METHOD OF FORMING AN OPTICAL STRUCTURE

Technical Field

Embodiments relate generally to a method of forming an optical structure, in particular, a method of forming optical waveguides and interconnects on a substrate.

Background

Optical devices, such as optical waveguides and interconnects, are commonly used in optical sensing systems as well as data communication systems. Optical waveguides and interconnects may be integrated with other types of optical components or electronic components to provide various functions.

Optical waveguides typically include a core layer surrounded by a cladding layer, wherein the refractive index of the core layer is higher than that of the cladding layer to allow a guided mode of light to form and transmit through the waveguides.

One approach for fabricating optical waveguides and interconnects is to selectively modify the refractive index of the material of the cladding layer or core layer by UV illumination.

Another approach for fabricating optical waveguides and interconnects is to selectively retain the high refractive material as core layer. For example, a conventional process includes depositing a lower cladding layer above a substrate, and depositing a core layer having high refractive index above the lower cladding layer. A photoresist layer or mask is then deposited on the core layer and is patterned to define the desired structure of the

core layer. The exposed core layer after patterning of the photoresist layer is etched away, and the photoresist layer or mask is then stripped or etched. Finally, an upper cladding layer is deposited above the patterned core layer and the lower cladding layer.

In the conventional approaches, the core layer need to be deposited over the entire substrate, and then selectively modified or removed to obtain the desired core layer structure. This would waste the core layer material in the fabrication process. Especially when the optical structure is to be formed on a portion of a substrate, substantial waste of material would be caused, as the material for the optical structure is formed over the entire substrate and then removed to expose other portions of the substrate having other electronic or optical components.

There is a need to save manufacturing material and reduce processing steps in the process of forming optical structure, thereby achieving a cost-saving fabrication process for optical structures.

Summary

Embodiments provide a method of forming an optical structure on a substrate. In an embodiment, the method may include forming a first cladding layer having a first cladding material on the substrate, forming a first photoresist layer on the first cladding layer, patterning the first photoresist layer to form one or more first openings, and depositing a core material selectively into the one or more first openings. The core material may form a core layer and the core layer may be in contact with the first cladding layer. The method may further include removing the first photoresist layer, and forming a second cladding layer having a second cladding material on the core layer and the first cladding layer.

Brief Description of the Drawings

In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the invention are described with reference to the following drawings, in which:

Fig. 1 shows a flowchart illustrating a method in accordance with one embodiment;

Figs. 2A-2H show a process of forming an optical structure according to an embodiment;

Fig. 3 shows the flowchart illustrating a method in accordance with another embodiment;

Figs. 4A-4L show a process of forming an optical structure according to another embodiment;

Figs. 5A-5K show a process of forming one or more optical structure according to an embodiment;

Figs. 6A-6D show a process of screen printing according to an embodiment;

Fig. 7A-7C show a process of screen printing according to another embodiment;

Fig. 8 shows an optical structure formed using the method according to an embodiment; and

Fig. 9 shows an optical structure formed using the method according to another embodiment.

Description

Embodiments provide a cost-saving method of forming an optical strucuture by selectively forming a core layer and/or cladding layers of the optical structure.

An embodiment provides a method of forming an optical structure on a substrate. The method may include forming a first cladding layer having a first cladding material on the substrate, forming a first photoresist layer on the first cladding layer, patterning the first photoresist layer to form one or more first openings, and depositing a core material selectively into the one or more first openings. The core material forms a core layer and the core layer is in contact with the first cladding layer. The method may further include removing the first photoresist layer, and forming a second cladding layer having a second cladding material on the core layer and the first cladding layer.

The one or more first openings may be formed such that they extend from the top surface of the first photoresist layer until the top surface of first cladding layer. The core material deposited into the one or more first openings is thus in contact with the first cladding layer.

According to an embodiment, the core material is deposited into the one or more first openings, such that a core layer in a patterned structure can be formed. The core material is deposited selectively into the first openings, which means that the core material is only deposited in the first openings that defines the patterned structure. In this manner, redundant core material does not need to be deposited and accordingly does not need to removed later, thereby saving manufacturing materials, manufacturing process and manufacturing time.

In one embodiment, the core material may be selectively deposited into the one or more first openings using printing technologies, such as screen printing or inkjet printing. Other examples of printing technologies may also be used in other embodiments, such as dispensing, gravure, slot die and transfer printing.

In another embodiment, the first cladding layer may be formed above the substrate by a process including forming a second photoresist layer on the substrate, patterning the second photoresist layer to form a second opening, and depositing the first cladding material selectively into the second opening. The first cladding material is in contact with the substrate. The second photoresist layer is then removed.

The second opening may be formed such that they extend from the top surface of the second photoresist layer until the top surface of substrate. The first cladding material deposited into the second opening is thus in contact with the substrate.

According to an embodiment, the first cladding material is deposited selectively into the second opening, such that the first cladding layer can be selectively formed on the substrate, e.g. in a patterned position defined by the second opening. The selective depositing of the first cladding material also save cladding material used in the fabrication process.

In one embodiment, the first cladding material may be selectively deposited into the second openings using printing technologies, such as screen printing or inkjet printing. Other examples of printing technologies, such as dispensing, gravure, slot die and transfer printing, may also be used in other embodiments.

In an alternative embodiment, the first cladding material may be deposited using other methods, such as chemical vapor deposition (CVD), plasma-enhanced CVD (PECVD), sol-gel, sputtering and vacuum evaporation. The first cladding material may be directly deposited to cover the surface of the substrate, without additional patterning and etching processes.

In a further embodiment, the second cladding layer may be formed above the core layer and the first cladding layer by a process including forming a third photoresist layer on the core layer and the first cladding layer, patterning the third photoresist layer to form one

or more third openings, and depositing the second cladding material selectively into the one or more third openings. The second cladding material is in contact with the core layer and the first cladding layer. The third photoresist layer is then removed, for example, by etching.

The one or more third openings may be formed such that the second cladding material deposited therein covers the core layer and the first cladding layer. Depending on the thickness of the third photoresist layer, the one or more third openings may be formed with the same depth or with different depths. In an illustrative embodiment wherein the third photoresist layer is thicker than the core layer and the first cladding layer, the one or more third openings may be formed with different depths, e.g., in two groups.One group of the third openings having a higher depth may be formed above the first cladding layer, and the other group of the third openings having a lower depth may be formed above the core layer. The second cladding material may be then deposited selectively into the two groups of the third openings to form the second cladding layer above the core layer and the first cladding layer.

According to an embodiment, the second cladding material is deposited selectively into the third openings using printing technologies, such as screen printing or inkjet printing. Other examples of printing technologies, such as dispensing, gravure, slot die and transfer printing, may also be used in other embodiments.

In an alternative embodiment, the second cladding material may be deposited using other methods, such as chemical vapor deposition (CVD), plasma-enhanced CVD (PECVD), sol-gel, sputtering and vacuum evaporation. The second cladding material may be directly deposited to cover the core layer and the first cladding layer, without additional patterning and etching processes.

In one embodiment, patterning of the first photoresist layer to form one or more first openings may be performed using photolithography, for example, by exposure and

development, to achieve the desired first openings. In other embodiments, patterning of the second photoresist layer in forming the first cladding layer and patterning of the third photoresist layer in forming the second cladding layer may be performed using photolithography as well.

In another embodiment, forming the optical structure on the substrate includes forming the optical structure selectively on a first portion of the substrate. The method may include forming the first cladding layer selectively on the first portion of the substrate, and forming the core layer and the second cladding layer selectively on the first cladding layer. The first cladding layer may be selectively formed on the first portion of the substrate by selectively depositing the first cladding material in the second opening selectively formed on the first portion of the substrate, and the core layer and the second cladding layer may be selectively formed on the first cladding layer similarly, as will be explained with regard to the figures below.

The substrate may include one or more electronic and/or micro-fluidics structure and/or other optical structures in or on a second portion of the substrate. For example, the so-formed device may integrate different components to provide a plurality of applications and functions. The method according to various embodiments above is therefore to form the optical structure only on a selected portion of the substrate, without affecting other portions of the substrate providing other functionalities.

According to an embodiment, the refractive index of the core material is higher than the respective refractive index of the first cladding material and the second cladding material. In this manner, light may be confined and transmitted within the core layer by total internal reflection.

In an embodiment, the substrate may include organic material, examples of which include but are not limited to polymer resin, epoxy resin, plastic, or thermosetting plastic. The substrate may include semiconductor material or glass in other embodiments.

The first cladding material and/or the second cladding material may be selected from one of the following: polymers and hybrid organic/inorganic sol-gel materials. Examples of polymers that are used as the first cladding material and/or the second cladding material may include, but are not limited to, polyimide, cycloolefin-copolymer and polymethyl methacrylene. In an embodiment, the first cladding material and the second cladding material may be selected as the same material.

The core material may be selected from one of the following: polymers and hybrid organic/inorganic sol-gel materials. Examples of polymers that are used as the core material may include, but are not limited to, polyimide, cycloolefin-copolymer and polymethyl methacrylene.

In an embodiment, the method according to the above embodiments of the invention forms a polymer optical structure, e.g. polymer optical waveguide and/or interconnects, above an organic substrate. Polymer optical structure on organic substrate allows more design flexibility and cost saving.

Fig. 1 shows a flowchart illustrating a method of forming an optical structure on a substrate according to an embodiment of the invention.

At 102, a first cladding layer is formed on the substrate, wherein the first cladding layer including a first cladding material, for example, selected as polymer or other material as described in the embodiments above.

At 104, a first photoresist layer is formed on the first cladding layer.

At 106, the first photoresist layer is patterned to form one or more first openings.

At 108, a core material is deposited selectively into the one or more first openings, wherein the core material forms a core layer and the core layer is in contact with the first cladding layer. The core material may be polymer or other material as described in the embodiments above.

At 110, the first photoresist layer is removed, e.g. to expose the first cladding layer covered by the patterned first photoresist layer.

At 112, a second cladding layer is formed on the core layer and the first cladding layer, wherein the second cladding layer includes a second cladding material which may be selected as polymer or other material as described in the embodiments above.

Figs. 2A – 2H show a process of forming an optical structure according to an embodiment.

In Fig. 2A, a substrate 202 is provided, which may include organic material or semiconductor material.

In Fig. 2B, a first cladding layer 204 is formed on the substrate 202 using printing technology, such as screen, inkjet, dispensing, gravure, slot die and transfer printing, or other technologies, such as chemical vapor deposition (CVD), plasma-enhanced CVD (PECVD), sol-gel, sputtering and vacuum evaporation.

In Fig. 2C, a photoresist layer 206, such as a layer of photo sensitive polymer material is coated or laminated on the first cladding layer 204. The photoresist layer 206 may be cured by heating to improve the adhesion to the first cladding layer 204.

In Fig. 2D, the photoresist layer 206 is selectively exposed to ultraviolet (UV) illumination 210 through an artwork or mask 208. Depending on the nature of the photoresist layer 206, the exposed or non-exposed area 212 of the photoresist layer 206 is reacting with the UV illumination 210.

In Fig. 2E, a developing process with chemical solution is performed to remove the exposed or non-exposed area 212 depending on the nature of the photoresist layer 206, thereby forming one or more openings 214. As a result, the photoresist layer 206 is patterned to form the one or more openings 214, within which a core layer may be formed.

In Fig. 2F, optical material 216 (such as polymer) having a higher refractive index than the first cladding layer 204, is selectively deposited into the openings 214 in the photoresist layer 206 by printing or coating. The optical material may be cured by thermal or UV illumination depending on the properties of the optical material. The optical material 216 deposited into the openings 214 forms a core layer 216.

In Fig. 2G, the photoresist layer 206 is stripped of, e.g., using wet or dry chemical etching technologies, to expose the core layer 216 and the first cladding layer 204.

In Fig. 2H, a second cladding layer 220 is deposited above the core layer 216 and the first cladding layer 204, thereby forming the entire optical waveguide and interconnects on the substrate.

In other embodiments, the optical structure may be formed on a portion of the substrate as described below.

Fig. 3 shows a flowchart illustrating a method of forming an optical structure according to another embodiment.

At 302, a second photoresist layer is formed on a substrate.

At 304, the second photoresist layer is patterned to form a second opening. The second opening may be at a predetermined portion or position of the substrate.

At 306, a first cladding material, for example, selected as polymer or other material as described in the embodiments above, is deposited selectively into the second opening. The first cladding material forms a first cladding layer and is in contact with the substrate. Accordingly, the first cladding layer selectively formed in the second opening may be

positioned at a portion of the substrate, which does not affect other portions of the substrate which may include other electronic, micro-fluid, or optical components.

At 308, the second photoresist layer is removed.

At 310, a first photoresist layer is formed on the first cladding layer.

At 312, the first photoresist layer is patterned to form one or more first openings.

At 314, a core material is deposited selectively into the one or more first openings, wherein the core material forms a core layer and the core layer is in contact with the first cladding layer. The core material may be polymer or other material as described in the embodiments above.

At 316, the first photoresist layer is removed, e.g. to expose the first cladding layer covered by the patterned first photoresist layer.

At 318, a second cladding layer is formed on the core layer and the first cladding layer, wherein the second cladding layer includes a second cladding material which may be selected as polymer or other material as described in the embodiments above.

Figs. 4A – 4L show a process of forming an optical structure according to another embodiment.

In Fig. 4A, a substrate 402 is provided, which may include organic material or semiconductor material. The substrate 402 may be a functional substrate, e.g. an electrical circuit board or an optical circuit board, which may include electronic, micro-fluidic, or optical components 404 on a portion of the substrate 402.

In Fig. 4B, a second photoresist layer 406, such as a layer of photo sensitive polymer material, is formed on the substrate 402, covering the entire substrate including the potion of the functional components 404 as shown in Fig. 4B. In other embodiments, the second photoresist layer 406 may also be formed to selectively cover part of the substrate, e.g. the portion of the substrate on which the optical structure is to be formed and the portion of the

substrate including the functional components 404. The second photoresist layer 406 may be cured by heating to improve its adhesion to the substrate 402.

In Fig. 4C, the second photoresist layer 406 is selectively exposed to UV light 410 through an artwork or mask 408. The mask 408 may define the region 412 of the second photoresist layer 406 which is to react with the UV light 410.

In Fig. 4D, a developing process with chemical solution is performed to remove the exposed or non-exposed area 412 depending on the nature of the second photoresist layer 406, thereby forming a second opening 414. As a result, the second photoresist layer 406 is patterned to form the second opening 414, within which a first cladding layer may be formed. The second opening 414 may be formed on a first portion 416 of the substrate, which is a different portion from a second portion 418 of the substrate 402 having other components 404.

In Fig. 4E, optical material 420 is selectively deposited into the second opening 414 in the second photoresist layer 406 by printing or coating. The optical material 420 may be cured by thermal or UV illumination depending on the properties of the optical material. The optical material 420 deposited into the second opening 414 forms a first cladding layer 420.

In Fig. 4F, the second photoresist layer 406 is stripped of, e.g., using wet or dry etching, to expose the first cladding layer 420 at the first portion 416 of the substrate 402 and the components 404 at the second portion 418 of the substrate 402.

The above process forms a first cladding layer 420 (or referred to as the lower cladding layer) selectively on a portion of the substrate 402. Similar process may be used to selectively form a core layer on the first cladding layer as described in the following.

In Fig. 4G, a first photoresist layer 422 is coated or laminated on the first cladding layer 420. The second portion 418 of the substrate including the components 404 is also

covered with by the first photoresist layer 422. The first photoresist layer 422 may be cured by heating to improve the adhesion to the underlying structures.

In Fig. 4H, the first photoresist layer 422 is selectively exposed to ultraviolet (UV) illumination 426 through a mask 424. Depending on the nature of the first photoresist layer 422, the exposed or non-exposed area 428 of the first photoresist layer 422 is reacting with the UV illumination 426.

In Fig. 4I, a developing process with chemical solution is performed to remove the exposed or non-exposed area 428 depending on the nature of the first photoresist layer 422, thereby forming one or more first openings 430. As a result, the first photoresist layer 422 is patterned to form the one or more first openings 430, within which a core layer may be formed.

In Fig. 4J, optical material 432 (such as polymer) having a higher refractive index than the first cladding layer 420, is selectively deposited into the first openings 430 in the first photoresist layer 422 by printing or coating. The optical material may be cured by thermal or UV illumination depending on the properties of the optical material. The optical material 432 deposited into the first openings 430 forms a core layer 432.

In Fig. 4K, the first photoresist layer 422 is stripped of, e.g., using wet or dry chemical etching technologies, to expose the core layer 432 and the first cladding layer 420. The other components 404 at the second portion of the substrate 402 are also exposed.

In Fig. 4L, a second cladding layer 434 is deposited above the core layer 432 and the first cladding layer 420, thereby forming the entire optical waveguide and interconnects on the substrate 402. The second cladding layer 434 may include optical material which has a lower refractive index than the material of the core layer 432. In an exemplary embodiment, the second cladding layer 434 may include the same material as the first cladding layer 420.

It is noticed that the second cladding layer 434 is selectively deposited on the core layer 432 and the first cladding layer 420 positioned at the first portion 416 of the substrate 402, without affecting the second portion 418 of the substrate 402 having other functional components 404. The second cladding layer 434 may be selectively formed using the similar process for selectively forming the first cladding layer 420 and the core layer 432, including forming a photoresist layer, patterning the photoresist layer to form one or more openings on the selected positions, depositing optical materials selectively into the one or more openings using printing technologies for example, and removing the photoresist layer to expose the second cladding layer formed within the one or more openings.

Figs. 5A – 5K show a process of forming one or more optical structure according to an embodiment.

In Fig. 5A, a substrate 502 is provided, which may include organic material or semiconductor material. The substrate 502 may be a functional substrate, e.g. an electrical circuit board or an optical circuit board, which may include electronic, micro-fluidic, or optical components 504 on a portion of the substrate 502.

In Fig. 5B, a second photoresist layer 506, such as a layer of photo sensitive polymer material, is formed on the substrate 502, covering the entire substrate including the potion of the functional components 504 as shown in Fig. 5B. In other embodiments, the second photoresist layer 506 may also be formed to selectively cover part of the substrate where the optical structure is to be formed. The second photoresist layer 506 may be cured by heating to improve its adhesion to the substrate 502.

In Fig. 5C, the second photoresist layer 506 is selectively exposed to UV light 510 through an artwork or mask 508. The mask 508 may define one or more regions 512 (in this example, two regions 512) of the second photoresist layer 506 which can react with the UV light 510.

In Fig. 5D, a developing process with chemical solution is performed to remove the exposed or non-exposed area 512 depending on the nature of the second photoresist layer 506, thereby forming one or more second openings 514 (in this example, two openings 514). As a result, the second photoresist layer 506 is patterned to form the one or more second openings 514, within which a first cladding layer may be formed. In this illustrative example, one of the second openings 514 may be formed on a first portion 516 of the substrate, and the other of the second openings 514 may be formed on a second portion 518 of the substrate 502 having other functional components 504.

In Fig. 5E, optical material 520 is selectively deposited into the second openings 514 in the second photoresist layer 506 by printing or coating. The optical material 520 may be cured by thermal or UV illumination depending on the properties of the optical material. The optical material 520 deposited into the second openings 514 forms a first cladding layer 520.

In Fig. 5F, the second photoresist layer 506 is stripped of, e.g., using wet or dry etching, to expose the first cladding layer 520. In this example, the first cladding layer 520 comprises two portions, wherein one portion is above the first portion 516 of the substrate 502 and another portion is covering the components 504 at the second portion 518 of the substrate 502.

The above process forms a first cladding layer 520 (or referred to as the lower cladding layer) selectively on one or more portions of the substrate 502. Similar process may be used to selectively form a core layer on the first cladding layer as described in the following.

In Fig. 5G, a first photoresist layer 522 is coated or laminated on the first cladding layer 520. The first photoresist layer 522 may be cured by heating to improve the adhesion to the underlying structures. The first photoresist layer 522 is then selectively exposed to

ultraviolet (UV) illumination 526 through a mask 524. Depending on the nature of the first photoresist layer 522, the exposed or non-exposed area 528 of the first photoresist layer 522 is reacting with the UV illumination 526.

In Fig. 5H, a developing process with chemical solution is performed to remove the exposed or non-exposed area 528 depending on the nature of the first photoresist layer 522, thereby forming one or more first openings 530. As a result, the first photoresist layer 522 is patterned to form the one or more first openings 530, within which a core layer may be formed. In this example, some first openings 530 are formed on the first cladding layer 520 above the first portion 516 of the substrate 502, and other first openings 530 are formed on the first cladding layer 520 above the second portion 518 of the substrate 502.

In Fig. 5I, optical material 532 (such as polymer) having a higher refractive index than the first cladding layer 520, is selectively deposited into the first openings 530 in the first photoresist layer 522 by printing or coating. The optical material may be cured by thermal or UV illumination depending on the properties of the optical material. The optical material 532 deposited into the first openings 530 forms a core layer 532. In this example, the core layer 532 is formed on both the first portion 516 and the second portion 518 of the substrate 502.

In Fig. 5J, the first photoresist layer 522 is stripped of, e.g., using wet or dry chemical etching technologies, to expose the core layer 532 and the first cladding layer 520. The first cladding layer 520 covering the other components 504 at the second portion of the substrate 402 is also exposed.

In Fig. 5K, a second cladding layer 534 is selectively deposited above the core layer 532 and the first cladding layer 520 formed on the first portion 516 of the substrate 502 and on the second portion 518 of the substrate 502 , thereby forming the respective optical waveguides and interconnects on the substrate 502. The second cladding layer 534 may

include optical material which has a lower refractive index than the material of the core layer 532. In an exemplary embodiment, the second cladding layer 534 may include the same material as the first cladding layer 520.

The second cladding layer 534 is selectively deposited on the core layer 532 and the first cladding layer 520, without affecting the portion of the substrate 502 not covered by the first cladding layer 520. The second cladding layer 534 may be selectively formed using the similar process for selectively forming the first cladding layer 520 and the core layer 532, including forming a photoresist layer, patterning the photoresist layer to form one or more openings on the selected positions, depositing optical materials selectively into the one or more openings using printing technologies for example, and removing the photoresist layer to expose the second cladding layer formed within the one or more openings.

In the above example as illustrated in Figs. 5A-5K, two optical structures are formed on the same substrate 502. One optical structure is formed on the first portion 516 of the substrate 502, and comprises a first cladding layer 520, a core layer 532 and a second cladding layer 534. The other optical structure is formed on the second portion 518 of the substrate 502, and comprises a first cladding layer 520 covering other functional components 504 formed on the substrate 502, a core layer 532 and a second cladding layer 534. By the process as described in the above embodiments, one or more optical structures may be formed on a substrate in the same process, thereby saving the manufacturing time and costs.

The process for selectively forming the cladding layer or the core layer using printing technologies in the embodiments above is described in detail below.

Figs. 6A – 6D show a process of screen printing according to an embodiment.

In Fig. 6A, a substrate 602, which may include functional components 604, is provided. The substrate 602 is coated with a photoresist layer 606 covering the entire substrate, including a first portion 616 and a second portion 618 of the substrate. An

opening 614 is formed in the photoresist layer 606 at the first portion 616 of the substrate, e.g., using photolithography. A screen or mask 640 is provided on the photoresist layer 606. The screen or mask 640 includes a patterned opening or mesh 642 corresponding to the opening 614 formed in the photoresist layer 506.

In Fig. 6B, a squeegee blade 644 is provided to apply optical material 646 into the opening 614 in the photoresist layer 606 through the patterned opening or mesh 642 of the screen 640. The optical material 646 may in this example be the material for the cladding layer, and is only selectively deposited into the opening 614 in the photoresist layer 606.

In Fig. 6C, the optical material 646 deposited into the opening 614 of the photoresist layer 606 forms a cladding layer 620. The screen or mask 640 is then removed.

In Fig. 6D, the photoresist layer 606 is removed to expose the cladding layer 620 and the functional components 604.

Similar printing process as illustrated in Figs. 6A – 6D may be applied to form the core layer as well.

Figs. 7A-7C show a process of screen printing according to another embodiment.

In Fig. 7A, a substrate 702 is provided. The substrate 702 may include a first portion 716 and a second portion 718 including functional components 704. This embodiment simply utilizes a screen or mask 740 with patterned opening or mesh 742, different from the embodiment of Figs. 6A-6D using a photoresist layer to pre-define openings within the photoresist layer. The patterned opening or mesh 742 is formed to correspond to a desired structure/position on the substrate, e.g., on the first portion 716 of the substrate 702.

In Fig. 7B, a squeegee blade 744 is provided to force optical material 746 onto the substrate 702 through the patterned opening or mesh 742 of the screen 740. The optical material 746 may be the material for the cladding layer or the core layer. By applying optical material 746 through the patterned opening or mesh 742, optical material 746 is

selectively deposited only in a structure/position on the substrate 702 corresponding to the patterned opening or mesh 742.

In Fig. 7C, the optical material 746 deposited onto the substrate 702, in this example onto the first portion 716 of the substrate 702, forms a cladding layer 720. The screen or mask 740 is then removed to expose the cladding layer 720 and the functional components 704.

Similar printing process as illustrated in Figs. 7A – 7C may be applied to form the core layer as well.

Fig. 8 shows an optical structure formed using the method according to an embodiment.

The optical structure is a three-layer structure formed on a substrate 802, including a first cladding layer 804, a core layer 806 formed on the first cladding layer 804, and a second cladding layer 808 formed on the first cladding layer 804 and the core layer 806. The core layer is formed selectively in a predetermined position or pattern, such as a predetermined.

Fig. 9 shows an optical structure formed using the method according to another embodiment.

Similar to the optical structure of Fig. 8, the optical structure formed on a substrate 902 in Fig. 9 includes a first cladding layer 904, a core layer 906 formed on the first cladding layer 904, and a second cladding layer 908 formed on the first cladding layer 904 and the core layer 906.

The optical structure is selectively formed on a portion of the substrate, e.g. on a first portion 910 of the substrate 902. The other portion of the substrate, e.g. a second portion 920 of the substrate 902 which may include other electronic, optical or micro-fluidic components 922, is separate from and not affected by the optical structure on the first portion 910 of the substrate 902. In this manner, the optical structure as formed according to the

method in accordance with various embodiments can be integrated with other components on the same substrate.

The method of forming the optical structure according to various embodiments therefore achieves selective deposition of cladding layers and/or core layer on the substrate, which is advantageous in cost-saving of optical materials as well as processing steps. A high aspect-ratio of the core layer can also be achieved using the method of the above embodiments. Further, non-UV sensitive material may be used for the core layer, as the core layer does not need to be partially modified to reach the desired pattern.

While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

What is claimed is:

1. A method of forming an optical structure on a substrate, the method comprising:

forming a first cladding layer on the substrate, the first cladding layer comprising a first cladding material,

forming a first photoresist layer on the first cladding layer,

patterning the first photoresist layer to form one or more first openings,

depositing a core material selectively into the one or more first openings, wherein the core material forms a core layer and the core layer is in contact with the first cladding layer,

removing the first photoresist layer, and

forming a second cladding layer on the core layer and the first cladding layer, the second cladding layer comprising a second cladding material.

2. The method of claim 1,

wherein depositing the core material selectively into the one or more first openings comprises using printing selected from one of the following: screen, inkjet, dispensing, gravure, slot die and transfer printing.

3. The method of claim 1,

wherein forming the first cladding layer above the substrate comprises:

forming a second photoresist layer on the substrate;

patterning the second photoresist layer to form a second opening;

depositing the first cladding material selectively into the second opening, wherein the first cladding material is in contact with the substrate, and

removing the second photoresist layer.

4. The method of claim 3,

wherein depositing the first cladding material selectively into the second opening comprises using printing selected from one of the following: screen, inkjet, dispensing, gravure, slot die and transfer printing.

5. The method of claim 1,

wherein forming the second cladding layer comprises:

forming a third photoresist layer on the core layer and the first cladding layer;

patterning the third photoresist layer to form one or more third openings;

depositing the second cladding material selectively into the one or more third openings, wherein the second cladding material is in contact with the core layer and the first cladding layer, and

removing the third photoresist layer.

6. The method of claim 5,

wherein depositing the second cladding material selectively into the one or more third openings comprises using printing selected from one of the following: screen, inkjet, dispensing, gravure, slot die and transfer printing.

7. The method of claim 1,

wherein patterning the first photoresist layer comprises using photolithography.

8. The method of claim 1, further comprising

forming the optical structure selectively on a first portion of the substrate, which comprises:

forming the first cladding layer selectively on the first portion of the substrate, and

forming the core layer and the second cladding layer selectively on the first cladding layer.

9. The method of claim 8,

wherein one or more electronic and/or micro-fluidics structures are comprised in/on a second portion of the substrate.

10. The method of claim 1,

wherein the refractive index of the core material is higher than the respective refractive index of the first cladding material and the second cladding material.

11. The method of claim 1,

wherein the substrate comprises an organic material or a semiconductor material.

12. The method of claim 1,

wherein the first cladding material and/or the second cladding material is selected from one of the following: polymers, and hybrid organic/inorganic sol-gel materials.

13. The method of claim 1,

wherein the first cladding material and/or the second cladding material is selected from one of the following polymers: polyimide, cycloolefin-copolymer, polymethyl methacrylene.

14. The method of claim 1,

wherein the core material is selected from one of the following: polymers, and hybrid organic/inorganic sol-gel materials.

15. The method of claim 1,

wherein the core material is selected from one of the following polymers: polyimide, cycloolefin-copolymer, polymethyl methacrylene.