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(54) **COMPOSITE FOR SENSING HEAT OR INFRARED LIGHT AND DEVICE INCLUDING SAME**

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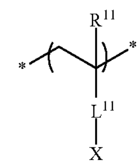
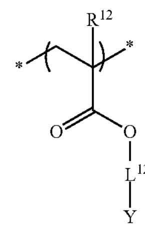
(57) **ABSTRACT**

A composite for sensing heat or infrared light includes a block copolymer including a first structural group represented by Chemical Formula 1, a second structural group represented by Chemical Formula 2, and a third structural group represented by Chemical Formula 3; and a polyvalent metal ion that is coordinated with a side chain group of the block copolymer.

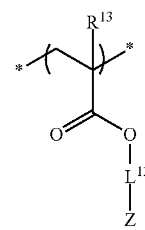
[Chemical Formula 1]



[Chemical Formula 2]



[Chemical Formula 3]



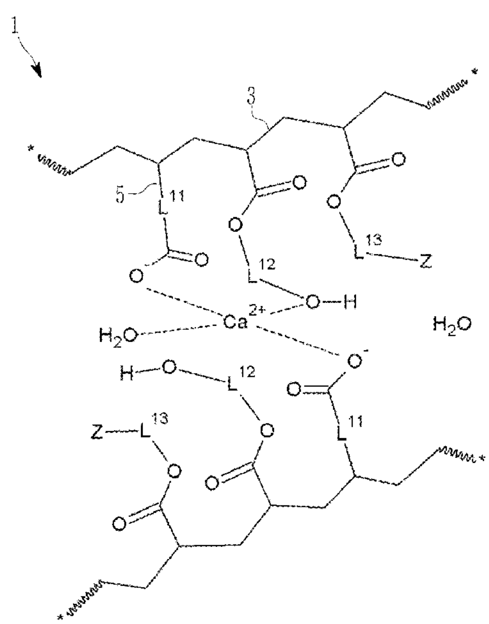


FIG. 1

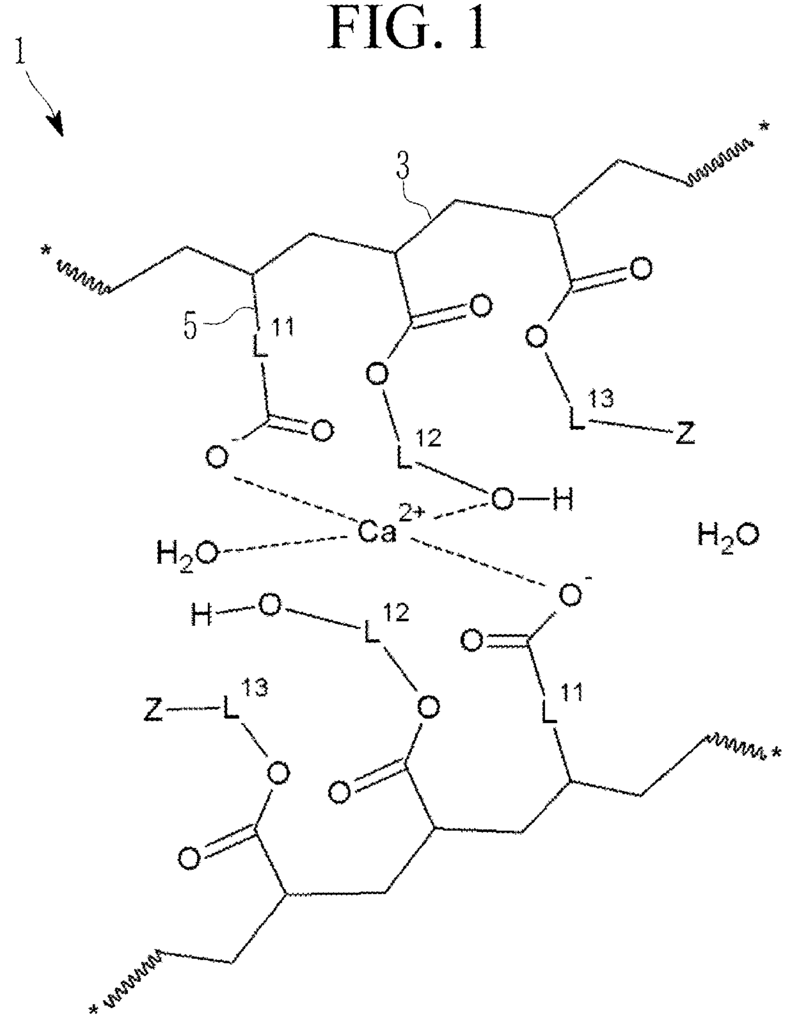


FIG. 2

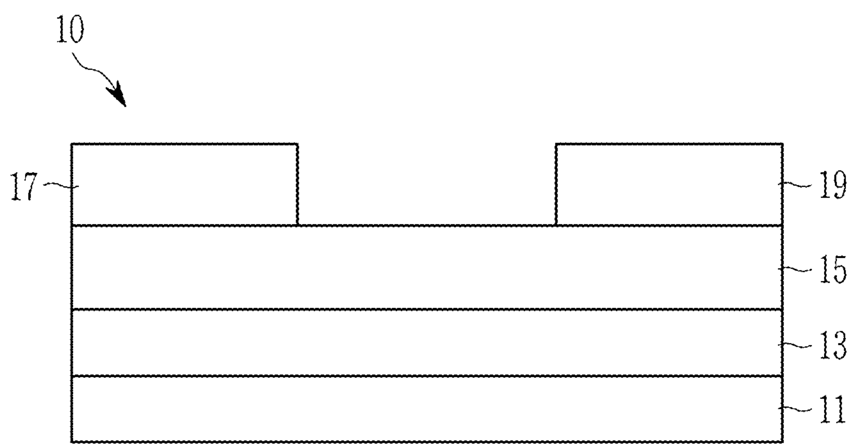


FIG. 3

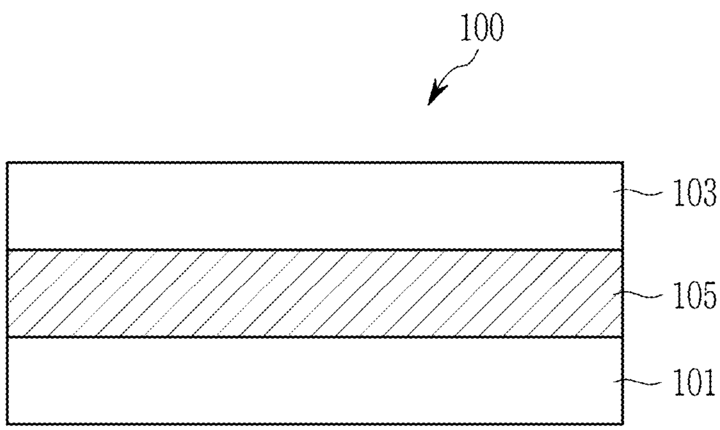


FIG. 4

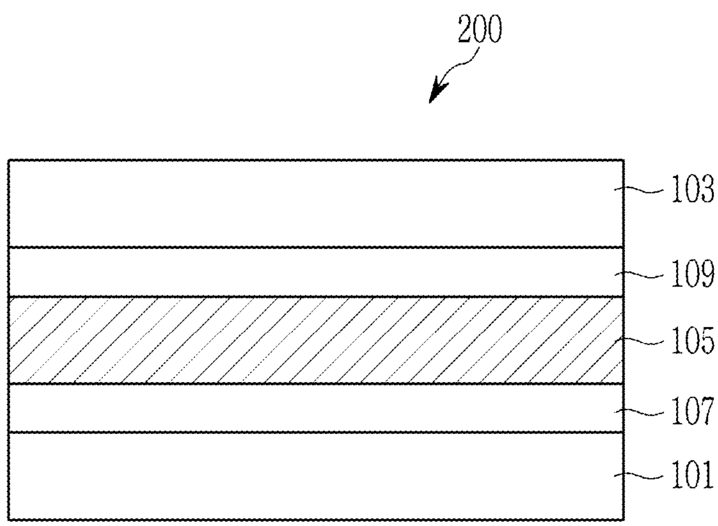


FIG. 5

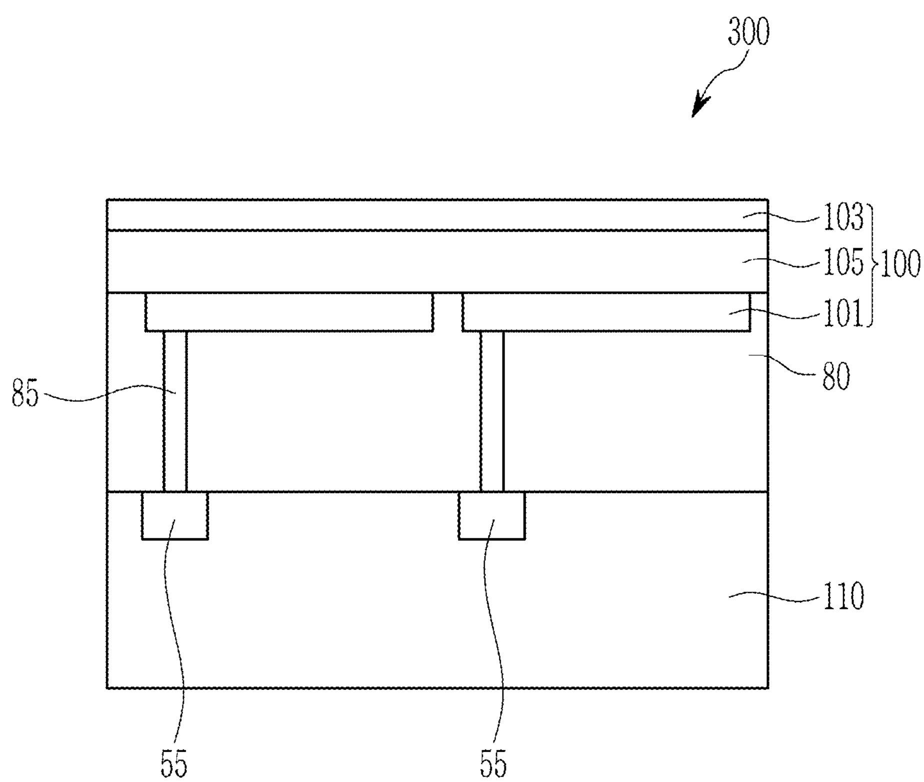


FIG. 6

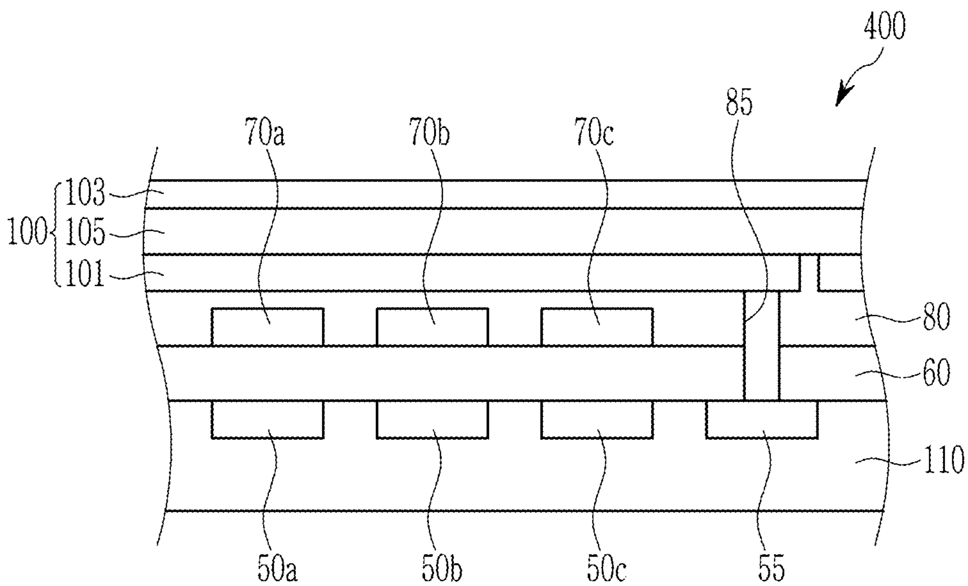


FIG. 7

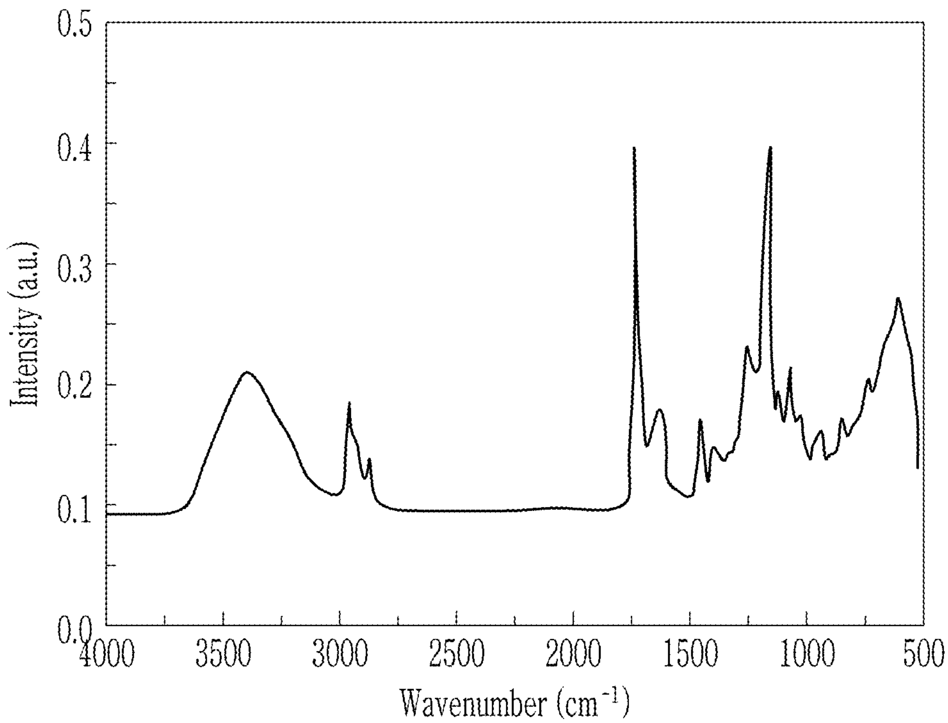

0.5
0.4
0.3
0.2
0.1
0.0
Intensity (a.u.)
4000
3500
3000
2500
2000
1500
1000
500
Wavenumber (cm-1)

FIG. 8A

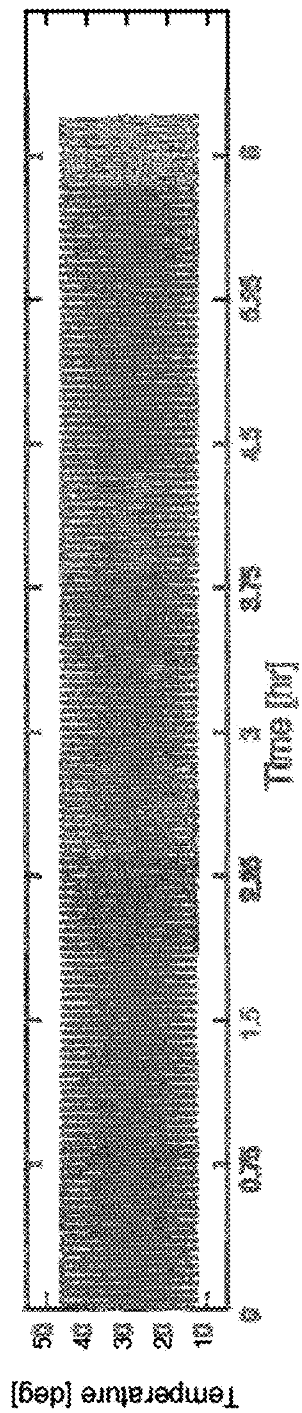


FIG. 8B

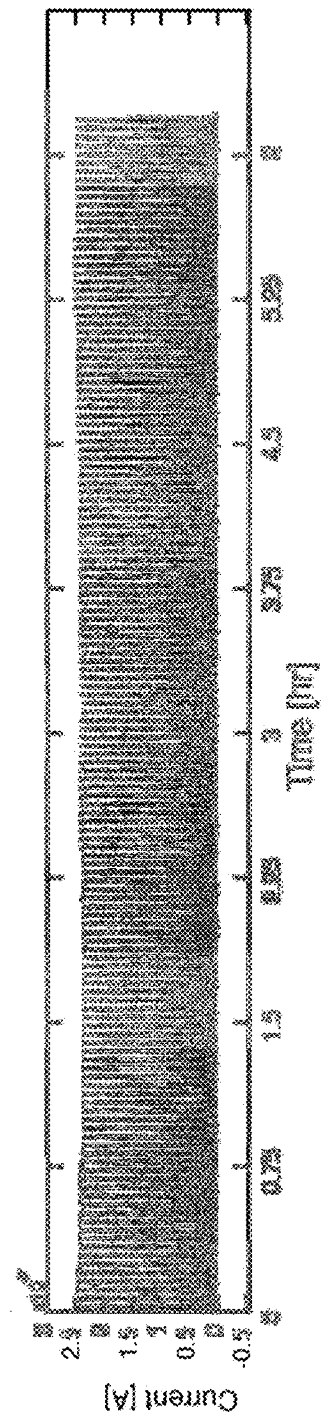
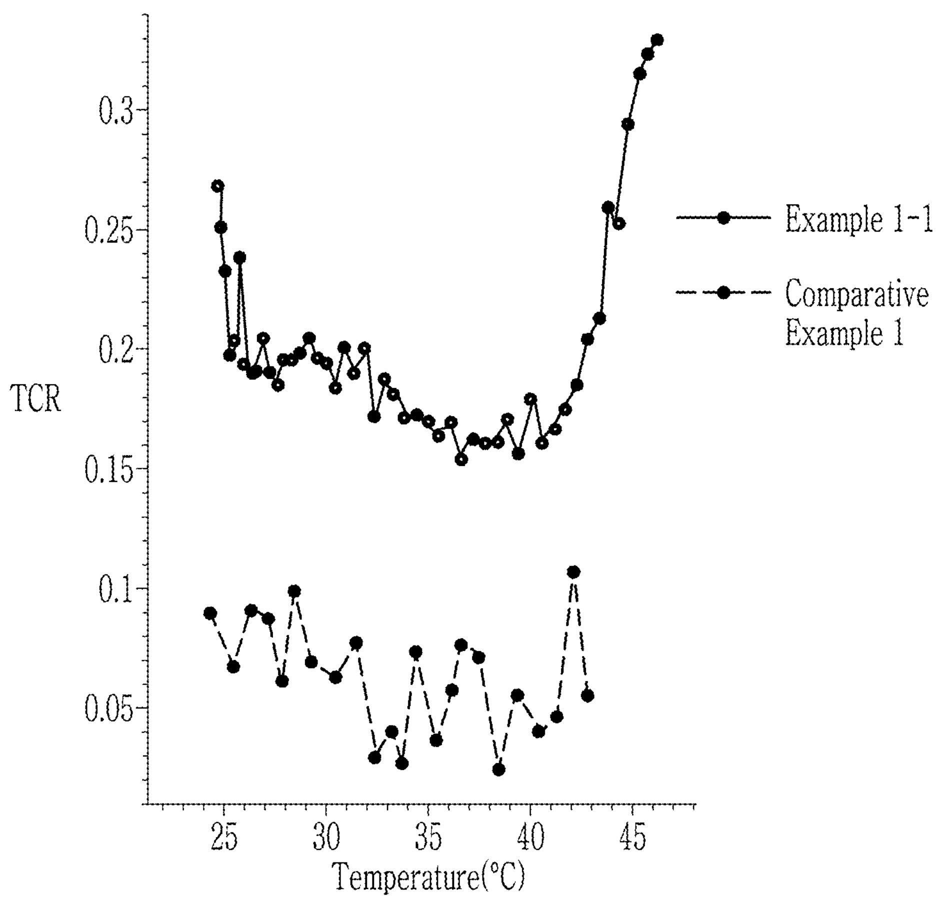


FIG. 9


0.3
0.25
0.2
0.15
0.1
0.05
TCR
25
30
35
40
45
Temperature(°C)
Example 1-1
Comparative
Example 1

COMPOSITE FOR SENSING HEAT OR INFRARED LIGHT AND DEVICE INCLUDING SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 62/994,405 filed in the United States Patent and Trademark Office on Mar. 25, 2020, the entire contents of which are incorporated herein based on reference.

BACKGROUND

1. Field

[0002] A composite for sensing heat or infrared light and a device including the same are disclosed.

2. Description of the Related Art

[0003] In digital cameras and camcorders, an imaging device that captures an image and stores it as an electrical signal is used, and the imaging device includes a sensor that decomposes incident light according to a wavelength and converts each component into an electrical signal.

[0004] In recent years, a device for sensing light in the infrared region for improving the sensitivity of a sensor in a low-light environment or for use as a biometric device has been studied.

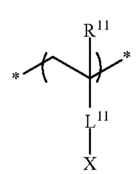
SUMMARY

[0005] Some example embodiments provide a composite having improved heat and infrared light sensing characteristics.

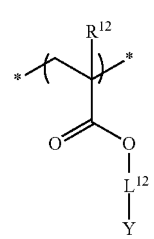
[0006] Some example embodiments provide a device (photoelectric device, thermal sensing device, and electronic device) including the composite.

[0007] According to some example embodiments, a composite for sensing heat or infrared light includes a block copolymer including a first structural group represented based on represented based on Chemical Formula 1, a second structural group represented based on Chemical Formula 2, and a third structural group represented based on Chemical Formula 3; and a polyvalent metal ion that is coordinated with a side chain group of the block copolymer.

[Chemical Formula 1]

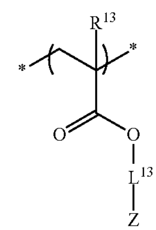


[Chemical Formula 2]



-continued

[Chemical Formula 3]



[0008] In Chemical Formulas 1 to 3,

[0009] R^{11}, R^{12}, and R^{13} are independently hydrogen or a C1 to C6 alkyl group,

[0010] L^{11} and L^{12} are independently a single bond, a substituted or unsubstituted C1 to C10 alkylene group, a C2 to C20 alkylene group in which at least one methylene group is replaced by a linker selected from —O—, —S—, —C(═O)—, —S(═O)—, —S(═O)^2—, —C(═O)—O—, —O—C(═O)—, —C(═O)NR— (wherein R is hydrogen or a C1 to C6 alkyl group), or a combination thereof, and a substituted or unsubstituted C6 to C10 arylene group,

[0011] L^{13} is selected from a single bond, a substituted or unsubstituted C1 to C20 alkylene group, a substituted or unsubstituted C3 to C20 cycloalkylene group, and a substituted or unsubstituted C6 to C20 arylene group,

[0012] X is a carboxyl group (—COOH), a sulfonic acid group ((—S(═O)$_2$OH), or a phosphoric acid group (—O—P(═O)(OH)$_2$),

[0013] Y is selected from a hydroxy group (—OH), an alkoxy group (—OR, wherein R is a linear or branched C1 to C10 alkyl group), an ester group (C(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group), a sulfonate ester group (—S(═O)$_2$OR, wherein R is a linear or branched C1 to C10 alkyl group), a phosphoric acid ester group (—O—P(═O)(OR)$_2$, wherein R is a linear or branched C1 to C10 alkyl group), an amine group, an isocyanate group (—N═C═O), and a urethane group (—NHC(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group), and

[0014] Z is selected from a substituted or unsubstituted linear or branch C1 to C20 alkyl group, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C3 to C30 heteroaryl group, a substituted or unsubstituted C3 to C30 cycloalkyl group, and a substituted or unsubstituted C3 to C30 heterocycloalkyl group.

[0015] The block copolymer may include a hydrophilic block (A) and a hydrophobic block (B). The block copolymer may include a linking group (L) between the hydrophilic block (A) and the hydrophobic block (B) and the linking group may include trithiocarbonate, dithiocarbonate, xanthate, or a combination thereof.

[0016] The hydrophilic block (A) and the hydrophobic block (B) may be symmetrically or asymmetrically present in the block copolymer with respect to the linking group (L).

[0017] The hydrophilic block (A) may include two or more first structural groups and two or more second structural groups, each of which may be in a form of block copolymerization, random copolymerization or alternating copolymerization. The hydrophobic block (B) may include two or more third structural groups, which may be in the form of block copolymerization, random copolymerization or alternating copolymerization.

[0018] In the block copolymer, a sum amount of the first structural unit and the second structural unit may be included in about 2 moles to about 50 moles relative to 100 moles of the third structural unit in the composite.

[0019] The block copolymer may have a weight average molecular weight of greater than or equal to about 5,000.

[0020] The block copolymer may be included in the composite in an amount of greater than or equal to about 20 volume % and less than or equal to about 99.9 volume % based on a total volume of the composite for sensing heat or infrared light. In some example embodiments, the block copolymer may be included in the composite in an amount of greater than or equal to about 70 volume % and less than or equal to about 99 volume % based on a total volume of the composite for sensing heat or infrared light. In some example embodiments, the block copolymer may be included in the composite in an amount of greater than or equal to about 20 volume % and less than or equal to about 50 volume % based on a total volume of the composite for sensing heat or infrared light.

[0021] The polyvalent metal ion may be a divalent or higher metal ion. Specific examples of the polyvalent metal ion may include an ion of a metal selected from Ca, Al, Cu, Co, Ba, Zn, Fe, Mn, Mg, Sr, Ba, Cr, Ti, Zr, Mo, V, and a combination thereof.

[0022] The polyvalent metal ion may be included in the composite in an amount of greater than or equal to about 0.1 volume % and less than or equal to about 80 volume % based on a total volume of the composite for sensing heat or infrared light. In some example embodiments, the polyvalent metal ion may be included in the composite in an amount of greater than or equal to about 1 volume % and less than or equal to about 30 volume % based on a total volume of the composite for sensing heat or infrared light. In some example embodiments, the polyvalent metal ion may be included in the composite in an amount of greater than or equal to about 50 volume % and less than or equal to about 80 volume % based on a total volume of the composite for sensing heat or infrared light.

[0023] The composite for sensing heat or infrared light may further include a reinforcing agent, and the reinforcing agent may further include graphite, carbon nanotubes, graphene, graphite nanoplates, fullerene, fullerene derivatives, quantum dots, metal oxides, or a combination thereof.

[0024] The reinforcing agent may be included in an amount of less than or equal to about 5 volume % based on a total volume of the composite for sensing heat or infrared light.

[0025] According to some example embodiments, a photoelectric device, a thermal sensing device, and an electronic device including the composite for sensing heat or infrared light is provided.

[0026] The composite for sensing heat or infrared light may improve elongation while maintaining improved charge mobility and electrical properties, and thus may be usefully applied to electronic devices requiring high stretchability and healing ability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. **1** is a view showing a coordination bonding state of a block copolymer and a polyvalent metal ion constituting a composite.

[0028] FIG. **2** is a schematic cross-sectional view showing a thin film transistor according to some example embodiments.

[0029] FIG. **3** is a cross-sectional view showing a photoelectric device according to some example embodiments.

[0030] FIG. **4** is a cross-sectional view showing a photoelectric device according to some example embodiments.

[0031] FIG. **5** is a cross-sectional view showing an example of an organic sensor according to some example embodiments.

[0032] FIG. **6** is a cross-sectional view showing an organic sensor according to some example embodiments.

[0033] FIG. **7** is a graph showing infrared absorption of the thin film according to Example 1-1.

[0034] FIG. **8**A is a view showing a cycle of temperature change applied to a thin film according to Example 1-1, and FIG. **8**B is a view showing a current detected in the thin film according to Example 1-1.

[0035] FIG. **9** is a graph showing the results of measuring temperature coefficient of resistance (TCR) according to temperature changes of the thin films according to Example 1-1 and Comparative Example 1.

DETAILED DESCRIPTION

[0036] Advantages and features of the technology described hereinafter, and a method of achieving them will be clarified based on referring to some example embodiments described below in detail together with the accompanying drawings. However, the example embodiments should not be construed as being limited to the example embodiments set forth herein. If not defined otherwise, all terms (including technical and scientific terms) in the specification may be defined as commonly understood by one skilled in the art. The terms defined in a generally-used dictionary may not be interpreted ideally or exaggeratedly unless clearly defined. Terms defined in a commonly used dictionary may be interpreted as having meanings consistent with their meanings in the related technical field and the context of the present specification, and may not be interpreted as idealized and excessively formal meanings, unless specifically defined herein. In addition, unless explicitly described to the contrary, the word “comprise”, and variations such as “comprises” or “comprising,” will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.

[0037] Further, the singular includes the plural unless mentioned otherwise.

[0038] In the drawings, the thickness is enlarged to clearly represent various layers and regions. The same reference numerals are used for similar portions throughout the specification.

[0039] In the present specification, when a first element such as a layer, film, region, plate, etc. is said to be “on” the second element, this includes not only the case of being “directly on” the other portion but also another portion in the middle (e.g., being “indirectly on” the other portion). In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present. It will be understood that an element that is “on” another element may be “above” or “beneath” the other element.

[0040] As used herein, when a definition is not otherwise provided, “substituted” refer to replacement of hydrogen of a compound or a functional group by a substituent selected from a halogen atom, a hydroxy group, a nitro group, a cyano group, an amino group, an azido group, an amidino group, a hydrazino group, a hydrazono group, a carbonyl group, a carbamyl group, a thiol group, an ester group, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1 to C20 alkyl group, a C1 to C20 alkoxy group, a C1 to C20 haloalkyl group, a C2 to C20 alkenyl group, a C2 to C20 alkynyl group, a C6 to C30 aryl group, a C7 to C30 arylalkyl group, a Cl to C20 heteroalkyl group, a C3 to C20 heteroarylalkyl group, a C3 to C30 cycloalkyl group, a C3 to C15 cycloalkenyl group, a C6 to C15 cycloalkynyl group, a C3 to C30 heterocycloalkyl group, and a combination thereof.

[0041] In addition, when a definition is not otherwise provided, “hetero” means that one or three heteroatoms selected from N, O, S, Si, Se, Te, and P are included in a given group or compound.

[0042] Hereinafter, “combination” includes two or more mixing, two or more lamination structures, or inter-substitution.

[0043] It will be understood that any elements and/or properties thereof as described herein (e.g., amounts) should be construed as including a manufacturing or operational tolerance (e.g., ±10%) around the stated elements and/or properties thereof.

[0044] When the terms “about” or “substantially” are used in this specification in connection with a numerical value, it is intended that the associated numerical value include a tolerance of ±10% around the stated numerical value. When ranges are specified, the range includes all values therebetween such as increments of 0.1%.

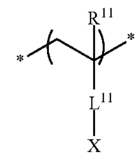
[0045] It will be understood that some or all of any of the devices according to any of the example embodiments as described herein may be included in, may include, and/or may be implemented based on one or more instances of processing circuitry such as hardware including logic circuits, a hardware/software combination such as a processor executing software; or a combination thereof. In some example embodiments, said one or more instances of processing circuitry may include, but are not limited to, a central processing unit (CPU), an application processor (AP), an arithmetic logic unit (ALU), a graphic processing unit (GPU), a digital signal processor, a microcomputer, a field programmable gate array (FPGA), a System-on-Chip (SoC) a programmable logic unit, a microprocessor, or an application-specific integrated circuit (ASIC), etc. In some example embodiments, any of the memories, memory units, or the like as described herein may include a non-transitory computer readable storage device, for example a solid state drive (SSD), storing a program of instructions, and the one or more instances of processing circuitry may be configured to execute the program of instructions to implement the functionality of some or all of any of the devices according to any of the example embodiments as described herein, including any of the methods of operating any of same.

[0046] As used herein, “(meth)acrylate” may mean both acrylate and methacrylate.

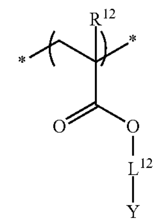
[0047] Hereinafter, a composite for sensing heat or infrared light according to some example embodiments is described.

[0048] A composite (also referred to interchangeably as a composite material or composite compound) for sensing heat or infrared light according to some example embodiments includes a block copolymer including a first structural unit (e.g., first structural group) represented by Chemical Formula 1, a second structural unit (e.g., second structural group) represented by Chemical Formula 2, and a third structural unit (e.g., third structural group) represented by Chemical Formula 3; and a polyvalent metal ion that coordinates with (e.g., is coordinated with) a side chain group of the block copolymer.

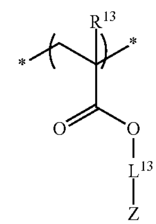
[Chemical Formula 1]



[Chemical Formula 2]



[Chemical Formula 3]



[0049] In Chemical Formulas 1 to 3,

[0050] R^{11}, R^{12}, and R^{13} are independently hydrogen or a C1 to C6 alkyl group,

[0051] L^{11} and L^{12} are independently a single bond, a substituted or unsubstituted C1 to C10 alkylene group, a C2 to C20 alkylene group in which at least one methylene group is replaced by a linker selected from —O—, —S—, —C(═O)—, —S(═O)—, —S(═O)$_2$—, —C(═O)—O—, —O—C(═O)—, —C(═O)NR— (wherein R is hydrogen or a C1 to C6 alkyl group), or a combination thereof, and a substituted or unsubstituted C6 to C10 arylene group,

[0052] L^{13} is selected from a single bond, a substituted or unsubstituted C1 to C20 alkylene group, a substituted or unsubstituted C3 to C20 cycloalkylene group, and a substituted or unsubstituted C6 to C20 arylene group,

[0053] X is a carboxyl group (—COOH), a sulfonic acid group ((—S(═O)$_2$OH), or a phosphoric acid group (—O—P(═O)(OH)$_2$),

[0054] Y is selected from a hydroxy group (—OH), an alkoxy group (—OR, wherein R is a linear or branched C1 to C10 alkyl group), an ester group (C(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group), a sulfonate ester group (—S(═O)$_2$OR, wherein R is a linear or branched C1 to C10 alkyl group), a phosphoric acid ester group (—O—P(═O)(OR)$_2$, wherein R is a linear or branched C1 to C10 alkyl group), an amine group, an isocyanate group (—N═C═O), and an urethane group (—NHC(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group), and

[0055] Z is selected from a substituted or unsubstituted linear or branch C1 to C20 alkyl group, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C3 to C30 heteroaryl group, a substituted or unsubstituted C3 to C30 cycloalkyl group, and a substituted or unsubstituted C3 to C30 heterocycloalkyl group.

[0056] In the block copolymer, X of the first structural unit may dissociate H to form an anionic group, and Y of the second structural unit may be a hydrophilic functional group. The anionic group of the first structural unit and the hydrophilic functional group of the second structural unit of the block copolymer form coordinated bonds with polyvalent metal ions based on electrostatic interactions to form a crosslinked polymer network. For example, oxygen (O) or nitrogen (N) of the second structural unit may form hydrogen bonding with the polyvalent metal ions. X of the first structural unit and Y of the second structural unit are charged moieties, forming a hydrophilic region with increased intermolecular attraction of the polymer chain via the polyvalent metal ions, and the hydrophilic region may retain water molecules. When water is included in the polymer network, charge mobility and temperature responsivity may be improved.

[0057] The third structural unit may function (e.g., may be configured to function) so that the block copolymer forms a polymer network with each other based on hydrophobic interactions, and the first structural unit and the second structural unit have an arrangement for forming coordination bonds with the polyvalent metal ions.

[0058] The structure of the polymer network is shown in FIG. **1** when X of the first structural unit is a carboxyl group, Y of the second structural unit is a hydroxyl group, and the polyvalent metal ion is Ca^{2+}.

[0059] FIG. **1** is a view showing a coordination bonding state of a block copolymer 3 and a polyvalent metal ion in a composite 1 for sensing heat or infrared light according to some example embodiments.

[0060] The polymer network as described above may be configured function so that the polymer chain and polyvalent metal ions of the polymer network are rearranged according to the ambient conditions (e.g., temperature, infrared light, etc.), and thus high charge mobility in the composite 1 for sensing heat or infrared light including the same may be provided, thereby improving conductivity of the composite 1 for sensing heat or infrared light.

[0061] The block copolymer 3 may include a hydrophilic block (A) and the block copolymer may further include a hydrophobic block (B). The hydrophilic block (A) may include a first structural unit (e.g., first structural group) and a second structural unit (e.g., second structural group), and hydrophobic block (B) may include a third structural unit (e.g., third structural group).

[0062] The block copolymer 3 may be an ABA triblock copolymer including a hydrophilic block (A), a hydrophobic block (B), and a hydrophilic block (A).

[0063] A linker (L) selected from trithiocarbonate, dithiocarbonate, xanthate, or a combination thereof may be further included between the hydrophilic block (A) and the hydrophobic block (B). In the block copolymer 3, the hydrophilic block (A) and the hydrophobic block (B) may be symmetrically or asymmetrically present (e.g., present in the block copolymer 3) with respect to the linking group (L). When the hydrophilic block (A) and the hydrophobic block (B) are symmetrically present, the block copolymer 3 may have an AB-L-BA structure, and when the hydrophilic block (A) and the hydrophobic block (B) are asymmetrically present, it may have an AB-L-AB structure.

[0064] The block copolymer 3 may include a plurality of block structural units (e.g., block structural groups), and each block structural unit may include the aforementioned first to third structural units described above.

[0065] The hydrophilic block (A) may include two or more first structural units (e.g., two or more first structural groups) and two or more second structural units (e.g., two or more second structural groups), and the two or more first structural units and two or more second structural units may each be in the form of block copolymerization, random copolymerization or alternating copolymerization. The hydrophobic block (B) may include two or more third structural units (e.g., two or more third structural groups), which may be in the form of block copolymerization, random copolymerization or alternating copolymerization.

[0066] In the block copolymer 3, a sum amount of the first structural unit and the second structural unit in the composite 1 may be about 2 moles to about 50 moles relative to 100 moles of the third structural unit in the composite 1. That is, the hydrophilic block (A) may be included in about 2 moles to about 50 moles relative to 100 moles of the hydrophobic block (B) in the composite 1. In some example embodiments, the sum amount of the first structural unit and the second structural unit may be greater than or equal to about 2.5 moles, greater than or equal to about 3 moles, greater than or equal to about 3.5 moles, greater than or equal to about 4 moles, greater than or equal to about 4.5 moles, or greater than or equal to about 5 moles and less than or equal to about 49 moles, about 48 moles, less than or equal to about 47 moles, less than or equal to about 46 moles, less than or equal to about 45 moles, less than or equal to about 44 moles, less than or equal to about 43 moles, less than or equal to about 42 moles, less than or equal to about 41 moles, or less than or equal to about 40 moles relative to 100 moles of the third structural unit.

[0067] The block copolymer 3 may have a weight average molecular weight (Mw) of greater than or equal to about 5,000, for example greater than or equal to about 6000, greater than or equal to about 7000, greater than or equal to about 8000, greater than or equal to about 9000, or greater than or equal to about 10000 and less than or equal to about 1,500,000, less than or equal to about 1,600,000, less than or equal to about 1,700,000, less than or equal to about 1,800,000, less than or equal to about 1,900,000, or less than or equal to about 2,000,000. When used in the above ranges, the coating property of the composition for preparing the composite 1 for sensing heat or infrared light may be easily adjusted. The weight average molecular weight of the block copolymer is measured based on gel permeation chromatography (hereinafter, referred to as "GPC") method and may be obtained based on polystyrene conversion.

[0068] A molecular weight distribution (PDI) of the block copolymer 3 may be less than about 2.0, less than or equal to about 1.9, less than or equal to about 1.8, or less than or equal to about 1.7. The molecular weight distribution (PDI) is obtained based on (weight average molecular weight (Mw) of block copolymer)/(number average molecular weight (Mn) of block copolymer). As the PDI is smaller, a copolymer having the narrower molecular weight distribution and aligned molecular weight, and when the value is 1.0, the narrowest molecular weight distribution is obtained.

[0069] The content of the block copolymer 3 forming the polymer network in the composite 1 (e.g., the amount of the block copolymer included in the composite 1) may be greater than or equal to about 20 volume %, for example greater than or equal to about 25 volume %, greater than or equal to about 30 volume %, greater than or equal to about 35 volume %, greater than or equal to about 40 volume %, greater than or equal to about 45 volume %, greater than or equal to about 50 volume %, greater than or equal to about 55 volume %, or greater than or equal to about 60 volume % based on a total volume of the composite 1 for sensing heat or infrared light. In addition, the content of the block copolymer in the composite 1 may be less than or equal to about 99.9 volume %, for example less than or equal to about 99 volume %, less than or equal to about 95 volume %, less than or equal to about 90 volume %, less than or equal to about 85 volume %, or less than or equal to about 80 volume % based on a total volume of the composite 1 for sensing heat or infrared light. Within the above ranges, mechanical and electrical properties of the composite 1 for sensing heat or infrared light may be easily controlled.

[0070] The polyvalent metal ion may form a coordination bond based on electrostatic interaction with the side chain 5 of the block copolymer. The polyvalent metal ion may be a divalent or higher metal ion, for example, a divalent, trivalent, or tetravalent metal ion. Specific examples of the polyvalent metal ion include ions of metals including Ca, Al, Cu, Co, Ba, Zn, Fe, Mn, Mg, Sr, Ba, Cr, Ti, Zr, Mo, V, or a combination thereof.

[0071] A content of the polyvalent metal ion in the composite (e.g., an amount of the polyvalent metal ion in the composite) may be greater than or equal to about 0.1 volume %, for example greater than or equal to about 0.2 volume %, greater than or equal to about 0.3 volume %, greater than or equal to about 0.4 volume %, or greater than or equal to about 0.5 volume % based on a total volume of the composite for sensing heat or infrared light. In addition, the content of the polyvalent metal ion in the composite may be less than or equal to about 80 volume %, for example less than or equal to about 75 volume %, less than or equal to about 70 volume %, less than or equal to about 65 volume %, less than or equal to about 60 volume %, less than or equal to about 55 volume %, less than or equal to about 50 volume %, or less than or equal to about 45 volume % based on a total volume of the composite for sensing heat or infrared light. Within the ranges, flexibility, stretchability, and electrical properties of the composite for sensing heat or infrared light may be improved.

[0072] In some example embodiments, each content of the block copolymer and the polyvalent metal ion in the composite may be adjusted according to the flexibility of the substrate of the device. For example, in the case of a device including a flexible substrate, the content of the block copolymer in the composite may be increased, and in the case of a rigid substrate, the content of the block copolymer in the composite may be lowered. In the case of a flexible substrate, a content of the block copolymer in the composite may be greater than or equal to about 70 volume %, for example greater than or equal to about 75 volume %, or greater than or equal to about 80 volume % and less than or equal to about 99 volume %, for example less than or equal to about 95 volume %, or less than or equal to about 90%, based on a total volume of the composite for sensing heat or infrared light and a content of the polyvalent metal ion may be greater than or equal to about 1 volume %, for example greater than or equal to about 5 volume %, or greater than or equal to about 10 volume % and less than or equal to about 30 volume %, for example less than or equal to about 25 volume %, or less than or equal to about 20% based on a total volume of the composite for sensing heat or infrared light. In the case of a rigid substrate, a content of the block copolymer in the composite may be greater than or equal to about 20 volume %, for example greater than or equal to about 25 volume %, or greater than or equal to about 30 volume % and less than or equal to about 50 volume %, for example less than or equal to about 45 volume %, or less than or equal to about 40%, and a content of the polyvalent metal ion may be greater than or equal to about 50 volume %, for example greater than or equal to about 55 volume %, or greater than or equal to about 60 volume % and less than or equal to about 80 volume %, for example less than or equal to about 75 volume %, or less than or equal to about 70% based on a total volume of the composite for sensing heat or infrared light.

[0073] The block copolymer may be prepared based on mixing a first vinyl-based monomer providing a first structural unit and a second vinyl-based monomer providing a second structural unit with a chain transfer agent and a living free radical initiator to polymerize the first and second vinyl-based monomers and then, mixing a third vinyl-based monomer providing a third structural unit with the living free radical initiator to polymerize the third vinyl-based monomer. Accordingly, a mole ratio of hydrophilic blocks (A) and hydrophobic blocks (B) in the composite may be easily adjusted.

[0074] A method of obtaining the block copolymer is not particularly limited but may be synthesized in a living free radical polymerization (LFRP) method such as an atom transfer radical polymerization (ATRP) method, a nitroxide-mediated polymerization (NMP) method, or a reversible addition-fragmentation chain transferpolymerization (RAFT) method, and the like.

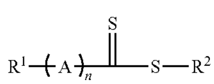
[0075] The first vinyl monomer may be a vinyl-based monomer including functional groups such as a carboxyl group, a sulfonic acid group, or a phosphoric acid group of the first structural unit and the like or these functional groups protected by a protecting group (e.g., a t-butyl group). Specific examples of the first vinyl-based monomer may include monomer obtained based on reacting crotonic acid, maleic acid, itaconic acid, or hydroxyalkyl (meth)acrylic such as 2-hydroxyethyl (meth)acrylate or 4-hydroxybutyl (meth)acrylate with an acid anhydride such as maleic anhydride, succinic anhydride, or phthalic anhydride, a vinyl-based monomer having a carboxyl group such as acrylic acid, methacrylic acid, carboxylalkyl(meth)acrylate (e.g., carboxylethyl(meth)acrylate, carboxylpentyl(meth)acrylate), and the like; a vinyl-based monomer having a sulfonic acid group such as vinyl sulfonic acid, styrene sulfonic acid, allyl sulfonic acid, 2-methylpropyl sulfonic acid (meth) acrylate, dimethylpropyl sulfonic acid (meth)acrylate, sulfonic acid ethyl(meth)acrylate, and the like; and a vinyl-based monomer having a phosphoric acid group such as (meth) acryloyloxyethyl phosphate ester and 2-hydroxyethyl (meth) acryloyl phosphate.

[0076] Specific examples of the second vinyl-based monomer may be hydroxyalkyl(meth)acrylate such as 2-hydroxyethyl(meth)acrylate, 2-hydroxypropyl(meth)acrylate, 2-hydroxybutyl(meth)acrylate, 3-hydroxypropyl(meth)acrylate, 4-hydroxybutyl(meth)acrylate, 6-hydroxyhexyl(meth)acrylate, 8-hydroxyoctyl(meth)acrylate, 10-hydroxydecyl(meth) acrylate, 12-hydroxylauryl(meth)acrylate, (4-hydroxymethylcyclohexyl)methyl(meth) acrylate, and the like; alkoxy (meth)acrylate such as n-butoxyethyl(meth)acrylate, butoxydiethylene glycol(meth)acrylate, methoxytriethylene glycol(meth)acrylate, methoxynonylethylene glycol(meth) acrylate, and the like.

[0077] Specific examples of the third vinyl-based monomer may be (meth)acrylic acid (e.g., C1 to C20, C4 to C20 or C4 to C15) alkylester such as methyl(meth)acrylate, ethyl(meth)acrylate, propyl(meth)acrylate, n-butyl(meth) acrylate, iso-butyl(meth)acrylate, sec-butyl(meth)acrylate, t-butyl(meth)acrylate, pentyl(meth)acrylate, isopentyl (meth)acrylate, hexyl(meth)acrylate, 2-ethylhexyl(meth) acrylate, heptyl(meth)acrylate, octyl(meth)acrylate, isooctyl (meth)acrylate, nonyl(meth)acrylate, isononyl(meth) acrylate, decyl(meth)acrylate, isodecyl(meth)acrylate, n-lauryl(meth)acrylate, undecyl(meth)acrylate, dodecyl (meth)acrylate, n-tridecyl(meth)acrylate, pentadecyl(meth) acrylate, cesyl(meth)acrylate, heptadecyl(meth)acrylate, isooctadecyl (meth)acrylate, nonadecyl(meth)acrylate, eicosyl (meth)acrylate, stearyl(meth)acrylate, and the like; (meth)acrylate having a (e.g., C4 to C20, C5 to C20 or C4 to C15) cycloalkyl group such as cyclobutyl(meth)acrylate, cyclopentyl (meth)acrylate, cyclohexyl (meth)acrylate, methylcyclohexyl (meth)acrylate, cyclododecyl (meth)acrylate, isobornyl (meth)acrylate, dicyclopentyl(meth)acrylate, and the like; or (meth)acrylate having a (e.g., C6 to C20 or C6 to C15) aryl group such as benzyl(meth)acrylate, phenyl (meth)acrylate, phenoxyethyl(meth)acrylate, and the like.

[0078] The chain transfer agent may be a compound represented by Chemical Formula 4, and specifically, trithiocarbonate, dithiocarbonate, xanthate-based material may be used.

[Chemical Formula 4]



[0079] In Chemical Formula 4,

[0080] A is O or S,

[0081] n is 0 or 1,

[0082] R^1 and R^2 are independently selected from a C1 to C20 alkyl group; a C2 to C20 alkenyl group; saturated or unsaturated hydrocarbon cyclic group (having 5 to 15 cyclic atoms) or saturated or unsaturated heterohydrocarbon cyclic group (having 5 to 15 cyclic atoms); a C6 to C20 aryl group or a C3 to C20 heteroaryl group; a C1 to C20 alkoxy group; a C2 to C20 dialkylamino group, and a carboxyl group, and

[0083] the C1 to C20 alkyl group, C2 to C20 alkenyl group, saturated or unsaturated hydrocarbon cyclic group (having 5 to 15 cyclic atoms), or saturated or unsaturated heterohydrocarbon cyclic group (having 5 to 15 cyclic atoms), C6 to C20 aryl group, C3 to C20 heteroaryl group, C1 to C20 alkoxy group and C2 to C20 dialkylamino group may be substituted with a substituent selected from an epoxy group, a hydroxy group, a C1 to C20 alkoxy group, a C6 to C20 aryl group, an acyl group, an acyloxy group, a carboxyl group and a salt thereof, a sulfonic acid group and a salt thereof, a C2 to C20 alkylcarbonyloxy group, an isocyanato group, a cyano group, a silyl group, a halogen, and a C2 to C20 dialkylamino group.

[0084] Specific examples of the chain transfer agent may be dibenzyl trithiocarbonate (DBTTC), benzyl dithiobenzoate, cumyl dithiobenzoate, 1-phenylethyl dithiobenzoate, S-(thiobenzoyl)thioglycolic acid, ethyl dithioacetate or alkali metal salts thereof.

[0085] In some example embodiments, the chain transfer agent may be used in an amount of about 0.01 to about 10 parts by weight based on 100 parts by weight of the total monomer mixture. For example, the chain transfer agent used in an amount of greater than or equal to about 0.02 parts by weight, greater than or equal to about 0.03 parts by weight, greater than or equal to about 0.04 parts by weight, or greater than or equal to about 0.05 parts by weight, and less than or equal to about 9.5 parts by weight, less than or equal to about 9 parts by weight, less than or equal to about 8.5 parts by weight, or less than or equal to about 8 parts by weight. When the chain transfer agent is used in the above range, a molecular weight distribution may be effectively controlled, and a polymerization rate may be adjusted to a desired range.

[0086] The living free radical initiator may be, for example, one or more selected from oxygen, hydroperoxide, perester, percarbonate, peroxide, persulfate, and an azo-based initiator, and more specifically hydrogen peroxide, t-butyl hydroperoxide, tertiary amyl hydroperoxide, azodiisobutyronitrile (AIBN), potassium persulfate and methylethyl ketone peroxide may be used.

[0087] The living free radical initiator may be used in an amount of about 0.01 to about 5 parts by weight based on 100 parts by weight of the vinyl-based monomer. For example, the living free radical initiator may be used in an amount of greater than or equal to about 0.02 parts by weight, greater than or equal to about 0.03 parts by weight, greater than or equal to about 0.04 parts by weight, or greater than or equal to about 0.05 parts by weight and less than or equal to about 4.5 parts by weight, less than or equal to about 4.0 parts by weight, less than or equal to about 3.5 parts by weight, or less than or equal to about 3 parts by weight. Within the above range, a polymerization reaction rate may be appropriately controlled, and a block copolymer having a molecular weight distribution (PDI) close to 1 may be prepared.

[0088] The composite for sensing heat or infrared light may further include a reinforcing agent for improving mechanical properties. The reinforcing agent may include graphite, carbon nanotubes, graphene, graphite nanoplates, fullerene, fullerene derivatives, quantum dots, metal oxides (e.g., silica, alumina (Al_2O_3), titania (TiO_2), zirconia (ZrO_2), ZnO, SnO_2, Sb_2O_3, boehmite, indium tin oxide (ITO), etc.), or a combination thereof. In some example embodiments, the reinforcing agent may desirably have a spherical shape.

[0089] For example, the quantum dots may include a Group II-VI semiconductor compound, a Group III-V semiconductor compound, a Group IV-VI semiconductor compound, a Group IV semiconductor compound, a Group I-III-VI semiconductor compound, a Group I-II-IV-VI semiconductor compound, a Group II-III-V semiconductor compound, or a combination thereof.

[0090] The reinforcing agent may be dispersed in the polymer network of the block copolymer.

[0091] The reinforcing agent may be present (e.g., included) in the composite in an amount of greater than or equal to about 0.1 volume %, for example greater than or equal to about 0.2 volume %, greater than or equal to about 0.3 volume %, greater than or equal to about 0.4 volume %, or greater than or equal to about 0.5 volume % based on a total volume of the composite for sensing heat or infrared light. The reinforcing agent may be present in the composite in an amount of less than or equal to about 5 volume %, for example less than or equal to about 4.5 volume %, less than or equal to about 4.0 volume %, less than or equal to about 3.5 volume %, or less than or equal to about 3.0 volume % based on a total volume of the composite for sensing heat or infrared light. In the above ranges, it is possible to improve the electrical properties of the composite for sensing heat or infrared light.

[0092] The composite for sensing heat or infrared light may be produced in a thin film form. The thin film may be produced based on a process in which a block copolymer and a salt of a polyvalent metal are mixed in a solvent to obtain a composition, and the composition is coated on a substrate and then dried.

[0093] The solvent may be water; a monovalent alcohol such as methanol, ethanol, propanol, isopropanol, n-butanol, sec-butanol, t-butanol, 2-ethylhexanol, heptanol, octanol, nonanol, dodecanol, and the like; polyhydric alcohol such as ethylene glycol, propylene glycol, butylene glycol, hexyleneglycol, dipropylene glycol, polyethylene glycol, polypropylene glycol, glycerol, and the like.

[0094] The salt of the polyvalent metal may include halides, carboxylates, acetylacetonates, hydroxides, nitrates, sulfates, or combinations thereof including a polyvalent metal, but is not limited thereto. The polyvalent metal may be a divalent or trivalent metal. Specific examples of the polyvalent metal include Ca, Al, Cu, Co, Ba, Zn, Fe, Mn, Mg, Sr, Ba, Cr, Ti, Zr, Mo, V, or a combination thereof.

[0095] The substrate may be, for example, a glass substrate or a polymer substrate, and the polymer substrate may be made of, for example, polyethylene terephthalate, polyethylene naphthalate, polycarbonate, polyacrylate, polyimide, or a combination thereof, but is not limited thereto.

[0096] The coating of the composition on the substrate may be performed, for example, based on spin coating, slit coating, bar coating, dip coating, spray coating, inkjet printing, etc., but is not limited thereto. In some example embodiments, the composition may be coated, for example, based on spin coating.

[0097] The thin film may be transferred on an elastic substrate (e.g. SEBS), for example, based on contacting the thin film with the elastic substrate to transfer it thereon and then, removing the elastic substrate.

[0098] The aforementioned composite for sensing heat or infrared light has excellent flexibility, stretchability, and the like, excellent charge mobility and electrical conductivity, and excellent absorption in a long wavelength region, for example, in an infrared region of about 1 micrometer (μm) to about 20 micrometers (μm).

[0099] Accordingly, the composite for sensing heat or infrared light may be used as an infrared absorber and thus applied to a photoelectric device and an organic sensor which sense infrared light. For example, the thin film-shaped composite for sensing heat or infrared light may be applied as a charge transport layer and/or an active layer or an infrared light absorption film in the photoelectric device and the organic sensor.

[0100] In addition, the aforementioned composite for sensing heat or infrared light may be applied to an electronic device such as a thin film transistor, a photodetector, a solar cell, an organic light emitting diode (OLED) display, and the like.

[0101] In addition, the composite for sensing heat or infrared light has improved temperature responsivity and may be applied as a thermal sensing conversion film of a thermal sensing device and a sensor including the same. Herein, since no cooler is needed to improve temperature responsivity, a thermal sensing device and a sensor manufactured based on applying the same may be down-sized. In addition, the electronic device may be a stretchable organic light emitting diode (OLED), a stretchable human motion sensor, a stretchable artificial muscle, or a stretchable actuator.

[0102] Hereinafter, an example of a thin film transistor including the composite for sensing heat or infrared light is described with reference to FIG. **2**.

[0103] FIG. **2** is a schematic cross-sectional view showing a thin film transistor according to some example embodiments.

[0104] Referring to FIG. **2**, a thin film transistor **10** includes a substrate **11**, an insulation layer **13**, a semiconductor layer **15**, a source electrode **17**, and a drain electrode **19**.

[0105] The substrate **11** may include a gate electrode or serve as a gate electrode as a whole. The substrate **11** may be made of transparent glass, silicon, or plastic. The gate electrode may be formed through internal doping of the silicon substrate at a high concentration or a conductive layer (e.g., a metal layer or a CNT layer formed of gold (Au), copper (Cu), nickel (Ni), aluminum (Al), molybdenum (Mo), chromium (Cr), tantalum (Ta), titanium (Ti), an alloy thereof, or a combination thereof) disposed on an insulating substrate (e.g., a rubber such as PDMS, SEBS, and the like and a polymer substrate such as polyester, polycarbonate, polyimide, and the like).

[0106] The insulation layer **13** is disposed on the substrate **11**. The insulation layer **13** separates the gate electrode, the source electrode **17**, the drain electrode **19**, and the semiconductor layer **15**. The insulation layer **13** may be an inorganic material thin film or an organic polymer film. Examples of the inorganic material may include silicon oxide, silicon nitride, aluminum oxide, barium titanate, and the like, but are not limited thereto. Examples of the organic polymer include polyester, polycarbonate, poly(vinyl phenol), polyimide, polystyrene, poly(methacrylate), poly(acrylate), an epoxy resin, and the like, but are not limited thereto. In addition, when the thin film including the composite for sensing heat or infrared light is transferred on the elastic substrate, the elastic substrate may play a role of an insulation layer. In some example embodiments, the insulation layer **13** may include a thin film that includes the aforementioned composite.

[0107] A thickness of the insulation layer **13** may vary depending on a dielectric constant of an insulating material but is not particularly limited. For example, the insulation layer **13** may have a thickness of greater than or equal to about 10 nm, for example, greater than or equal to about 50 nm, or greater than or equal to about 100 nm, but is not limited thereto. The insulation layer **13** may have a thickness of less than or equal to about 2000 nm, for example, less than or equal to about 500 nm, but is not limited thereto. The insulation layer **13** may have conductivity of less than or equal to about 10^{-12} S/cm, but is not limited thereto.

[0108] On the insulation layer **13**, the semiconductor layer **15** is disposed and may include the aforementioned composite for sensing heat or infrared light. In some example embodiments, the semiconductor layer **15** may be a thin film that includes the aforementioned composite.

[0109] On the semiconductor layer **15**, the source electrode **17** and the drain electrode **19** electrically connected to the semiconductor layer **15** are disposed.

[0110] Examples of materials for the source electrode **17** and the drain electrode **19** include a metal such as gold (Au), copper (Cu), nickel (Ni), aluminum (Al), molybdenum (Mo), chromium (Cr), tantalum (Ta), titanium (Ti), an alloy thereof, and the like, a conductive polymer, and a conductive ink, but are not limited thereto. Thicknesses of the source electrode **17** and drain electrode **19** may be appropriately determined.

[0111] Herein, the thin film transistor may, for example, have a top contact/bottom gate structure but is not limited thereto but equally have all other structures such as a bottom contact/top gate structure, a bottom contact/bottom gate structure, or a top contact/top gate structure.

[0112] The thin film transistor including the composite for sensing heat or infrared light may be used as a heat-sensing sensor measuring a temperature of an object. In other words, when heat is applied to the thin film transistor **10**, and a voltage is applied to the gate electrode, charge mobility of the semiconductor layer **15** is increased, and resistance of the source electrode **17** and the drain electrode **19** is decreased, and accordingly, a drain current flowing between the source electrode **17** and the drain electrode **19** is increased. On the contrary, when the heat is removed from thin film transistor **10**, the drain current flowing between the source electrode **17** and the drain electrode **19** is decreased. Accordingly, since electrical signal strength of the thin film transistor **10** is changed depending on a temperature, the thin film transistor **10** may work as a heat sensor or a thermal sensing device.

[0113] The thin film transistor including the composite for sensing heat or infrared light may work as a switching element or a driving element of various electronic devices. In some example embodiments, the electronic devices may be stretchable electronic devices. For example, the electronic devices may be stretchable organic light emitting diode (OLED) displays, stretchable human motion sensors, stretchable artificial muscles, prosthetics, or stretchable actuators.

[0114] In some example embodiments, the aforementioned composite for sensing heat or infrared light may be applied to (e.g., included in) a photoelectric device.

[0115] Hereinafter, a photoelectric device according to some example embodiments is described with reference to FIG. **3**.

[0116] FIG. **3** is a cross-sectional view showing a photoelectric device according to some example embodiments.

[0117] Referring to FIG. **3**, a photoelectric device **100** according to some example embodiments includes a first electrode **101** and a second electrode **103** facing each other, and an active layer **105** between the first electrode **101** and the second electrode **103**.

[0118] One of the first electrode **101** or the second electrode **103** may be an anode, and the other may be a cathode. One of the first electrode **101** or the second electrode **103** may be a light-transmitting electrode, and the light-transmitting electrode may be made of, for example, a transparent conductor such as indium tin oxide (ITO) or indium zinc oxide (IZO), or a metal thin layer of a thin monolayer or a multilayer. When one of the first electrode **101** or the second electrode **103** is an opaque electrode, it may be made of an opaque conductor such as aluminum (Al).

[0119] The active layer **105** may include the aforementioned composite.

[0120] The photoelectric device **100** may further include a photoelectric conversion layer including a p-type semiconductor compound and an n-type semiconductor compound on or under the active layer **105**. In some example embodiments, the photoelectric conversion layer may include the active layer **105**.

[0121] The photoelectric conversion layer is a layer including a p-type semiconductor compound and an n-type semiconductor compound to form a bulk heterojunction (BHJ), which receives light from outside to generate excitons, and then separates the generated excitons into holes and electrons.

[0122] Hereinafter, a photoelectric device according to some example embodiments is described with reference to FIG. **4**.

[0123] FIG. **4** is a cross-sectional view showing a photoelectric device according to some example embodiments.

[0124] Referring to FIG. **4**, a photoelectric device **200** according to some example embodiments includes a first electrode **101** and a second electrode **103** facing each other, and an active layer **105** between the first electrode **101** and the second electrode **103**, as in the photoelectric device shown in FIG. **3**.

[0125] However, in the photoelectric device **200** according to some example embodiments, unlike some example embodiments, including the example embodiments shown in FIG. **2**, the charge auxiliary layers **107** and **109** may be disposed between the first electrode **101** and the active layer **105** and between the second electrode **103** and the active layer **105**, respectively. The charge auxiliary layers **107** and **109** may make holes and electrons separated in the active layer **105** be transported easily to improve efficiency.

[0126] The charge auxiliary layers **107** and **109** may include at least one selected from a hole injection layer (HIL) for facilitating hole injection, a hole transport layer (HTL) for facilitating hole transport, an electron blocking layer (EBL) for preventing electron transport, an electron injection layer (EIL) for facilitating electron injection, an electron transport layer (ETL) for facilitating electron transport, and a hole blocking layer (HBL) for preventing hole transport.

[0127] The charge auxiliary layers **107** and **109** may include, for example, an organic material, an inorganic material, or an organic/inorganic material. The organic material may be an organic material having hole or electron characteristics and the inorganic material may be for example a metal oxide such as a molybdenum oxide, a tungsten oxide, or a nickel oxide.

[0128] One of the charge auxiliary layers **107** and **109** may be omitted.

[0129] The photoelectric device further includes a photoelectric conversion layer including a p-type semiconductor compound and an n-type semiconductor compound between the active layer **105** and the charge auxiliary layer **107** and/or between the active layer **105** and the charge auxiliary layer **109**.

[0130] In some example embodiments, the active layer **105** may include the composite.

[0131] The photoelectric device **100** and/or **200** may be applied to (e.g., included in) an organic cell, a solar cell, an image sensor, a photodetector, and a photosensor, but is not limited thereto.

[0132] The organic sensor may be an organic CMOS sensor, for example an organic CMOS infrared light sensor or an organic CMOS image sensor.

[0133] FIG. **5** is a cross-sectional view showing an example of an organic sensor according to some example embodiments.

[0134] The organic sensor **300** according to some example embodiments includes a semiconductor substrate **110**, an insulation layer **80**, and a photoelectric device **100**.

[0135] The semiconductor substrate **110** may be a silicon substrate and is integrated with a transmission transistor (not shown) and a charge storage **55**. The charge storage **55** may be integrated in each pixel. The charge storage **55** is electrically connected to the photoelectric device **100** that will be described later and information of the charge storage **55** may be transferred by the transmission transistor.

[0136] A metal wire (not shown) and a pad (not shown) are formed on the semiconductor substrate **110**. In order to decrease signal delay, the metal wire and pad may be made of a metal having low resistivity, for example, aluminum (Al), copper (Cu), silver (Ag), and alloys thereof, but are not limited thereto. Further, it is not limited to the structure, and the metal wire and pad may be disposed under the semiconductor substrate **110**.

[0137] The insulation layer **80** is formed on the metal wire and pad. The insulation layer **80** may be made of an inorganic insulating material such as a silicon oxide and/or a silicon nitride, or a low dielectric constant (low K) material such as SiC, SiCOH, SiCO, and SiOF. The insulation layer **60** has a trench **85** exposing the charge storage **55**. The trench **85** may be filled with fillers.

[0138] The aforementioned photoelectric device **100** is formed on the insulation layer **80**. As described above, the photoelectric device **100** includes a first electrode **101**, a second electrode **103**, and an active layer **105**.

[0139] In some example embodiments, the active layer **105** may include the composite.

[0140] The first electrode **101** and the second electrode **103** may both be transparent electrodes, and the active layer **105** is the same as described above. The active layer **105** may selectively absorb light in the infrared wavelength range. The light incident from the second electrode **103** side may have high absorbance characteristics in the infrared wavelength range based on the active layer **105**, and thus, may exhibit good photoelectric conversion characteristics.

[0141] FIG. **5** illustrates an example including the photoelectric device of FIG. **3**, but is not limited thereto, and may include the photoelectric device of FIG. **4**.

[0142] Focusing lens (not shown) may be further formed on the photoelectric device **100**. The focusing lens may control a direction of incident light and gather the light in one region. The focusing lens may have a shape of, for example, a cylinder or a hemisphere, but is not limited thereto.

[0143] The organic sensor according to some example embodiments may be an organic infrared light sensor, for example an iris sensor or a depth sensor.

[0144] The iris sensor identifies a person based on using unique iris characteristics of every person and specifically, taking an image of an eye of a user within an appropriate distance, processing the image, and comparing it with his/her stored image.

[0145] The depth sensor identifies a shape and a location of an object from its three-dimensional information based on taking an image of the object within an appropriate distance with a user and processing the image. This depth sensor may be, for example, used as a face recognition sensor.

[0146] FIG. **6** is a cross-sectional view showing an example of an organic sensor according to some example embodiments.

[0147] An organic sensor according to some example embodiments may be an organic CMOS image sensor.

[0148] Referring to FIG. **6**, an organic sensor **400** according to some example embodiments includes a semiconductor substrate **110** integrated with photo-sensing devices **50***a*, **50***b*, and **50***c*, a transmission transistor (not shown), and a charge storage **55**, a lower insulation layer **60**, color filters **70***a*, **70***b*, and **70***c*, an upper insulation layer **80**, and a photoelectric device **100**.

[0149] The semiconductor substrate **110** may be integrated with photo-sensing devices **50***a*, **50***b*, and **50***c*, a transmission transistor (not shown), and a charge storage **55**. The photo-sensing devices **50***a*, **50***b*, and **50***c* may be photodiodes.

[0150] The photo-sensing devices **50***a*, **50***b*, and **50***c*, the transmission transistor, and/or the charge storage **55** may be integrated in each pixel. For example, the photo-sensing device **50***a* may be included in a red pixel, the photo-sensing device **50***b* may be included in a green pixel, and the photo-sensing device **50***c* may be included in a blue pixel.

[0151] The photo-sensing devices **50***a*, **50***b*, and **50***c* sense light, the information sensed by the photo-sensing devices may be transferred by the transmission transistor, the charge storage **55** is electrically connected to the photoelectric device **100** (also referred to herein as a photoelectric diode) that will be described later, and the information of the charge storage **55** may be transferred by the transmission transistor.

[0152] A metal wire (not shown) and a pad (not shown) are formed on the semiconductor substrate **110**. In order to decrease signal delay, the metal wire and pad may be made of a metal having low resistivity, for example, aluminum (Al), copper (Cu), silver (Ag), and alloys thereof, but are not limited thereto. Further, it is not limited to the structure, and the metal wire and pad may be disposed under the photo-sensing devices **50***a* and **50***b*.

[0153] The lower insulation layer **60** is formed on the metal wire and the pad.

[0154] Color filters **70***a*, **70***b*, and **70***c* are formed on the lower insulation layer **60**. The color filters **70***a*, **70***b*, and **70***c* includes a red filter **70***a* formed in a red pixel, a green filter **70***b* formed in a green pixel, and a blue filter **70***c* formed in a blue pixel.

[0155] The upper insulation layer **80** is formed on the color filters **70***a*, **70***b*, and **70***c*. The upper insulation layer **80** eliminates steps caused by the color filters **70***a*, **70***b*, and **70***c* and planarizes the surface. The upper insulation layer **80** may have a same material composition as the insulation layer **80** of the organic sensor **300** shown in FIG. **5**.

[0156] The aforementioned photoelectric device **100** is formed on the upper insulation layer **80**. As described above, the photoelectric device **100** includes a first electrode **101**, an active layer **105**, and a second electrode **103**. Even though a structure in which the first electrode **101**, the active layer **105**, and the second electrode **103** are sequentially stacked is shown as an example in the drawing, the present disclosure is not limited to this structure, and the second electrode **103**, the active layer **105**, and the first electrode **101** may be arranged in this order.

[0157] FIG. **6** illustrates an example including the photoelectric device of FIG. **3**, but is not limited thereto, and may include the photoelectric device of FIG. **4**.

[0158] In some example embodiments, one or more, or all (e.g., any) of the elements **110**, **50***a*-**50***c*, **55**, **60**, **80**, **85**, **70***a*-**70***c*, **101**, **103**, **105**, **110** of organic sensor **400** may include the composite. For example, the active layer **105** may include the composite.

[0159] The first electrode **101** and the second electrode **103** may both be transparent electrodes, and the active layer **105** is the same as described above. The active layer **105** may selectively absorb light in an infrared wavelength region.

[0160] Incident light from the side of the second electrode **103** may be photoelectrically converted based on mainly absorbing light in an infrared wavelength region in the active layer **105**. Light in the remaining wavelength region may pass through the first electrode **101** and the color filters **70***a*, **70***b*, and **70***c*, the light in a red wavelength region passing through the color filter **70***a* may be sensed by the photo-sensing device **50***a*, the light in a green wavelength region passing through the color filter **70***b* may be sensed by the photo-sensing device **50***b*, and the light in a blue wavelength region passing through the color filter **70***c* may be sensed by the photo-sensing device **50***c*.

[0161] The aforementioned organic sensor may be applied to various electronic devices, for example and the electronic devices may include for example a camera, a camcorder, a mobile phone internally having them, a display device, a security device, or a medical device, but are not limited thereto. Accordingly, in some example embodiments, an electronic device may include the composite.

[0162] Hereinafter, the embodiments are illustrated in more detail with reference to examples. However, the example embodiments are not limited to these examples.

EXAMPLES

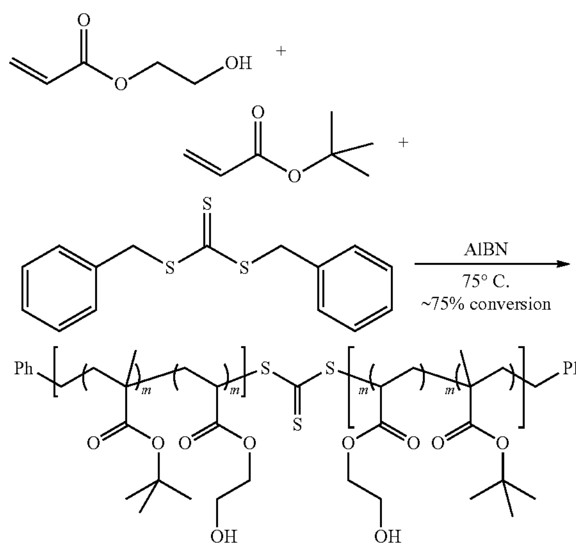
Synthesis Example 1

Preparation of Block Copolymer

[0163] A starting material and a reagent are purchased from Sigma Aldrich Co., Ltd. and purged with nitrogen to remove oxygen before a reaction.

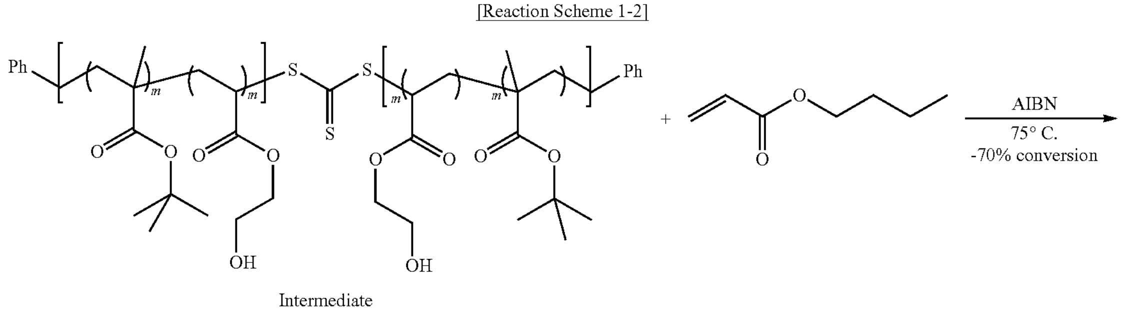
[0164] First, as shown in Reaction Scheme 1-1, 2-hydroxyethyl acrylate (1.16 g, 10 mmole) and t-butyl acrylate (1.28 g, 10 mmole) are mixed in a mole ratio of 1:1, and S,S-dibenzyl trithiocarbonate (29 mg, 0.1 mmole) is added thereto and then, purged with nitrogen for 5 minutes. Herein, azodiisobutyronitrile (AIBN) is added thereto and then, stirred at 75° C. under a nitrogen atmosphere. When the reaction proceeds about 75%, gas inside the reactor is discharged to block free radicals therein and cooled down to room temperature. Non-reacted 2-hydroxyethyl acrylate and t-butyl acrylate are vacuum-removed to obtain Intermediate of yellow oil (Mw: 162, Yield: 80%).

[Reaction Scheme 1-1]

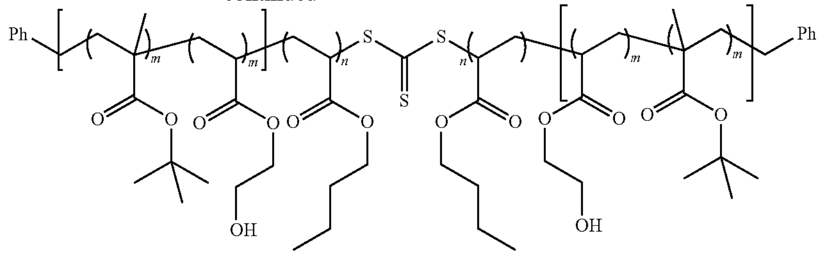


[0165] As shown in Reaction Scheme 1-2, Intermediate obtained in Reaction Scheme 1-1, n-butyl acrylate (6.4 g, 50 mmole), and AIBN are put and then, polymerized under a nitrogen atmosphere at 75° C. for about 1 hour. When the reaction proceeds about 75%, gas inside the reactor is discharged and then, cooled down to room temperature to obtain Polymer A.

[Reaction Scheme 1-2]



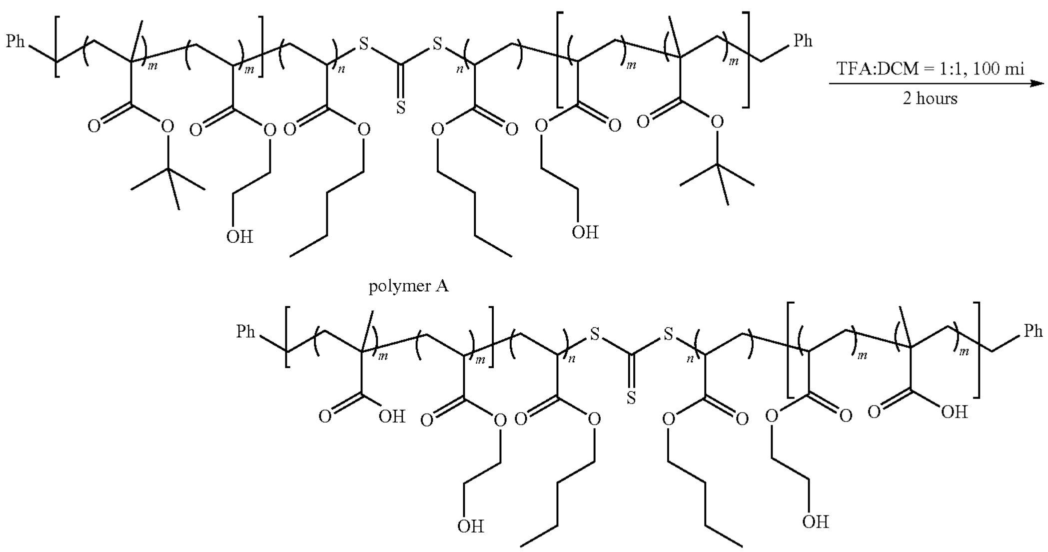
-continued



polymer A

[0166] As shown in Reaction Scheme 1-3, Polymer A is maintained in a mixed solution of dichloromethane (DCM) and trifluoroacetic acid (TFA) (a volume ratio of 1:1, 100 ml) for 2 hours to remove a t-butyl group and thus prepare an ABA block copolymer (a final polymer).

[Reaction Scheme 1-3]



Final Polymer

Example 1-1

Production of Thin Film

[0167] 99.9 ml of the block copolymer obtained in Synthesis Example 1 is dissolved in ethanol at a concentration of 2 wt % and then, stirred at 80° C. until a uniform solution is obtained. A 0.3 M $CaCl_2$ ethanol solution is prepared. The block copolymer solution is injected into a mold, and 172.8 ml of the $CaCl_2$ ethanol solution is added thereto for gelation. After the gelation reaction, a thin film obtained therefrom is dried at room temperature overnight.

Examples 1-2 to 1-4

Production of Thin Film

[0168] Thin films are formed according to the same method as Example 1-1 except that the $CaCl_2$ ethanol solution is used in each amount of 86.4 ml, 43.2 ml, and 17.3 ml.

Examples 2-1 to 2-4

Production of Thin Film

[0169] Thin films are formed according to the same method as Example 1-1 except that a 0.3 M $CoCl_2$ ethanol solution is used in each amount of 200.1 ml, 100.05 ml, 50.03 ml, and 20.01 ml instead of the $CaCl_2$ ethanol solution.

Examples 3-1 to 3-4

Production of Thin Film

[0170] Thin films are formed according to the same method as Example 1-1 except that the 0.3 M $CuCl_2$ ethanol solution is respectively used in each amount of 207.2 ml, 103.6 ml, 51.8 ml, and 20.7 ml instead of the $CaCl_2$ ethanol solution.

Examples 4-1 to 4-4

Production of Thin Films

[0171] 99.9 ml of the block copolymer according to Synthesis Example 1 is dissolved in ethanol at a concentration of 2 wt % at 80° C. and then, stirred until a uniform solution is obtained. Graphite is dispersed in glycerol to prepare graphite dispersion. A 0.3 M $CaCl_2$ ethanol solution is prepared. The graphite dispersion is mixed with the $CaCl_2$ ethanol solution to prepare a mixture. A used amount of the graphite is controlled to be 0.1 volume % in a final thin film. The $CaCl_2$ ethanol solution is used in each amount of 172.8 ml, 86.4 ml, 43.2 ml, and 17.28 ml. The block copolymer solution is injected into a mold, and the mixture is added thereto for gelation. After the gelation reaction, thin films obtained therefrom are dried at room temperature overnight.

Example 4-5

Production of Thin Film

[0172] A thin film is formed according to the same method as Example 4-1 except that the amount of graphite is controlled to be 1 volume % in a final film.

Comparative Example 1

Production of Thin Film

[0173] Vanadium oxide is deposited to form a thin film.

Comparative Example 2

Production of Thin Film

[0174] Polyvinyl alcohol is dispersed in water at a concentration of 1.5 wt % and then, coated and dried to form a thin film.

EVALUATIONS

Evaluation 1

Infrared Absorption

[0175] Absorptions of the thin films according to Examples 1-1 to 4-5 are evaluated by using a FT-IR spectrometer. The absorption of the thin film according to Example 1-1 is shown in FIG. **7**. FIG. **7** is a graph showing an infrared absorption of the thin film according to Example 1-1. Referring to FIG. **7**, the thin film according to Example 1-1 exhibits excellent absorption in an infrared region.

Evaluation 2

Thermal Stability of Thin Films

[0176] In order to evaluate thermal stability of the thin films according to Examples 1-1 to 1-3, a thermogravimetric analysis (TGA) is performed. Variation ratios of weight of the thin films of Examples 1-1 to 1-3 decomposed at a first decomposition temperature (210° C., T_1) and weights of the thin films decomposed at a second decomposition temperature (280° C., T_2) are calculated according to Equation 1 and then, shown in Table 1. Variation ratios of weights of the thin films of Examples 2-1 to 2-3 decomposed at a first decomposition temperature (200° C., T_1) and weights of the thin films decomposed at a second decomposition temperature (270° C., T_2) are calculated according to Equation 1 and then, shown in Table 1.

$$\text{Variation ratio (\%)}=((T_2-T_1)/T_1)X100 \qquad \text{[Equation 1]}$$

[0177] In the Equation 1, T_1 is the first decomposition temperature, and T_2 is the second decomposition temperature.

TABLE 1

	Variation ratio (%)
Example 1-1	1.78
Example 1-2	1.67
Example 1-3	2.04
Example 2-1	1.53
Example 2-2	2.39
Example 2-3	2.16

[0178] Referring to Table 1, the thin films according to Examples 1-1 to 1-3 exhibit a low variation ratio of less than or equal to 2.04% between the first decomposition temperature (T_1) and the second decomposition temperature (T_2), and the thin films according to Examples 2-1 to 2-3 exhibit a low variation ratio of less than or equal to 2.39% between the first decomposition temperature (T_1) and the second decomposition temperature (T_2). Accordingly, the thin films exhibit almost no material change within a semiconductor process temperature range of 200° C. to 240° C. and thus excellent process stability.

Evaluation 3

Temperature Responsivity

[0179] The thin films according to Examples 1-1 to 4-5 and Comparative Examples 1 and 2 are individually electrically connected to carbon tapes to measure a current depending on a temperature change based on using a 2-channel source meter (Keithley 2636B).

[0180] A temperature change of the thin film according to Example 1-1 and a current detected in the thin film, when 40000 cycles of temperature changes are performed, are measured and respectively shown in FIGS. **8**A and **8**B. FIG. **8**A is a view showing a cycle of temperature change applied to a thin film according to Example 1-1, and FIG. **8**B is a view showing a current detected in the thin film according to Example 1-1. Referring to FIGS. **8**A and **8**B, the same current curve as the temperature change cycle is detected, and accordingly, the thin film of Example 1 exhibits excellent current detection intensity depending on a temperature change.

[0181] The thin films of Examples 1-1 to 4-5 and Comparative Examples 1 and 2 are respectively electrically connected to carbon tapes to measure TCR (temperature coefficient of resistance) according to temperature changes based on using a 2-channel source meter (Keithley 2636B).

[0182] TCR measurement results of the thin films of Example 1-1 and Comparative Example 1 according to temperature changes are shown in FIG. **9**. FIG. **9** is a graph showing the results of measuring the TCR according to temperature changes of the thin films according to Example 1-1 and Comparative Example 1. Referring to FIG. **9**, the thin film according to Example 1-1 exhibits high TCR and a constant change and thus excellent temperature responsivity, but the thin film according to Comparative Example 1 exhibits a very irregular reaction depending on a temperature.

[0183] While this disclosure has been described in connection with what is presently considered to be practical example embodiments, it is to be understood that the inventive concepts are not limited to the disclosed example embodiments. On the contrary, the inventive concepts are intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A composite for sensing heat or infrared light, the composite comprising:

a block copolymer including

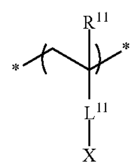
a first structural group represented by Chemical Formula 1,

a second structural group represented by Chemical Formula 2, and

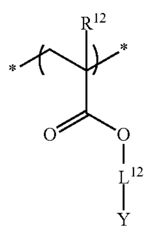
a third structural group represented by Chemical Formula 3; and

a polyvalent metal ion coordinated with a side chain group of the block copolymer,

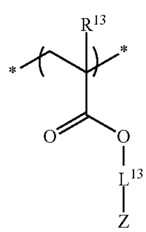
[Chemical Formula 1]



[Chemical Formula 2]



[Chemical Formula 3]



wherein, in Chemical Formulas 1 to 3,

R_{11}, R^{12}, and R^{13} are independently hydrogen or a C1 to C6 alkyl group,

L^{11} and L^{12} are independently

a single bond,

a substituted or unsubstituted C1 to C10 alkylene group,

a C2 to C20 alkylene group in which at least one methylene group is replaced by a linker selected from —O—, —S—, —C(═O)—, —S(═O)—, —$S(═O)_2$—, —C(═O)—O—, —O—C(═O)—, —C(═O)NR— wherein R is hydrogen or a C1 to C6 alkyl group, or a combination thereof, and

a substituted or unsubstituted C6 to C10 arylene group,

L^{13} is selected from a single bond, a substituted or unsubstituted C1 to C20 alkylene group, a substituted or unsubstituted C3 to C20 cycloalkylene group, and a substituted or unsubstituted C6 to C20 arylene group,

X is a carboxyl group (—COOH), a sulfonic acid group ((—$S(═O)_2OH$), or a phosphoric acid group (—O—$P(═O)(OH)_2$),

Y is selected from

a hydroxy group (—OH),

an alkoxy group (—OR, wherein R is a linear or branched C1 to C10 alkyl group),

an ester group (C(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group),

a sulfonate ester group (—$S(═O)_2OR$, wherein R is a linear or branched C1 to C10 alkyl group),

a phosphoric acid ester group (—O—$P(═O)(OR)_2$, wherein R is a linear or branched C1 to C10 alkyl group),

an amine group,

an isocyanate group (—N═C═O), and

a urethane group (—NHC(═O)OR, wherein R is a linear or branched C1 to C10 alkyl group), and

Z is selected from

a substituted or unsubstituted linear or branch C1 to C20 alkyl group,

a substituted or unsubstituted C6 to C30 aryl group,

a substituted or unsubstituted C3 to C30 heteroaryl group,

a substituted or unsubstituted C3 to C30 cycloalkyl group, and a

substituted or unsubstituted C3 to C30 heterocycloalkyl group.

2. The composite of claim **1**, wherein

the block copolymer includes a hydrophilic block (A) and a hydrophobic block (B)

the block copolymer further includes a linking group (L) between the hydrophilic block (A) and the hydrophobic block (B), wherein the linking group includes trithiocarbonate, dithiocarbonate, xanthate, or a combination thereof.

3. The composite of claim **2**, wherein the hydrophilic block (A) and the hydrophobic block (B) are symmetrically or asymmetrically present in the block copolymer with respect to the linking group (L).

4. The composite of claim **1**, wherein

the block copolymer includes a hydrophilic block (A) and a hydrophobic block (B), and

the hydrophilic block (A) includes two or more first structural groups and two or more second structural groups, wherein each structural group of the two or more first structural groups and two or more second structural groups is in a form of block copolymerization, random copolymerization, or alternating copolymerization.

5. The composite of claim **1**, wherein

the block copolymer includes a hydrophilic block (A) and a hydrophobic block (B), and

the hydrophobic block (B) includes two or more third structural groups, wherein the two or more third structural groups are in a form of block copolymerization, random copolymerization or alternating copolymerization.

6. The composite of claim **1**, wherein a sum amount of the first structural group and the second structural group in the block copolymer is about 2 moles to about 50 moles relative to 100 moles of the third structural group in the composite.

7. The composite of claim **1**, wherein the block copolymer has a weight average molecular weight of greater than or equal to about 5,000.

8. The composite of claim **1**, wherein the block copolymer is included in the composite in an amount of greater than or equal to about 20 volume % and less than or equal to about 99.9 volume % based on a total volume of the composite.

9. The composite of claim **1**, wherein the block copolymer is included in the composite in an amount of greater than or equal to about 70 volume % and less than or equal to about 99 volume % based on a total volume of the composite.

10. The composite of claim **1**, wherein the block copolymer is included in the composite in an amount of greater than or equal to about 20 volume % and less than or equal to about 50 volume % based on a total volume of the composite.

11. The composite of claim **1**, wherein the polyvalent metal ion is a divalent or higher metal ion.

12. The composite of claim **1**, wherein the polyvalent metal ion is an ion of a metal selected from Ca, Al, Cu, Co, Ba, Zn, Fe, Mn, Mg, Sr, Ba, Cr, Ti, Zr, Mo, V, and a combination thereof.

13. The composite of claim **1**, wherein the polyvalent metal ion is included in the composite in an amount of greater than or equal to about 0.1 volume % and less than or equal to about 80 volume % based on a total volume of the composite.

14. The composite of claim **1**, wherein the polyvalent metal ion is included in the composite in an amount of greater than or equal to about 1 volume % and less than or equal to about 30 volume % based on a total volume of the composite.

15. The composite of claim **1**, wherein the polyvalent metal ion is included in the composite in an amount of greater than or equal to about 50 volume % and less than or equal to about 80 volume % based on a total volume of the composite.

16. The composite of claim **1**, further comprising:

a reinforcing agent,

wherein the reinforcing agent includes graphite, carbon nanotubes, graphene, graphite nanoplates, fullerene, fullerene derivatives, quantum dots, metal oxides, or a combination thereof.

17. The composite of claim **16**, wherein the reinforcing agent is included in the composite in an amount of less than or equal to about 5 volume % based on a total volume of the composite.

18. A photoelectric device comprising the composite of claim **1**.

19. A thermal sensing device comprising the composite of claim **1**.

20. An electronic device comprising the composite of claim **1**.

* * * * *