A bonded article of thin glass and support substrate with a unique interlayer in between. The interlayer has adhesion on both surfaces. The adhesion force between the thin glass and interlayer is less than 1 N/mm; the thickness of the adhesive between interlayer and support substrate is more than 50 mm. This bonded article can be subjected to an easy 2-step debonding method: the support substrate is firstly removed from the bonded article by a blade, and then the interlayer is peeled off from the thin glass without any breakage of the thin glass.

Fig. 1
Bonded article of thin glass and support substrate,
and methods for producing and debonding thereof

Technical field

The invention is related to easy and safe post-processing of thin
glass, especially thin glass with a thickness of less than 0.3 mm, including
both the bonding of thin glass and support substrate and the subsequent
debonding of thin glass from support substrate after the post-processing is
over.

Background

In the field of consumer electronics, there is an increasing
requirement for products with smaller weight to facilitate carrying and
satisfy better experience. As one of the major components, glass with
lighter weight and thinner thickness will be very helpful for decreasing the
total weight of consumer electronics products. When the thickness of a
glass is less than 0.3 mm, it becomes flexible but more fragile, leading to
difficulties in both transporting and post-processing thereof. One ideal way
is to carry the glass in the form of a roll and adopt the roll-to-roll process
for its post-processing. However, the roll-to-roll technology for glass is
still in development and far away from real application. The weakness of
thin glass induces potential risk during roll-to-roll process, e.g., the
breakage of roll will cause the ceasing of production and even the damage
of the apparatus. In such circumstances, it is not realistic for manufacturers
to adopt roll-to-roll technology for the post-processing of thin glass in the
near future.

Naturally, more interests are focused in handling of thin glass sheet.
One feasible way is the solution of "glass-on-carrier", i.e., thin glass is
bonded with a support substrate during post-processing thereof. Apparently, one advantage of this solution is that the existing facilities in the current industrial line for the processing of thin glass can be directly utilized for the handling of the bonded article of thin glass and support substrate, without new investment in the fixed assets. To fulfill such requirement, the total thickness of the bonded article should be in the range of 0.5-0.7 mm. Moreover, after bonded with support substrate, the thin glass should have a very flat surface, so as to lower down the possibility of breakage during the post-processing of bonded article. For example, if there is any dust or air bubble in the bonding interface, potential risk of breakage arises when pressure is applied on the bonded article during cleaning or printing process. In addition, for some high temperature processes, for example, high temperature coating, the expansion of bubble will cause the inaccuracy of the coating pattern.

However, direct bonding of thin glass and support substrate often causes formation of bubbles in the bonding interface, because of the flexible nature of thin glass (as described in SCHOTT patent PCT/CN2013/077585). And the existence of dust in the environment is another reason for the formation of bubbles, which means the bonding process should be executed in an ultraclean environment.

Therefore, to make a bonded article without any bubbles in the bonding interface of thin glass and support substrate, an easy and reliable way is to apply an interlayer between them. The interlayer is relatively soft so that even dust or particle is embedded in, a very flat surface of thin glass for the bonded article can still be achieved. Different interlayers can be used, depending on different post-processing for the bonded article. For example, if the bonded article will undergo a high temperature coating process, interlayer with high temperature resistance, e.g., silicone layer,
needs to be adopted.

In addition to the defects in the bonding interface, another factor that needs to be considered is the bonding strength between the interlayer and thin glass or support substrate. The bonding strength should be appropriate, i.e., strong enough to ensure the stability of bonded article throughout the post-processing thereof, but not too strong to detach thin glass from the bonded article after the post-processing is over. Unfortunately, during some post-processing, the bonding strength between interlayer and thin glass or support substrate can become bigger due to the chemical reaction that occurs in the bonding interface, leading to difficulties in the subsequent debonding process.

Generally, two issues including stable adhesion and easy debonding constitute the main concerns of the solutions to temporarily bonding of thin glass and carrier. The available solutions include:

1. adhesive with special chemical and physical properties is used as interlayer material (AGC US2008135175, AGC US8377552B2, CORNING US20110111194 and CORNING US 2005001201)

2. special structures comprising both low and high adhesion areas are adopted (NEG US2012080403, SCHOTT US2005129909, CORNING WO13082076A1 and CORNING WO2013119737)

However, current solutions are either complicated or high cost, and they are not applicable for mass production. For example, the cost for the adhesive with special properties can be very high and the risk of the breakage of thin glass still exists in the debonding process. In fact, most temporary bonding methods are actually originated from the processing of silicon wafer, which cannot be simply applied in the disposal of thin glass, because of the easy breakage nature of thin glass. In addition, solvent or
heat treatment is normally used for debonding of silicon wafer, which is also not good for glass.

Although through formation of both low and high adhesion areas in the bonding interface, the debonding of thin glass from the bonded article becomes much easier, the whole process is much more complicated. Meanwhile, due to the complicated structure of the bonding interface, it is not easy to keep the surface of thin glass flat during the post-processing of bonded article, increasing the risk of breakage of thin glass.

In fact, the fracture probability of thin glass is tightly correlated with its curvature, on the condition that edge quality has been decided by the melting and cutting processes. Under bending status, the tensile stress applied on thin glass can be described by formula (1), where $R$ represents the curvature radius of thin glass, $T$ represents the thickness of thin glass, and $E$ represents the Young's modulus of thin glass. Considering $R$ is far bigger than $T$, formula (1) can be deduced to formula (1)' approximately.

\[
\sigma = \frac{ET}{R^2} \quad (1)
\]

\[
\sigma \approx \frac{ET}{2R} \quad (1)'
\]

Correspondingly the fracture probability of such bended glass sheet can be calculated according to formula (2), where $L$ represents the length of thin glass, $S$ represents the span for 3-point bending test of thin glass, $\sigma$ represents the tensile stress on the bended thin glass, and $m$ and $\sigma_c$ are the shape and scale parameters respectively when fitting the data of 3-point bending strength of thin glass according to a Weibull distribution.
Replacing the $\sigma$ in formula (2) with formula (1)', the fracture probability can be calculated as follows:

$$F \cong 1 - \exp\left(-2 \frac{L}{\delta} \left(\frac{\sigma}{\sigma_c}\right)^m\right)$$

(2)

As can be seen from formula (3), when bending a certain glass sheet with a specific length, its fracture probability is decided by the curvature radius, i.e., decreasing the radius of bended thin glass sheet leads to increasing of the risk in breakage.

Actually during normal debonding process, if the bonding strength is too strong between thin glass and support substrate, bigger force needs to be applied for the detachment, which means thin glass sheet would be in a bending status with bigger curvature, therefore causing a higher fracture probability.

In this invention, a unique bonded article of thin glass and support substrate is provided, to facilitate both the post-processing of thin glass and subsequent detachment of thin glass from the bonded article. Instead of peeling thin glass sheet from the support substrate, thin glass sheet is always kept flat during the debonding process, so as to lower down the fracture probability greatly.

**Summary** of the invention

The existence of interlayer between thin glass and support substrate makes the final bonded article much more stable and leads to easier
post-processing. After the post-processing is over, the thin glass needs to be detached from the bonded article. The existing solutions to this problem are either adopting interlayer with special physical and chemical properties or making a special interface structure between thin glass and support substrate. However, those solutions are relatively complicated and high cost, and will be difficult to carry out in mass production. Furthermore, because big force is applied on thin glass to overcome the bonding strength between thin glass and support substrate during such common debonding process, thin glass needs to be in a bended status even with high curvature, resulting in easy breakage thereof.

In this invention, a bonded article with a unique structure is provided, where a soft material is adopted as the interlayer between thin glass and support substrate. There are adhesive layers on the top and bottom surfaces of the interlayer. The bigger adhesion force between thin glass sheet and interlayer and the thicker thickness of the adhesive layer between support substrate and interlayer are two unique features for the bonded article, compared with those described in other literatures. These features are tightly correlated with a unique way of easy debonding. The thicker adhesive layer between the interlayer and support substrate makes support substrate easy to be detached from the bonded article, for example, by applying a blade. After the support substrate is detached, thin glass is then debonded from the interlayer. Instead of directly peeling thin glass off, the soft interlayer can be peeled off from the thin glass. During this process, thin glass is always kept flat, to avoid the risk of breakage resulting from the big curvature during bending. By using this unique debonding method, the increasing bonding strength between thin glass sheet and interlayer after some post processing is overcome.

This invention discloses a bonded article comprising thin glass,
support substrate and interlayer. Also the invention discloses a method of producing and debonding the bonded article as well as use of the bonded article.

5 In the current invention, a bonded article is disclosed comprising:
a thin glass (1) having a first surface (1a) and a second surface (1b),
a support substrate (2) having a first surface (2a) and a second surface (2b),
an interlayer (3) having a first surface (3a) and a second surface (3b),
and having adhesive layer on both surfaces,
wherein one of the first and second surfaces of the thin glass is bonded onto the first surface of interlayer,
and wherein one of the first and second surfaces of the support substrate is bonded onto the second surface of interlayer.

10 In one aspect of the invention, there is an additional layer between the interlayer and the support substrate.

In another aspect of the invention, the interlayer is a soft material with adhesive I and adhesive II on the top and bottom surfaces to be bonded with the thin glass and the support substrate, respectively.

20 In yet another aspect of the invention, the adhesion force between the interlayer and the thin glass is smaller than 1 N/mm, preferably smaller than 0.5 N/mm, preferably smaller than 0.3 N/mm.

In yet another aspect of the invention, the thickness of adhesive II is bigger than 20 µm, preferably bigger than 50 µm, preferably bigger than 70 µm, preferably bigger than 100 µm, preferably bigger than 150 µm, preferably bigger than 200 µm.

25 In one embodiment, the thickness of the thin glass is less than 0.3 mm, preferably less than 0.2 mm, preferably less than 0.1 mm, preferably less than 70 µm, preferably less than 50 µm, preferably less than 30 µm, but not less than 10 µm.
In another embodiment, the thin glass is a chemically toughened glass.

In yet another embodiment, the support substrate is selected from the group consisting of glass, glass ceramic and ceramic.

In still another embodiment, the thickness of the support substrate is no more than 0.7 mm, preferably no more than 0.5 mm, preferably no more than 0.3 mm.

In one embodiment, the thin glass is borosilicate, aluminosilicate or soda-lime produced by down draw, float, micro-float, slot draw or fusion draw.

In one aspect of the invention, the interlayer is an organic film with adhesive on both surfaces, preferably the organic film is selected from the group consisting of polyester such as polyethylene terephthalate (PET), acrylic resin such as polymethylmethacrylate (PMMA), polycarbonate (PC), triacetyl cellulose (TAC), polysulfone (PS), polyarylate, polyimide (PI), polyvinyl chloride, polyvinyl acetate, polyethylene (PE), polypropylene (PP), ethylene-propylene copolymer, and preferably the adhesive comprises silicone, acrylic, epoxy, polyacrylate, polyurethane, polyester, polyolefin or polyether.

In another aspect of the invention, the interlayer is polyimide film with silicone on its both surfaces.

In yet another aspect of the invention, a force of peeling polyimide film with silicone off from the thin glass is in the range of 0.1-0.25 N/mm at room temperature and 0.3-0.85 N/mm after heat treatment at 250 °C for 1 hour.

In another aspect of the invention, the interlayer is PET film with acrylic adhesive on its both surfaces.

In yet another aspect of the invention, a force of peeling PET film with acrylic adhesive off from the thin glass is in the range of 1-50mN/mm at room temperature.
In another aspect of the invention, the interlayer is PE film with epoxy on its both surfaces.

In yet another aspect of the invention, a force of peeling PE film with epoxy off from the thin glass is in the range of 1-50mN/mm at room temperature.

In one aspect of the invention, the additional layer is a thick layer of adhesive, which comprises silicone, acrylic, epoxy, polyacrylate, polyurethane, polyester, polyolefin or polyether, and preferably comprises silicone, acrylic or epoxy.

In another aspect of the invention, the thickness of the additional layer is 0.05 mm or more, 0.07 mm or more, 0.1 mm or more.

In one embodiment, the bonded article can be heated up to 550 °C, up to 450 °C, up to 350 °C, up to 250 °C, up to 150 °C, or up to 60 °C, and the surface of thin glass keeps very flat without gas releasing.

In another embodiment, the bonded article can be further coated with ITO layer and OLED functional layers.

In yet another embodiment, the additional layer of adhesive is deposited on the support substrate by spin coating or blade coating.

In one embodiment, interlayer is bonded with support substrate via a laminating process.

In another embodiment, thin glass is bonded with interlayer via a laminating process.

In yet another embodiment, the bonded article does not have any defect in the bonding interface, making a very flat surface of thin glass to facilitate its post-processing.

In the present invention, the above mentioned bonded article can be used for handling and transportation of a thin glass, especially the post processing of a thin glass such as coating, lithography, patterning, or structuring.

In the present invention, the above mentioned bonded article can be
used for application in OLED display, OLED lighting, thin film battery, PCB/CCL, capacitor, E-paper or MEMS/MOEMS, and any other application where a thin glass or cover is used.

In the current invention, a method of producing a bonded article is disclosed, comprising steps of:

Providing a thin glass (1) having a first surface (1a) and a second surface (lb).

Providing a support substrate (2) having a first surface (2a) and a second surface (2b),

Providing an interiayer (3) having a first surface (3a) and a second surface (3b),

Bonding the surface (3b) of the interiayer with the surface (2a) of the support substrate via a laminating process;

Bonding the surface (lb) of the thin glass with the surface (3a) of the interiayer via a laminating process.

In the current invention, another method of producing a bonded article is disclosed, comprising steps of:

Providing a thin glass (1) having a first surface (la) and a second surface (lb),

Providing a support substrate (2) having a first surface (2a) and a second surface (2b),

Providing an interiayer (3) having a first surface (3a) and a second surface (3b),

Depositing an additional layer of adhesive on the support substrate by spin coating or blade coating, and the coating thickness is not less than 0.05 mm;

Bonding the interiayer onto the support substrate with the additional layer via a laminating process;

Bonding the thin glass onto the interiayer via a laminating process.

After the post-processing is finished, thin glass needs to be debonded
from the bonded article.

A unique 2-step method is provided by the current invention, comprising steps of:

- Detaching the support substrate from the bonded article;
- Detaching the interlayer from the thin glass.

In another embodiment, the support substrate can be easily detached from the bonded article by a mechanical method of applying a blade through the adhesive II or focusing a laser beam on the adhesive II.

In yet another embodiment, the support substrate can be easily detached from the bonded article by a mechanical method of applying a blade through the additional adhesive layer or focusing a laser beam on the additional adhesive layer, between the support substrate and the interlayer.

In still another embodiment, after the removal of the support substrate, the interlayer can be easily detached from the thin glass by applying a dragging force on the interlayer.

In still another embodiment, the interlayer is detached from the thin glass by dragging a tape from one corner of the interlayer.

In a further embodiment, the interlayer is detached from the thin glass by applying a vacuum suction cup on the corner of interlayer.

In a further embodiment, when dragging the interlayer along the dragging direction, the angle between the interlayer and the thin glass is less than 45 degree, preferably less than 30 degree, preferably less than 15 degree, preferably less than 10 degree, preferably less than 5 degree.

In one embodiment, the interlayer is detached from the thin glass, without residua on the surface of the thin glass.

In another embodiment, a force of peeling polyimide film with silicone off from the thin glass is in the range of 0.1-0.25 N/mm at room temperature and 0.3-0.85 N/mm after heat treatment at 250 °C for 1 hour.

In yet another embodiment, a force of peeling PET film with acrylic
adhesive off from the thin glass is in the range of 1-50mN/mm at room temperature.

In still another embodiment, a force of peeling PE film with epoxy off from the thin glass is in the range of 1-50mN/mm at room temperature.

In one embodiment, thin glass is fixed on a vacuum table and the soft interlayer is dragged by a tape and gradually peeled off from thin glass.

In another embodiment, thin glass is fixed on a vacuum table and the soft interlayer is peeled off by a vacuum suction cup from thin glass.

In one embodiment, the peeling force for the detachment of interlayer and thin glass sheet is smaller than 1 N/mm, preferably smaller than 0.5 N/mm, more preferably smaller than 0.3 N/mm.

The conventional bonding and debonding solutions for thin glass are either high cost or complicated, and they are not applicable for mass production. Furthermore, the risk of glass breakage is always a problem to be faced when thin glass sheet is in the bended status during such conventional debonding process.

By using the bonded article of the present invention, the above disadvantages are overcome. In the current invention, a bonded article with a unique structure comprising thin glass, interlayer and support substrate can be easily prepared. After post processing, a unique debonding method without using expensive apparatus can be carried out, which facilitates easy detachment of thin glass. The bonded article of the present invention allows relatively big adhesion force up to 1 N/mm between thin glass and interlayer, and allows thin glass always in the flat status during debonding, and thus the risk of glass breakage is greatly reduced. The easy-bonding and debonding processes allow mass production of desired functional thin glass, and represents huge advantages relative to the conventional processes.

Brief Description of the Drawings
Fig. 1 shows a bonded article of thin glass and support substrate with an interlayer in between.

Fig. 2 shows the structure of the interlayer.

Fig. 3 shows a bonded structure of thin glass and support substrate with an interlayer and an additional adhesive layer in between.

Fig. 4 shows debonding of the support substrate with a blade.

Fig. 5 shows the bonded article after debonding of the support substrate.

Fig. 6 shows that the interlayer can be easily peeled off from thin glass.

Fig. 7 shows that lower force applied on thin glass from the perpendicular direction ensures the safety of thin glass during debonding.

Detailed Description

When the thickness of thin glass is less than 0.3 mm, especially less than 0.1 mm, it becomes flexible but more fragile, leading to difficulties in both transporting and post-processing thereof. "Thin glass on a carrier" is a feasible way of solving those problems. Without necessity of update of existing facilities in the industrial line, the bonded article of thin glass and support substrate can be easily processed if its total thickness is in the range of 0.5-0.7mm.

After bonded with support substrate, thin glass should have a very flat surface to facilitate post-processing. Any defect in the bonding interface will increase the risk of breakage of thin glass. For example, the existence of bubble in the bonding interface may cause breakage of the thin glass, when a pressure related process is applied on the bonded article.

Therefore, it is better to apply an interlayer between thin glass and support substrate. The interlayer should be some kinds of soft material, so
that even tiny dust or particle is embedded in, a very flat surface of thin glass is still ensured. Theoretically, the bonding between interlayer and thin glass or support substrate should be not only strong enough but also stable during post-processing. In fact, the bonding strength can change during some post-processing. For example, *interfacial* chemical reaction can occur when the bonded article undergoes a high temperature process, causing increased bonding strength between thin glass and interlayer. Unfortunately, the increased bonding strength would lead to difficulties in subsequent detachment of thin glass from the bonded article, after the whole post-processing process of bonded article is over.

To solve the detachment problem caused by the increased bonding strength in the bonded article, different solutions are proposed. Those solutions can be classified into two groups. One is to adopt interlayer with special physical and chemical properties. The other is to provide co-existence of strong and weak bonding regions in the bonding interface of thin glass and interlayer. The disadvantages of current bonding solutions have been discussed in the part of "background" of this invention. Generally, those solutions are either high cost or complicated, and they are not applicable for mass production. Furthermore, the risk of glass breakage is always a problem to be faced when thin glass sheet is in the bended status during such conventional *debonding* process and the fracture probability of thin glass sheet is mainly decided by its curvature. In current invention, a unique structure of bonded article of thin glass sheet and support substrate is presented to facilitate easy detachment of thin glass sheet after post processing thereof.

**Structure of a bonded article**

The bonded article comprises thin glass sheet, interlayer and support substrate. The interlayer is a kind of organic film with adhesive layers on
its both sides, which play an important role in both bonding and debonding processes. In one embodiment, the bonded article has the following structure: thin glass/interlayer/support substrate, the adhesive layer on the side of support substrate is very thick, for example, more than 50 microns, as illustrated in Fig. 2. In another embodiment, there is an additional thick adhesive layer between interlayer and support substrate. The schematic structure of the bonded article (thin glass/interlayer/additional adhesive layer/support substrate) is shown in Fig. 3.

The bonded article possesses two unique features. One is that the adhesion force between thin glass and interlayer is smaller than 1 N/mm, smaller than 0.5 N/mm, smaller than 0.3 N/mm, depending on the properties of interlayer and the condition of post-processing. The other is that the thickness of the adhesive layer between support substrate and interlayer is more than 50 microns, more than 0.1 mm, more than 0.15 mm, more than 0.2 mm. These two features are correlated with each other and the unique post debonding process. Although smaller adhesion force will be advantageous for the debonding process, the bonding strength is unavoidably increased after some processing, e.g., high temperature coating. However, by using the bonded article of the present invention, the relatively big adhesion force between thin glass sheet and interlayer can be still overcome by a unique debonding method, which represents a huge advantage of the present bonded article.

Thin glass is borosilicate, aluminosilicate or soda-lime produced by-down draw, float, micro-float, slot draw or fusion draw. The thickness of the thin glass is less than 0.5 mm, less than 0.2 mm, less than 0.1 mm, less than 70 µτ, less than 50 µτ, or less than 30 µτ, but not less than 0.01 µτ. The thin glass can be chemically toughened glass.
Support substrate comprises glass, glass ceramic or ceramic. The thickness of support substrate is no more than 0.7 mm, no more than 0.5 mm, no more than 0.3 mm.

The interlayer is a kind of organic film with adhesive on both surfaces. Its schematic graph is shown in Fig. 2. Different types of interlayers can be selected, depending on different kinds of post-processing.

In one embodiment, the interlayer is a polyimide film with silicone on both surfaces.

In another embodiment, the interlayer is a PET film with acrylic adhesive on both surfaces.

In another embodiment, the interlayer is a PE film with epoxy on both surfaces.

In the embodiment that polyimide film with silicone on both sides is used as interlayer, the adhesion force between interlayer and thin glass is 0.25 N/mm at room temperature, and it becomes 0.35 N/mm after I/O coating process at 250 °C for 1 hour.

By adopting different types of interlayers, the bonded article can be used for different post-processing of thin glass, such as coating, lithography, patterning, or structuring. The final applications include OLE!) display, OLED lighting, thin film battery, PCB/CCL, capacitor, E-paper or MEMS/MOEMS, etc.

**Production of bonded article**

In the current invention, a method of producing a bonded article is disclosed, comprising steps of: firstly, bonding one surface of interlayer with support substrate via a laminating process, secondly, bonding thin
glass with the other surface of the interlayer via a laminating process to obtain the bonded article. The interlayer is a soft material with adhesive I and adhesive II on the top and bottom surfaces to be bonded with the thin glass and the support substrate, respectively. Preferably, the soft material is an organic film.

In the current invention, another method of producing a bonded article is disclosed, comprising steps of:

Firstly, an additional thick layer of adhesive is deposited on the support substrate, by either spin coating or blade coating. The thickness of this additional layer should be 0.05 mm or more, 0.07 mm or more, 0.1 mm or more, 0.15 mm or more.

Secondly, interlayer is bonded onto the support substrate with the additional thick layer via a laminating process. The interlayer is an organic film with adhesive on both surfaces.

Thirdly, thin glass is bonded onto the interlayer to obtain the final bonded article. In one embodiment, the size of thin glass can be the same as that of interlayer. In another embodiment, the size of thin glass is smaller than that of interlayer, which will facilitate the subsequent debonding process.

Debonding of bonded article

After all the post-processing for the bonded article is over, thin glass with functional layers is detached from the bonded article via a two-step method.

As the first step, support substrate is removed from the bonded article. In one embodiment, the bonded article is fixed on a table by either vacuum
adhesion or screwing. Then support substrate is detached by cutting along the additional adhesive layer or the adhesive II between the organic film of the interlayer and support substrate with a blade, as illustrated in Fig. 4. Depending on the thickness of the adhesive layer, the blade should have different thickness. For example, if the thickness of adhesive between the organic film and support substrate is 100 microns, the blade should have a thickness of about 50 microns. In fact, this detaching process can be carried out very easily, because requirements on the cutting quality are not strict, as long as the support substrate is removed from the bonded article, as shown in Fig. 5. In another embodiment, support substrate is released from the bonded article by focusing a laser beam on and along the bonding interface of support substrate and interlayer.

As the second step, the debonding of interlayer and thin glass is carried out. Fix the bonded article of interlayer and thin glass on a table by vacuum adhesion of one surface of thin glass with functional layers. In other words, the interlayer is free to be detached. Then apply a force to drag the interlayer and allow it to leave out of thin glass gradually. In one embodiment, a force is applied by dragging a tape pasted on one corner of the interlayer. In another embodiment, a force is applied by a vacuum suction cup.

The advantages of the unique debonding method provided in this invention are as follows: 1) the 2-step method is very simple and no expensive apparatus is involved, and thus it is easy to be realized in mass production; 2) Compared with traditional debonding method, the present solution is much more helpful for the improving the final yield. Due to the weak nature of thin glass, it is apt to break when it is bended. The probability of breakage will be greatly increased when the curvature of thin glass is near a limit. Therefore, the ideal way of avoiding breakage of
thin glass is to always keep it flat. The debonding method provided in this invention satisfies such a requirement. In fact, due to the super-flexibility of interlayer, the angle between interlayer and thin glass can be kept at nearly 180 degree when interlayer is peeling off from thin glass, as shown in Fig. 6. This means the force applied on thin glass is always in parallel with thin glass itself, and no additional force is applied on thin glass in the perpendicular direction. Thus thin glass can be kept in the flat status during the whole debonding process, causing a low probability of breakage. Therefore, when making such bonded article, it is better to adopt a bigger interlayer than thin glass, which will benefit the subsequent debonding process from the easy initiation of peeling interlayer off from thin glass.

The biggest advantage of the bonding structure is the relatively big adhesion force between thin glass sheet and interlayer, which can reach 1 N/mm. According to the disclosure of some prior art reference (US 8377552), when the adhesion between thin glass sheet and interlayer is stronger than 0.35 N/mm, their debonding becomes much difficult. In this invention, even when the adhesion force between thin glass sheet and interlayer is bigger than 0.5 N/mm or even reaches 1 N/mm, the bonded article can be still detached without breakage of the thin glass sheet, due to both the unique bonding structure and debonding method.

**Examples**

**Example 1**

To serve as the substrate of OLED lighting device, alumino-borosilicate thin glass AF32 with a thickness of 0.05 mm is subjected to an ITO coating process. Thin glass AF32 is bonded onto a carrier glass AF32 with a thickness of 0.5 mm by applying a double-side tape as interlayer in between. The double-side tape is polyimide film with silicone layers on its both sides, and the silicone layers are bonded with the
surfaces of thin glass and support substrate glass, respectively. The thickness of the silicone layer between tape and support substrate AF32 and between tape and thin glass is 0.1 mm and 0.05 mm, respectively. The adhesion force between thin glass AF32 and the tape is 0.1 N/mm. Firstly, double-side tape and support substrate glass is bonded via a laminating process, and then thin glass is bonded onto the other side of the tape via the same laminating process. The surface of thin glass then becomes very flat, which is good for post-processing of the thin glass.

The bonded article undergoes an ITO coating process at a temperature of 250 °C for 1 hour. Then different OLED functional layers including conductive layer and emissive layer are also deposited onto such ITO coated surface of bonded article. After that a layer of silver is deposited on the top as the cathode of OLED lighting device. When these processes are over, thin glass AF32 with functional layers needs to be detached from the bonded article. Firstly, the support substrate is detached from the bonded article, by cutting along the silicone layer between the tape and support substrate with a blade; then the thin glass is fixed via vacuum adhering to make sure that the tape side is on the top; the tape is peeled off from the surface of thin glass by keeping an angle of 10 degree between the tape and thin glass and with a peeling force of 0.5 N/mm (which indicates an increased bonding force between thin glass and the tape during the ITO coating process), without damaging of both the thin glass and the functional layer thereon; finally thin glass with OLED function layers is obtained by releasing air into the vacuum chamber. Thereafter, an OLED lighting unit consisting of thin glass, electrodes and function layers is obtained.

Example 1'

In this example, all the other conditions are identical to those in
Example 1, the only differences are: the adhesion force between thin glass AF32 and the tape is 0.2 N/mm and after ITO coating process at a temperature of 250 °C for 1 hour according to the above debonding process the tape is detached from thin glass AF32 by a peeling force of 0.8 N/mm without any breakage of thin glass AF32.

Example 2

Thin glass D263T is used as the cover and the substrate of optical sensor, and a sensitive layer is required to be formed on the thin glass. To attain high quality coating, the surface of thin glass should be very flat. In this example, D263T with a thickness of 0.05 and 0.5 mm are used as thin glass and support substrate, respectively. A PET film with acrylic adhesive on its both sides is applied between thin glass and support substrate as the interlayer. The thickness of the acrylic adhesive between tape and support substrate D263T and between tape and thin glass D263T is 0.15 mm and 0.03 mm, respectively. Firstly, PET film is bonded onto support substrate via a laminating process; then thin glass is bonded onto the other side of PET film via the same laminating process. The adhesion force between thin glass D263T and the PET film is 4 mN/mm. The thickness of acrylic adhesive between PET film and support substrate D263T is 0.07 mm. Then the bonded article is put into a vacuum chamber for deposition of a sensitive layer via magnetic sputtering process. After the coating process, support substrate is firstly detached from the bonded article by focusing a laser beam on the acrylic adhesive between the PET film and support substrate; then thin glass D263T is fixed on a vacuum table and the PET film is peeled off from the coated thin glass with a force of 5 mN/mm. During the peeling process, the angle between the tape and thin glass is kept at 5 degree to keep the thin glass always in a flat status, resulting in safe debonding of thin glass without any damage. Finally thin glass D263T with a sensitive layer thereon is obtained.
Example 2’

In this example, all the other conditions are identical to those in Example 2, the only differences are: the adhesion force between thin glass D263T and the PET film is 35 mN/mm; after the deposition of a sensitive layer via magnetic sputtering process, the detachment of thin glass D263T from the bonded article is done according to the above debonding method; the PET film is peeled off from thin glass D263T with a force of 40 mN/mm without any breakage of thin glass D263T.

Example 3

Thin glass AF32 is used as the substrate of a touch sensor. To fulfill such application, the surface of the thin glass should be very flat and strong enough to facilitate the printing of conductive pattern. Before the ink printing process, thin glass AF32 with a thickness of 0.05 mm is bonded onto a support substrate AF32 with a thickness of 0.5 mm by applying a PE film with epoxy in between. The thickness of epoxy between PE film and support substrate AF32 and between tape and thin glass AF32 is 0.2 mm and 0.05 mm, respectively. The adhesion force between thin glass AF32 and PE film is 0.01 N/mm. Then a silk printing process is carried out for the bonded article where the ink is printed on the surface of thin glass, and after the UV curing or heat treatment, conductive pattern can be formed on the thin glass. After that thin glass needs to be detached from the bonded article. Firstly, support substrate is detached from the bonded article by cutting it off along the epoxy between PE film and support substrate AF32. Then the PE film is peeled off by a vacuum suction cup from the thin glass, which is fixed on a vacuum table. During the peeling process, the angle between the PE film and thin glass is kept at 15 degree and the peeling force is 0.05 N/mm without breakage of the thin glass. Finally thin glass with a conductive pattern thereon is obtained.
Example 3’
In this example, all the other conditions are identical to those in Example 3, the only differences are: the adhesion force between thin glass AF32 and PE film is 0.03 N/mm; after the printing of conductive pattern, the detachment of thin glass AF32 from the bonded article is done according to the above debonding method; PE film is peeled off from thin glass AF32 with a force of 0.05 N/mm without any breakage of thin glass AF32.

Example 4
To increase the efficiency of OLED lighting device, a light extraction film is laminated with OLED function layer, which is fabricated on a thin glass AF32 with a thickness of 0.07 mm. The following are the processes to make such device/structure. Firstly thin glass AF32 with a thickness of 0.07 mm is bonded onto a carrier glass AF32 with a thickness of 0.5 mm with a double-side tape as interlayer in between. The double-side tape is PET with acrylic layers on its top and bottom sides. The acrylic layers on the top and bottom sides both have a thickness of 0.05 mm. Before bonding double-side tape and support substrate AF32, an additional acrylic adhesive layer with a thickness of 0.15 mm is deposited on the support substrate AF32 glass by spin coating process. Then the coated support substrate and thin glass are bonded with the two surfaces of double-side tape through laminating process. The adhesion force between thin glass AF32 and the tape is 6 mN/mm. The thickness of acrylic layer between the tape and support substrate AF32 is 0.15 mm. After that a transparent conductive layer is printed onto the thin glass sheet via an ink printing process, and will serve as the bottom electrode of OLED lighting device. Then OLED functional layer and top metal electrode are deposited on the transparent conductive layer respectively. Then a light extraction film is
further laminated with OLED functionalized thin glass by using acrylic adhesive to increase the light yield up to 30-60%. After the OLED device is fabricated, functionalized thin glass needs to be detached from the bonded article. Firstly, carrier glass is detached by cutting along the bonding interface between the double-side tape and support substrate with a blade. Secondly, the OLED device is fixed via vacuum adhering and the tape is peeled off from the surface of thin glass with a force of 0.1 N/mm. During the peeling process, the angle between the tape and thin glass is kept at an angle of 5 degree and no breakage of thin glass occurs. Finally, thin glass with both OLED functional layers and light extraction film is obtained.

Test Example 1A: Bonded article of the present invention

Thin glass AF32 with a thickness of 0.05 mm is bonded onto support substrate AF32 glass with a thickness of 0.5 mm with an interlayer in between. The interlayer is a double-side tape of polyimide film with silicone on its both surfaces. The thickness of the silicone layer between tape and support substrate AF32 and between tape and thin glass is 0.1 mm and 0.05 mm, respectively. The adhesion force between the tape and thin glass or support substrate is 0.05 N/mm. The thickness of silicone layer between the tape and thin glass is 50 µm. The bonded article is then held at 250 °C for 1 hour to deposit an ITO layer on the surface of thin glass. Then detachment of thin glass from the bonded article is carried out by the unique 2-step method disclosed in this invention. Firstly, support substrate is detached by cutting through the silicone layer between the tape and support substrate with a blade. Secondly, thin glass is fixed on a vacuum table and then the double-side tape is peeled off from thin glass. Through the whole detachment process, no damage occurs for thin glass and the biggest dragging force reaches 0.85 N/mm. On one hand, the force applied on thin glass is parallel with the dragging force applied on the double-side
tape. On the other hand, the angle between tape and thin glass is smaller than 10 degree during the debonding process. Therefore, compared with traditional debonding method, the force applied on thin glass from the perpendicular direction is much lower, and thin glass is always kept in the flat status during the whole debonding process, as illustrated in the Fig. 7. Consequently, a greatly decreased probability of breakage is achieved.

**Conventional** bonded article (comparative example 1)

Thin glass AF32 with a thickness of 0.05 mm is bonded onto support substrate AF32 glass with a thickness of 0.5 mm with an interlayer in between. The interlayer is a silicone layer with a thickness of 50 µm. The adhesion force between interlayer and thin glass or support substrate is 0.05 N/mm. After deposition of ITO coating under the temperature of 250 °C for 1 hour, the adhesion between interlayer and thin glass or support substrate becomes much bigger. Thin glass is then peeled off from the bonded article by directly applying a force on the thin glass. When the dragging force reaches 0.3 N/mm and the curvature radius of thin glass is smaller than 100 mm, thin glass is broken.

As can be seen, due to the unique bonding structure, the biggest advantage of the bonded article disclosed by this invention is the easy detaching of thin glass from the bonded article, with which the probability of breakage of thin glass can be greatly decreased.

The above data are summarized in the following Table 1:
Table 1: comparison of the articles of the present invention and the conventional bonded articles

<table>
<thead>
<tr>
<th>Example</th>
<th>Support substrate</th>
<th>Thin glass</th>
<th>Interlayer</th>
<th>Adhesive I on interlayer facing thin glass</th>
<th>Adhesive II on interlayer facing support substrate</th>
<th>Additional adhesive layer</th>
<th>Peeling force @ RT for removing interlayer from thin glass</th>
<th>Peeling force after processing for removing interlayer from thin glass</th>
<th>Peeling angle of interlayer (degree)</th>
<th>Thermal stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AF32 50x80</td>
<td>AF32</td>
<td>Polyimide 40x60</td>
<td>Silicone 0.05</td>
<td>Silicone 0.1</td>
<td>None</td>
<td>0.1 N/mm</td>
<td>0.5 N/mm at 250 °C, 1h</td>
<td>10</td>
<td>Stable at the temperature less than 500 °C</td>
</tr>
<tr>
<td>2</td>
<td>D265T 80x150</td>
<td>D265T</td>
<td>PET 50x110</td>
<td>Acrylic resin 0.03</td>
<td>Acrylic resin 0.15</td>
<td>None</td>
<td>4 mN/mm</td>
<td>5 mN/mm at 150 °C, 0.5h</td>
<td>5</td>
<td>Stable at the temperature less than 180 °C</td>
</tr>
<tr>
<td>3</td>
<td>AF32 100x150</td>
<td>AF32</td>
<td>PE 70x120</td>
<td>Epoxy 0.05</td>
<td>Epoxy 0.2</td>
<td>None</td>
<td>0.01N/mm</td>
<td>0.05N/mm at 80 °C, 15 min</td>
<td>15</td>
<td>Stable at the temperature less than 100 °C</td>
</tr>
<tr>
<td>4</td>
<td>AF32 70x70</td>
<td>AF32</td>
<td>PET 40x60</td>
<td>Acrylic resin 0.05</td>
<td>Acrylic resin 0.05</td>
<td>Acrylic resin 0.15</td>
<td>6 mN/mm</td>
<td>0.1N/mm at 150 °C, 15 min</td>
<td>5</td>
<td>Stable at the temperature less than 180 °C</td>
</tr>
<tr>
<td>Test Example 1A</td>
<td>AF32 50x80</td>
<td>AF32</td>
<td>Polyimide 40x60</td>
<td>Silicone 0.05</td>
<td>Silicone 0.1</td>
<td>None</td>
<td>0.05 N/mm</td>
<td>0.85 N/mm at 250 °C, 1h</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Comparative example 1</td>
<td>AF32 50x80</td>
<td>AF32</td>
<td>None</td>
<td>Silicone 0.05</td>
<td>none</td>
<td>none</td>
<td>0.05 N/mm</td>
<td>Thin glass broken when peeling force reaches 0.3 N/mm at 250 °C, 1h</td>
<td>&lt;100 mm</td>
<td></td>
</tr>
</tbody>
</table>

Peeling thin glass directly from substrate glass @ RT
Peeling thin glass directly from substrate glass after high temperature processing
Bending radius thin glass
List of Reference Symbols

1  thin glass
2  support substrate
3  interlayer
3 0  soft material
3 1  adhesive I
3 2  adhesive II
4  additional layer
5  blade
What is claimed:

1. A bonded article comprising:
   a thin glass (1) having a first surface (1a) and a second surface (1b), a support substrate (2) having a first surface (2a) and a second surface (2b), an interlayer (3) having a first surface (3a) and a second surface (3b),
   wherein one of the first and second surfaces of the thin glass is bonded onto the first surface of interlayer,
   and wherein one of the first and second surfaces of the support substrate is bonded onto the second surface of interlayer.

2. A bonded article according to claim 1, wherein there is an additional layer between the interlayer and the support substrate.

3. A bonded article according to claim 1, wherein the interlayer is a soft material with adhesive I and adhesive II on the top and bottom surfaces to be bonded with the thin glass and the support substrate, respectively.

4. A bonded article according to claim 1, wherein the adhesion force between the interlayer and the thin glass is smaller than 1 N/mm, preferably smaller than 0.5 N/mm, preferably smaller than 0.3 N/mm.

5. A bonded article according to claim 3, wherein the thickness of adhesive II is bigger than 20 μm, preferably bigger than 50 μm, preferably bigger than 70 μm, preferably bigger than 100 μm, preferably bigger than 150 μm.

6. A bonded article according to claim 1, wherein the thickness of
the thin glass is less than 0.3 mm, preferably less than 0.2 mm, preferably less than 0.1 mm, preferably less than 70 µm, preferably less than 50 µm, preferably less than 30 µm, but not less than 10 µm.

7. A bonded article according to claim 1, wherein the thin glass is a chemically toughened glass.

8. A bonded article according to claim 1, wherein the support substrate is selected from the group consisting of glass, glass ceramic and ceramic.

9. A bonded article according to claim 1, wherein the thickness of the support substrate is no more than 0.7 mm, preferably no more than 0.5 mm, preferably no more than 0.3 mm.

10. A bonded article according to claim 1, wherein the thin glass is borosilicate, aluminosilicate or soda-lime produced by down draw, float, micro-float, slot draw or fusion draw.

11. A bonded article according to claim 3, wherein the interlayer is an organic film with adhesive on both surfaces, preferably the organic film is selected from the group consisting of polyester such as polyethylene terephthalate, acrylic resin such as polymethylmethacrylate, polycarbonate, triacetyl cellulose, polysulfone, polyarylate, polyimide, polyvinyl chloride, polyvinyl acetate, polyethylene, polypropylene, ethylene-propylene copolymer, and preferably the adhesive comprises silicone, acrylic, epoxy, polyacrylate, polyurethane, polyester, polyolefin or polyether.

12. A bonded article according to claim 11, wherein the interlayer is polyimide film with silicone on its both surfaces.
13. A bonded article according to claim 12, wherein a force of peeling polyimide film with silicone off from the thin glass is in the range of 0.1-0.25 N/mm at room temperature and 0.3-0.85 N/mm after heat treatment at 250 °C for 1 hour.

14. A bonded article according to claim 11, wherein the interlayer is polyethylene terephthalate film with acrylic adhesive on its both surfaces.

15. A bonded article according to claim 14, wherein a force of peeling polyethylene terephthalate film with acrylic adhesive off from the thin glass is in the range of 1-50mN/mm at room temperature.

16. A bonded article according to claim 11, wherein the interlayer is polyethylene film with epoxy on its both surfaces.

17. A bonded article according to claim 16, wherein a force of peeling polyethylene film with epoxy off from the thin glass is in the range of 1-50mN/mm at room temperature.

18. A bonded article according to claim 2, wherein the additional layer is a thick layer of adhesive, which comprises silicone, acrylic, epoxy, polyacrylate, polyurethane, polyester, polyolefin or polyether, and preferably comprises silicone, acrylic or epoxy.

19. A bonded article according to claim 2, wherein the thickness of the additional layer is 0.05 mm or more, 0.07 mm or more, 0.1 mm or more.
20. A bonded article according to claim 1, wherein the bonded article can be heated up to 550 °C, up to 450 °C, up to 350 °C, up to 250 °C, up to 150 °C, or up to 60 °C, and the surface of thin glass keeps very flat without gas releasing.

21. A bonded article according to anyone of claims 1-20, wherein the bonded article can be further coated with JTO layer and OLED functional layers.

22. Use of the bonded article according to anyone of claims 1-20 for handling and transportation of a thin glass, especially the post processing of a thin glass such as coating, lithography, patterning, or structuring.

23. Use of the bonded article according to anyone of claims 1-20 for application in OLED display, OLED lighting, thin film battery, PCB/CCL, capacitor, E-paper or MEMS/ MOEMS, and any other application where a thin glass or cover is used.

24. A method of producing a bonded article, comprising steps of:
   Providing a thin glass (1) having a first surface (1a) and a second surface (1b),
   Providing a support substrate (2) having a first surface (2a) and a second surface (2b),
   Providing an interlayer (3) having a first surface (3a) and a second surface (3b),
   Bonding the surface (3b) of the interlayer with the surface (2a) of the support substrate via a laminating process;
   Bonding the surface (lb) of the thin glass with the surface (3a) of the interlayer via a laminating process.
25. A method of producing a bonded article, comprising steps of:

Providing a thin glass (1) having a first surface (la) and a second surface (lb),

Providing a support substrate (2) having a first surface (2a) and a second surface (2b),

Providing an interlayer (3) having a first surface (3a) and a second surface (3b),

Depositing an additional layer of adhesive on the support substrate by spin coating or blade coating, and the coating thickness is not less than 0.05 mm;

Bonding the interlayer onto the support substrate with the additional layer via a laminating process;

Bonding the thin glass onto the interlayer via a laminating process.

26. A debonding method of detaching thin glass from the bonded article according anyone of claims 1 to 20, comprising:

Detaching the support substrate from the bonded article;

Detaching the interlayer from the thin glass.

27. A debonding method according to claim 26, wherein the support substrate can be easily detached from the bonded article by a mechanical method of applying a blade through the adhesive II or focusing a laser beam on the adhesive II.

28. A debonding method according to claim 26, wherein the support substrate can be easily detached from the bonded article by a mechanical method of applying a blade through the additional adhesive layer or focusing a laser beam on the additional adhesive layer, between the support substrate and the interlayer.
29. A debonding method according to claim 26, wherein after the removal of the support substrate, the interlayer can be easily detached from the thin glass by applying a dragging force on the interlayer.

30. A debonding method according to claim 29, wherein the interlayer is detached from the thin glass by dragging a tape from one corner of the interlayer.

31. A debonding method according to claim 29, wherein the interlayer is detached from the thin glass by applying a vacuum suction cup on the corner of interlayer.

32. A debonding method according to claim 29, wherein when dragging the interlayer along the dragging direction, the angle between the interlayer and the thin glass is less than 45 degree, preferably less than 30 degree, preferably less than 15 degree, preferably less than 10 degree, preferably less than 5 degree.

33. A debonding method according to claim 30, wherein the interlayer is detached from the thin glass, without residua on the surface of the thin glass.

34. A debonding method according to claim 30, wherein a force of peeling polyimide film with silicone off from the thin glass is in the range of 0.1 -0.25 N/mm at room temperature and 0.3-0.85 N/mm after heat treatment at 250 °C for 1 hour.

35. A debonding method according to claim 30, wherein a force of peeling polyethylene terephthalate film with acrylic adhesive off from the
thin glass is in the range of 1-50mN/mm at room temperature.

36. A debonding method according to claim 30, wherein a force of peeling polyethylene film with epoxy off from the thin glass is in the range of 1-50mN/mm at room temperature.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
   B32B 17/06(2006.01)i; B32B 17/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
   B32B; C03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<tr>
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<td>US 2008053604 A1 (ELECTRONICS&amp;TELECOM RES INST) 06 March 2008 (2008-03-06) claims 1-18, and description, paragraphs [0021], [0025], and [0034]-[0036]</td>
<td>1-36</td>
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<td>A</td>
<td>KR 20080001142 A (LG DISPLAY CO LTD) 03 January 2008 (2008-01-03) the whole document</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search 08 September 2015

Date of mailing of the international search report 28 September 2015

Name and mailing address of the ISA/CN

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Form PCT/ISA/210 (second sheet) (July 2009)
INTERNATIONAL SEARCH REPORT

Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claim 1 a bonded article;
2. Claim 22 use of the bonded article;
3. Claim 23 use of the bonded article;
4. Claim 24 a method of producing a bonded article;
5. Claim 25 a method of producing a bonded article;
6. Claim 26 a debonding method.
7. The same technical features between claim 1 and anyone of claims 22-26, between claims 22 or 23 and anyone of claims 24-26 and between any two of claims 24-26 are the bonding article stated in claim 1. The same technical feature between claims 22 and 23 is the bonded article of anyone of claims 1-20. It is found that the same technical features mentioned above do not make contribution to prior art, therefore, the any two between claims 1 and 22-26 do not have same or corresponding special technical features, that is, the any two between claims 1 and 22-26 are not so linked as to form a single general inventive concept and do not have unity of invention as required by the PCT Rule 13.1.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.
## INTERNATIONAL SEARCH REPORT

### Information on patent family members

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
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