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)\left(dx_i - \overline{dx}\right)}{\sum_{i=1}^{72}(x_i - 132)^2} \quad \text{Eq. (1)}$$

$$Y - Direction\ Compaction = \frac{\sum_{i=1}^{72}(y_i - 132)\left(dy_i - \overline{dy}\right)}{\sum_{i=1}^{72}(y_i - 132)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *I* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

[0014] ~~According to a fourth aspect, there is provided~~Herein disclosed is a method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the first thin glass sheet has a first QCOLED compaction value, and a second thin glass sheet coupled to the first thin glass sheet and to the carrier;

subjecting the first article to a first processing cycle to form a first device on the second thin glass sheet, wherein after the first processing cycle, the first thin glass sheet has a second QCOLED compaction value that is less than the first QCOLED compaction value;

removing the second thin glass sheet from the first article so as to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the first thin glass sheet.

[0014a] According to a third aspect, there is provided a method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the first thin glass sheet has a first QCOLED compaction value, and a second thin glass sheet coupled to the first thin glass sheet or to the carrier;

subjecting the first article to a first processing cycle to form a first device on the second thin glass sheet, wherein after the first processing cycle, the first thin glass sheet has a second QCOLED compaction value that is less than the first QCOLED compaction value;

removing the second thin glass sheet from the first article so as to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the first thin glass sheet,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,
4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X - Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)(dx_i - \overline{dx})}{\sum_{i=1}^{72}(x_i - 132)^2} \quad \text{Eq. (1)}$$

$$Y - Direction\ Compaction = \frac{\sum_{i=1}^{72}(y_i - 132)(dy_i - \overline{dy})}{\sum_{i=1}^{72}(y_i - 132)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *i* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

[0015] ~~According to a fifth aspect, t~~There is provided the method of the third aspect 4, wherein the carrier has a QCOLED compaction value that decreases ≤ 5% in any subsequent processing step~~is dead-annealed~~.

[0016] The carrier may be dead-annealed prior to being coupled to the first or second thin glass sheet.

[0017] ~~According to a sixth aspect, t~~There is provided the method of the third aspect 4, wherein the second thin glass sheet is located on the same side of the carrier as is the first thin glass sheet.

[0018] ~~According to a seventh aspect, t~~There is provided the method of any one of the above aspects ~~1-6~~, wherein during the second processing cycle a maximum processing temperature used is less than that used during the first processing cycle.

[0019] ~~According to an eighth aspect, t~~There is provided the method of any one of the above aspects ~~1-7~~, wherein the first processing cycle includes a maximum temperature in the range of greater than 450°C to ≤ 700°C.

[0020] The second processing cycle may include a maximum temperature ≤ 450°C.

[0021] The first device may be a polycrystalline semiconductor device, a microcrystalline semiconductor device, a low temperature poly-silicon device, or a crystalline oxide TFT device.

[0022] The first processing cycle may include a maximum temperature in the range of greater than 250°C to ≤ 450°C.

[0023] The second processing cycle may include a maximum temperature ≤ 250°C.

[0024] The first device may be an amorphous semiconductor device, an amorphous oxide TFT device, or an amorphous silicon LCD.

[0025] The second device may be a touch sensor, a transparent conductive material film, or a color filter.

[0026] ~~According to a ninth aspect, t~~There is provided the method of any one of the above aspects ~~1-6~~, wherein the second processing cycle maximum temperature is greater than that in the first processing cycle.

[0027] The first processing cycle may include a maximum temperature in the range of greater than 250°C to ≤450°C.

[0028] The first device may be an amorphous semiconductor device, an amorphous oxide TFT, or an amorphous silicon LCD device.

[0029] The second processing cycle maximum temperature may be in the range of greater than 450°C to ≤ 700°C.

[0030] The second device may be a polycrystalline semiconductor device, a microcrystalline semiconductor device, a low temperature poly-silicon device, or a crystalline oxide TFT device.

[0031] The carrier may have a thickness of ≥ 200 microns.

[0032] The thin glass sheet may have a thickness of ≤ 300 microns.

[0033]. ~~According to a tenth aspect, t~~There is provided the method of any one of the above aspects ~~1-9~~, further comprising providing a protective layer on a side of the carrier opposite to that on which the thin glass sheet is located during processing.

[0034] The protective layer may be one of a hard-coat layer and a thin glass sheet.

[0035] The carrier may be glass.

[0036] The carrier may have an area ≥ 0.1 square meter.

[0037] The thin glass sheet may have an area ≥ 0.1 square meter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] FIG. 1 is a side view of one embodiment of an article having a thin glass sheet coupled to a carrier.

[0039] FIG. 2 is an exploded view of the article shown in FIG. 1.

[0040] FIG. 3 is a time-temperature graph for a QCOLED compaction test.

[0041] FIG. 4 is a schematic view of scribe lines and node locations for measurements in the QCOLED compaction test of FIG. 3

[0042] FIG. 5 is a schematic process flow.

What is Claimed is:

1. Method of processing electronic devices comprising:

obtaining an article comprising a thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the article to a first processing cycle to form a first device on the thin glass sheet, wherein after the first processing cycle, the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the thin glass sheet from the carrier; and

~~subjecting~~ using the carrier ~~to~~ as a substrate in a second processing cycle to form a second device on the carrier,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,
4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X - Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)(dx_i - \overline{dx})}{\sum_{i=1}^{72}(x_i - 132)^2} \quad \text{Eq. (1)}$$

$$Y - Direction\ Compaction = \frac{\sum_{i=1}^{72}(y_i - 132)(dy_i - \overline{dy})}{\sum_{i=1}^{72}(y_i - 132)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *i* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

2. The method of claim 1, wherein the carrier is chemically strengthened prior to the second processing cycle, and further wherein the second device includes an anti-glare, anti-fingerprint, anti-smudge, or anti-microbial, film.

3. A method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the carrier has a first QCOLED compaction value;

subjecting the first article to a first processing cycle to form a first device on the first thin glass sheet, the first processing cycle comprising a first maximum temperature held for a first amount of time, wherein after the first processing cycle~~,~~ the carrier has a second QCOLED compaction value that is less than or equal to the first QCOLED compaction value;

removing the first thin glass sheet from the carrier;

coupling the carrier to a second thin glass sheet to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the second thin glass sheet, the second processing cycle comprising a

second maximum temperature held for a second amount of time, wherein the second maximum temperature differs from the first maximum temperature and/or the second amount of time differs from the first amount of time, wherein after the second processing cycle the carrier QCOLED compaction value decreases ≤ 5%,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,
4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X-Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)\left(dx_i - \overline{dx}\right)}{\sum_{i=1}^{72}(x_i - 132)^2} \qquad \text{Eq. (1)}$$

$$Y-Direction\ Compaction=\frac{\sum_{i=1}^{72}\left(y_i-132\right)\left(dy_i-\overline{dy}\right)}{\sum_{i=1}^{72}\left(y_i-132\right)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *I* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

4. A method of processing electronic devices comprising:

obtaining a first article comprising a first thin glass sheet coupled to a carrier, wherein the first thin glass sheet has a first QCOLED compaction value, and a second thin glass sheet coupled to the first thin glass sheet ~~and~~ or to the carrier;

subjecting the first article to a first processing cycle to form a first device on the second thin glass sheet, wherein after the first processing cycle, the first thin

glass sheet has a second QCOLED compaction value that is less than the first QCOLED compaction value;

removing the second thin glass sheet from the first article so as to form a second article; and

subjecting the second article to a second processing cycle to form a second device on the first thin glass sheet,

wherein QCOLED compaction value is determined by:

1. scribing 11 lines across a sample at 20 mm pitch in both the horizontal and vertical directions, the sample having a size of 254 x 254 mm,
2. determining the initial location of 72 reference nodes located at the intersections associated with the two outermost scribe lines on each edge of the sheet, relative to fiducial marks on a gauge,
3. heat treating the samples, wherein the samples are heat treated in a box furnace according to a thermal profile wherein the furnace is first preheated to slightly above 590 °C and is set to maintain that temperature, the samples are then plunged into the furnace through a small slit in the front of the furnace, after thirty minutes the samples are quenched out of the furnace into ambient air, wherein the total time the samples reside in the furnace having the peak temperature 590 °C is about 18 minutes,
4. remeasuring the locations of the 72 reference nodes, and
5. determining the compaction by averaging the displacement of all nodes relative to their initial position,

wherein the remeasurement of the reference nodes in step 4, after the samples have been thermally treated, comprises measuring the location of the nodes to determine their displacements in the *X* direction, *dx*, and *Y* direction, *dy*, and

wherein the compaction value for each direction as determined in step 5 is the slope of the linear regression of displacement as a function of location determined according to:

$$X - Direction\ Compaction = \frac{\sum_{i=1}^{72}(x_i - 132)(dx_i - \overline{dx})}{\sum_{i=1}^{72}(x_i - 132)^2} \quad \text{Eq. (1)}$$

$$Y - Direction\ Compaction = \frac{\sum_{i=1}^{72}(y_i - 132)(dy_i - \overline{dy})}{\sum_{i=1}^{72}(y_i - 132)^2} \quad \text{Eq. (2)}$$

in which equations (1) and (2) *i* is a subscript identifying a measurement node, *x* and *y* specify the coordinates of each node, *dy* and *dx* are direction specific displacements of each node relative to the initial measurement, and further wherein the *X* and *Y* direction compactions are averaged to obtain the compaction value of a given sample.

5. The method of claim 4, wherein the carrier has a QCOLED compaction value that decreases ≤ 5% in any subsequent processing step~~is dead-annealed~~.

6. The method of claim 4, wherein the second thin glass sheet is located on the same side of the carrier as is the first thin glass sheet.

7. The method of any one of claims 1, 3, or 4, wherein during the second processing cycle a maximum processing temperature used is less than that used during the first processing cycle.

8. The method of any one of claims 1, 3, or 4, wherein the first processing cycle includes a maximum temperature in the range of greater than 450°C to ≤ 700°C.

9. The method of claim 8, wherein the second processing cycle includes a maximum temperature ≤ 450°C.

10. The method of any one of claims 1, 3, or 4, wherein the first processing cycle includes a maximum temperature in the range of greater than 250°C to ≤ 450°C.

11. The method of claim 10, wherein the second processing cycle includes a maximum temperature ≤ 250°C.

12. The method of any one of claims 1, 3, or 4, wherein the second processing cycle maximum temperature is greater than that in the first processing cycle.

13. The method of claim any one of claims 1, 3, or 4, wherein the first processing cycle includes a maximum temperature in the range of greater than 250°C to ≤450°C.

14. The method of claim 13, wherein the second processing cycle maximum temperature is in the range of greater than 450°C to ≤ 700°C.