

SPECIFICATION

TITLE OF THE INVENTION

ROTARY UV CURING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to a method and apparatus for utilizing ultraviolet (UV) light to cure a disk-shaped product using UV-LED chips mounted in an array and providing for relative movement between the array and the disk-shaped product, thereby to cure a curable ink, coating or adhesive mounted in the disk-shaped product. The inks, coatings and adhesives have UV photo initiators which, when exposed to UV light, convert monomers in the inks, coatings and adhesives to linking polymers to solidify the curable material.

2. Description of the Related Art.

Heretofore, UV-LED arrays have been proposed for curing inks, coatings or adhesives.

The prior proposals teach one to stagger rows of UV-LED's in different arrays on a panel positioned closely adjacent a product to be cured, to move the product past the array, to move the array in a generally orbital path to uniformly apply UV light on the product and to inject an inert, heavier than air or lighter than air gas in the area between the panel and the product.

Also it has been learned that different wavelengths of UV light are better suited for different thicknesses of ink, coating or adhesive and/or for different components in the ink coating or adhesive.

For example, thick polymers require longer wavelengths for curing. Surface curing requires shorter wavelengths.

Further, a common use of UV curable adhesives and coatings is in the manufacture of compact disks, CD's.

It is, therefore, desirable to provide an improved UV method and apparatus for applying UV light at one or more wavelengths to a disk-shaped UV curable product to more effectively cure UV inks, coatings and adhesives in or on the product, by causing relative rotation between the UV light and the disk-shaped product.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, there is provided a method and apparatus for curing an UV curable product, article, ink coating or adhesive in or on a disk including the step of or mechanisms for causing relative rotational movement between an array of UV-LED chips mounted on a panel and a disk containing the UV curable product, article, ink coating or adhesive.

Also, according to the present invention there is provided at least one staggered array of UV LED assemblies on at least one panel with the UV LED assemblies being arranged in rows with each row being staggered from adjacent rows. A mechanism is provided for causing relative rotational movement between the panel and a disk-shaped product.

In one preferred embodiment, the disk-shaped product containing the UV curable product, article or other object to be cured is arranged to rotate. A gas having a molecular weight heavier than air or lighter than air can be injected into the area of rotation of the UV curable product, article or other object having a UV ink, coating, or adhesive thereon as it rotates past a panel of arrays of UV LED assemblies.

In another preferred embodiment, the panel or a + shaped (cross-shaped) structure comprising four panels is caused to rotate relative to the disk-shaped product.

Advantageously, the method and apparatus of the present invention provide better uniformity of light application from a flat panel having an array of UV-LED's. This result can be obtained when the product and/or the light fixture is rotated relative to and across the UV light beams from the UV-LED assemblies. The rotational movement has the ability to provide enhanced uniformity. Desirably, the rotation of the UV curable product or the rotation of the light array provides outstanding uniformity of UV light and UV curing of the product.

A more detailed explanation of the invention is provided in the following detailed description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a panel or substrate mounting an array of UV-LED chips positioned above a disk-shaped product, which is caused to rotate underneath the array;

FIG. 2 is a vertical sectional view through the disk and panel or substrate shown in FIG. 1 and also shows a dispensing apparatus for dispensing liquid having a UV photo initiator therein onto the disk-shaped product as it rotates under the dispensing apparatus;

FIG. 3 is a top plan view of a + shaped (cross-shaped) arrangement of four panels each having an array of UV-LED chips mounted thereon for rotation above a disk; and

FIG. 4 is a vertical, partially sectional view of the cross-shaped panel assembly shown in FIG. 3 and shows a glass or plastic shield between the UV-LED chips in the four arrays and the disk therebeneath and also shows an auxiliary array of UV-LED chips on the side of the disk and a glass or plastic protecting shield between the auxiliary array and the side of the disk.

DETAILED DESCRIPTION OF THE INVENTION

A detailed description of the preferred embodiments and best modes for practicing the invention are described herein.

Referring now to FIG. 1, there is illustrated therein a generally rectangular-shaped, horizontal, substantially planar or flat, fixed panel 10 mounting an array 12 of staggered, offset UV-LED chips 14. It will be understood that the array 12 shown on the upper side of the panel 10 is for the convenience of showing the array 12 and that actually, the array 12 of UV-LED chips 14 are mounted on the underside of the panel 10. The array 12 of UV-LED chips 14 is better shown in FIG. 2. The panel 10 can be supported by an upright vertically disposed support structure in the form of a cantilevered base 15 (FIG. 2), so that the panel 10 can be positioned over a generally disk-shaped product 16, or, simply a disk 16. The arrow 18 in FIG. 1

indicates the direction of rotation of the disk 16 in a UV-LED chip apparatus 20 including the panel 10 for curing UV photo initiators on or in the disk 16.

As shown in FIG. 2, the apparatus 20 can include a support pad 22 for supporting the disk 16. The support pad 22 can be fixed to an output shaft 24 at one end of a motor 26. The motor 26 can be energized periodically to rotate a disk 16 placed on the support pad 22 to enable UV light from the UV-LED chip array 12 to cure an UV curable product, article, ink coating or adhesive in or on the disk 16. Between the array 12 of UV-LED chips 14 and the disk 16 there can be positioned a glass or plastic sheet or plate 28 for protecting the UV-LED chips in the array 12 from splatter.

The UV-LED chips 14 are preferably arranged in an offset staggered array 12 on at least one panel 10. If desired, at least one row of UV LED chips 14 can emit light in the visible light spectrum whereby a user can visually determine that power is being supplied to the array 12 of UV LED chips 14.

Further, a heavier than air or lighter than air, non-oxygen, non-combustion-supporting gas can be provided in the area between the panel and the product to enhance UV curing. Also, the gas can be circulated by a fan to enhance cooling of the UV-LED chips 14 and heat dissipating fins can be mounted on the top side of panel 10 to further enhance cooling of the UV-LED chips 14.

Also shown in FIG. 2, is a dispenser 30 for dispensing a liquid 32 having one or more UV photo initiators therein onto the upper surface of the rotating disk 16. The dispenser 30 is preferably positioned above the disk 16 and can have a dispensing point 34 near the center of the disk 16 so that that liquid 32 dispensed can flow by centrifugal force radially outwardly to a periphery of the disk 16 as the disk 16 rotates. At the same time, the UV curable liquid coated portion of the disk 16 passing beneath the array 12 of UV-LED chips can be cured, polymerized and solidified, by the UV light emitted from the UV-LED chips 14.

In FIG. 3, there is illustrated another UV-LED chip apparatus 40 for curing UV photo initiators in or on a stationary or fixed disk 16. As shown, the apparatus 40 includes a cross-shaped or + shaped structure 42 including four rotatable, generally horizontal, substantially flat or planar portions or panels 44, 46, 48 and 50, each mounting an array 52 of UV-LED chips 54. In it's simplest form, the structure 40 can include at least one elongated panel 44, 46, 48 or 50. The UV LED chips 54 are preferably arranged in an offset staggered array on at least one panel 44, 46, 48 or

50. Also, while the arrays 52 are shown in FIG. 3 on the upper side of each panel portion 44-50, it will be understood that this is only for the convenience of showing the arrays 52 and that actually, the arrays 52 are mounted on the underside of each panel portion 44-50, as better shown in FIG. 4.

In the apparatus 40 of FIG. 4, a center panel portion 56 that is integral or connected to the panel portions 44-50 having the four arrays 52 of UV-LED chips, is mounted to a shaft 58 at one end of a motor 60, so that the panel portions 44-50 and the arrays 52 can be rotated relative to the disk 16. It will be understood that a suitable support can be provided for the disk 16, such as a pedestal (not shown).

If desired at least one row of UV LED chips 54 can emit light in the visible light spectrum whereby a user can visually determine that power is being supplied to the array (s) 52 of UV LED chips 54.

Further, a heavier than air or lighter than air, non-oxygen, non-combustion-supporting gas can be provided in the area between the panel portions 44, 46, 48 and 50 and the product to enhance curing. Also, the gas can be circulated by a fan to enhance cooling of the UV-LED chips 54 and heat dissipating fins can be mounted on the top side of the panels 44-50 to further enhance cooling of the UV-LED chips 54.

Advantageously, in the apparatus 40 of FIG. 4, a glass or plastic plate 62 is positioned between the UV-LED arrays 52 mounted on the undersides of the four panel portions 44-50 and the top of the disk 16. The disk 16 can have one or more UV curable photo initiators in or on the upper surface of the disk 16.

In the apparatus 40 of FIG. 4, there is provided at least one, generally vertically arranged, auxiliary array 64 of UV-LED chips 66 that can be mounted on a generally upright vertical panel 68 positioned adjacent the periphery of the disk 16 to provide curing light at the side or periphery of the disk 16. Also, a plastic or glass sheet or plate 70 can be positioned between the auxiliary array 64 and the disk 16 to shield the UV-LED chips 66 from splatter.

If desired, the upright panel 68 (FIG. 4) can be attached to and/or depend from one of the horizontal panel portions 44-50. Alternatively, each of the horizontal panel portions 44-50 can have an upright panel 68 attached thereto and/or depending therefrom, with the shielding sheet or plate 70 attached to the upright panel(s) 68 in front of the array 64.

The glass or plastic sheets described above for the apparatus of FIGS. 2 and 4 are preferably transparent or translucent, as well as rigid or semi-rigid, to provide impact-resistant light transmissive barriers to protect and shield the UV LED chips from splatter, dust, particularly, liquid containing UV photo initiators and other liquids.

The disk-shaped product or the at least one elongate panel can be rotated a predetermined number of times between two and twenty (20) to enhance polymerization and curing of the UV curable photo-initiators. Insertion and ejection mechanisms can be provided for sequentially moving a disk-shaped product onto and off of the stationary or rotatable support pad or pedestal in a mass production operation of the apparatus of the present invention.

The method and apparatus of the present invention provide techniques and structures for applying UV light emitted from UV-LED's more uniformly so that such light is more effective in curing inks, coatings and adhesives and, by applying the UV light more evenly, reducing, if not all together eliminating, "hot spots".

One of the techniques is to provide staggered arrays of UV LED assemblies on a panel with the UV LED assemblies being arranged in rows with each row being staggered from adjacent rows.

Basically a spacing offset between adjacent rows of $1/x$ can be provided in an array of UV-LED chips, where x equals the number of rows.

In addition to the staggering of the UV LED assemblies in adjacent rows, relative movement is provided between a UV curable product, article or other object having a UV ink, coating or adhesive to be cured and the arrays of UV-LED assemblies.

Further, the panel is moved or rotated, thereby to cause a sweeping of the light from each UV LED assembly over a circular area, thereby minimizing the creation of "hot spots" and to uniformly apply UV light to the product, article or other object having the UV ink, coating or adhesive.

The method and apparatus of the present invention provide uniformity of light application from a flat panel having an array of UV-LED's. This result is obtained when the product and/or the light fixture is moved relative to and across, i.e., rotated, relative to the UV light beams from the UV-LED assemblies in the light fixture and/or product. This movement in of itself has the ability to offer one element of uniformity. That is, the movement of the product or the movement of the light array addresses

the problem of providing uniformity in the direction of the product flow or of the lamp movement.

In an X-Y arrangement, the "X Axis" uniformity is addressed by the movement of the product or of the LED array.

The "Y Axis" uniformity is addressed by how the LED chips are arranged. To achieve the cure rates that are associated with typical UV curing applications, a very large number of UV-LED chips are arranged to deliver, the amount of UV energy necessary to cure the polymers.

The first step in building these arrays is to create either a series or parallel electrical circuit either in series or in which the LED chips are placed in a linear fashion of equal distance from each other. (Lets say a distance of X). The second row would start its row at a distance $\frac{1}{2} X$ and each LED chip would then be spaced from adjacent LED chips in the row by the distance X.

The third row would start at a distance $\frac{1}{2} X$ in from the start of the second row. This offset would continue for each row of LED chips in the array. Two things happen when this is done. First the light uniformity is increased because of the alternating position of the UV-LED chips. This creates an overlap of light emissions. Then, having each row begin half the distance of the row it precedes will create a stair case effect. This will allow uniformity in the Y Axis as the array grows in size.

There is another way to position the LED chips, and achieve the same uniformity. This would be to use 3 rows to achieve the uniformity. That is, to have the LED chips arranged at a distance of X, and to have the next row (row 2) start at a distance $\frac{1}{3}$ in from the start of the first row and the next row (row 3) start at a distance $\frac{2}{3}$ in from the start of the first row or at a distance $\frac{1}{3}$ in from the start of the second row.

Still another way is to provide 4 rows to create the uniformity, with the LED chips in the first row being spaced at a distance of X from each other. The second row starts its first LED chip at a distance $\frac{1}{4} X$ in from the first LED chip in the first row. The third row starts its row at a distance $\frac{1}{2} X$ in from the first LED chip in the first row or at a distance $\frac{1}{4} X$ in from the start of the previous row.

Additionally, in situations where UV curable ink or adhesive may splatter onto the array of LED's, a thin transparent plastic sheet or layer is positioned over the array to protect the array, and the sheet or layer is periodically cleaned or replaced.

If desired, a row of UV-LED chips that radiate light in the visible spectrum is added to provide a means for quickly and visually checking to see if the apparatus or device is turned on and working, even if the ink, coating or adhesive does not contain photo initiators that are activated by the light having a wavelength in the visible spectrum.

UV light at two or more different wavelengths also can be employed to better cure the ink coating or adhesive in the product. Further, the ink, coating or adhesive can contain photo initiators that are activated by light at more than one wavelength, such as for example photo initiators which are activated by light that is peak at approximately 365 nm and by light that is peak at approximately 385 nm.

Since the intensity of light emitted by UV-LED chips is affected or attenuated, by an increase in the temperature of the UV-LED chips, one embodiment of the present invention contemplates the provision of a cooling system including heat radiating fins on a substrate mounting the chips and the blowing of cooling air past the fins to keep the temperature of the UV-LED chips within a predetermined range.

Also, the temperature of the substrate or the intensity of the light emitted can be monitored and used to control current or voltage to a fan blowing cooling air on the substrate thereby to increase cooling of the substrate to maintain a constant temperature of the substrate thereby to maintain generally constant light intensity as heating of the chips tends to cause light intensity to diminish.

Further, "forward voltage matching techniques", V_F , are employed, (selection of chips) to provide strings or rows of LED chips wherein the current drawn by the chips only varies between about 5% and about 10%, thereby to minimize "current hogging".

The distance between the light source and the product being irradiated with light affects the intensity of the light. However, if the product is too close to the UV-LED arrays, there will not be a uniform radiance pattern. Accordingly the preferred distance between the UV-LED chip arrays is a distance which will provide a uniform pattern of light from the light diverging from the UV-LED chips and at 50% of the power output from the UV-LED chip. This distance is defined as the Viewing Cone Angle of $2\theta_{1/2}$.

As other UV wavelength emitting diodes become available, a wide range of UV light can be employed in curing apparatus and devices.

Further, to achieve a greater variation of wavelengths, UV-LED chip arrays can be placed next to other sources of light, such as a fluorescent lamp whose phosphors are chosen to augment the increase of light wavelengths. For example, OSRAM SYLVANIA, INC. of Danvers MA offers a type 2011C fluorescent lamp that emits 51nm, a type 2052 that emits 371 nm, a type 2092 that emit 433 nm, and a type 2162 that emits 420nm.

It is also contemplated that large junction UV-LED chips (over 400 microns on a side) can be employed since they emit UV light at higher light density.

Among the many advantages of the rotary UV curing method and apparatus of the invention are:

1. The disk-shaped product or at least one panel having an array of offset staggered UV-LED chips thereon can be rotated.
2. A transparent or translucent glass or plastic shield can be provided for maintaining the UV-LED chips free from debris.
3. A non-oxygen gas can be provided for enhancing curing and can be circulated to enhance cooling of the UV-LED chips.
4. Outstanding curing.
5. Excellent results.
6. Greater product output.
7. Super quality.
8. Fewer defective products.
9. User friendly.
10. Economical.
11. Efficient.
12. Effective.

From the foregoing description, it will be apparent that the method and apparatus of the present invention have a number of advantages, some of which have been described above and others of which are inherent in the invention and examples.

Although embodiments of the invention have been shown and described, it will be understood that various modifications and substitutions, as well as rearrangements of components, parts, equipment, apparatus, process (method) steps, and uses thereof, can be made by those skilled in the art without departing

from the teachings of the invention. Accordingly, the scope of the invention is only to be limited as necessitated by the accompanying claims.

CLAIMS

What is claimed is:

1. A method for curing an UV curable product, article, ink coating or adhesive in or on a disk, characterized in that the method comprises: causing relative rotational movement between an array of UV-LED chips mounted on a panel and a disk containing the UV curable product, article, ink coating or adhesive.
2. The method of claim 1, characterized in that:
 - the disk is rotated relative to a substantially fixed panel mounting an array of UV-LED chips; and/or
 - a panel mounting the array of UV-LED chips is rotated relative to the disk having the UV curable product, article, ink coating or adhesive therein or thereon; and/or
 - UV-LED chips are arranged in an offset staggered array on at least one panel; and/or
 - a glass or plastic sheet or plate is positioned between the array of UV-LED chips and the disk to help protect the UV-LED chips from splatter of liquid containing UV photo initiators; and/or
 - an auxiliary array of UV-LED chips is positioned at the periphery of the disk for emitting UV light at the disk from a side of the disk; and/or
 - a glass or plastic sheet or plate is positioned between the array of UV-LED chips and the disk to help protect the UV-LED chips from splatter of liquid containing UV photo initiators.
3. A UV-curing apparatus for applying UV light to UV photo initiators in an UV curable product, article, ink coating or adhesive in or on a disk-shaped product for use with the method of any of the preceding claims, characterized in that the UV-curing apparatus comprises:
 - at least one elongated panel mounting an array of UV-LED chips; and
 - a motor operatively associated with the panel for causing relative rotation between the panel and the disk-shaped product to be cured.

4. The UV-curing apparatus of claim 3, characterized in that the UV-curing apparatus comprises:

four elongated panels each containing an array of UV-LED chips, and the panels are arranged in a generally cross-shaped pattern relative to the disk-shaped product to be cured; and/or

at least one generally horizontal panel positioned adjacent the disk-shaped product, and the horizontal panel is operatively connected to and rotated by the motor; and/or

a generally cylindrical pad for supporting the disk-shaped product, and the cylindrical pad is operatively connected to and rotated by the motor; and/or

UV-LED chips are arranged in an offset staggered array on at least one panel; and/or

an auxiliary array of UV-LED chips arranged at the periphery of the disk-shaped product for emitting UV light at the disk-shaped product from a side of the disk-shaped product; and/or

a glass or plastic sheet or plate positioned between the array of UV-LED chips and the disk-shaped product to help protect the UV-LED chips from splatter of liquid containing UV photo initiators; and/or

a shield positioned between the array of UV-LED chips and the disk-shaped product to help protect the UV-LED chips from splatter of liquid containing UV photo initiators; and the shield comprises a glass sheet, plastic sheet, or a plate; and/or

a liquid dispensing device for dispensing a liquid having a photo initiator therein onto the surface of a rotating disk-shaped product at a point near the center of the disk so that centrifugal force causes the liquid to move radially, outwardly from the point of dispensing to an outer periphery of the disk-shaped product.

5. The UV-curing apparatus of claim 3 or 4, characterized in that the motor comprises a shaft operatively connected to at least one panel containing the array of UV-LED chips adjacent a disk-shaped product.