(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 November 2016 (24.11.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/185096 A1

(51) International Patent Classification:
B32B 27/08 (2006.01) *H05K 5/00* (2006.01)
H05K 1/03 (2006.01) *H01L 23/538* (2006.01)
H05K 3/28 (2006.01) *F21K 9/00* (2016.01)

(21) International Application Number:
PCT/FI2016/050337

(22) International Filing Date:
19 May 2016 (19.05.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/163,410 19 May 2015 (19.05.2015) US

(71) Applicant: **TACTOTEK OY** [FI/FI]; Takatie 6, 90440 Kempele (FI).

(72) Inventors: **HEIKKINEN, Mikko**; Kurjenpolvi 2 D 6, 90580 Oulu (FI). **SÄÄSKI, Jarmo**; Niittyrannantie 84, 90440 Kempele (FI). **TORVINEN, Jarkko**; Tiilipellontie 1 A 4, 90440 Kempele (FI).

(74) Agent: **BERGGREN OY AB**; P.O. Box 16 (Eteläinen Rautatiekatu 10 A), 00101 Helsinki (FI).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: THERMOFORMED PLASTIC COVER FOR ELECTRONICS AND RELATED METHOD OF MANUFACTURE

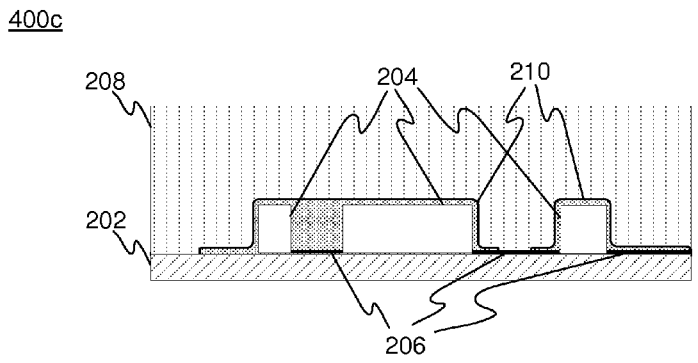


FIG. 4C

(57) Abstract: A multilayer structure for an electronic device comprising a flexible substrate film (202) for accommodating electronics (204); at least one electronic component (204) provided on said substrate film (202); and a number of conductive traces (206) provided on said substrate film (202) for electrically powering and/or connecting electronics including said at least one electronic component (204), wherein at least one preferably thermoformed cover (210) is attached to said sub-strate film (202) on top of said at least one electronic component (204), the at least one thermoformed cover (210) and the substrate film (202) accommodating the electronics (204) being overmolded with thermoplastic material (208). The invention also relates to a method for manufacturing a multilayer structure for an electronic device.

WO 2016/185096 A1

Thermoformed plastic cover for electronics and related method of manufacture

TECHNICAL FIELD

The present invention concerns in general the technical field of electronics, related devices, structures, and methods of manufacture. In particular, however not exclusively, the present invention concerns manufacturing a multilayer structure for integrated and embedded electronics.

BACKGROUND

Generally there exists a variety of different stacked assemblies and structures in the context of electronics and electronic products.

The motivation behind the integration of electronics and related products may be as diverse as the related use contexts. Relatively often size savings, weight savings, cost savings, or just efficient integration of components is sought for when the resulting solution ultimately exhibits a multilayer nature. In turn, the associated use scenarios may relate to product packages or food casings, visual design of device housings, wearable electronics, personal electronic devices, displays, detectors or sensors, vehicle interiors, antennae, labels, vehicle electronics, etc.

Electronics such as electronic components, ICs (integrated circuit), and conductors, may be generally provided onto a substrate element by a plurality of different techniques. For example, ready-made electronics such as various surface mount devices (SMD) may be mounted on a substrate surface that ultimately forms an inner or outer interface layer of a multilayer structure. Additionally, technologies falling under the term “printed electronics” may be applied to actually produce electronics directly to the associated substrate. The term “printed” refers in this context to various printing techniques capable of producing electronics/electrical elements, including but not limited to screen printing, flexography, and inkjet printing, through substantially additive printing process. The used substrates may be flexible and printed materials organic, which is however, not necessarily always the case.

For example, the aforementioned wearable electronics and generally wearable technology such as smart clothing fuses textiles, other wearable materials and

electronic devices to make a wearer's life easier by implementing different aspects of ubiquitous computing for both private and business purposes in wearable items such as garments. Recent advancements in material technology and miniaturization have brought forward solutions that the users have only dreamed about a decade or two ago. Hard shell wearable technology such as various smart watches or generally wristop devices has been limitedly available for some time now starting from the 80's wristop calculator watches evolving into sports/fitness computers, activity monitors and most recently, various communications-enabled apparatuses approaching e.g. cell phones and tablets in terms of embedded features. Yet, few wearable smart glasses and e.g. personal security-related products have hit the markets since. Actual e-textiles or 'smart textiles' have also been introduced during the last few years with reference to fabrics that provided for integration with electronics such as sensory integration. The e-textiles may incorporate both electrically conductive materials, such as conductive yarn, and insulating materials for providing the desired electrical properties to the components embedded therewithin.

Fig. 1 illustrates one example of a multilayer structure 100 of integrated and embedded electronics. A substrate 102 is provided to accommodate a number of electronic components 104 and a number of conductor traces 106 for connecting the electronic components 104. Additionally, a top layer 108 is provided on top of the electronic components 104 and substrate layer 102 as a support structure using a suitable lamination method involving the use of e.g. adhesives, elevated temperatures and/or pressure.

However, one drawback of the prior art solution is that the electronic components 104 may easily crack or break when the top layer 108 is provided on top of the electronic components 104. In Figure 1 a prospective crack in the component is illustrated with a dashed line 110. For example the regulation of the pressure/temperature to maintain it at a decent level during the lamination is challenging. If the pressure/temperature is too high the components 104 may crack or break, and on the other hand if the pressure/temperature is too low the composition of the top layer 108 turns out incorrect and/or the top layer is not attached properly, for instance. The cracking or breaking of the electronic components 104 during the manufacturing process cause increase in manufacturing costs for multilayer structural electronic devices. Therefore there exists a need for improving the manufacturing procedure of the multilayer structures for the electronic devices.

SUMMARY

An objective of the invention is to present a multilayer structure and method for an electronic device at least alleviating one or more of the defects of the prior art described above.

The objectives of the invention are reached by a multilayer structure and a method as defined by the respective independent claims. Various embodiments of the multilayer structure and the method for an electronic device provide a solution to protect and optionally secure the electronics when a further top layer is provided on top of the electronics or from environmental conditions such as moisture, heat, cold, dirt, shocks, etc.

According to a first aspect a multilayer structure for an electronic device comprises a flexible substrate film for accommodating electronics; at least one electronic component provided on said substrate film; and a number of conductive traces provided on said substrate film for electrically powering and/or connecting electronics including said at least one electronic component, wherein at least one cover is attached to said substrate film on top of said at least one electronic component, being overmolded with thermoplastic material.

Preferably said cover is or comprises plastic, most preferably plastic thermoformed so as to substantially define a dome or other applicable cap shape for accommodating underlying electronics.

The at least one cover may comprise a single cover placed on top of a plurality of electronic components. Alternatively or in addition, the multilayer structure may comprise at least two covers placed at least partially on top of at least two electronic components, respectively. A plurality of at least functionally separate covers may be physically provided as a one continuous, optionally monolithic, object or as a plurality of discrete physical objects.

The substrate film (surface) may be encompassed partially or completely by at least one, preferably plastic, cover. The at least one cover may define a number of optionally rounded, preferably dome-shaped, protective caps for electronics. Additionally, the at least one cover may comprise optically transparent or translucent material having regard to predefined electromagnetic wavelengths including wavelengths of e.g. visible spectrum. The at least one cover may further comprise or define a number of through-holes configured, for in-

stance, to enable the light emitted and/or captured by the at least one electronic component to propagate therewithin and outcouple therefrom.

The substrate film may comprise optically transparent or translucent material as to predefined electromagnetic wavelengths including wavelengths of e.g. visible spectrum.

Also the thermoplastic material may comprise optically transparent or translucent material having regard to predefined wavelengths including e.g. wavelengths of visible spectrum. The thermoplastic material may optionally comprise a plurality of layers, wherein different layers may exhibit different properties such as elasticity, optical transparency/transmittance, glass transition temperature, and/or melting point.

The at least one electronic component may include at least one optoelectronic, light-emitting, light-detecting, and/or light-sensing component, preferably a LED (light-emitting diode) or photodiode. Alternatively or additionally it may include e.g. a communications, memory and/or processing element, optionally in a form of an integrated circuit. For example, a microcontroller or a communication chip may be included.

According to a second aspect, an electronic device is provided. The electronic device is optionally a light-emitting device, light-detecting device, light-sensing device, smart garment or other wearable electronics, smart compression garment, wristop device, armband device, cellular device, tablet, phablet, controller device, computer mouse, joystick, other computer accessory, a display device, vehicle or in-vehicle (e.g. dashboard) electronics, or e.g. a laptop computer, comprising an embodiment of the multilayer structure as described above.

According to a third aspect, a method for manufacturing a multilayer structure for an electronic device is provided. The method comprises steps of obtaining a flexible substrate film for accommodating electronics; providing, preferably printing, a number of conductor traces on said substrate film for electrically powering and/or connecting electronic components and/or a number of predefined areas on the substrate; providing at least one electronic component on said substrate film, preferably by means of printed electronics and/or surface mounting; placing at least one cover at least partially on top of said at least one electronic component; attaching said at least one cover to said substrate

film; and molding thermoplastic material on said at least one cover and substrate film accommodating the electronic components.

The method may further comprise initially thermoforming the cover.

The selected printing method may be one of so-called printed electronics printing methods including e.g. screen printing and ink jetting. Preferably, additive manufacturing such as additive printing technology is thus applied in connection with embodiments of the present invention.

The attaching may comprise securing the at least one cover with adhesive, soldering, and/or mechanical fixing such as hook and loop fasteners. The molding may comprise injection molding. The method may further comprise providing a number of through-holes to the cover to enable the light emitted, detected and/or sensed by the at least one component to propagate therewithin and outcouple therefrom.

The expression "a number of" may herein refer to any positive integer starting from one (1).

The expression "a plurality of" may refer to any positive integer starting from two (2), respectively.

The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objectives and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF FIGURES

The embodiments of the invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

Figure 1 illustrates one example of a prior art multilayer structure.

Figure 2 illustrates a side view of an embodiment of a multilayer structure according to the present invention.

Figure 3 illustrates a side view of a second embodiment of a multilayer structure according to the present invention.

Figure 4A illustrates a side view of a third embodiment of a multilayer structure according to the present invention.

Figure 4B illustrates a side view of a fourth embodiment of a multilayer structure according to the present invention.

Figure 4C illustrates a side view of a fifth embodiment of a multilayer structure according to the present invention.

Figure 5 illustrates a flow diagram disclosing an embodiment of a method according to the present invention.

DESCRIPTION OF SOME EMBODIMENTS

Figure 2 illustrates a side view of an embodiment of a planar type multilayer structure 200 according to the present invention comprising a substrate film 202, at least one electronic component 204, at least one, preferably thermoformed, cover 210, and at least one thermoplastic material layer 208. The substrate 202, preferably a flexible plastic film, foil, or sheet, is shown as cut and/or otherwise configured into a substantially rectangular or other desired shape. The substrate 202 may be generally shaped according to the requirements set by each use scenario. It may also exhibit e.g. a circular or square general shape.

The substrate film 202 may substantially consist of or at least comprise one material selected from the group consisting of: polymer, thermoplastic material, PMMA (Polymethyl methacrylate), Poly Carbonate (PC), polyimide, a copolymer of Methyl Methacrylate and Styrene (MS resin), glass and Polyethylene Terephthalate (PET).

In some embodiments, the substrate film 202 may be coated or covered by further material layers e.g. on the side facing the environment (i.e. not the electronics). E.g. a textile layer or biological or bio-based materials (e.g. leather, wood, paper, cardboard) in addition to or instead of more conventional additional layers may be provided. Also e.g. rubber or generally rubberous material may be used.

Additionally, the substrate film 202 may at least partially be optically substantially opaque or at least translucent, if not transparent, having regard to predefined wavelengths e.g. in visible spectrum. The substrate film 202 may have been initially provided with visually distinguishable, decorative/aesthetic and/or informative, features such as graphical pattern thereon. The features may have been provided on the same side of the substrate film 202 with the electronics 204 so that they have been also sealed by the overmolded plastic material layer 208. Accordingly, IML (in-mold labeling) or IMD (in-mold decoration) technique may be thus applied in the manufacturing phase. Optionally, a number of optical features could be provided by surface relief forms such as grooves or protrusions of the substrate film 202. Such features could be obtained by embossing, carving, stamping, molding, etc.

The substrate film 202 may contain recesses, notches, cuts or openings for providing optical path and/or e.g. access to the elements provided on the substrate film 202, on either side thereof. For example, for enabling a battery change (of embedded battery) or generally component change, or for accessing a UI (user interface) feature (e.g. touch-sensitive area, button or switch) the substrate film 202 could be provided with a related access route.

The multilayer structure 200 presented in Figure 2 comprises at least one electronic component 204 that is provided on the substrate film 202. The multilayer structures may comprise electronics 204 including one or more electronic components such as passive components and/or active components, which may comprise optoelectronic component(s). The optoelectronic component(s) may include a number of LEDs (light-emitting diode), or other light-emitting components, for example. Alternatively or additionally, the component(s) may include a light-receiving or light-sensitive component such as a photodiode, photoresistor, other photodetector, or e.g. a photovoltaic cell.

The electronics 204 may include at least one element selected from the group consisting of: optoelectronic component, microcontroller, microprosessor, signal processor, DSP (digital signal processor), sensor, programmable logic chip, memory, transistor, resistor, capacitor, inductor, memory array, memory chip, data interface, transceiver, wireless transceiver, transmitter, receiver, wireless transmitter, and wireless receiver. Different sensing and/or other functionalities may be implemented by the embedded ICs, dedicated components, or shared ICs/electronics (multi-purpose electronics).

The electronics 204 may include printed electronics obtained by printed electronics technology such as screen printing or ink jetting. Additionally or alternatively, the electronics 204 may include e.g. surface-mounted elements. For example, adhesive may be utilized for mechanically securing the electronics on the substrate.

Electrical connections such as a number of traces 206 between the electronic components 204 or between the electronic component(s) 204 and e.g. external electronics disposed outside the multilayer structure may be provided by conductors and contact areas, which may be printed, for instance, on the substrate 202 by means of printed electronics and e.g. conductive ink. The conductive traces 206 may be used for power supply and signalling of control and/or other data. Conductive materials such as conductive adhesive and/or solder may be applied for establishing electrical and also mechanical connections.

The cover 210 defining e.g. a protective cap may be placed at least partially on top of the electronic component 204. The cover 210 is configured to be attached to the substrate film 202 with e.g. adhesive, solder, and/or mechanical fixing such as screws, nails, bolts, or hook and loop fasteners (colloquially known as Velcro) applicable for securing the thermoformed cover 210 on the substrate film 202. The cover 210 protects and optionally secures the electronic components 204 when thermoplastic material 208 is further molded on the substrate film 202 already accommodating the electronic components 204. Additionally, the cover 210, which may indeed define a protective cap for the underlying electronics, may be configured to protect the electronics 204 from e.g. environmental conditions such as moisture, heat, cold, dirt, shocks, etc. Thermoforming from plastic sheet or film is a fast and low-cost procedure to obtain a cover with desired shapes to protect and secure the electronic com-

ponents 204. Additionally, the placing and attaching of the cover 210 may be provided so that the electronic components 204 are not damaged.

The cover 210 may substantially consist of or at least comprise at least one material selected from the group consisting of: polymer, thermoplastic material, PMMA (Polymethyl methacrylate), Poly Carbonate (PC), polyimide, a copolymer of Methyl Methacrylate and Styrene (MS resin), glass and Polyethylene Terephthalate (PET). The cover 210 may also consist of or comprise rubber or rubbery material, e.g. natural rubber such as latex or synthetic rubber such as styrene butadiene (SBR), polybutadiene (BR), polyether urethane (EU), or fluoro silicone (FMQ), etc. The elasticity of the rubbery material may be preferable at some situations. Additionally, the cover 210 may also consist of or at least comprise conductive metallic material such as aluminium, copper or other similar materials to provide e.g. a Faraday cage around the electronic components 204 to protect the components 204 from electric charges.

The material of cover 210 may in some embodiments be opaque. Alternatively, it may at least partially be optically transparent or translucent so that the visible light and/or electromagnetic radiation at some other predefined wavelength(s) are enabled to pass through it with negligible loss. The transmittance may be at least about 80%, 85%, 90%, or 95% at those wavelength(s). Alternatively or in addition, the thermoformed cover 210 may comprise a number of through-holes, cuts, and/or openings configured to enable e.g. the light emitted, detected and/or sensed by at least one electronic component 204 to propagate therewithin and outcouple therefrom. Generally, the holes or cuts may enable more efficient interaction of the embedded electronics with the environment outside the cover 210.

The shape and generally dimensions of the cover 210 may be decided application-specifically. The shape may be angular, rounded e.g. dome-shaped etc. The rounded-shaped cover 210 may exhibit better pressure distribution and/or durability. The shape and/or dimensions of the cover 210 may also be defined according to the shape and/or dimensions of the relating electronic components 204. The cover 210 may coat partially or completely the surface of the substrate film 202 that accommodates the electronic components 204. In Figure 2 the cover 210 extends at the edges of the substrate film 202 to overlay the (top surface of the) substrate film 202 completely. Alternatively, the cover 210 could overlap the substrate film 202 partially as illustrated in Figure 2,

where the cover 210 might alternatively end e.g. at the location of a dashed line 212.

Instead of or in addition to opaque material, the molded thermoplastic material 208 may comprise optically substantially transparent or translucent material so as to enable the visible light and/or electromagnetic radiation at some other predefined wavelength(s) to pass through it with negligible loss. The transmittance may be at least about 80%, 85%, 90%, or 95% at those wavelength(s). The radiation/light may be emitted, detected and/or sensed by the electronics 204 provided on the substrate film 202. The shape and generally dimensions of the molded layer 208 may be decided application-specifically. In Figure 2, the molded layer 208 exhibits a rectangular profile but e.g. a rounded profile is possible as well.

The thermoplastic material may comprise multiple layers, which is illustrated with a side view of an embodiment in Figure 3. The materials of thermoplastic layers 302, 304 may differ from each other in a variety of ways such as dimensions and/or thickness, elasticities, optical transparencies/transmittances, glass transition temperatures, and/or melting points. Also the functionalities of the different thermoplastic material layers 302, 304 may be different from each other.

In some optional embodiments as indicated by numeral 202B and the dashed potentially missing/removed portion 304B of molded second material 304 thereon, one or more edges or edge areas of the substrate 202 may indeed be left unmolded or the molded material may be removed therefrom afterwards so that e.g. electrical coupling to external elements and/or mounting is facilitated. Such edge portions may accommodate part of the conductors 206 for the purpose. Alternatively or additionally, the electrical coupling elements such as conductors could be funnelled from the inside of the multilayer structure 300 to the border/edge therefor in favour of external connectivity even if the substrate edge 202B was not kept free from the molded material.

Figure 4A presents a side view of one embodiment of e.g. planar type multilayer structure 400a according to the present invention comprising substrate film 202, a number of electronic components 204, one preferably thermoformed cover 210, and at least one thermoplastic material layer 208 molded thereon. The considerations set forth regarding Figure 2 or Figure 3 generally

apply also here and vice versa what comes to properties and configuration of different materials, dimensions, electronics, etc. The cover 210 may be placed at least partially on top of the multiple electronic components 204 for protecting and securing the electronic components 2104 when the thermoplastic material 208 is molded on the substrate film 202 accommodating the electronic components 204.

Another embodiment of a planar type multilayer structure 400b according to the present invention comprising substrate film 202, a number of electronic components 204, a plurality of at least functionally separable (e.g. in the light of target electronics such as components such as passive components or chips to be protected) if not physically separate, preferably thermoformed, covers 210, and at least one thermoplastic material layer 208 is illustrated in Figure 4B. The considerations set forth regarding Figure 2 or 3 generally apply also here and vice versa what comes to properties and configuration of different materials, dimensions, electronics, etc. Each cover 210 of said number may be placed at least partially on top of exactly one or at least one electronic component 204 for protecting and securing the underlying electronic component(s) 204 when the thermoplastic material 208 is molded on the substrate film 202 accommodating the components 204.

Some optional embodiments of multilayer structures according to the present invention may comprise combinations of the features of the embodiments presented in Figures 4A and 4B. Figure 4C thus illustrates a side view of one further embodiment, which discloses a multilayer structure 400c comprising a number of electronic components 204 and a number of preferably thermoformed covers 210, so that at least one cover 210 may be placed at least partially on top of exactly one electronic component 204 and at least one other cover 210 may be placed at least partially on top of a plurality of electronic components 204.

As alluded to above, the cover 210 layer may define or incorporate a substantially continuous piece or object of material for a plurality of thermoformed covers and/or discrete item for each thermoformed cover. In other words, functionally a plurality of thermoformed covers 210 may be provided as a one physically continuous object defining multiple suitable cover shapes such as domes or recesses depending on the viewpoint for the underlying electronics as illustrated in Figure 4B, or each of the thermoformed covers 210 may be provided

as a discrete object as illustrated in Figure 4C (on the right), or a combination of these approaches may be used to provide the thermoformed covers. A single cover or object of multiple covers may comprise one or more different materials. The cover materials may mutually differ even within a multilayer structure. And, the cover(s) 210 may at least collectively extend substantially completely over the surface of the concerned substrate film 202 that accommodates the electronics 204 as presented in Figures 4A and 4B, or the overlap may only be partial as presented in Figure 4C.

The dimensions and the thickness of the thermoformed cover 210 may vary from an embodiment to another. For example the dimensions may be defined by the dimensions of the electronic component(s) 204. The thickness of the established multilayer structure may be few hundreds of microns or one or few millimetres, for instance. Accordingly, the thickness of the molded thermoplastic layer 208, 302, 304 may be few hundreds of microns or e.g. one or few millimetres. The thickness of the molded thermoplastic layer 208, 302, 304 may be constant or vary. Accordingly, the order of magnitude of the size of the electronic components 204 may be generally similar or smaller so that the structure can still host and embed them to a sufficient extent. The dimensions and thickness of the substrate film 202 may also vary from an embodiment to another. The thickness may be about 100 microns or few hundred microns, or a millimetre, for instance. The dimensions of the cover 210 may generally be similar, for instance. Wall thicknesses of the cover 210 may be considerably less than the actual height of the cover 210 as the cover may define dome or other hollow space for accommodating protrusions of electronics 204 on the substrate 202 . The dimensions of the features of the embodiments illustrated in Figures are not in any particularly preferred scale with each other but have been mainly selected for clarity reasons instead.

Multilayer structures presented herein may find use in various electronic devices. For example, a portable electronic apparatus such as a wristop device could be provided with an embodiment of the structure, the structure optionally forming at least part of the associated wristband. Alternatively or additionally, the multilayer structures may be used in a light-emitting device, light-detecting device, light-sensing device, smart garment/wearable electronics, armband device, cellular device, tablet, phablet, controller device, computer mouse, joystick, other computer accessory, a display device, or a laptop computer. The suggested solution may further find use in vehicle electronics.

Figure 5 is a flow diagram disclosing an embodiment of a method according to the present invention.

At the beginning of the method for manufacturing the multilayer structure, a start-up phase 502 may be executed. During start-up 502, the necessary tasks such as material, component and tools selection, acquisition, calibration and other configuration may take place. Specific care must be taken that the individual elements and material selections work together and survive the selected manufacturing and installation process, which is naturally preferably checked up-front on the basis of the manufacturing process specifications and component data sheets, or by investigating and testing the produced prototypes, for example. The used equipment such as molding/IMD (in-mold decoration), lamination, bonding, thermoforming, and/or printing equipment, among others, may be thus ramped up to operational status at this stage.

At 504, at least one, preferably flexible, substrate film for accommodating electronics is obtained. A ready-made element of substrate material, e.g. roll of plastic film, may be acquired. In some embodiments the substrate film itself may be first produced in-house by molding or other methods from the desired starting material(s). Optionally, the substrate film is processed. It may be, for example, provided with openings, notches, recesses, cuts, reliefs, etc.

At 506, a number of conductive elements, such as conductor traces and contact areas (e.g. pads) for electrically coupling to the electronic components are provided on the substrate, preferably by one or more techniques of printed electronics. For example, screen, inkjet, flexographic, gravure or offset lithographic printing may be utilized. The traces may provide necessary electrical interconnections between the components and electronics in general.

At 508, electronics are provided on the substrate. Ready-made components such as various SMDs (surface-mount device) may be attached to the contact areas by solder and adhesives. Alternatively or additionally, printed electronics technology may be applied to actually manufacture at least part of the components, such as OLEDs (Organic LED), directly onto the film.

At 510, at least one cover for protecting and securing the electronic components is obtained. It is typically thermoformed. The thermoforming of the cover may be done by using a mold corresponding to the related electronic components, so that cover material is shaped in the presence of suction/heat accord-

ing to the shape of the mold. The cover is configured to be attached 512 to the substrate film on top of the electronic component(s) with e.g. adhesive, soldering, and/or mechanical fixing such as hook and loop fasteners (colloquially known as Velcro). Alternatively or additionally, the cover(s) may be produced directly on top of the related electronic component provided on substrate film. The covers may be provided well in advance and a number of covers provided in advance may be stored in the meantime. The covers may also be purchased as ready-made or almost ready-made.

In some embodiments, a number of through-holes may be provided 520 to the cover to enable e.g. the light emitted, detected and/or sensed by the at least one component to propagate therewithin and outcouple therefrom. The through-holes may be for example drilled or stamped through the cover after e.g. thermoforming and before attaching the cover to the substrate film on top of the electronic components. Alternatively, the through-hole may be provided to the cover before e.g. thermoforming. In case the cover is manufactured by molding, hole(s) may be produced by proper mold design. The though-holes may enable the thermoplastic material to be molded through the through-holes also inside the cover between the cover and the electronics. Alternatively, the through-holes may be dimensioned so that the molded thermoplastic material will not enter the through-hole during the molding procedure or enters the hole and following space e.g. in a limited, more controllable fashion.

At 514, the thermoplastic material is molded upon at least one side of the substrate film and at least partially covered electronics thereon, such as a number of electronic components, related traces and contact areas. The applicable molding methods include injection molding, for instance. In some embodiments a plurality of thermoplastic material layers may be utilized. The plurality of thermoplastic materials may be molded using a multi-shot molding method. A molding machine with multiple molding units may be utilized. Alternatively, multiple machines or a single re-configurable machine could be used for sequentially providing the materials.

Item 516, refers to possible post-processing tasks. Further layers may be added into the multilayer structure. The layers may be of indicative or aesthetic value, for instance, and contain e.g. textile or rubber materials instead of or in addition to further plastics. The structure may be installed at a host device or host element such as a piece of footwear (e.g. shoes or (in)sole), helmet, shirt,

trousers, compression garment, other garment, etc. Further elements such as electronics may be installed at the outer surface(s) of the structure, such as the exterior surface of the substrate.

At 518, method execution is ended.

Features reviewed in the preceding description may be used in combinations other than the combinations explicitly indicated. Although certain functions have been described with reference to certain features, those functions may be performable by other features whether described or not. Although some features have been described with reference to certain embodiments only, those features may also be present in other embodiments whether described or not.

CLAIMS

1. A multilayer structure (200, 300, 400a, 400b, 400c) for an electronic device, comprising

a flexible substrate film (202) for accommodating electronics (204),

at least one electronic component (204) provided on said substrate film (202),

a number of conductive traces (206) provided on said substrate film (202) for electrically powering and/or connecting electronics including said at least one electronic component (204), wherein

at least one, preferably thermoformed, cover (210) is attached to said substrate film (202) on top of said at least one electronic component (204), being overmolded with thermoplastic material (208).

2. The structure of claim 1, wherein said at least one cover comprises a cover (400a, 210) placed at on top of a plurality of electronic components (204).

3. The structure of any preceding claim, comprising at least two covers (400c, 210) placed at least partially on top of at least two electronic components (204) respectively.

4. The structure of any preceding claim, wherein a continuous, optionally monolithic, object (400b, 210) defines multiple cover shapes, each cover shape being configured to accommodate one or more electronic components

5. The structure of any preceding claim, wherein said at least one cover (210) extends over the surface of the substrate film (202) accommodating said at least one electronic component partially or completely.

6. The structure of any preceding claim, wherein said at least one cover (210) defines a number of optionally rounded, preferably dome-shaped, protective caps for electronics (204).

7. The structure of any preceding claim, wherein said at least one cover (210) comprises optically transparent or translucent material having regard to predefined electromagnetic wavelengths preferably including wavelengths of visible spectrum.

8. The structure of any preceding claim, wherein said at least one cover (210) comprises a number of through-holes optionally configured to enable the light emitted and/or detected by the at least one electronic component (201) to propagate therewithin and outcouple therefrom.

9. The structure of any preceding claim, wherein said substrate film (202) comprises optically transparent or translucent material as to predetermined electromagnetic wavelengths preferably including wavelengths of visible spectrum.

10. The structure of any preceding claim, wherein said thermoplastic material (208) comprises optically transparent or translucent material having regard to predefined wavelengths preferably including wavelengths of visible spectrum.

11. The structure of any preceding claim, wherein said thermoplastic material comprises a plurality of layers (302, 304), wherein the thermoplastic material layers (302, 304) exhibit different elasticities, optical transparencies/transmittances, glass transition temperatures, and/or melting points.

12. The structure of any preceding claim, wherein said at least one electronic component (204) includes at least one optoelectronic, light-emitting, light-detecting, and/or light-sensing component, preferably a LED (light-emitting diode) or photodiode.

13. An electronic device, optionally a light-emitting device, light-detecting device, light-sensing device, smart garment, smart compression garment, wristop device, armband device, cellular device, tablet, phablet, controller device, computer mouse, joystick, other computer accessory, a display device, or a laptop computer, comprising the structure of any preceding claim.

14. A method for manufacturing a multilayer structure for an electronic device, comprising

obtaining a flexible substrate film for accommodating electronics (504),

providing, preferably printing, a number of conductor traces on said substrate film for electrically powering and/or connecting electronic components and/or a number of predefined areas on the substrate (506),

providing at least one electronic component on said substrate film (508), preferably by means of printed electronics and/or surface mounting,

placing at least one preferably thermoformed cover at least partially on top of said at least one electronic component (510),

attaching said at least one cover to said substrate film (512), and

molding a thermoplastic material on said at least one thermoformed cover and substrate film accommodating the electronic components (514).

15. The method of claim 14, further comprising thermoforming the cover.

16. The method of any of claims 14-15, wherein said attaching comprises securing the at least one cover with adhesive, soldering, and/or mechanical fixing such as hook and loop fasteners.

17. The method of any of claims 14-16, wherein said molding comprises injection molding.

18. The method of any of claims 14-17, comprising providing a number of through-holes to the cover to enable the light emitted, detected and/or sensed by the at least one component to propagate therewithin and outcouple therefrom (520).

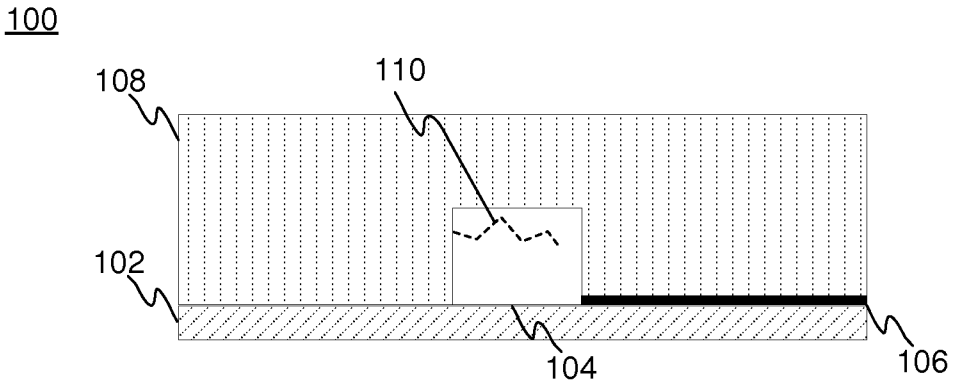


FIG. 1 PRIOR ART

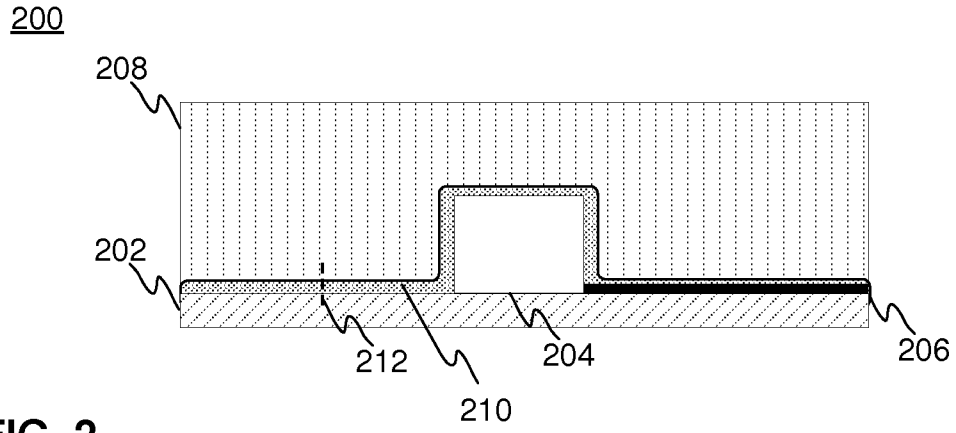


FIG. 2

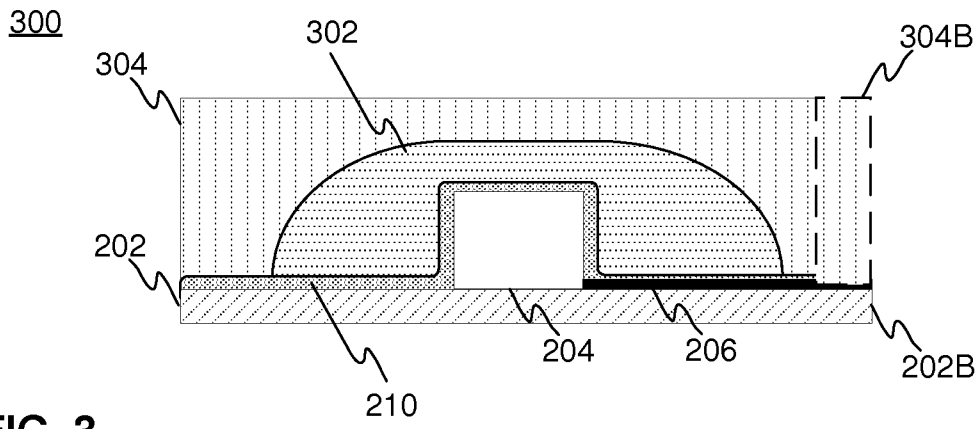


FIG. 3

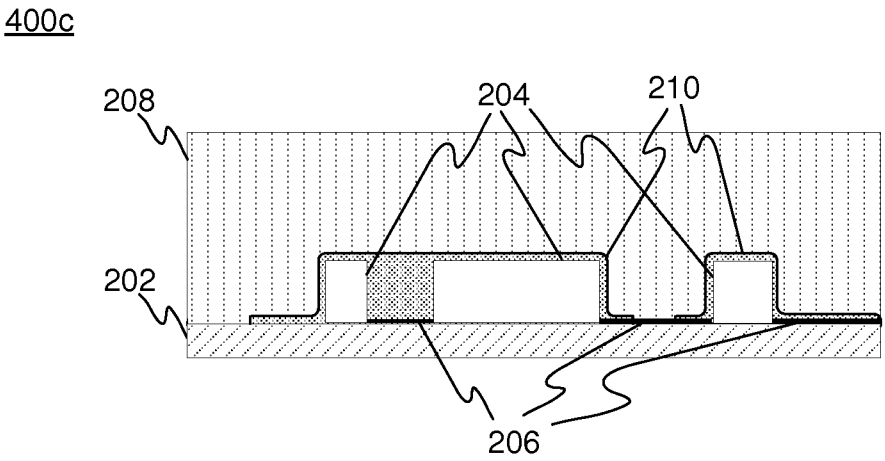


FIG. 4C

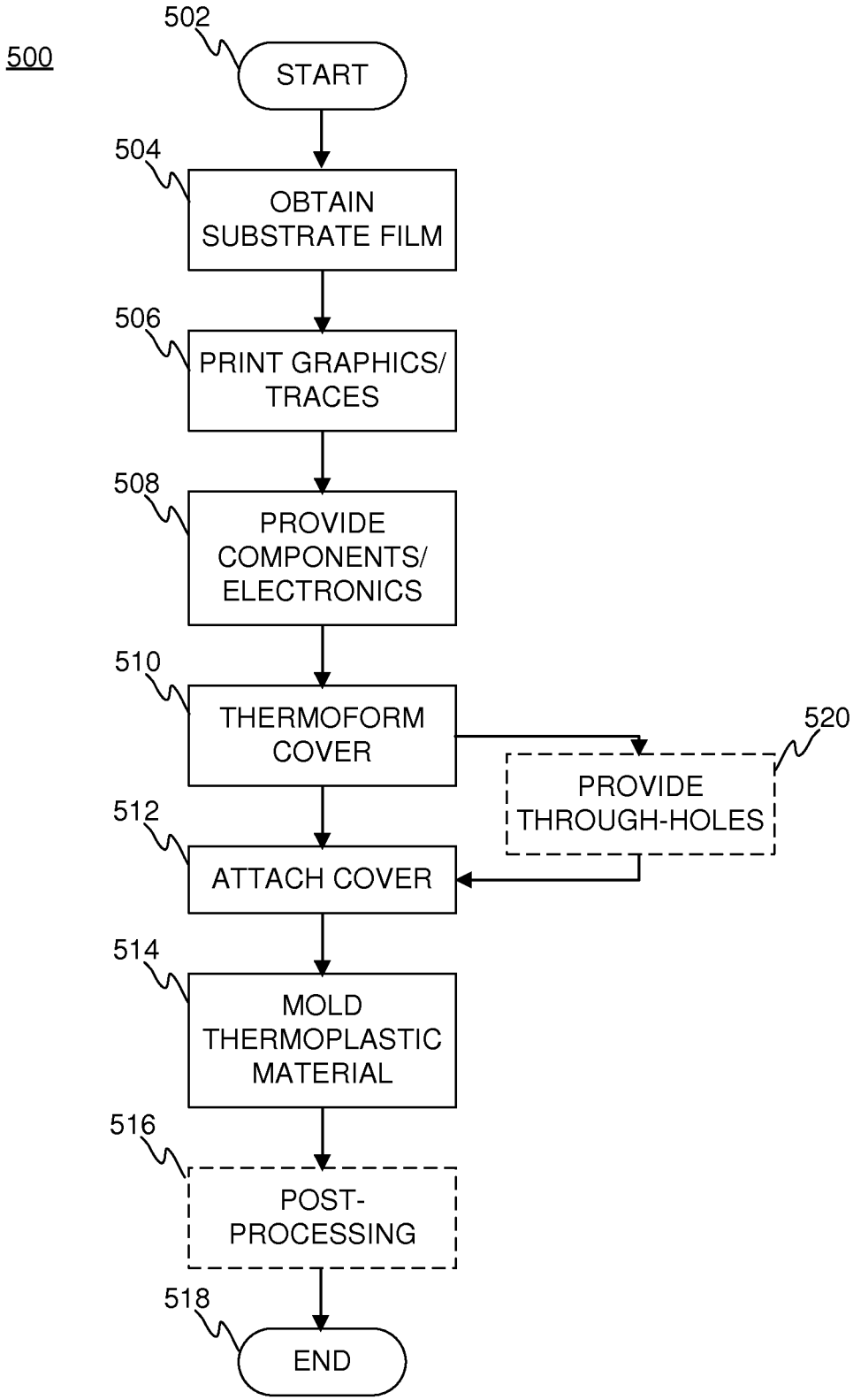

500
502
START
504
OBTAIN SUBSTRATE FILM
506
PRINT GRAPHICS/ TRACES
508
PROVIDE COMPONENTS/ ELECTRONICS
510
THERMOFORM COVER
520
PROVIDE THROUGH-HOLES
512
ATTACH COVER
514
MOLD THERMOPLASTIC MATERIAL
516
POST-PROCESSING
518
END

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2016/050337

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

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)

IPC: B32B, H05K, H01L, F21K

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

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPO-Internal & translations from EPO-database, WPIAP, PRH-Internal, XPAIP, XPESP, XPI3E, XPIEE, XPIETF, XPIOP, XPMISC, BIOSIS, COMPDX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009154182 A1 (VEENSTRA THOMAS J [US] et al.) 18 June 2009 (18.06.2009) paragraphs [0064], [0069]-[0073], [0095]-[0097], [0106], [0109]; figures 4-6, 14-15, 40 and 44-45; claims 1, 2, 11, 20-23, 27-29, 40, 41 and 45	1-18
X	ALAJOKI, T. et al. Hybrid In-Mould Integration for Novel Electrical and Optical Features in 3D Plastic Products, 4th Electronic System-Integration Technology Conference, ESTC 2012 (published 17.09.2012) chapter "Demonstrator 2 – Plastic Embedded Flexible OLED foil"; figures 1, 2 and 10	1, 5, 12-14, 17
X	US 2012201024 A1 (VAN DE VEN ANTONY PAUL [CN]) 09 August 2012 (09.08.2012) paragraphs [0057], [0076], [0077]; figures 2B and 2C; claims 1, 3, 21, 27, 28, 43 and 45	1, 13

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"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)	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search	Date of mailing of the international search report
29 August 2016 (29.08.2016)	30 August 2016 (30.08.2016)

Name and mailing address of the ISA/FI
Finnish Patent and Registration Office
P.O. Box 1160, FI-00101 HELSINKI, Finland
Facsimile No. +358 9 6939 5328

Authorized officer
Mika Lahelin
Telephone No. +358 9 6939 500

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2016/050337

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013299789 A1 (YAMAZAKI SHUNPEI [JP] et al.) 14 November 2013 (14.11.2013) paragraphs [0038], [0185]-[0197], [0224]-[0236]; figure 7; claims 1 and 6-8	1-18

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2016/050337

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2009154182 A1	18/06/2009	US 8230575 B2	31/07/2012
		CN 101918245 A	15/12/2010
		CN 101918245 B	01/05/2013
		EP 2232592 A2	29/09/2010
		EP 2232592 B1	17/07/2013
		EP 2240345 A1	20/10/2010
		EP 2240345 B1	18/09/2013
		US 2008253140 A1	16/10/2008
		US 7712933 B2	11/05/2010
		US 2010186214 A1	29/07/2010
		US 8408773 B2	02/04/2013
		WO 2009075924 A1	18/06/2009
		WO 2009076579 A2	18/06/2009
US 2012201024 A1	09/08/2012	US 9395057 B2	19/07/2016
		CN 103492801 A	01/01/2014
		WO 2012109060 A2	16/08/2012
US 2013299789 A1	14/11/2013	US 9088006 B2	21/07/2015
		JP 2014197522 A	16/10/2014
		KR 20130125715 A	19/11/2013
		US 2015325812 A1	12/11/2015

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2016/050337

CLASSIFICATION OF SUBJECT MATTER

IPC
B32B 27/08 (2006.01)
H05K 1/03 (2006.01)
H05K 3/28 (2006.01)
H05K 5/00 (2006.01)
H01L 23/538 (2006.01)
F21K 9/00 (2016.01)