embodiments, it is important to provide reliable, compact, and cost effective means to energize components within an ophthalmic device. In some embodiments, these energization elements may include batteries that may in turn be formed from "alkaline" cell-based chemistry. Connected to these energization elements may be other components that utilize electrical energy. In some embodiments, these other components may include transistors to perform circuit functions. It may also be desirable to include semiconductor devices in such devices organic.

SUMMARY

Accordingly, the present invention includes methods and apparatus to define organic semiconductor transistors upon one or more ophthalmic lens insert surfaces which may contain three-dimensional shapes and which may be inserted into an ophthalmic device. In some embodiments, an ophthalmic lens insert is provided that may be energized and incorporated into an ophthalmic device.

In some embodiments, a method of forming an ophthalmic device comprising depositing an organic semiconductor layer on a substrate, dividing the substrate into insert pieces wherein each insert piece comprises an organic semiconductor, attaching an insert piece onto an ophthalmic lens insert, and forming an encapsulating layer around the ophthalmic lens insert are disclosed

In some embodiments, the substrate is silicon wafer. In some embodiments, the encapsulating layer is parylene. In some other embodiments, the encapsulating layer is forming a hydrogel around the lens insert.

In some embodiments, methods of forming at least a first gate conductor on the substrate are disclosed. In some embodiments, additionally methods of depositing an energization element upon the substrate in electrical communication with the first gate conductor are disclosed. In some embodiments, the energization element is an electrochemical cell.

In some embodiments, the organic semiconductor layer comprises an n-type organic semiconductor. In some embodiments, the organic semiconductor layer comprises a p-type organic semiconductor. In some embodiments, the organic semiconductor layer comprises an n-type organic semiconductor, a p-type organic semiconductor, and a combination thereof. In some embodiments, the n-type organic

semiconductor layer comprises copper hexadecafluorophthalocyanine ($F_{15}CuPc$). In some embodiments, the p-type organic semiconductor layer comprises pentacene.

In some embodiments, the energization element is comprised of more than one electrochemical cell, which are connected at least in part in a series manner. In some embodiments, the first gate conductor comprises a transparent electrode. In some embodiments, the transparent electrode comprises indium tin oxide.

In some embodiments, the ophthalmic lens insert may be formed in a number of manners to result in a three-dimensional shape upon which organic semiconductor transistors and other electrical devices may be formed. Non-limiting examples of electrical devices include resistors, capacitors, diodes, inductors, and similar such devices. Thereafter, energization elements may be formed in contact with or upon these organic semiconductor devices. In some embodiments, the energization elements may be formed by applying films that contain battery cell-related chemicals to electrical interconnections. In some other embodiments, the energizing elements may also be used in creating circuits of the organic semiconductor devices. In related embodiments, the application may be performed by printing processes that may apply mixtures of the chemicals by using needles or other application tools.

An ophthalmic lens may be formed by encapsulating a three-dimensionally formed ophthalmic insert in polymerized material. A method of forming the lens may include the polymerization of a reactive mixture between mold pieces where the ophthalmic insert is placed before polymerization. In some embodiments, numerous functional components or regions may be located within the ophthalmic insert. In some embodiments, the insert may contain at least one transistor that is formed from an organic semiconductor layer. Other common elements may include, but are not limiting to, conductive traces, energization elements, activation elements, and active ophthalmic devices. The active ophthalmic devices may be capable of dynamically changing the focal characteristics of the light that passes through the ophthalmic lens. A non-limiting example of a component capable of dynamically changing the focal characteristics may include a liquid meniscus lens element. Non-limiting examples of activation elements may include pressure sensitive switches, and magnetic field sensors. Non-limiting examples of magnetic field sensors may include Hall Effect

Proceeding to Fig. 4, parallel processing flows 400 and 450 are illustrated that produce complementary p- and n-type organic semiconductor devices. At step 410 for each type of device the substrate may be a flat or planar upon which the devices may be formed. Next, at step 415, a metallic or conductive material is deposited to form the gate electrode in this "bottom gate" electrode type of processing flow. There may be numerous means to form the gate electrode including screened deposition from a sputtered or evaporated source. Other methods may include blanket deposition followed by patterned etching processes. Any method of forming isolated conductive gate structures may be consistent with the art herein.

In the following step 420, a gate dielectric layer is deposited to cover and surround the gate electrode. An effective method for this deposition may be to spin on the dielectric from a liquid precursor followed by curing. In other embodiments, the dielectric may be deposited by vapor deposition. In some embodiments, the dielectric may be subsequently planarized by a technique such as, but not limiting to, chemical mechanical polishing.

Referring back to Fig. 4, at step 425, the n-type organic semiconductor layer may be deposited upon the dielectric layer. This deposition may be regionally controlled by masked deposition of vapor phase forms of the organic semiconductor. In other embodiments, a blanket film may be applied followed by a patterned removal process. In some other embodiments, at 426, the n-type organic semiconductor layer may not be present. In some examples of ambipolar devices, the n-type organic semiconductor film may be present in the p-type devices and then later covered by p-type organic semiconductor material (not shown). Some materials for this layer may include N, N'-bis(n-octyl)-dicyanoperylene-3,4,9,10-bis(dicarboximide) otherwise called (PDI-8CN2); carbonyl functionalized (α,ω-diperfluorohexyl-4T) otherwise called (DFHCO-4T) and copper hexadecafluorophthalocyanine otherwise called ($F_{15}CuPc$) as a few non-limiting exemplary options.

Referring back to Fig. 4, at step 456, the p-type organic semiconductor layer may be deposited upon the dielectric layer. This deposition may be regionally controlled by masked deposition of vapor phase forms of the organic semiconductor.

CLAIMS

1. A method of forming an ophthalmic device comprising:

depositing an organic semiconductor layer on a substrate;

dividing said substrate into insert pieces wherein each insert piece comprises an organic semiconductor;

attaching an insert piece onto an ophthalmic lens insert; and

forming an encapsulating layer around the ophthalmic lens insert.

2. The method of claim 1, wherein the substrate is silicon wafer.

3. The method of claim 1, wherein the encapsulating layer is paralene.

4. The method of claim 3, wherein the encapsulating layer is forming a hydrogel around the lens insert.

5. The method of claim 4 additionally comprising:

forming at least a first gate conductor on the substrate.

6. The method of claim 5 additionally comprising:

depositing an energization element upon the substrate in electrical communication with the first gate conductor.

7. The method of claim 6 wherein:

the energization element is an electrochemical cell.

8. The method of claim 1, wherein the organic semiconductor layer comprises an n-type organic semiconductor.

9. The method of claim 1, wherein the organic semiconductor layer comprises a p-type organic semiconductor.

10. The method of claim 1, wherein the organic semiconductor layer comprises an n-type organic semiconductor, a p-type organic semiconductor, and a combination thereof.

11. The method of claim 8, wherein the n-type organic semiconductor layer comprises copper hexadecafluorophthalocyanine ($F_{15}CuPc$).

12. The method of claim 9, wherein the p-type organic semiconductor layer comprises pentacene.

13. The method of claim 6, wherein the energization element is comprised of more than one electrochemical cell which are connected at least in part in a series manner.

14. The method of claim 5, wherein the first gate conductor comprises a transparent electrode.

15. The method of claim 14, wherein the transparent electrode comprises indium tin oxide.

embodiments, it is important to provide reliable, compact, and cost effective means to energize components within an ophthalmic device. In some embodiments, these energization elements may include batteries that may in turn be formed from "alkaline" cell-based chemistry. Connected to these energization elements may be other components that utilize electrical energy. In some embodiments, these other components may include transistors to perform circuit functions. It may also be desirable to include semiconductor devices in such devices organic.

SUMMARY

Accordingly, the present invention includes methods and apparatus to define organic semiconductor transistors upon one or more ophthalmic lens insert surfaces which may contain three-dimensional shapes and which may be inserted into an ophthalmic device. In some embodiments, an ophthalmic lens insert is provided that may be energized and incorporated into an ophthalmic device.

In some embodiments, a method of forming an ophthalmic device comprising depositing an organic semiconductor layer on a substrate, dividing the substrate into insert pieces wherein each insert piece comprises an organic semiconductor, attaching an insert piece onto an ophthalmic lens insert, and forming an encapsulating layer around the ophthalmic lens insert are disclosed

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semiconductor layer comprises copper hexadecafluorophthalocyanine(F_{16}CuPC). In some embodiments, the p-type organic semiconductor layer comprises pentacene.

In some embodiments, the energization element is comprised of more than one electrochemical cell, which are connected at least in part in a series manner. In some embodiments, the first gate conductor comprises a transparent electrode. In some embodiments, the transparent electrode comprises indium tin oxide.

In some embodiments, the ophthalmic lens insert may be formed in a number of manners to result in a three-dimensional shape upon which organic semiconductor transistors and other electrical devices may be formed. Non-limiting examples of electrical devices include resistors, capacitors, diodes, inductors, and similar such devices. Thereafter, energization elements may be formed in contact with or upon these organic semiconductor devices. In some embodiments, the energization elements may be formed by applying films that contain battery cell-related chemicals to electrical interconnections. In some other embodiments, the energizing elements may also be used in creating circuits of the organic semiconductor devices. In related embodiments, the application may be performed by printing processes that may apply mixtures of the chemicals by using needles or other application tools.

An ophthalmic lens may be formed by encapsulating a three-dimensionally formed ophthalmic insert in polymerized material. A method of forming the lens may include the polymerization of a reactive mixture between mold pieces where the ophthalmic insert is placed before polymerization. In some embodiments, numerous functional components or regions may be located within the ophthalmic insert. In some embodiments, the insert may contain at least one transistor that is formed from an organic semiconductor layer. Other common elements may include, but are not limiting to, conductive traces, energization elements, activation elements, and active ophthalmic devices. The active ophthalmic devices may be capable of dynamically changing the focal characteristics of the light that passes through the ophthalmic lens. A non-limiting example of a component capable of dynamically changing the focal characteristics may include a liquid meniscus lens element. Non-limiting examples of activation elements may include pressure sensitive switches, and magnetic field sensors. Non-limiting examples of magnetic field sensors may include Hall Effect

Proceeding to Fig. 4, parallel processing flows 400 and 450 are illustrated that produce complementary p- and n-type organic semiconductor devices. At step 410 for each type of device the substrate may be a flat or planar upon which the devices may be formed. Next, at step 415, a metallic or conductive material is deposited to form the gate electrode in this "bottom gate" electrode type of processing flow. There may be numerous means to form the gate electrode including screened deposition from a sputtered or evaporated source. Other methods may include blanket deposition followed by patterned etching processes. Any method of forming isolated conductive gate structures may be consistent with the art herein.

In the following step 420, a gate dielectric layer is deposited to cover and surround the gate electrode. An effective method for this deposition may be to spin on the dielectric from a liquid precursor followed by curing. In other embodiments, the dielectric may be deposited by vapor deposition. In some embodiments, the dielectric may be subsequently planarized by a technique such as, but not limiting to, chemical mechanical polishing.

Referring back to Fig. 4, at step 425, the n-type organic semiconductor layer may be deposited upon the dielectric layer. This deposition may be regionally controlled by masked deposition of vapor phase forms of the organic semiconductor. In other embodiments, a blanket film may be applied followed by a patterned removal process. In some other embodiments, at 426, the n-type organic semiconductor layer may not be present. In some examples of ambipolar devices, the n-type organic semiconductor film may be present in the p-type devices and then later covered by p-type organic semiconductor material (not shown). Some materials for this layer may include N, N'-bis(n-octyl)-dicyanoperylene-3,4,9,10-bis(dicarboximide) otherwise called (PDI-8CN2); carbonyl functionalized (α,ω-diperfluorohexyl-4T) otherwise called (DFHCO-4T) and copper hexadecafluorophthalocyanine otherwise called (F_{16}CuPC) as a few non-limiting exemplary options.

Referring back to Fig. 4, at step 456, the p-type organic semiconductor layer may be deposited upon the dielectric layer. This deposition may be regionally controlled by masked deposition of vapor phase forms of the organic semiconductor.

Claims

1. A method of forming an ophthalmic device comprising:

depositing an organic semiconductor layer on a substrate;

dividing said substrate into a plurality of insert pieces, wherein each of said insert pieces comprises an organic semiconductor layer on a substrate;

attaching at least one of the insert pieces onto an ophthalmic lens insert; and

forming an encapsulating layer around the ophthalmic lens insert.

2. The method of claim 1, wherein the substrate is silicon wafer.

3. The method of claim 1, wherein the encapsulating layer is parylene.

4. The method of claim 3, wherein the encapsulating layer is forming a hydrogel around the lens insert.

5. The method of claim 4 additionally comprising:

forming at least a first gate conductor on the substrate.

6. The method of claim 5 additionally comprising:

depositing an energization element upon the substrate in electrical communication with the first gate conductor.

7. The method of claim 6 wherein:

the energization element is an electrochemical cell.

8. The method of claim 1, wherein the organic semiconductor layer comprises an n-type organic semiconductor.

9. The method of claim 1, wherein the organic semiconductor layer comprises a p-type organic semiconductor.

10. The method of claim 1, wherein the organic semiconductor layer comprises an n-type organic semiconductor, a p-type organic semiconductor, and a combination thereof.

11. The method of claim 8, wherein the n-type organic semiconductor layer comprises copper hexadecafluorophthalocyanine ($F_{16}CuPC$).

12. The method of claim 9, wherein the p-type organic semiconductor layer comprises pentacene.

13. The method of claim 6, wherein the energization element comprises a plurality of electrochemical cells connected at least in part in a series manner.

14. The method of claim 5, wherein the first gate conductor comprises a transparent electrode.

15. The method of claim 14, wherein the transparent electrode comprises indium tin oxide.