

Packaging System and Packaging Method for Laser-Sealed Glass Package

TECHNICAL FIELD

The present invention relates to organic light-emitting diode (OLED) packaging and, more particularly, to packaging systems and methods for laser sealing of a glass package.

BACKGROUND

In recent years, organic light-emitting diodes (OLEDs) have become a focus of research and development efforts in the field of flat-panel display and lighting thanks to their spontaneous light emission, structural simplicity, ultra-thinness, fast response, high color contrast, wide viewing angle, low power consumption, feasibility of flexible display and other excellent properties. For OLED devices, it is particularly important to prevent the ingress of external oxygen and water vapor because presence of such substances in an OLED device may cause cathode oxidation, delamination, organic crystallization and other adverse consequences, which can lead to early aging or even damage of the device. As a result, the device may suffer from defects commonly seen as black spots, pixel shrinkage and light intensity attenuation. In accordance with certain standards established in this art, a commercialized OLED product should have a service life span of at least 10,000 hours and a storage life of at least 50,000 hours, achievement of which requires a water vapor transmission rate (WVTR) of less than 10^{-6} g/m²/day and an oxygen transmission rate (OTR) of less than 10^{-5} cc/bar/m²/day. These requirements are higher than those for liquid crystal display (LCD) devices. Therefore, the development of OLED packaging processes and materials are crucial in the manufacture of OLED devices.

Currently, there are majorly three OLED packaging techniques: capping sealing using an ultraviolet (UV) adhesive, thin-film packaging and laser sealing using a

glass frit. Among them, the glass frit-enabled laser sealing is the latest developed one in which an optical system made up of reflectors and lenses or of optical fibers focuses a light beam produced by a laser onto an area to be sealed to form a heat-affected zone where the glass frit, i.e., the packaging material, is softened and melted, gluing together, and hence forming a hermetical seal between, two glass substrates disposed above and under the frit.

At present, sealing an OLED device by laser heating of a glass frit can be accomplished by sequentially scanning portions of the frit along a path or in a synchronous manner. In the sequential scanning method, a laser beam conditioned to have a certain power profile is vertically focused on the frit which has been pre-cured along a strip to be sealed and then it moves along the frit so that different portions of the frit are sequentially heated to a temperature higher than its softening point. Therefore, the portions of the frit are allowed to cool sequentially, forming the seal. However, this method fails to provide a good seal due to the non-uniform heating process.

In the synchronous sealing method, a two-dimensional light pattern that matches the strip to be sealed in shape is formed by putting together multiple laser beams or conditioning a single beam using a spatial light modulator (e.g., a DOE, MMA, etc.) and then it is irradiated on the glass frit distributed along the strip so that the frit can be entirely and synchronously heated to a temperature higher than the softening point and then cooled to form a seal. However, this process is associated with high complexity, high difficulties in implementation and a low yield.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a packaging system and method for laser sealing of a glass package which can provide a more uniform temperature distribution and enables a higher yield.

To this end, there is proposed a packaging system for laser sealing of a glass package, which comprises a laser, a gantry and at least one laser scanning unit arranged on the gantry. Each laser scanning unit is able to project a laser beam produced by the laser onto the glass package to define an associated scanning field. The packaging system further comprises a controller configured to control at least one of a position, a movement path and an operating state of the scanning field of each laser scanning unit based on the number of the at least one laser scanning unit and an area of the glass package to be sealed.

Additionally, the glass package may be provided with a glass frit sealing strip, wherein the scanning field of each laser scanning unit covers at least one of a length, a width and a corner portion of the glass frit sealing strip.

Additionally, the controller may be further configured to control the gantry to drive each laser scanning unit to move so that the scanning field of each laser scanning unit dynamically covers the glass frit sealing strip.

Additionally, the gantry may move in a stepping manner, wherein subsequent to each stepping of the gantry, the controller adjusts at least one of the position, the movement path and the operating state of the scanning field of each laser scanning unit.

Additionally, the gantry may move in a scanning manner, wherein the controller adjusts in real time at least one of the position, the movement path and the operating state of the scanning field of each laser scanning unit.

Additionally, the laser may be a CO₂ laser.

Additionally, the laser beam produced by the laser may have a wavelength ranging from 800 nm to 900 nm and an operating power in the range of from 100 W to 500 W.

Additionally, the laser may be coupled to each laser scanning unit via an optical fiber.

Additionally, each laser scanning unit may be a galvanometer scanning unit comprising one or more reflectors, a scanning motor and a servo drive unit, wherein the servo drive unit is configured to generate and send to the scanning motor a signal indicative of an angle of pivot so that the scanning motor controls the one or more reflectors to pivot by the angle.

Additionally, the angle of pivot for the reflectors may range from -20° to 20° .

There is also proposed in this invention a packaging method for laser sealing of a glass package by heating a glass frit on the glass package to form a hermetic seal, which comprises the steps of:

a) arranging at least one laser scanning unit on a gantry, wherein each laser scanning unit is able to project a laser beam produced by a laser onto a sealing strip on the glass package to define an associated scanning field;

b) controlling at least one of a position, a movement path and an operating state of the scanning field of each laser scanning unit based on the number of the at least one laser scanning unit and an area surrounded by the sealing strip so that the laser beam periodically scans and thus heats a powder of the glass frit that forms the sealing strip until the powder is melted.

Additionally, one laser scanning unit may be arranged on the gantry, and the area surrounded by the sealing strip is greater than the scanning field, and wherein step b) comprises:

b1) maintaining the gantry stationary and rotating the laser scanning unit so that the laser beam periodically scans a section of the sealing strip within the scanning field along a predefined path at a predetermined speed; and

b2) causing the gantry and hence the laser scanning unit to step forward a predetermined distance, and repeating step b1), until the sealing strip has been entirely heated.

Additionally, one laser scanning unit may be arranged on the gantry, and the

area surrounded by the sealing strip is greater than the scanning field, and wherein step b) comprises: the gantry moving together with the laser scanning unit along the sealing strip in a scanning manner, concurrently with the laser beam scanning the sealing strip along a predefined path at a predetermined speed until the sealing strip has been entirely heated.

Additionally, a plurality of laser scanning units may be arranged on the gantry, each corresponding to a glass package to be sealed, wherein step b) comprises: maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans the sealing strip of the corresponding glass package along a predefined path at a predetermined speed.

Additionally, a plurality of laser scanning units may be arranged on the gantry, and the scanning fields of the laser scanning units cover the sealing strip, and wherein step b) comprises: maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans a section of the sealing strip within the corresponding scanning field along a predefined path at a predetermined speed.

Additionally, a plurality of laser scanning units may be arranged on the gantry, and the scanning fields of the laser scanning units cover a length of the sealing strip, and wherein step b) comprises:

b3) maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans a section of the sealing strip within the corresponding scanning field along a predefined path at a predetermined speed; and

b4) causing the gantry and hence the plurality of laser scanning units to step forward a predetermined distance in a width-wise direction of the sealing strip, and repeating step b3), until the sealing strip has been entirely heated.

Compared to the prior art, the present invention majorly offers the following

benefits: the laser beam(s) is/are projected by the laser scanning unit(s) onto the glass package(s) and performs rapid, periodic scanning and hence heating thereon, entailing a quasi-synchronous sealing approach which can achieve a more uniform temperature distribution and a higher yield for diverse patterns to be sealed.

In addition, one or more laser scanning units can be arranged on the gantry and move therewith in a step-wise manner. This enables the sealing of a large-sized glass package or simultaneous sealing of multiple glass packages, resulting in a significant improvement in yield.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and spirit of the present invention can be better understood from the following specific embodiments and the accompanying drawings in which:

Fig. 1 is a schematic illustration of a packaging system for laser sealing of a glass package in accordance with a first embodiment of the present invention;

Fig. 2 is a cutaway view of the packaging system in accordance with the first embodiment of the present invention;

Fig. 3 is a top view of a glass package to be sealed in accordance with the first embodiment of the present invention;

Fig. 4 shows an optical path of a laser beam in a laser scanning unit in accordance with the first embodiment of the present invention;

Figs. 5a to 5c schematically illustrate a single-galvanometer unit cell-wise packaging method in accordance with a second embodiment of the present invention;

Figs. 6a to 6b schematically illustrate a single-galvanometer unit scanning packaging method in accordance with a third embodiment of the present invention;

Fig. 7 schematically illustrates a multi-galvanometer unit packaging method in accordance with a fourth embodiment of the present invention;

Fig. 8 is a top view of multiple rows of glass packages to be sealed in

accordance with the fourth embodiment of the present invention;

Fig. 9 schematically illustrates a multi-galvanometer unit stationary cell-wise packaging method in accordance with a fifth embodiment of the present invention; and

Fig. 10 schematically illustrates a multi-galvanometer unit dynamic cell-wise packaging method in accordance with a sixth embodiment of the present invention.

DETAILED DESCRIPTION

Packaging systems and methods for laser sealing of a glass package according to the present invention will be described in greater detail in the following description which presents preferred embodiments of the invention and is to be read in conjunction with the accompanying drawings. It is to be appreciated that those of skill in the art can make changes to the invention disclosed herein while still obtaining the beneficial results thereof. Therefore, the following description shall be construed as being intended to be widely known by those skilled in the art rather than as limiting the invention.

For simplicity and clarity of illustration, not all features of the disclosed specific embodiment are described. Additionally, description and details of well-known functions and structures are omitted to avoid unnecessarily obscuring the invention. The development of any specific embodiment of the present invention includes specific decisions made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, such a development effort might be complex and time consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art.

The present invention will be further described in the following paragraphs by way of examples with reference to the accompanying drawing. Features and

advantages of the invention will be more apparent from the following detailed description, and from the appended claims. Note that the accompanying drawings are provided in a very simplified form not necessarily presented to scale, with the only intention of facilitating convenience and clarity in explaining a few illustrative examples of the invention.

EMBODIMENT1

Referring to Figs. 1 to 4, in this Embodiment, a proposed packaging system for laser sealing of a glass package includes a laser 1, a gantry 3 and a laser scanning unit 4. The laser scanning unit 4 is arranged on the gantry 3, and a laser beam produced by the laser 1 is projected onto the glass package to be sealed via the laser scanning unit 4. As shown in Fig. 3, in a general case, the glass package includes two glass substrates 8 in an up-down configuration, an OLED chip 9 between the glass substrates 8 that is to be packaged, and a soldering material 10 such as the powdery glass frit surrounding the chip 9.

In this Embodiment, the laser 1 is selected as a CO₂ laser which is coupled to the laser scanning unit 4 via an optical fiber 2. The laser beam 7 emanated from the laser 1 has a wavelength ranging from 800 nm to 900 nm, for example, 850 nm, as well as a power ranging from 100 W to 500 W, for example, 300 W. The laser scanning unit 4 is a galvanometer scanning unit comprising one or more reflectors 40 (as shown in Fig. 4), a scanning motor and a servo drive unit (not shown). In the case shown in Fig. 4, the galvanometer scanning unit includes two reflectors 40 each being able to pivot or swing about the respective axes in the respective directions indicated by the arrows in the figures. The servo drive unit can transmit a signal indicative of an angle of pivot to the scanning motor which then controls the reflectors 40 to pivot by the angle so that the laser beam 7 can periodically scan the glass frit 10 on the glass package under the cooperation of the two reflectors 40. Reasonably, the angle of

pivot of the reflectors 40 is in the range of from -20° to 20° , for example, $\pm 15^{\circ}$, which can ensure avoidance of the reflectors 40 vibrating or having an inertia that adds a delay in implementation of the control signal at an excessively large swing amplitude. The gantry 3 is configured to allow the galvanometer scanning unit to be hung thereon so that the laser scanning unit 4 can move freely with the gantry 3 within a plane, i.e., moving in X- and Y- directions freely within the same plane.

As stated above, since the reflectors 40 in the laser scanning unit 4 are able to pivot within a predetermined angle range, the direction in which the laser beam 7 exits the unit is variable. As such, with the gantry 3 being maintained stationary, the laser scanning unit 4 is associated with a heating field 5, i.e., the range reachable by the laser beam 7 emanating from the laser scanning unit 4. A scanning path for the laser beam 7 can be designed within the heating field 5 according to a sealing strip 6 of the glass frit on the glass package to be sealed. The laser beam 7 from the reflectors 40 for heating the glass frit is collimated to form a round light spot with a truncated-shaped energy distribution.

A quasi-synchronous sealing process can be performed in which, as shown in Figs. 1 and 2, a light spot is first formed on the glass frit 10 by alignment, and the laser scanning unit 4 then controls the direction of the laser beam 7 so that the light spot moves fast along the sealing strip 6 periodically, i.e., repeated scanning. As a result, the glass frit 10 is heated. Upon the temperature of the glass frit 10 exceeding its softening point, the heating is stopped. After that, during the cooling of the glass substrates 8, the soldering material, i.e., the glass frit powder 10, disposed between the glass substrates 8, firmly glues them to each other to form a hermetic seal. Fig. 3 shows the OLED chip 9 encapsulated within the so hermetically sealed package.

Preferably, the packaging system is a single-galvanometer laser scanning system, i.e., with one galvanometer laser scanning unit 4 on the gantry 3. Alternatively, the packaging system may also be a multi-galvanometer laser scanning

system i.e., with multiple galvanometer laser scanning units 4 on the gantry 3, which is capable of processing large-sized packages and thus has an expanded scope of application. The number of the galvanometer laser scanning units 4 can be selected depending on the size of the package, without any limitations.

It is noted that in the case of multiple galvanometer laser scanning units 4, the laser 1 may have only one laser beam unit which is coupled to the laser scanning units 4 via respective optical fibers 2. Alternatively, the laser 1 may have a plurality of laser beam units each coupled to corresponding one or more of the laser scanning units 4 via one or more optical fibers 2. Similarly, when multiple galvanometer laser scanning units 4 are used, the gantry 3 may have one arm on which all the laser scanning units 4 are mounted or multiple arms on each of which one or more of the laser scanning units 4 are fixed. When the gantry 3 moves, these arms move with it as a whole in synchronization.

In another aspect of this Embodiment, there is also proposed a method for laser sealing of the glass package, which uses the packaging system as defined above to heat the glass frit on the glass package to form a hermetic seal and includes the steps of:

S100: projecting, by the laser scanning unit 4, the laser beam 7 from the laser 1 onto the sealing strip 6 on the glass package;

S200: controlling the direction of the laser beam 7 by the laser scanning unit 4 and/or gantry 3 so that the laser beam 7 scans the sealing strip 6 periodically and thereby heats the glass frit powder 10 distributed along the sealing strip 6 until it is melted and glues the overlying and underlying glass substrates 8 together, forming a hermetic seal for the glass package.

In this Embodiment, the packaging system is a single-galvanometer laser scanning system suitable for use when the glass package has a relatively small size (i.e., the area surrounded by the sealing strip 6 of the glass frit is smaller than the

heating field 5 associated with the laser scanning unit 4). In the sealing process, the laser beam 7 emitted by the laser 1 is projected by the laser scanning unit 4 onto and heat the glass frit 10 along the sealing strip 6 without needing to move, optionally step-wise, the gantry 3. The laser scanning unit 4 rotates fast so that the laser beam 7 scans and heats the glass frit along the sealing strip 6 in a predetermined path at a high speed, thereby forming the seal for the glass package. As the scanning provided by the laser beam is performed at a very high speed, different portions of the glass frit are heated almost at the same time (or with a minor time difference). This enables quasi-synchronous sealing which can result in a more uniform temperature distribution and a higher yield.

EMBODIMENT 2

Referring to Figs. 5a to 5c, in this Embodiment, a packaging system that is a single-galvanometer laser scanning system is used to seal a glass package in a cell-wise manner. An according packaging method comprises the steps as detailed below.

The glass package is partitioned into multiple cells. In the embodiment shown in Figs. 5a to 5c, there are three cells, i.e., a cell A, a cell B and a cell C. Step-wise movement of the gantry 3 allows each of the cells A, B and C to be dynamically covered by the heating field 5 of the laser scanning unit 4.

During the sealing of each cell, the gantry 3 is kept stationary, with the laser scanning unit 4 being rotated to allow the laser beam 7 to periodically scan a corresponding section of the sealing strip within the cell along a predefined path at a predetermined speed. As shown in Fig. 5a, the gantry 3 is first held in the cell A, with the angles of pivot and swing frequencies of the reflectors 40 in the laser scanning unit 4 being so configured that the laser beam 7 emanating the laser scanning unit 4 periodically scans and hence heats a corresponding part of the glass frit 10 coated

along the sealing strip section 6A (corresponding to a first section of the sealing strip, as shown in Fig. 5a) within the heating field 5 at a predetermined speed, thereby enabling sealing of the corresponding cell.

After the processing of this cell has been completed, the gantry 3 is moved with the laser scanning unit 4 to the next cell, followed by periodic scanning of the sealing strip section in this cell. This is repeated until the whole sealing strip has been scanned and completing the sealing of the glass package. Specifically, as shown in Fig. 5b, after the cell A has been sealed, the gantry 3 is moved with the laser scanning unit 4 in the step-wise movement direction (as indicated by the arrow in the figure) into the cell B, where the angles of pivot and swing frequencies of the reflectors 40 in the laser scanning unit 4 are so configured that the laser beam 7 exiting from the laser scanning unit 4 periodically scans and hence heats a corresponding part of the glass frit 10 along the sealing strip section 6B (corresponding to a second section of the sealing strip, as shown in Fig. 5b) at a predetermined speed. Subsequently, as shown in Fig. 5c, the gantry 3 is further moved with the laser scanning unit 4 in the step-wise movement direction into the next cell C, where the angles of pivot and swing frequencies of the reflectors 40 in the laser scanning unit 4 are so configured that the laser beam 7 from the laser scanning unit 4 periodically scans and hence heats a corresponding part of the glass frit 10 along the sealing strip section 6C (corresponding to a third section of the sealing strip, as shown in Fig. 5c) at a predetermined speed. As such, the entire sealing strip (consisting of the first, second and third sections) on the glass package has been scanned, thus completing the sealing of the package.

Although the glass package has been described above and illustrated as being partitioned into three cells, the present invention is not limited to this regard, as the number of the cells may be determined according to the size of the package, in particular the area surrounded by the sealing strip, and the heating field 5 of the laser

scanning unit 4. In addition, it will be appreciated by those skilled in the art that adjacent sealing strip sections may either be strictly contiguous or having an overlap therebetween in order to ensure the whole sealing strip can be scanned. It will also be appreciated by those skilled in the art that, for each of the cells, the gantry 3 may not be necessarily held at its center. Instead, in order for the sealing strip to be scanned in a more efficient way, the positions of the gantry 3 in the cells may be properly determined according to the shapes of the respective sealing strip sections within the cells.

The packaging method disclosed in this Embodiment is suitable for use in scenarios where a single-galvanometer laser scanning system is used to seal a medium-sized glass package.

EMBODIMENT 3

In this Embodiment, a packaging system that is a single-galvanometer laser scanning system is used to seal a large-sized glass package in a manner in which the gantry is moved to drive the laser beam to accomplish the sealing. In an according packaging method, the gantry 3 is moved within a plane above the sealing strip 6, concurrently with the laser beam scanning the glass frit 10 on the sealing strip 6 along a predefined path at a predetermine speed until the glass package has been entirely sealed.

As shown in Figs. 6a and 6b, the galvanometer in the laser scanning unit is vibrated at a high frequency, causing the laser beam to rotate at a certain angle and speed to define a heating field 5. The gantry 3 is moved so that the heating field 5 sweeps across the sealing strip, concurrently with the laser beam repeatedly scanning the sealing strip section within the heating field 5 along a predefined path at a predetermined speed, until the glass package has been entirely sealed.

The packaging method disclosed in this Embodiment in which the gantry 3 is

moved so that the heating field 5 sweeps across the sealing strip is capable of rapid sealing of a large-sized glass package.

EMBODIMENT 4

Referring to Figs. 7 and 8, in this Embodiment, a packaging system that is a multi-galvanometer laser scanning system is used to seal a plurality of glass packages, and an according packaging method comprises the steps as detailed below.

The plurality of glass packages are arranged in a number of rows. In each row, the number of glass packages is equal to the number of the galvanometer scanning units, and the galvanometer scanning units are arranged at positions corresponding to those of the respective glass packages. As such, each glass package in each row can be handled by a corresponding one of the galvanometer scanning units.

During the sealing of each row of glass packages, the gantry 3 is maintained stationary, with each of the laser scanning units 4 rotating to allow its laser beam 7 to periodically scan the sealing strip on a corresponding glass package in the specific row along a predefined path at a predetermined speed so as to form a hermetic seal for the glass package.

Specifically, m laser scanning units 4 are arranged on the gantry 3 at a predetermined spacing that is arbitrarily adjustable and settable. The glass packages are arranged into n rows, and there are m glass packages in each row. During the sealing of each row of glass packages, the gantry 3 is not moved, and each of the laser scanning units 4 rotates rapidly so that each laser beam 7 scans and hence heats a sealing strip 6 along a predefined path at a predetermined speed for multiple times. The m laser scanning units 4 can simultaneously seal m glass packages in the same row. After that, the gantry 3 is moved with all the laser scanning units 4 to a position suitable for processing of the next row. This process is repeated until all the n rows have been processed.

The packaging method disclosed in this Embodiment can be used to seal glass packages in batches, effectively improving the packaging efficiency and significantly enhancing the packaging yield.

EMBODIMENT 5

Referring to Fig. 9, in this Embodiment, a packaging system that is a multi-galvanometer laser scanning system is used to seal a glass package in a stationary cell-wise manner, and an according packaging method comprises the steps as detailed below.

The glass package is partitioned into multiple cells (two are shown in Fig. 9 for the purpose of illustration). The same number of galvanometer scanning units as that of the cells are arranged on the gantry 3 and are configured in correspondence to the respective cells such that each cell can be handled by a corresponding one of the galvanometer scanning units.

During the sealing, the gantry 3 is held stationary, with each of the laser scanning units 4 rotating to allow its laser beam 7 to periodically scan a sealing strip section within the corresponding cell along a predefined path at a predetermined speed so as to form a hermetic seal for the glass package.

Thereafter, the gantry is moved together with the laser scanning units to a position suitable for processing of the next glass package, and the same process is then carried out.

When the packaging method disclosed in this Embodiment is used to seal a large-sized glass package, it should be ensured that a combination of the heating fields 5 associated with the laser scanning units 4 (i.e., galvanometer units, two are shown in Fig. 9 for the purpose of illustration) can encompass the entire glass package.

EMBODIMENT 6

Referring to Fig. 10, in this Embodiment, a packaging system that is a multi-galvanometer laser scanning system is used to seal a large-sized glass package in a dynamic cell-wise manner, and an according packaging method comprises the steps as detailed below.

The glass package is partitioned into multiple rows of cells, and a plurality of galvanometer scanning units are arranged on the gantry 3 in correspondence to the respective cells in one of the rows, such that each of the cells can be handled by a corresponding one of the galvanometer scanning units.

During the sealing of the cells in the row, the gantry is held stationary, with each of the laser scanning units 4 rotating to allow its laser beam to periodically scan a sealing strip section within the corresponding cell along a predefined path at a predetermined speed.

After that, the gantry is moved together with the laser scanning units to a position suitable for processing of the next row of cells, and the same process is then carried out. This process is repeated until the glass package is sealed.

Specifically, as shown in Fig. 10, the plurality of laser scanning units 4 (N are shown in Fig. 10 for the purpose of illustration) are arranged on the gantry 3 at a predetermined spacing that is arbitrarily adjustable and settable. During the sealing, the large-sized sealing strip 6 is partitioned into two or more sections in the X-direction, for example, also N sections. The gantry 3 is moved with the plurality of laser scanning unit 4 step-wise (or in a scanning manner in the step-wise movement direction, i.e., the Y-direction), with each of the laser scanning unit 4 rotating fast and taking the same actions as in Embodiment 4 or 5 until the glass package has been sealed.

The packaging method disclosed in this Embodiment can be used for the sealing of a large-sized glass package which is difficult to be achieved

conventionally.

It is apparent from the foregoing Embodiments that the packing methods according to the present invention offer the following advantages:

1. They are suitable for use in sealing of packages with various sizes and sealing strips in various shapes.

2. They address the low-yield and low-synchronization issues arising from the use of the conventional sequential scanning method.

3. Use of the galvanometer(s) capable of high-speed scanning allows them to have better performance in process window and yield compared to the conventional sequential scanning method.

4. They combine the flexibility and programmability of the sequential scanning method and the synchronous and uniform temperature rise properties of the synchronous sealing method.

5. The sealing process can be carried out under closed-loop temperature control enabled by synchronous temperature sampling and monitoring, which is conducive to process optimization and packaging quality improvement.

6. Programmable control over the output power of laser beam enables controllability of the heating and cooling processes while not compromising the yield.

7. Since the gantry is held stationary relative to the glass package with the galvanometer(s) being rotated, lower requirements for movement properties of the gantry are made possible.

8. Step-wise or scanning movement of multiple galvanometers together with the gantry allows the simultaneous sealing of a plurality of cells and the sealing of a large-size cell.

In summary, in the packaging systems and methods according to the embodiments of the present invention, the laser beam(s) is/are projected by the laser scanning unit(s) onto the glass package(s) and performs rapid, periodic scanning and

hence heating thereon. This quasi-synchronous sealing can achieve a more uniform temperature distribution and a higher yield for diverse patterns to be sealed. Moreover, one or more laser scanning units can be arranged on the gantry and move therewith in a step-wise manner. This enables the sealing of a large-sized glass package in a cell-wise packaging manner or simultaneous sealing of multiple glass packages, resulting in a significant improvement in yield.

The foregoing description presents merely preferred embodiment examples of the present invention and does not limit the scope of the invention in any sense. All equivalent substitutions or modifications made to the subject matter disclosed herein by those of ordinary skill in the art without departing from the scope of the present invention fall within the scope of the invention.

CLAIMS

1. A packaging system for laser sealing of a glass package, comprising a laser, a gantry and at least one laser scanning unit arranged on the gantry, each of the at least one laser scanning unit being able to project a laser beam produced by the laser onto the glass package to define an associated scanning field,

wherein the packaging system further comprises a controller configured to control at least one of a position, a movement path and an operating state of the scanning field of each laser scanning unit based on a number of the at least one laser scanning unit and an area of the glass package to be sealed.

2. The packaging system for laser sealing of a glass package of claim 1, wherein the glass package is provided with a glass frit sealing strip, and wherein the scanning field of each laser scanning unit covers at least one of a length, a width and a corner portion of the glass frit sealing strip.

3. The packaging system for laser sealing of a glass package of claim 2, wherein the controller is further configured to control the gantry to drive each laser scanning unit to move so that the scanning field of each laser scanning unit dynamically covers the glass frit sealing strip.

4. The packaging system for laser sealing of a glass package of claim 3, wherein the gantry moves in a stepping manner, and wherein subsequent to each stepping of the gantry, the controller adjusts at least one of the position, the movement path and the operating state of the scanning field of each laser scanning unit.

5. The packaging system for laser sealing of a glass package of claim 3, wherein the gantry moves in a scanning manner, and wherein the controller adjusts in real time at least one of the position, the movement path and the operating state of the scanning field of each laser scanning unit.

6. The packaging system for laser sealing of a glass package of claim 1, wherein the laser is a CO₂ laser.

7. The packaging system for laser sealing of a glass package of claim 6, wherein the laser beam produced by the laser has a wavelength ranging from 800 nm to 900 nm and an operating power in a range of from 100 W to 500 W.

8. The packaging system for laser sealing of a glass package of claim 6, wherein the laser is coupled to each laser scanning unit via an optical fiber.

9. The packaging system for laser sealing of a glass package of claim 1, wherein each laser scanning unit is a galvanometer scanning unit comprising one or more reflectors, a scanning motor and a servo drive unit, and wherein the servo drive unit is configured to generate and send to the scanning motor a signal indicative of an angle of pivot so that the scanning motor controls the one or more reflectors to pivot by the angle.

10. The packaging system for laser sealing of a glass package of claim 9, wherein the angle of pivot for the reflectors ranges from -20° to 20° .

11. A packaging method for laser sealing of a glass package by heating a glass frit on the glass package to form a hermetic seal, the packaging method comprising the steps of:

a) arranging at least one laser scanning unit on a gantry, wherein each laser scanning unit is able to project a laser beam produced by a laser onto a sealing strip on the glass package to define an associated scanning field;

b) controlling at least one of a position, a movement path and an operating state of the scanning field of each laser scanning unit based on a number of the at least one laser scanning unit and an area surrounded by the sealing strip so that the laser beam periodically scans and thus heats a powder of the glass frit that forms the sealing strip until the powder of the glass frit is melted.

12. The packaging method for laser sealing of a glass package of claim 11, wherein one laser scanning unit is arranged on the gantry and the area surrounded by the sealing strip is greater than the scanning field, and wherein step b) comprises:

b1) maintaining the gantry stationary and rotating the laser scanning unit so that the laser beam periodically scans a section of the sealing strip within the scanning field along a predefined path at a predetermined speed; and

b2) causing the gantry and hence the laser scanning unit to step forward a predetermined distance, and repeating step b1), until the sealing strip has been entirely heated.

13. The packaging method for laser sealing of a glass package of claim 11, wherein one laser scanning unit is arranged on the gantry, and the area surrounded by the sealing strip is greater than the scanning field, and wherein step b) comprises: the gantry moving together with the laser scanning unit along the sealing strip in a scanning manner, concurrently with the laser beam scanning the sealing strip along a predefined path at a predetermined speed until the sealing strip has been entirely heated.

14. The packaging method for laser sealing of a glass package of claim 11, wherein a plurality of laser scanning units are arranged on the gantry, each laser scanning unit corresponding to a glass package to be sealed, and wherein step b) comprises: maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans the sealing strip of a corresponding glass package along a predefined path at a predetermined speed.

15. The packaging method for laser sealing of a glass package of claim 11, wherein a plurality of laser scanning units are arranged on the gantry, and the scanning fields of the laser scanning units cover the sealing strip, and wherein step b) comprises: maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans a section of the sealing strip within the corresponding scanning field along a predefined path at a predetermined speed.

16. The packaging method for laser sealing of a glass package of claim 11, wherein a plurality of laser scanning units are arranged on the gantry, and the scanning fields of the laser scanning units cover a length of the sealing strip, and wherein step b) comprises:

b3) maintaining the gantry stationary and rotating each laser scanning unit so that a laser beam projected from each laser scanning unit periodically scans a section of the sealing strip within the corresponding scanning field along a predefined path at a predetermined speed; and

b4) causing the gantry and hence the plurality of laser scanning units to step forward a predetermined distance in a width-wise direction of the sealing strip, and repeating step b3), until the sealing strip has been entirely heated.