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(71) Applicant (for all designated States except US): **MOLD-MAN SYSTEMS LLC** [US/US]; 4649 Aircenter Cir., Reno, Nevada 89502 (US).

(72) Inventors; and

(71) Applicants (for US only): **HOPKINS, Ryan R.** [US/US]; 1095 South University Park Lp, Reno, Nevada 89512

(US). **TAMS, Frederic Randall** [US/US]; 9579 Mammoth Drive, Reno, Nevada 89521 (US).

(74) Agent: **BRIDGE, Jeremy R.**; Reinhart Boerner Van Deuren, 2215 Perrygreen Way, Rockford, Illinois 61108 (US).

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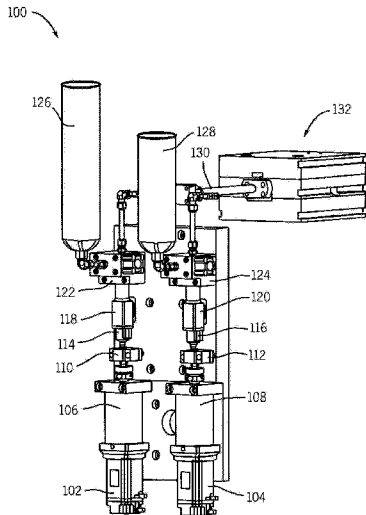


FIG. 1

(57) Abstract: A molding system is provided. The molding system includes a resin source and a mold set. The mold set defines a cavity and includes an LED and a covering portion configured to separate the LED from the contents of the cavity. A light pipe portion is configured to deliver light from the LED to a portion of the cavity away from the LED. The mold set defines a resin input port through which the cavity is configured to receive resin from the resin source. The mold set includes a valve configured to prevent resin flow into the cavity in a closed configuration and to prevent light from the LED in the cavity from exiting the cavity through the input port when the valve is in a closed configuration. The molding system includes a controller configured to cause the LED to illuminate when the valve is in a closed configuration and to cause the LED not to illuminate when the valve is in an open configuration.

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## LIGHT CURE MOLDING SYSTEM AND METHOD

### FIELD OF THE INVENTION

**[0001]** The present invention relates generally to the field of molding and more particularly to overmolding materials over substrates using materials that react to and initiate curing of the material when exposed to particular frequencies of light.

### BACKGROUND OF THE INVENTION

**[0002]** Various components, e.g., electronic components, may be encapsulated using, e.g., potting processes, conformal spraying or dipping, etc., for example, to provide different textures, various additional components, etc. An earbud, for example, may include electronics, such as a speaker. Material such as resin may be over molded over the speaker to create a portion of the earbud to hold the speaker in a user's ear. Different resins are activated, e.g., begin curing, based on different factors. For example, some resins begin curing when the resin is subjected to a predetermined amount of heat or reaches a predetermined temperature. Other resins begin curing when the resin is subjected to predetermined amount of pressure. Light curing resins involve a photopolymerization process which fuses resin molecules together to form molecular chains when exposed to light.

### SUMMARY OF THE INVENTION

**[0003]** New and improved systems and methods for molding are provided. More particularly, new and improved systems and methods of molding and using light cure materials are provided.

**[0004]** In one embodiment, a molding system including a first material source, a mold set and a controller is provided. The first material source supplies a light cure material. The mold set defines a cavity. The mold set includes a light source and a covering portion configured to separate the light source from the contents of the cavity. The covering portion is configured to pass light from the light source therethrough into the cavity. A light redirecting arrangement is positioned between the light source and the cavity. The light redirecting arrangement delivers

light from the light source to a portion of the cavity away from the light source. The mold set defines an input port through which the cavity receives the material from the first material source. A valve prevents material flow into the cavity in a closed configuration and allows material flow into the cavity in an open configuration. Light from the light source in the cavity is prevented from exiting the cavity through the input port when the valve is in a closed configuration. The controller controls the light source to illuminate when the valve is in a closed configuration and controls the light source not to illuminate when the valve is in an open configuration.

**[0005]** In one embodiment, the cavity holds a substrate therein to be overmolded with the material. The substrate is located between the light source and a shadow portion of the cavity. The light redirecting arrangement redirects light from the light source to the shadow portion of the cavity.

**[0006]** In one embodiment, the material is a multi-cure material to be cured by exposure to light as well as a second cure mechanism.

**[0007]** In one embodiment, the second cure mechanism is at least one of moisture, condensation, Michael addition, thermal, or pressure.

**[0008]** In one embodiment, a second material source, a motor, and a static mixer are provided. The first and second material sources each being configured to deliver material to the static mixer which forms the light cure material.

**[0009]** In one embodiment, the controller independently controls the amount of material delivered from the first material source to the static mixer and from the second material source to the static mixer.

**[0010]** In one embodiment, the valve includes a pin configured to close the input port.

**[0011]** In one embodiment, the mold set includes a mold housing defining an internal cavity and plurality of internal mold components. The internal mold components are located within the internal cavity of the mold housing. The internal mold components define the cavity. At least one of the internal mold components is interposed between the light source and the cavity.

**[0012]** In one embodiment, the at least one internal mold component is interposed between the light source and the cavity and is formed, at least in part, from an optically clear material to permit light to pass therethrough.

**[0013]** In one embodiment, the optically clear material is silicone.

**[0014]** In one embodiment, the light redirecting arrangement is embedded into the optically clear material.

**[0015]** In one embodiment, the light redirecting arrangement is provided by light redirecting beads embedded within the optically clear material such that the optically clear material acts as a substrate. In a more particular embodiment, the light redirecting beads have a different refractive index from the optically clear material that forms the substrate.

**[0016]** In one embodiment, the light redirecting arrangement is in the form of a light pipe.

**[0017]** In one embodiment, the internal mold components are molded components. By being molded components, if the internal mold components get damages or undesirably stuck together they can be easily and cheaply be remanufactured by molding. The cost of forming mold blanks is thus used to form the internal mold components rather than the end molds that will do the molding which are subject to higher risk of damage.

**[0018]** In one embodiment, a method of overmolding a light cure material over a substrate is provided. The method includes locating a substrate in a cavity of a mold. The mold has a light source. The light source is configured to project light into the cavity. The method includes introducing the light cure material into the cavity through a port. The light cure material is curable upon illumination by the light of the light source. The method includes closing the port with a valve that prevents light from exiting the mold through the port. The method includes illuminating the light source, after closing the port to begin curing the light cure material within the cavity of the mold.

**[0019]** In one method, the method further includes redirecting a portion of the light from the light source to a portion of the cavity away from the light source that is shadowed by a portion of the substrate.

**[0020]** In one method, the light cure material is also curable by a second curing mechanism and the method includes using a second curing mechanism to further cure the light cure material.

**[0021]** In one method, using the second curing mechanism occurs after the light source has been illuminated such that the light cure material has been partially cured by the light and using the second curing mechanism occurs after the partially cured material has been removed from the cavity of the mold.

**[0022]** In one method, a portion of the substrate is located between the light source and a shadow portion of the cavity.

[0023] In one method, the method includes delivering light from the light source to the shadow portion of the cavity with a light redirecting arrangement.

[0024] In one method, the light redirecting arrangement is in the form of an internal mold component located between the light source and the cavity. The internal mold component has an optically clear substrate and a plurality of light redirecting beads embedded therein which cause the light of the light source to scatter and be redirected.

[0025] In one method, the material is forced into the cavity at a pressure of less than between 0.1 psi to 1000 psi.

[0026] In one method, the mold includes a mold housing defining an internal cavity and the mold includes at least one internal mold component located within the internal cavity. The at least one internal mold component defines at least part of the cavity.

[0027] In one method, the method further includes the step of molding the at least one internal mold component.

[0028] In one method, the method includes replacing the at least one internal mold component with a replacement internal mold component formed by molding.

[0029] Alternative exemplary embodiments relate to other features and combinations of features as may be generally recited in the claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0030] This application will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements in which:

[0031] FIG. 1 is a perspective view of a light molding machine according to an exemplary embodiment;

[0032] FIG. 2 is a perspective view of the light molding machine of FIG. 1 according to an exemplary embodiment;

[0033] FIG. 3 is a side view of the light molding machine of FIGS. 1 and 2 according to an exemplary embodiment;

[0034] FIG. 4 is a cross-sectional view of a light mold set of the light molding machine of FIGS. 1-3 according to an exemplary embodiment;

- [0035] FIG. 5 is a cross-sectional view of a light mold set according to an exemplary embodiment;
- [0036] FIG. 6 is a cross-sectional view the light mold set of FIG. 5 illustrating an injection point according to an exemplary embodiment;
- [0037] FIG. 7 is a cross-sectional view of a substrate including a component shown schematically according to an exemplary embodiment;
- [0038] FIG. 8 is a cross-sectional view of a substrate including a component shown schematically according to an exemplary embodiment;
- [0039] FIG. 9 is a cross-sectional view of a substrate including a component shown schematically according to an exemplary embodiment;
- [0040] FIG. 10 is an exploded illustration of a simplified embodiment of a mold set for use in systems according to the invention;
- [0041] FIG. 11 is a simplified cross-sectional illustration of the mold set of FIG. 10 with the mold cavity empty;
- [0042] FIG. 12 is a simplified cross-sectional illustration of the mold set of FIG. 11 with a substrate in the mold cavity and an initial injection of material injected into the mold cavity;
- [0043] FIG. 13 is a simplified cross-sectional illustration of the mold set of FIG. 12 with the retractable pins supporting the substrate retracted and voids thereof filled in with material; and
- [0044] FIG. 14 is a simplified cross-sectional illustration of a mold set that utilizes light diffusion beads to help distribute light throughout the mold cavity.

#### DETAILED DESCRIPTION

[0045] Referring generally to the figures, an embodiment of a light molding machine 100 is described. Light cure materials such as light cure resins undergo photochemical reactions when exposed to particular wavelengths of light, e.g., UV, etc., to produce energy needed to initiate curing of the material. The light molding machine 100 provides a direct material feed system incorporated within the mold and a light source incorporated within the mold, which may provide for low material waste and efficient light transfer throughout the mold cavity. The light molding machine 100 is configured to accept multiple different molds for molding multiple different parts, including for overmolding over various different parts and particularly for over molding of electronic components.

**[0046]** A delivery system of the light molding machine 100 allows for low injection pressures (pressures can range from 0.5 psi to 1000 psi) for resin encapsulation of delicate parts to be overmolded, such as for example electronic components such as printed circuit boards. However, the concepts of the system could be incorporated into systems that produce significantly higher pressures such as for example 2500 psi or greater.

**[0047]** With reference to FIGS. 1-3, in one embodiment, the light molding machine 100 includes a pair of motors, shown as servo motors 102 and 104. Coupled to each of the motors 102 and 104 is a gearbox 106 and 108. The machine 100 also includes a pair of ball screw supports 110 and 112, a pair of ball screws 114 and 116, and a pair of piston plungers 118 and 120 located between the gear boxes 106 and 108 and a pair of plunger and valve housings 122 and 124. The machine 100 also includes a pair of material reservoirs 126 and 128 each holding a material to be mixed to form light cure resin for molding. The servo motors 102 and 104, the gearboxes 106 and 108, the ball screw supports 110 and 122 and ball screws 114 and 116, the piston plungers 118 and 120 and the plunger and valve housings 122 and 124 are configured to move material from the reservoirs 126 and 128 into a static mixer 130 where the materials are mixed to form a light cure resin which is moved from the mixer 130 into a mold set 132. A controller is configured to control the relative amounts of material that are moved from each reservoir 126 and 128 into the mixer 130 based on a variety of different factors, e.g., type of material being created, etc.

**[0048]** With reference to FIG. 4, in one embodiment, the mold set 132 includes various components including a mold base 134 and an upper mold portion 136. The mold base 134 and the upper mold portion 136 define a mold cavity 138 therebetween. Located in the mold cavity 138 is a substrate 140 to be encapsulated, e.g., partially encapsulated, in other embodiments fully encapsulated, etc., by the light cure resin.

**[0049]** With further reference to FIG. 4, in one embodiment, embedded in the mold base 134 and facing and configured to direct light into the cavity 138 are a pair of light sources shown as LEDs 142 and 144. Molded over the LEDs 142 and 144 is a covering portion 145 that protects the LEDs 142 and 144 from the resin injected into the cavity 138 but that allows transmission of the frequency of light emitted by the LEDs 142 and 144 therethrough such that the light emitted can enter the cavity 138.

**[0050]** In one embodiment, extending from the covering portion 145 is or forms part of a light redirecting arrangement in the form of a light pipe portion 146. The light pipe portion 146 is positioned between the light sources 142, 144 and the cavity 138. The light pipe portion 146 extends from the LEDs 142 and 144 around the cavity 138, e.g., to various different locations within the cavity 138. In various embodiments, light pipe portions may be formed in various different shapes to deliver light to various different portions of the cavity, for example, based on the shape of the substrate. The light pipe portion 146 is configured to deliver light from the LEDs 142 and 144 to other portions of the cavity 138 away from the LEDs 142 and 144.

**[0051]** For example, in some embodiments, based on the shape of the substrate 140 to be overmolded with resin, the substrate 140 would cast a shadow over portions of resin in the cavity 138 if only light directly from the LEDs 142 and 144 were present, causing portions of resin in the shadow not to receive light and therefore not to cure. The light pipe portion 146 is shaped to deliver light to portions of the cavity 138 containing resin that would otherwise be in the shadow of the substrate 140 to cause the resin in those portions to cure. The light pipe portion 146 may have a different shape based on the shape of the substrate 140, e.g., light may be delivered to different portions of the cavity 138 with different light pipe configurations based on the shape of the substrate 140 to be over molded.

**[0052]** In order for the light to effectively cure the material, multiple light sources can be used and incorporate into the tool design. Further, each of the multiple light sources could provide a different wavelength of light. Additionally, implementing the light sources directly inside the mold within a short proximity of the actual part reduces losses and in efficiency by decreasing the distance the light needs to travel.

**[0053]** In one embodiment, the covering portion 145 and the light pipe portion 146 are formed from acrylic. In another embodiment, the covering portion 145 and the light pipe portion 146 is formed from polymethylpentene, commercially available from Mitsui Chemicals America, Inc., sold under the tradename TPX®. In other embodiment, other suitable materials may be used.

**[0054]** In some embodiments, the entire cavity 138 of the mold set 132 used to mold the parts can be made out of optically clear materials including optically clear materials that exhibit non-stick properties. For instance, optically clear silicones can be used to form and define the entire cavity 138. Unfortunately, many materials that have optical clarity have characteristics

that result in multiple resins forming bonds to the material used for the cavity, and mold releases would be required for these applications. In these situations, silicon sprays can be used.

However, cavities made out of optical grade silicones do not require the use of mold releases.

**[0055]** Further, in some embodiments, the portions of the mold set 132 that define the cavity 138 in which the resin will be molded and through which the light travels can be formed by molding the portions out of optically clear materials and preferably optically clear grade silicones. By molding these components, if the components become damaged or glued together due to the particular resin being molded, the components can be easily and cost-effectively replaced. These components that define the mold cavity can be housed in light impermeable materials such as metal to prevent premature light penetration and curing of the light cure resin.

**[0056]** In one embodiment, the covering portion 145 and the light pipe portion 146 are made by injection molding. In another embodiment, the covering portion 145 and the light pipe portion 146 are made by 3D printing. In other embodiments, other suitable forming methods may be used.

**[0057]** With further reference to FIG. 4, in one embodiment, the mold set 132 defines an input port 148 and a valve shown as a pin valve 150. Resin is pumped from the static mixer 130 (see FIG. 3) through the input port 148 and into the cavity 138 when the valve 150 is in an open configuration. The valve 150 is closed by a controller when an appropriate amount of resin has been metered into the cavity 138. The valve 150 is configured such that it prevents light from the LEDs 142 and 144 in the cavity 138 from exiting the cavity 138 through the input port 148 when the valve 150 is in a closed configuration (as shown in FIG. 4), which prevents light from reaching and initiating curing of resin in conduits leading to the input port 148. When the valve 150 is in the closed configuration, the controller causes the LEDs 142 and 144 to illuminate. The light causes resin in the cavity 138, which comes into contact with the light, to cure, thereby overmolding the resin over the substrate 140.

**[0058]** With reference to FIGS. 5 and 6, another embodiment of a mold set 232 is illustrated. The mold set 232 has various similarities to the mold set 132 but is configured to overmold resin over a substrate with a different shape than the substrate 140. The mold set 232 includes a mold base 234 and an upper mold portion 236. The mold base 234 and upper mold portion 236 define a mold cavity 238 therebetween. The upper wall 239 defining the mold cavity 238 is transparent to light from the light source shown as UV LED 242. Located in the cavity 238 is a substrate

240 to which resin will be overmolded. In the illustrated embodiment, the substrate 240 is annular. The mold set 232 includes an input port 248 through which resin may be metered into the cavity 238 and a valve (not shown in FIGS. 5 and 6) to control the flow of resin in to the cavity 238 and to prevent light from exiting the cavity 238 through the input port 248. With resin in the cavity 238 and the valve in a closed configuration, a controller causes the UV LED 242 to illuminate. Light from the UV LED 242 travels through the transparent upper wall 239 into the cavity 238 and causes the resin in the cavity 238 overmolding the resin onto the substrate 240.

**[0059]** In the embodiments described above, the location of the LEDs 142 and 144 and the UV LED 242 in close proximity to the resin and with only a small amount of material through which to pass to reach the resin allows for LEDs 142 and 144 and UV LED 242 to be used, the cross section thickness of the material required to be cured will be linked to the power required for the LED's to cure within the desired time. For example a part with 15 grams of material with a 2 mm cross sectional thickness could be cured in 5 seconds using a single 90 W LED. Curing times associated with the materials, and required LED power supplies should be sized based on the geometry of the part being molded, and the time associated with the curing of the material. Longer curing times are associated with thicker cross sections, lengthening the distance of the light source from the part being cured, and lowering the power of the light source (decreasing the intensity of the light). Inversely, increasing the intensity of the light source, decreasing the distance from the light source to the substrate being cured, and making thinner cross sections would result in shorter curing time. Additionally, in various embodiments, substrates to be overmolded may be sensitive to certain conditions, e.g., heat, pressure, etc. Therefore, in various embodiments, a molding machine as described above may use resin with a relatively low viscosity and the resin may be pumped or metered into the cavity of the mold set at a relatively low pressure.

**[0060]** Traditional low pressure molding materials (polyamides) are thermoplastics and are injected in to the cavity of the tool around the substrate being overmolded at a temperature ranges between 350 degrees F, and 475 deg. F. These materials viscosities typically range between 1500 cPs and 35,000 cPs. Due to the thermoplastic nature of the materials, they require a fast fill time to get the materials into the cavity prior to the material solidifying. Because the materials need to be injected into the cavity at a fast rate, the injection pressures would be related

to the cross sectional thicknesses and viscosities of the material. Low viscous materials flowing into a thick cross section at a slow rate would have injection pressures somewhere between 50 and 500 psi. It is not uncommon for injection pressures to reach 1500 psi or even exceed 2000 psi in some cases.

**[0061]** As opposed to thermoplastic materials, the UV or light cure materials can be injected at very low velocities since the materials do not cure until they are exposed to light. Because high injection velocities are not required to fill the cavity prior to the material curing, slower injection velocities can be used (velocities can be fractions of a gram per second), which result in injection pressures that may be below 10 psi, or the flow could be controlled to mimic that of a gravity fed system. High injection velocities may result in high injection pressures. Each application would be customized according to its needs.

**[0062]** For example, electronics, such as a speaker, may be overmolded as described above without subjecting the electronics to temperatures or pressures that could be harmful to the electronics using light to cure the resin overmolding the electronics. This can also be used to encapsulate electronics such as printed circuit boards.

**[0063]** In various embodiments, mold sets such as those described above may include coolant lines within the mold platens, e.g., to cool the mold through conduction, etc.

**[0064]** With reference to FIGS. 7-9, shadowing is further described. A substrate 340 including a component 343 is illustrated. Resin 335 is applied over the substrate 340 and the component 343. However, based on the location of the light source 342, the substrate 340 may block light from the light source 342 from reaching a shadow portion 347 of the resin 335 and therefore resin 335 in the shadow portion 347 may not cure. As discussed above, in one embodiment, light redirecting arrangements such as light pipes may be used to deliver light from the light source 342 to the shadow portion 347.

**[0065]** With reference to FIG. 8, in one embodiment, a substrate 440 may include a component 443. The substrate 440 and the component 443 may be covered with resin 435. With the light source 442 located above the substrate 440 and the component 443, the component 443 does not create a shadow portion. However, with reference to FIG. 9, for another substrate 540 and component 543 configuration, the component 543 creates a shadow portion 547 of the resin 535 based on the location of the light source 542. Light pipes may be used to redirect the light and deliver light from the light source 542 to the shadow portion 547.

**[0066]** Some embodiments that have shadowing can use secondary curing processes to cure the shadow portion 547. For example, in one embodiment, the resin 535 may include additional curing agents. For example, curing agents that utilize time elapse, heat, moisture, addition of chemicals, catalytic curing processes, etc., may be included in the resin 535. After application of the light to the resin 535, the additional curing process, e.g., based on the additional curing agent or agents that have been included in the resin 535, for example, heating, letting time elapse, adding moisture or other chemicals, etc., to the resin 535, which may aid in causing resin 535 located in the shadow portion 537 to cure.

**[0067]** FIGS. 10 and 11 illustrate a simplified embodiment of a mold set 632 according to an embodiment of the invention. The mold set 632 can be used with the machine 100 described above. The mold set 632 includes two mold housing components in the form of mold halves 634, 636 that prevent light transmission therethrough. These mold halves 634, 636 define a cavity 635. Stored within the cavity 635 of the mold halves 634, 636 are two internal mold components in the form of mold sections 637, 639 that are formed from, at least in part, optically clear material and preferably from a non-stick material such as a non-stick optically clear silicone. The two mold sections 637, 639 are preferably removable from the cavity 635 such that if they become damaged, worn or accidentally secured together, they can be replaced. Even more preferably, the mold sections 637, 639 are molded components such that they can be easily and cost effectively remade if they are damaged.

**[0068]** These two mold sections 637, 639 combine to form the mold cavity 638 in which a component will be molded using a light cure material. The mold cavity 638 is illustrated as a simple rectangle in the illustrated embodiment but could take other more complex shapes depending on the desired shape of the component to be molded.

**[0069]** A first set of light sources 642 are fitted in mold section 637 while a second set of light sources 644 are fitted in mold section 639. The light sources can be LEDs as discussed in other embodiments. Further, while two light sources are illustrated in each mold section 637, 639 more or less light sources can be provided depending on the power requirements and potential shadowing. The light produced by the light sources 642, 644 will pass through the mold sections 637, 639, when activated, to cure, at least in part, the light cure material after it has been dispensed into the mold cavity 638. The mold sections 637, 639 also provide a covering

portion that protects the light sources 642, 642 from the light cure material when it is injected into the mold cavity 638.

**[0070]** Typically, the mold halves 634, 636 will completely surround the mold sections 637, 639 and prevent light from passing into the mold cavity 638 prematurely. Further, any internal passage ways through which the uncured light cure material passes prior to entering the mold cavity 638 are also preferably light impermeable to prevent undesirable curing of the material within those passageways. This would undesirably prevent subsequent parts from being manufactured. While not illustrated, the mold set 632 will typically include one or more input ports and corresponding valve arrangement for metering of the light cure material into the mold cavity 638 while preventing the escape of light as discussed above.

**[0071]** With reference to FIGS. 11 and 12, the mold set 632 may be used to overmold or otherwise encapsulate a substrate 640, such as, for example, an electronic component. The substrate 640 is initially supported by retractable pins 641 that can support the substrate 640 during initial injection of light cure material 643. With reference to FIG. 13, once the initial shot of material 643 is injected into the mold cavity 638, retractable pins 641 can be retracted from the mold cavity 638 and the voids left by the retractable pins 641 can be filled with material.

**[0072]** In some embodiments, the initial shot of light cure material can be exposed to initial amount of light from light sources 642, 644 to allow the light cure material to provide some support for the substrate 640 prior to retracting the retractable pins 641. After the voids left by the pins 641 have been filled, the light sources 642, 644 can again be activated to cure this additional material and/or to finish or more fully cure the light cure material 643 that is encapsulating the substrate 640. The light sources 642, 644 may be deactivated between the initial shot and the second shot of material or could remain on depending on the particular light cure material. The mold set 632 can include a light redirecting arrangement for assisting in preventing shadow portions.

**[0073]** A further embodiment is illustrated in FIG. 14 and is similar to the prior embodiment. The mold sections 737, 739 are formed primarily from an optically clear material such that light from light sources 742, 744 can be transmitted into mold cavity 738. However, in this embodiment, the optically clear material is a substrate in which a light redirecting arrangement is embedded. In this embodiment, the light redirecting arrangement is in the form of light diffusing beads 745 distributed throughout the optically clear substrate used to form the mold sections 737,

739. The light diffusing beads 745 cause the light from the light sources 742,744 to be redirected to more uniformly distribute the light as it passes into the mold cavity 638. The light diffusing beads 745 can cause the light to scatter such that it enters into the mold cavity 638 substantially at all different angles so as to better eliminate any shadow portions, such as shadow portion 347 in FIG. 7 or shadow portion 547 in FIG. 9.

**[0074]** The light diffusing beads 745 could be in the form of small polymer beads embedded within the optically clear substrate, e.g. optically clear silicone. The light diffusion is mainly controlled by the following aspects of the beads: bead size; bead composition / difference in refractive index between the polymer comprising the beads and the optically clear substrate in which the beads 745 are embedded.

**[0075]** Other factors that can impact performance of the beads include bead shape, bead surface roughness, bead surface treatment, chemistry at the surface, composition inside the bead, e.g. solid, single void or multiple voids; narrowness of distribution of bead size (e.g. are they 10 um +/- 1 um or 10 um +/- 10 um); etc.

**[0076]** These various characteristics can be modified to better illuminate the mold cavity 738 and eliminate shadow portions depending on the shape of the part to be molded.

**[0077]** Some commercial examples of products include: Sekisui Techpolymer MBX-5; Sekisui Techpolymer SBX-102; Microbeads AS Spheromers CA-10. The first two materials being produced by Sekisui Plastics having a principle place of business in Tokyo, Japan and the third material being produced by Microbeads AS having a principle place of business in Skedsmokorset, Norway.

**[0078]** When using the light diffusing beads 745, it can be particularly beneficial to form the mold sections 737, 739 by molding the mold sections 737, 739 such that different material compositions can be tested to mold particular shapes in a cost efficient manner.

**[0079]** Further, while the embodiment of FIG. 14 illustrates the light dispersion mechanism as part of the mold sections 737, 739, other embodiments could incorporate a light dispersion mechanism directly in the material being molded, i.e. into the light cure material to further facilitate light curing of the material.

**[0080]** The use of the light cure systems and methods of the disclosure find particular benefits when the light cure material being molded is a dual cure material. More particularly, the light cure material may also have a separate synergistic cure mechanism. For instance,

synergistic cure mechanisms may include moisture, condensation, Michael addition, thermal, pressure, etc. By being a dual cure material, the material can first be light cured to gel or set the material to provide an initial level of stability such that the molded part can be removed from the mold set and particularly the mold cavity without damage to the shape of the molded part. The part can then be exposed to the second cure mechanism to finalize the curing of the molded part while freeing the mold set to be used to form another part. The secondary cure completes the crosslinking and brings the product to the final fully hardened state. While this is preferred, embodiments are not prevented from performing the secondary cure step within the mold set.

**[0081]** Potential light sources that could be used include UV light as defined as 200 to 400 nm. Visible light used in this type of reaction is typically 380-450 nm. Gamma rays or X-rays can generate free radicals and initiate cure. An electron beam generates low energy electrons that are available for further reaction. A LASER could be the light source. Moisture, heat, microwave, radio frequency or ultrasonic waves could also be part of the dual cure mechanism.

**[0082]** Some examples of light cure and moisture cure dual cure materials include Dymax 9481-E, 9482, 9101, 9102, 9103 (acrylated urethane); Silicone Solutions SS-154, SS5293 (silicone); Novagard RTV 800-240 (silicone); HumiSeal UV40 (acrylated urethane); Loctite LOCA 5192 (silicone).

**[0083]** Some examples of light cure and heat cure dual cure materials include Masterbond UV15-7DC, UV10DCTK, UV15DC80 (epoxy); Addison AC A535-15, AC A1708-A, AC A1705-A, AC A1702-A, AC A1705-TX, TCR-1003, TCR-1002, (epoxy); Loctite LOCA 3192 (acrylic); Henkel Loctite 3131 (epoxy, acrylate); and ITW Devcon Tru-Bond DC 1000 (acrylate).

**[0084]** Dual cure materials can include silicones, epoxies, urethanes, polyesters, acrylates, polybutadiene, or any polymeric system containing chemical functional groups including acrylate, methacrylate, allyl, or vinyl groups. The cure mechanism of the resin may include free radical, cationic, or anionic.

**[0085]** Various additives can be added to the light cure material including, but not limited to surfactants, defoamers, thickeners, solvents, wetting aids, flow agents, matting agents, leveling agents, thixotropic agents, dyestuffs, pigments, colorants, fillers, initiators, catalysts, antioxidants, UV absorbers, moisture scavengers, plasticizers, reactive or nonreactive diluents, brighteners, adhesion promoters, release agents, cure inhibitors, flame retardants

**[0086]** It is also noted that oxygen can inhibit light cure reactions and particularly UV reactions. In some embodiments, an inert gas can be piped into the mold cavity to eliminate the presence of oxygen and making the light cure more efficient. This can be done in single cure or multiple cure systems and methods.

**[0087]** In various embodiments, light cure materials and resins discussed herein may include UV cure silicones, UV cure epoxies, urethanes, etc.

**[0088]** It should be understood that the figures illustrate the exemplary embodiments in detail, and it should be understood that the present application is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology is for the purpose of description only and should not be regarded as limiting.

**[0089]** Further modifications and alternative embodiments of various aspects of the invention will be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only. The construction and arrangements, shown in the various exemplary embodiments, are illustrative only. Although only a few embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter described herein. Some elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. The order or sequence of any process, logical algorithm, or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may also be made in the design, operating conditions and arrangement of the various exemplary embodiments without departing from the scope of the present invention.

**[0090]** For purposes of this disclosure, the term “coupled” means the joining of two components directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional member being attached to one another.

Such joining may be permanent in nature or alternatively may be removable or releasable in nature.

**[0091]** While the current application recites particular combinations of features in the claims appended hereto, various embodiments of the invention relate to any combination of any of the features described herein whether or not such combination is currently claimed, and any such combination of features may be claimed in this or future applications. Any of the features, elements, or components of any of the exemplary embodiments discussed above may be used alone or in combination with any of the features, elements, or components of any of the other embodiments discussed above.

**[0092]** In various exemplary embodiments, the relative dimensions, including angles, lengths and radii, as shown in the Figures are to scale. Actual measurements of the Figures will disclose relative dimensions, angles and proportions of the various exemplary embodiments. Various exemplary embodiments extend to various ranges around the absolute and relative dimensions, angles and proportions that may be determined from the Figures. Various exemplary embodiments include any combination of one or more relative dimensions or angles that may be determined from the Figures. Further, actual dimensions not expressly set out in this description can be determined by using the ratios of dimensions measured in the Figures in combination with the express dimensions set out in this description.

**[0093]** In various embodiments, controllers described herein may include a general purpose processor, an application specific processor, a circuit containing one or more processing components, a group of distributed processing components, e.g., distributed computers configured for processing, etc. Embodiments of controllers may be or include any number of components for conducting data processing and/or signal processing. According to an exemplary embodiment, any distributed and/or local memory device may be utilized with and/or included in the controllers of this disclosure. In one embodiment, controllers may include memory communicably connected to the controllers (e.g., via a circuit or other connection) and may include computer code for executing one or more processes described herein.

**[0094]** In various embodiments, the controllers may be implemented in software. In another embodiment, the controllers may be implemented in a combination of computer hardware and software. In various embodiments, systems implementing controllers discussed herein include one or more processing components, one or more computer memory components, and one or

more communication components. In various embodiments, the controllers may include a general purpose processor, an application specific processor (ASIC), a circuit containing one or more processing components, a group of distributed processing components, a group of distributed computers configured for processing, etc., configured to provide the functionality discussed herein. In various embodiments, the controllers may include memory components such as one or more devices for storing data and/or computer code for completing and/or facilitating the various processes described in the present disclosure, and may include database components, object code components, script components, and/or any other type of information structure for supporting the various activities described in the present disclosure. In various embodiments, communication components may be used by the controllers described herein and may include hardware and software for communicating data for the system and methods discussed herein. For example, communication components may include, wires, jacks, interfaces, wireless communications hardware etc., for receiving and transmitting information as discussed herein. In various specific embodiments, the controllers and/or methods described herein, may be embodied in nontransitory, computer readable media, including instructions (e.g., computer coded) for providing the various functions and performing the various steps discussed herein. In various embodiments, the computer code may include object code, program code, compiled code, script code, executable code, instructions, programmed instructions, non-transitory programmed instructions, or any combination thereof. In other embodiments, controllers described herein may be implemented by any other suitable method or mechanism.

**WHAT IS CLAIMED IS:**

1. A molding system comprising:
  - a first material source of a light cure material;
  - a mold set defining a cavity, the mold set including a light source and a covering portion configured to separate the light source from the contents of the cavity, the covering portion being configured to pass light from the light source therethrough into the cavity, light redirecting arrangement between the light source and the cavity, the light redirecting arrangement delivers light from the light source to a portion of the cavity away from the light source, the mold set defines an input port through which the cavity receives the material from the first material source and a valve preventing material flow into the cavity in a closed configuration and allowing material flow into the cavity in an open configuration, light from the light source in the cavity being prevented from exiting the cavity through the input port when the valve is in a closed configuration; and
  - a controller controlling the light source to illuminate when the valve is in a closed configuration and controlling the light source not to illuminate when the valve is in an open configuration.
2. The molding system of claim 1, wherein the cavity holds a substrate therein to be overmolded with the material, the substrate being located between the light source and a shadow portion of the cavity, the light redirecting arrangement redirecting light from the light source to the shadow portion of the cavity.
3. The molding system of claim 1, wherein the material is a multi-cure material to be cured by exposure to light as well as a second cure mechanism.
4. The molding system of claim 3, wherein the second cure mechanism is at least one of moisture, condensation, Michael addition, thermal, or pressure.

5. The molding system of claim 1, further comprising a second material source, a motor, and a static mixer, the first and second material sources each being configured to deliver material to the static mixer which forms the light cure material.

6. The molding system of claim 5, wherein the controller is configured to independently control amount of material delivered from the first material source to the static mixer and from the second material source to the static mixer.

7. The molding system of claim 1, wherein the valve includes a pin configured to close the input port.

8. The molding system of claim 1, wherein the mold set includes a mold housing defining an internal cavity and plurality of internal mold components, the internal mold components located within the internal cavity of the mold housing, the internal mold components defining the cavity, at least one of the internal mold components being interposed between the light source and the cavity.

9. The molding system of claim 8, wherein the at least one internal mold component being interposed between the light source and the cavity is formed at least in part from an optically clear material to permit light to pass therethrough.

10. The molding system of claim 9, wherein the optically clear material is silicone.

11. The molding system of claim 9, wherein the light redirecting arrangement is embedded into the optically clear material.

12. The molding system of claim 11, wherein the light redirecting arrangement is provided by light redirecting beads embedded within the optically clear material such that the optically clear material acts as a substrate.

13. The molding system of claim 11, wherein the light redirecting arrangement is in the form of a light pipe.

14. The molding system of claim 1, wherein the light redirecting arrangement is in the form of a light pipe.

15. The molding system of claim 8, wherein the internal mold components are molded components.

16. A method of overmolding a light cure material over a substrate, the method comprising:

locating a substrate in a cavity of a mold, the mold having a light source, the light source projects light into the cavity when illuminated;

introducing the light cure material into the cavity through a port, the light cure material being curable upon illumination by the light of the light source;

closing the port with a valve that prevents light from exiting the mold through the port; and

illuminating the light source, after closing the port to begin curing the light cure material within the cavity of the mold.

17. The method of Claim 16, further comprising redirecting a portion of the light from the light source to a portion of the cavity away from the light source that is shadowed by a portion of the substrate.

18. The method of Claim 16, wherein the light cure material is also curable by a second curing mechanism and the method includes using a second curing mechanism to further cure the light cure material.

19. The method of Claim 18, wherein using the second curing mechanism occurs after the light source has been illuminated such that the light cure material has been partially

cured by the light and using the second curing mechanism occurs after the partially cured material has been removed from the cavity of the mold.

20. The method of Claim 16, wherein a portion of the substrate is located between the light source and a shadow portion of the cavity.

21. The method of Claim 20, further comprising delivering light from the light source to the shadow portion of the cavity with a light redirecting arrangement.

22. The method of claim 21, wherein the light redirecting arrangement is in the form of an internal mold component located between the light source and the cavity, the internal mold component having an optically clear substrate and a plurality of light redirecting beads embedded therein which cause the light of the light source to scatter and be redirected.

23. The method of Claim 16, wherein the material is forced into the cavity at a pressure of less than between 0.1 psi to 1000 psi.

24. The method of claim 16, wherein the mold includes a mold housing defining an internal cavity and the mold includes at least one internal mold component located within the internal cavity, the at least one internal mold component defining at least part of the cavity.

25. The method of claim 24, further comprising molding the at least one internal mold component.

26. The method of claim 25, further comprising replacing the at least one internal mold component with a replacement internal mold component formed by molding.

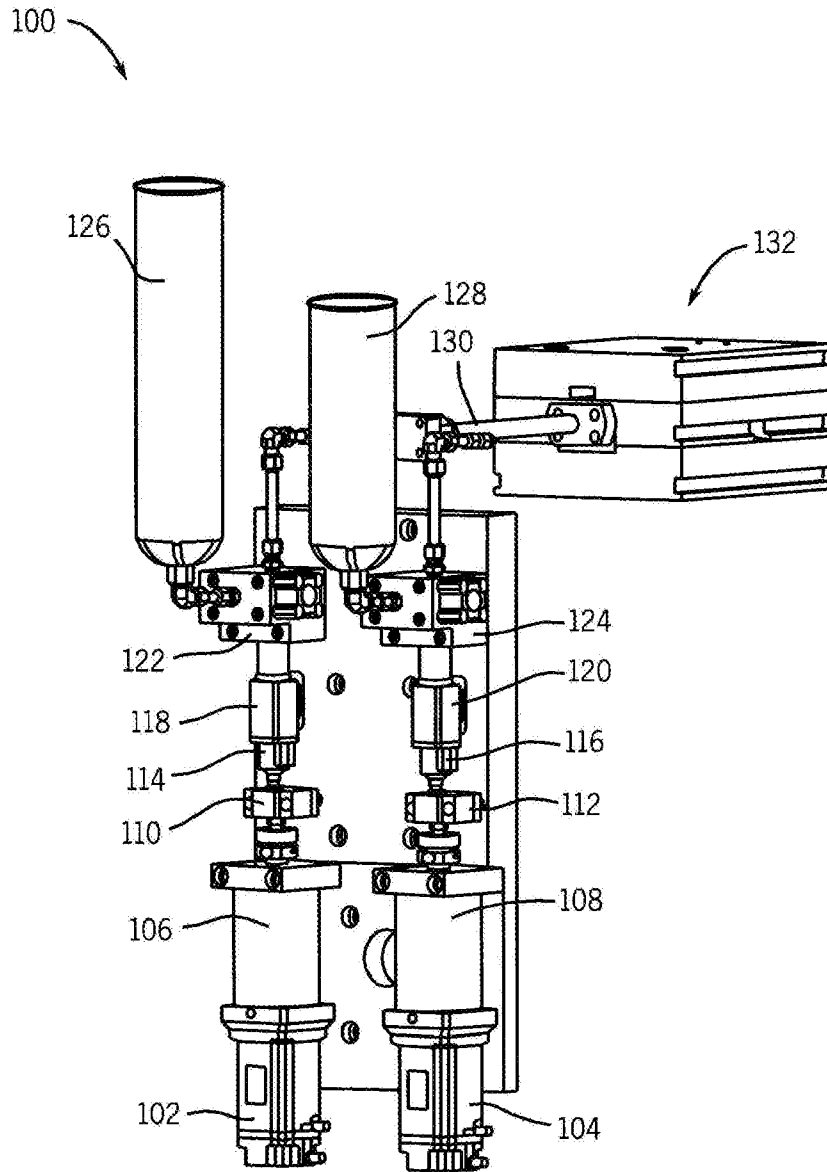


FIG. 1

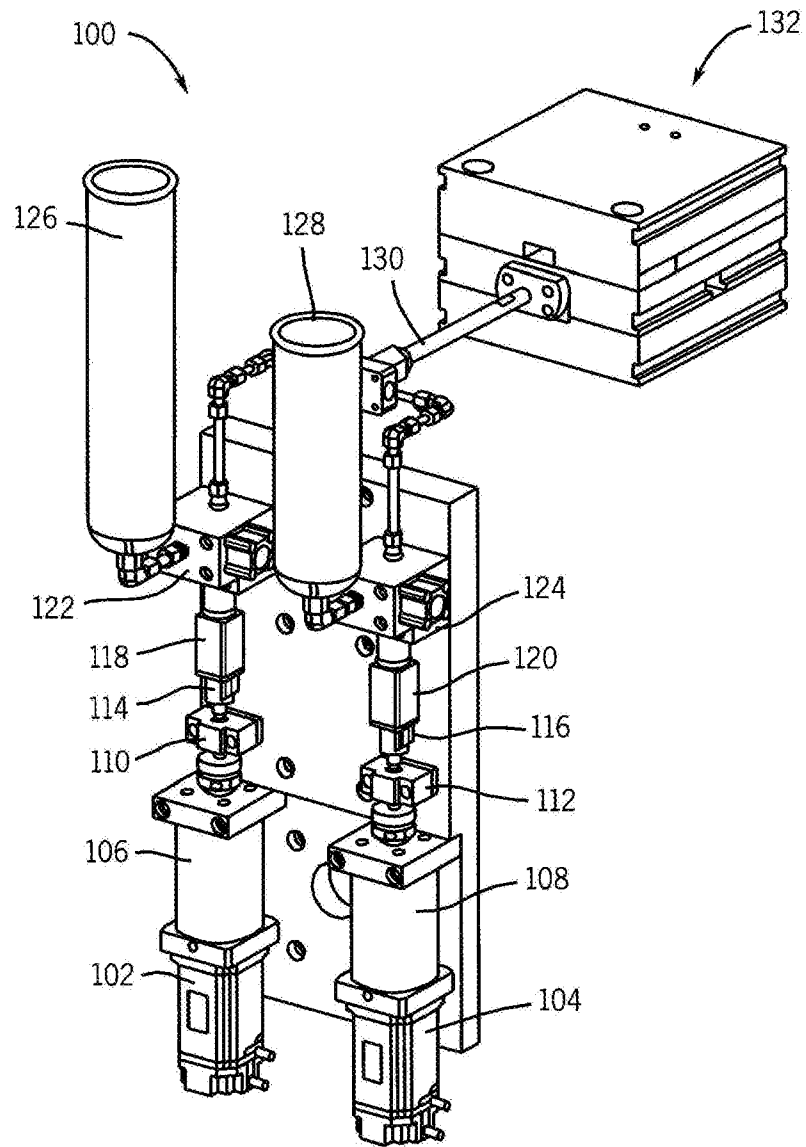


FIG. 2

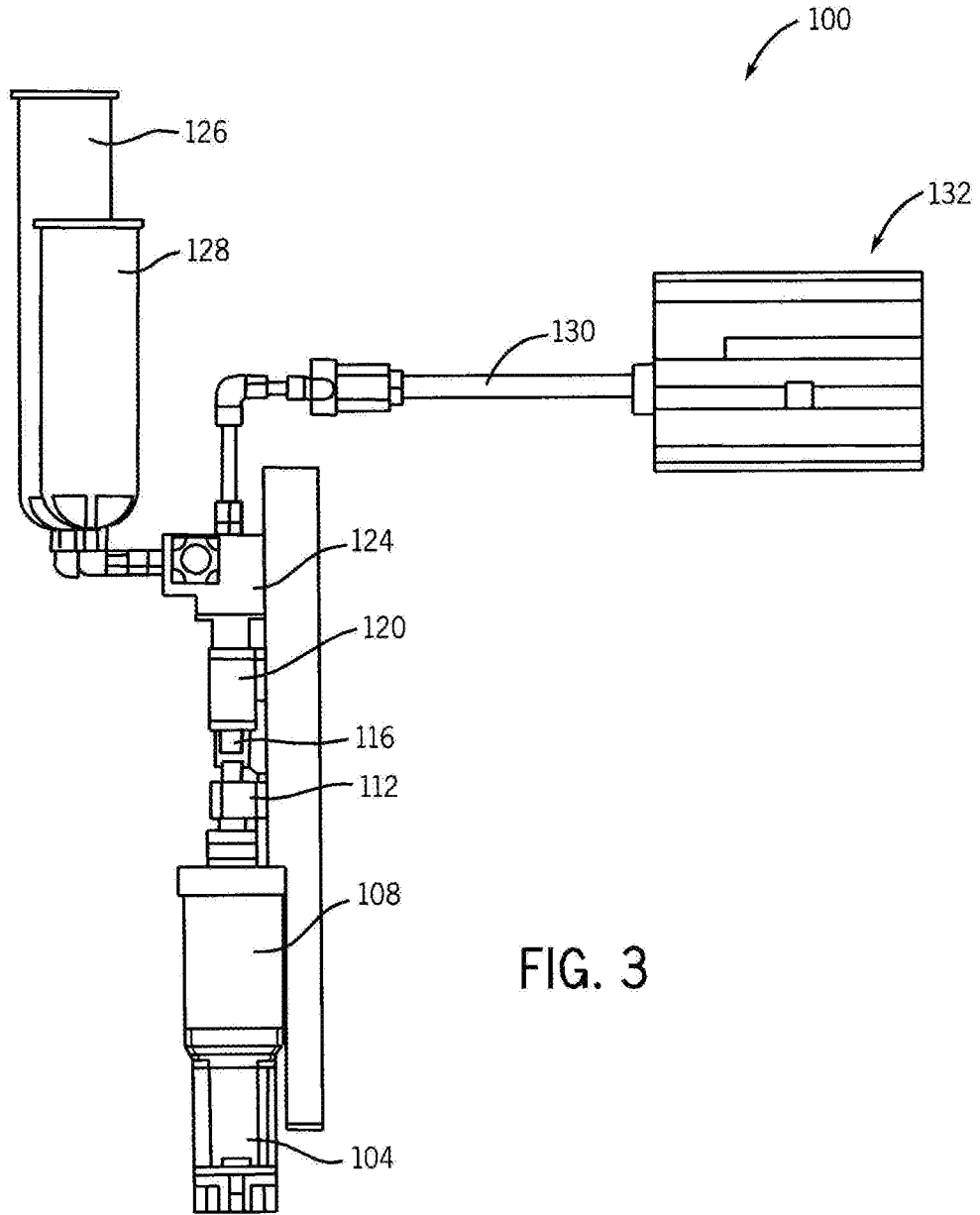


FIG. 3

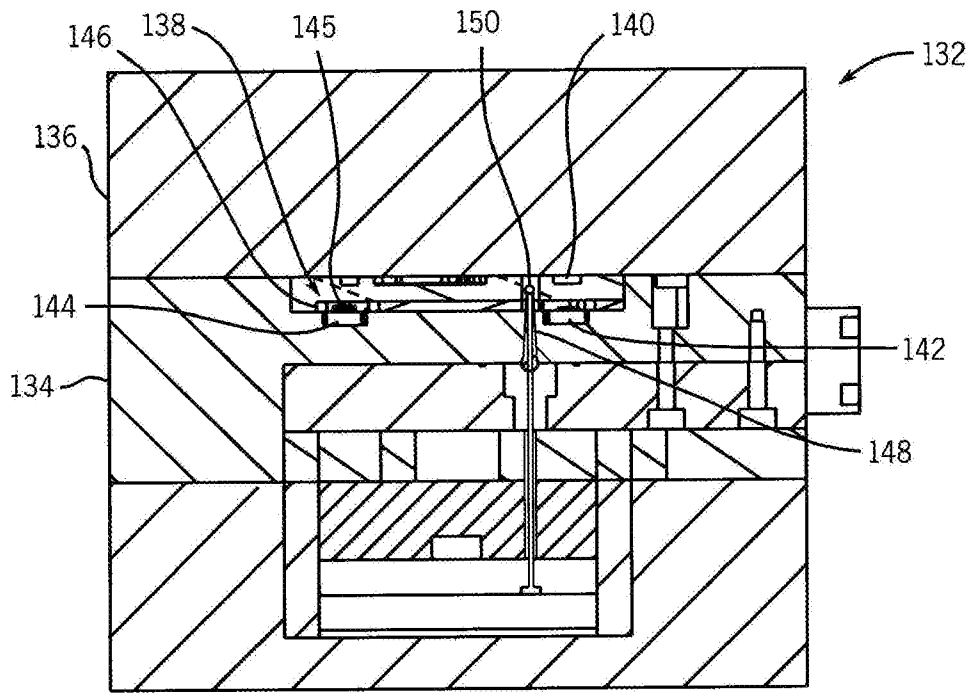


FIG. 4

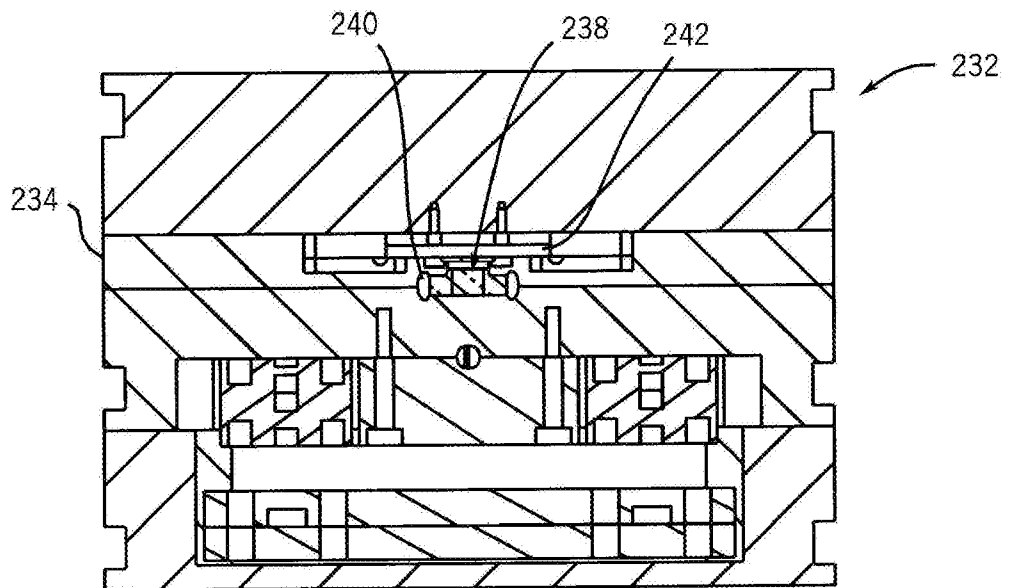


FIG. 5

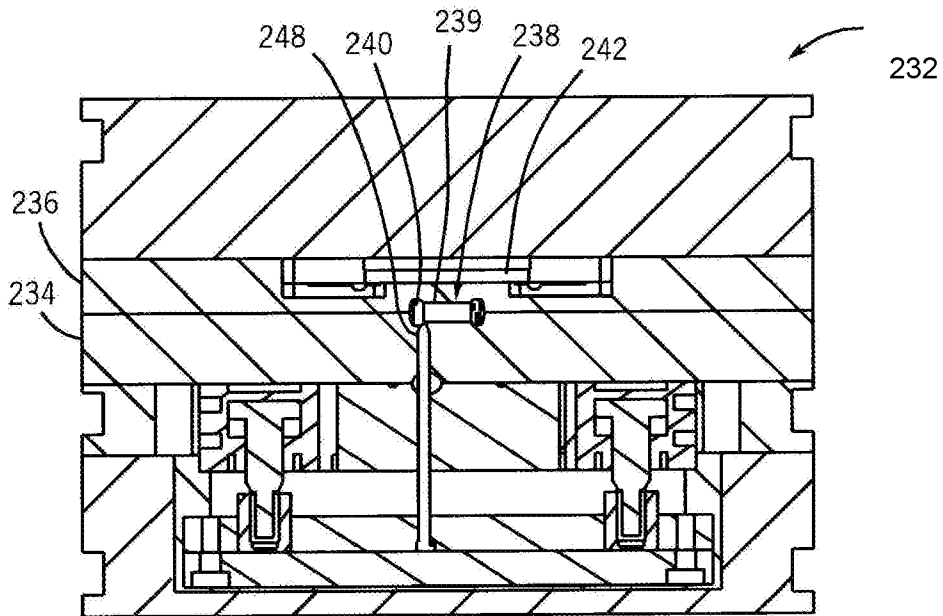
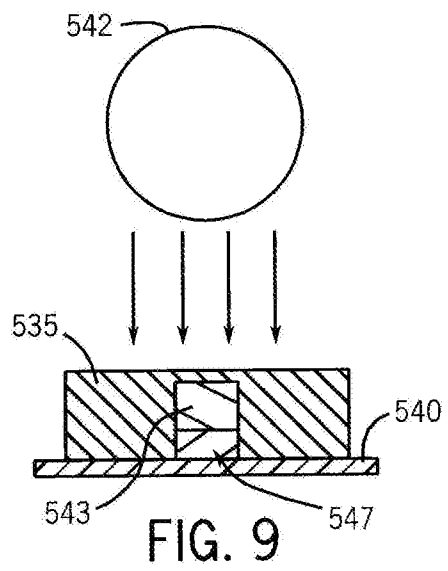
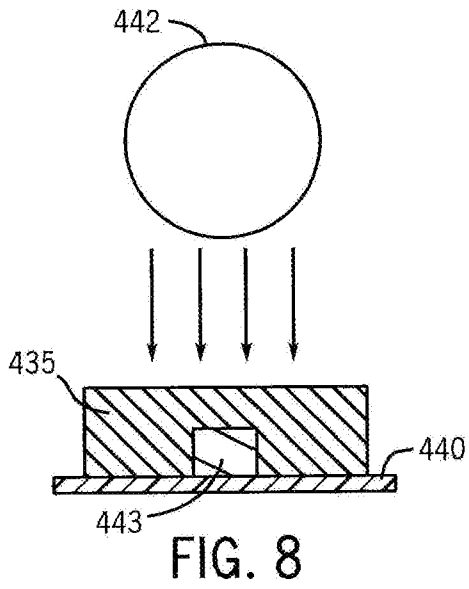
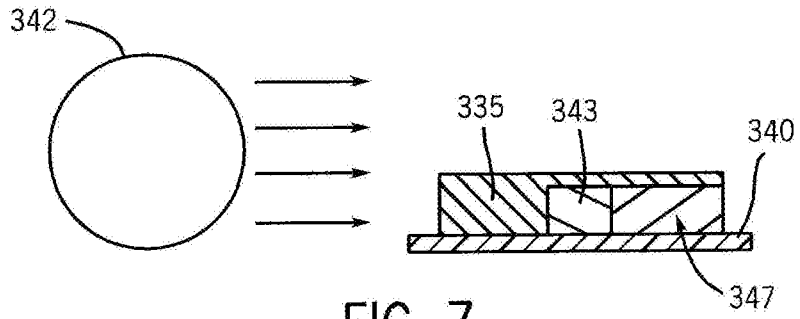
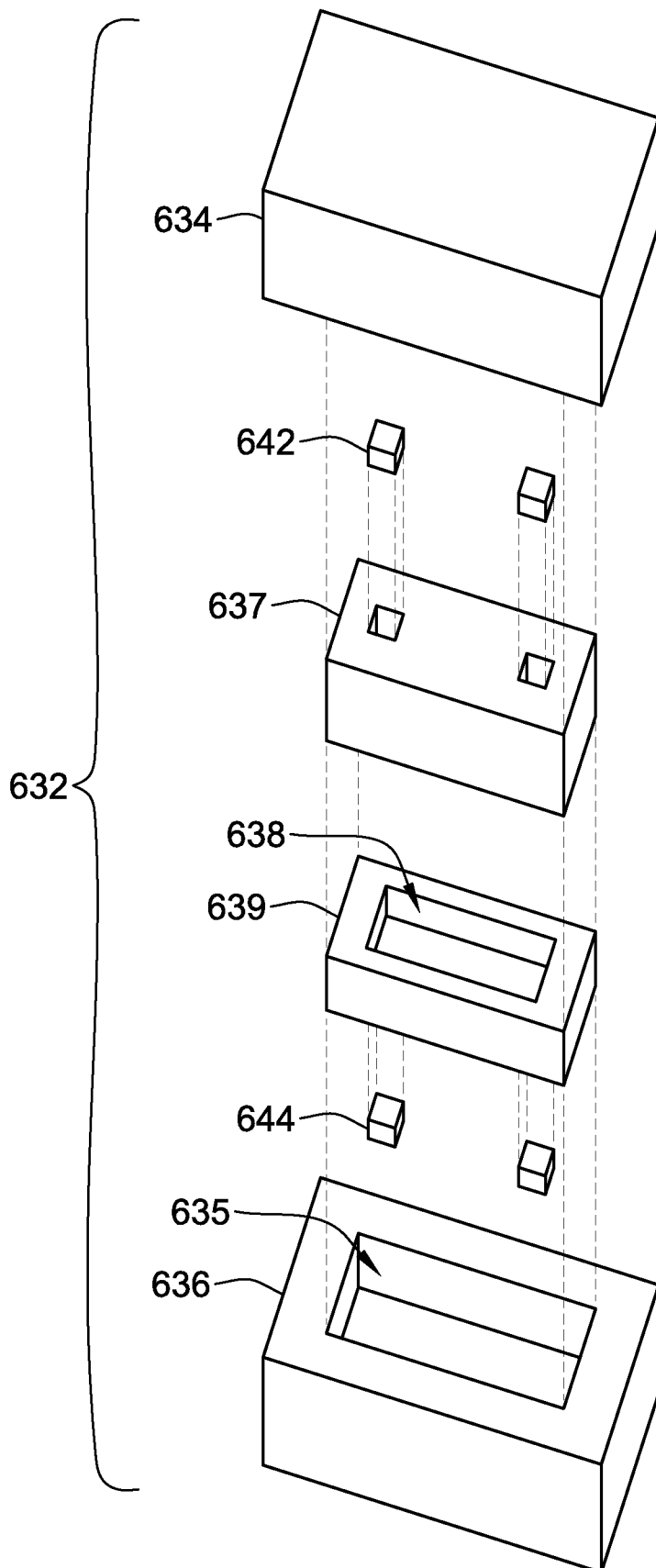


FIG. 6





**FIG. 10**

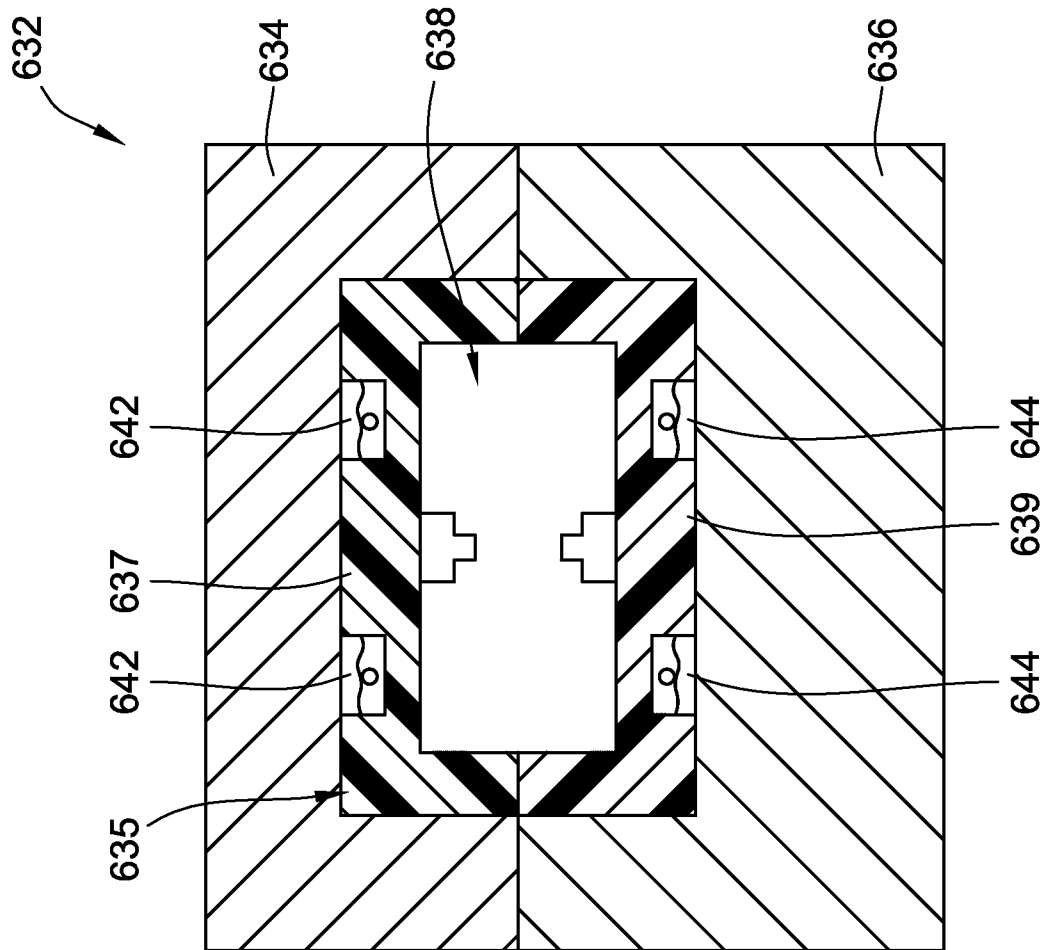


FIG. 11

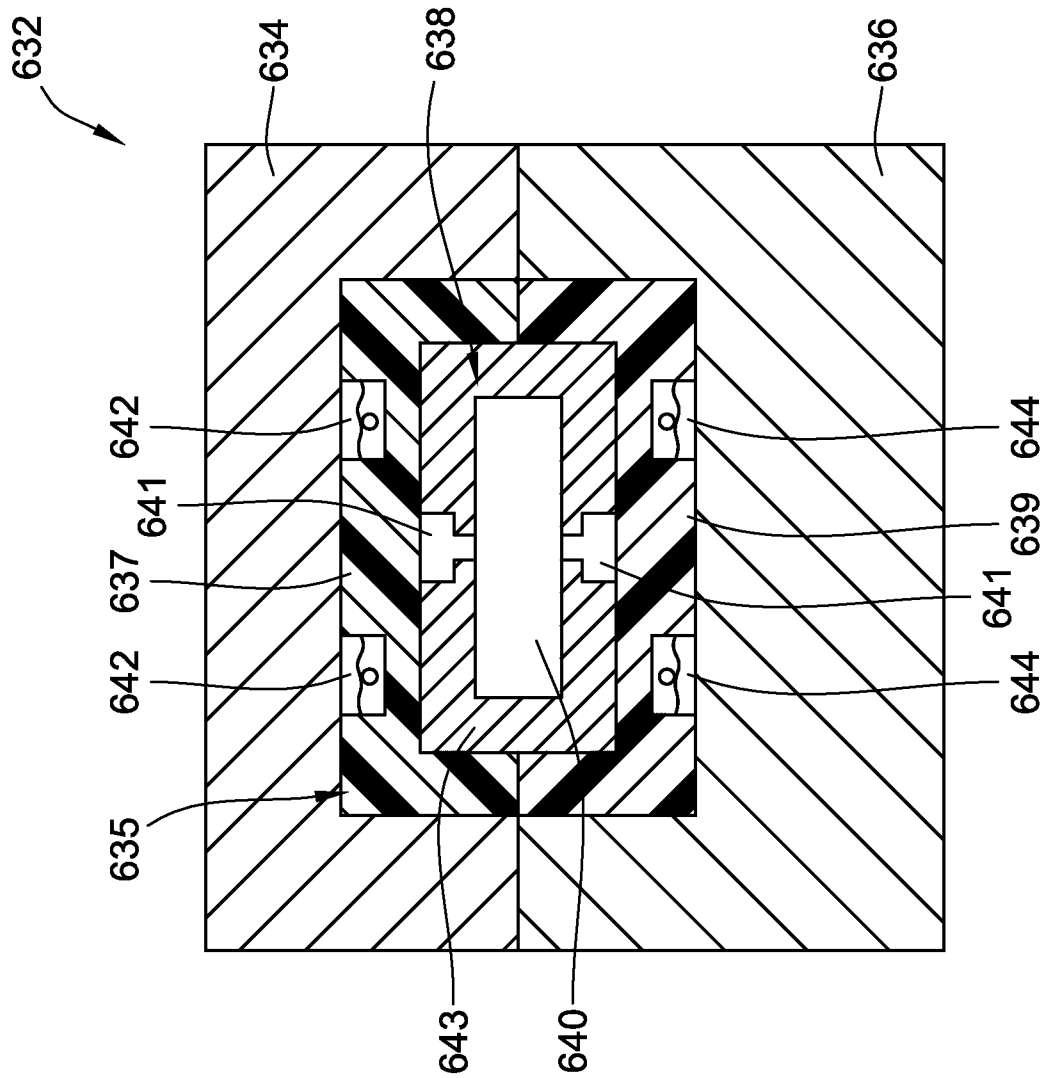


FIG. 12

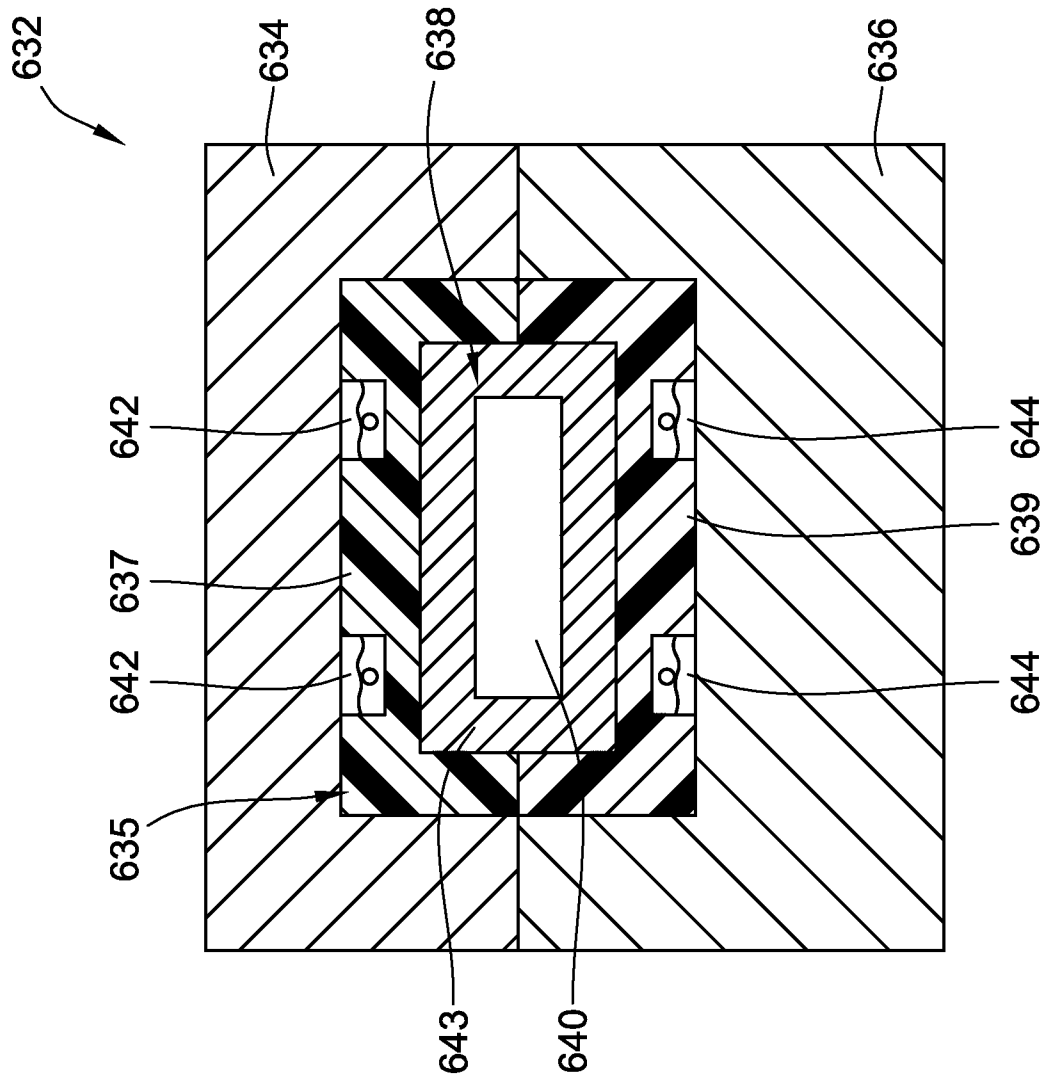


FIG. 13



**A. CLASSIFICATION OF SUBJECT MATTER****B29C 33/06(2006.01)i, B29C 33/20(2006.01)i, B29B 7/26(2006.01)i, B29B 7/24(2006.01)i, B29B 7/28(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)  
B29C 33/06; G02F 1/13; B29C 35/08; B29C 33/20; B29B 7/26; B29B 7/24; B29B 7/28Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
Korean utility models and applications for utility models  
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
eKOMPASS(KIPO internal) & Keywords: light, cure, material, mold, cavity**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0278845 A1 (OLEG PISHNYAK et al.) 24 October 2013 See paragraph [0057] and claim 1.	1-26
A	US 2005-0248065 A1 (KOJI OWADA) 10 November 2005 See paragraph [0031], claim 1 and figure 5.	1-26
A	US 2010-0019417 A1 (TZE PENG CHUA et al.) 28 January 2010 See paragraphs [0053]-[0065] and figures 2-3.	1-26
A	US 2008-0174050 A1 (SHIGEKI KIKUCHI) 24 July 2008 See paragraphs [0029]-[0038] and figures 1(a)-1(b).	1-26
A	US 2008-0012185 A1 (SUSUMU IIDA et al.) 17 January 2008 See claims 1,7 and figure 5.	1-26

 Further documents are listed in the continuation of Box C. See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

18 May 2017 (18.05.2017)

Date of mailing of the international search report

**18 May 2017 (18.05.2017)**

Name and mailing address of the ISA/KR

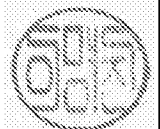
International Application Division  
Korean Intellectual Property Office  
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

LEE, Myung Jin

Telephone No. +82-42-481-8474



**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2017/019418**

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