

【DESCRIPTION】

【Invention Title】

QUENCHER CONTAINING WATER-SOLUBLE POLYMER- CONJUGATED NANOMATERIAL AND USE THEREOF

5 【Technical Field】

The present invention relates to a quencher containing a water-soluble polymer-conjugated nanomaterial and a use thereof.

【Background Art】

Methods for detecting a specific nucleic acid (DNA or RNA) or protein are
10 critical techniques in the field of scientific research. As a specific nucleic acid or protein can be detected, researchers were able to determine which genetic or biological marker is a marker indicating the health condition of a human. According to such methods for detecting a nucleic acid or protein, modification of a pathogenic gene present in a sample or the expression of a specific gene present in a
15 sample may be found.

However, an organic or inorganic polymer, such as graphene oxide, having a planar structure filled with a two-dimensional lattice and derivatives thereof can transfer electrons. Such electron transfer is caused by physical properties such as the crystalline and lattice structures of the polymer. Particularly, the fluorescent
20 signal of an organic fluorescent dye may be quenched by fluorescence resonance energy transfer (FRET).

Therefore, a change in the fluorescent signal of a fluorescent dye-conjugated

nucleic acid polymer may be observed using the physical properties of a material such as graphene oxide, and thus a biomaterial such as a nucleic acid or a protein may be detected (Korean Patent Publication No. 10-1496671). In addition, a method for detecting the activity of a fluorescence analysis-based enzyme using such a material was developed (Korean Patent Publication No. 10-1554173). Recently, techniques using such a material have been used to observe a gene or protein of a pathogen present in a sample, and therefore have become significant in the initial research on a disease and an illness.

However, while such a detection method using graphene oxide is simple, it can be greatly influenced by an amount of a target material included in a sample, and since the size distribution of nucleic acid polymers used in detection is not uniform, an error range is wide. In addition, in an *in vitro* environment for *in vitro* diagnosis, the polymers are instable, and thus reproducibility is reduced.

【Disclosure】

15 【Technical Problem】

It is an object of the present invention to provide a quencher containing water-soluble polymer-conjugated nanomaterial and a composition including the quencher and a fluorescent material-conjugated probe. In addition, it is another object of the present invention to provide a method for providing information necessary for the diagnosis of a disease using the composition.

【Technical Solution】

To achieve the objects, the present invention provides a quencher containing

a water-soluble polymer-conjugated nanomaterial.

In addition, the present invention provides a composition including the quencher and a fluorescent material-conjugated probe.

In addition, the present invention provides a method for providing
5 information necessary for the diagnosis of a disease, the method including: preparing
a mixture by mixing the composition with an isolated sample; measuring a
fluorescence level of the mixture; and comparing the resulting level with a
fluorescence level of a normal control sample.

In addition, the present invention provides a kit including the quencher and a
10 fluorescent material-conjugated probe.

【Advantageous Effects】

A quencher containing a water-soluble polymer-conjugated nanomaterial of
the present invention effectively quenches the fluorescence emitted from a
fluorescent material-conjugated probe. In addition, the water-soluble polymer-
15 conjugated nanomaterial is stably bound with the fluorescent material-conjugated
probe. Moreover, in the presence of a target material, as the probe is bound to the
target material, the probe can be easily released from the water-soluble polymer-
conjugated nanomaterial, and thus the target material can be effectively detected.
Therefore, a composition including the quencher and the fluorescent material-
20 conjugated probe can also detect a target material present at a low concentration.
For this reason, the composition can be effectively used as a composition or kit for
providing information necessary for the detection of a biomaterial or the diagnosis of
a disease.

【Description of Drawings】

FIG. 1 is a schematic diagram illustrating a method for preparing a water-soluble polymer-conjugated nanomaterial and a method for detecting a biomaterial using the material prepared thereby.

5 FIG. 2 is an atomic force microscope (AFM) image of a graphene oxide nanocolloid (GON) prepared in an example.

FIG. 3 includes scanning-transmission electron microscope (STEM; a) and AFM (b) images of two-dimensional nanomaterial, manganese dioxide, prepared in an example.

10 FIG. 4 is an AFM image of nano graphene oxide (NGO) prepared in an example.

FIG. 5 includes an AFM image (a) and a graph representing Raman spectra (b) of GON which is surface-modified with dextran (DReGON).

15 FIG. 6 is an AFM image of NGO which is surface-modified with polyethylene glycol (PEG-NGO; a), or GON which is surface-modified with PEG and polyethyleneimine (PEI) (PEG-PEI-GON; b).

FIG. 7 is a graph representing a fluorescent signal emitted from a mixture of DReGON and PNA-US5-2 (a) or PNA-DENV (b) as a probe, to confirm whether a detection composition is formed or not.

20 FIG. 8 is a graph representing a fluorescent signal emitted from a mixture of PEG-NGO and PNA-Sa (a) or PNA-Pa (b) as a probe, to confirm whether a detection composition is formed or not.

FIG. 9 is a graph representing a fluorescent signal emitted from a mixture of

PEG-PEI-GON and PNA-TS as a probe, to confirm whether a detection composition is formed or not.

FIG. 10 includes diagrams for comparing the fluorescence stability of GON (a) with that of DReGON (b).

5 FIG. 11 is a graph for confirming the target material detection capability of DReGON and GON .

FIG. 12 is a graph for confirming the detection capability of PEG-NGO when miR-21 (a) or miR-223 (b) is added as a target material at various concentrations.

FIG. 13 is a graph for confirming the detection capability of PEG-PEI-GON
10 when miR-TS is added as a target material at various concentrations.

FIG. 14 includes images for confirming that no fluorescent signal is detected when a probe is not added to various cancer cell lines.

FIG. 15 includes images for confirming the cancer cell detection capability of DReGON mixed with PNA484 or PNA31 as a probe in various cancer cell lines.

15 FIG. 16 includes graphs for confirming the blood cell detection capability of DReGON mixed with PNA21, PNA223, Let-7a or a mixture thereof (scrambled) as a probe.

FIG. 17 is a graph of fluorescence levels shown after various concentrations of a fluorescence-labeled nucleic acid sequence specifically binding to *Pseudomonas*
20 *aeruginosa* (a) or *Staphylococcus aureus* (b) are mixed with PEG-NGO, and mixed with *Pseudomonas aeruginosa* or *Staphylococcus aureus*.

FIG. 18 is a graph of fluorescence levels shown after a nucleic acid sequence specifically binding to human cytomegalovirus (a) or dengue virus (b) is mixed with DReGON, and mixed with human cytomegalovirus or dengue virus.

【Modes of the Invention】

Hereinafter, the present invention will be described in detail.

In one aspect, the present invention provides a quencher containing a water-soluble polymer-conjugated nanomaterial.

5 The term “water-soluble polymer” used herein refers to a resin or polymer that can be dissolved in water or dispersed as fine particles in water. The water-soluble polymer may be a natural polymer, semi-synthetic polymer or synthetic polymer. The water-soluble polymer that can be used in the present invention may have a molecular weight of 1 to 20 kDa, 5 to 15 kDa or 8 to 12 kDa. In one
10 embodiment, the molecular weight of the water-soluble polymer may be 10 kDa.

 The water-soluble polymer may be selected from the group consisting of chitosan and a derivative thereof, a chitosan salt, dextran and a derivative thereof, hyaluronic acid and a derivative thereof, a hyaluronate, pectin and a derivative thereof, pectin salt, an alginate and a derivative thereof, alginic acid, agar, a
15 galactomannan and a derivative thereof, a galactomannan salt, xanthan and a derivative thereof, a xanthan salt, β -cyclodextrin and a derivative thereof, a β -cyclodextrinate, polyethylene glycol (PEG), polyethyleneimine (PEI) and a combination thereof. In an embodiment, the water-soluble polymer may be selected from the group consisting of dextran, polyethylene glycol, polyethyleneimine and a
20 combination thereof.

 The term “nanomaterial” used herein refers to a nano-scale material. Due to a small size, the nanomaterial may easily pass through a cell membrane. The nanomaterial may be in a sheet or particle shape. The sheet may consist of a single

layer or multiple layers. In addition, the sheet conformation may include a flat or curved surface, and may be present in various forms. In one embodiment, the nanomaterial may be a two-dimensional single-layer sheet-type nanomaterial. In addition, the particle shape may include various forms such as a sphere, an oval, a rod, and a polygon.

A particle size of the nanomaterial may be approximately 10 to 500, 10 to 200, 10 to 150, 10 to 100, 10 to 50, 20 to 200, 20 to 150, 20 to 100, 20 to 50, 30 to 200, 30 to 150, 30 to 100, 30 to 50, 50 to 200, 50 to 150, 50 to 100, 50 to 80, 60 to 200, 60 to 100, 60 to 80, 80 to 200, 80 to 150, 80 to 100, 90 to 200, 90 to 150, or 90 to 100 nm, but the present invention is not limited thereto. In one embodiment of the present invention, the particle size of the nanomaterial is preferably 50 to 80, 90 to 200, 90 to 150 or 80 to 100 nm. Here, the particle size is an average of experimental values measured using dynamic light scattering or sizes shown in AFM or STEM images, referring to a value obtained under the assumption that the nanomaterial is spherical or circular.

The nanomaterial may be prepared as a carbon nanomaterial or manganese dioxide. Here, the carbon nanomaterial may be selected from the group consisting of NGO and a derivative thereof, reduced graphene oxide and a derivative thereof, GON and a combination thereof. In one embodiment, the nanomaterial may be NGO, GON or manganese dioxide.

The term “quencher” used herein refers to a material that absorbs fluorescence energy of a material emitting fluorescence by absorbing light or a wavelength. A quenching effect occurs due to the interaction between a fluorescent material and a nanomaterial. The quenching effect usually occurs when the

fluorescent material is located a short distance, for example, approximately 10 nm or less, from the nanomaterial. Here, the fluorescent material serves as an energy donor, and the nanomaterial serves as an energy acceptor.

The quencher may be prepared by modifying the surface of a nanomaterial by
5 a water-soluble polymer. Here, the water-soluble polymer and the nanomaterial may be conjugated by a chemical or physical bond. The chemical bond may be an amide bond, an ester bond or an ether bond, but the present invention is not limited thereto. In addition, the chemical bond may be achieved through a crosslinker. In one embodiment, the water-soluble polymer and the nanomaterial may be conjugated
10 by EDC coupling. In addition, the physical bond may be an electrostatic attraction, a hydrogen bond, or a Van der Waals bond, but the present invention is not limited thereto. In addition, such a nanomaterial which is surface-modified with a water-soluble polymer may be improved in dispersibility, stability and biocompatibility.

In addition, in another aspect, the present invention provides a composition
15 including the quencher and a fluorescent material-conjugated probe.

The term “probe” used herein refers to a material capable of specifically binding to a target material. The probe may be any one selected from the group consisting of an antibody, a nucleic acid, a peptide, a protein and a combination thereof. In addition, any material that is known as a material with high affinity to a
20 target material can be used. In an embodiment, the antibody may specifically bind to an epitope of a target protein to detect the target material. In addition, when the nucleic acid has a complementary sequence to the sequence of a nucleic acid of the target material, the nucleic acid may bind to a target base sequence to detect the target material. In addition, the peptide may specifically bind to a receptor or

ligand expressed on a cell surface to detect the target material.

The nucleic acid may be any one selected from the group consisting of DNA, RNA, mRNA, miRNA, non-coding RNA, double helix RNA, double helix DNA, a DNA-based enzyme, a deoxyribozyme, an aptamer, a peptide nucleic acid (PNA), a
5 locked nucleic acid (LNA) and a combination thereof.

Here, while the nucleic acid may consist of 10 to 50, 10 to 30, 12 to 28, 15 to 25, or 18 to 22 bases, if the nucleic acid is capable of complementary binding to a target nucleic acid sequence, there is no limit to the number of bases. In one embodiment, the nucleic acid may consist of 15 to 22 bases. In one embodiment of
10 the present invention, the nucleic acid may be any one selected from the group consisting of SEQ ID NOs: 1 to 20.

A fluorescent material binds to the probe according to the present invention. The fluorescent material is present in a quenched state by absorption of fluorescence energy by a water-soluble polymer-conjugated nanomaterial, and when the probe is
15 released from the nanomaterial due to specific binding to the target material, fluorescence is emitted. The fluorescent material may bind to one end or the middle of the probe. When the probe is a nucleic acid, the fluorescent material may be located at the 5' or 3' position of the nucleic acid or in the nucleic acid. When the probe is a peptide, the fluorescent material may bind to the N- or C-terminal of the
20 peptide, or in the peptide. The fluorescent material may bind to the probe directly or through a crosslinker.

The fluorescent material may be selected from the group consisting of fluorescein, fluorescein chlorotriazinyl, rhodamine green, rhodamine red, tetramethylrhodamine, fluorescein isothiocyanate (FITC), Oregon green, an Alexa

Fluor dye, carboxyfluorescein (FAM), 6-carboxy-4',5'-dichloro-2',7'-dimethoxyfluorescein (JOE), carboxy-X-rhodamine (ROX), 6-carboxy-2',4,4',5',7,7'-hexachlorofluorescein (HEX), Texas red (sulforhodamine 101 acid chloride), 6-carboxy-2',4,7',7-tetrachlorofluorescein (TET), tetramethylrhodamine-isothiocyanate (TRITC), carboxytetramethylrhodamine (TAMRA), a cyanine-based dye, a thiodicarbocyanine dye, and a combination thereof. The cyanine-based dye may be selected from the group consisting of Cy3, Cy5, Cy5.5, Cy7 and a combination thereof.

The quencher may detect one or more targets. To detect one or more targets, the nanomaterial may include two or more different probes. Here, each probe may include a different fluorescent material. Here, each probe may bind a different target material so as to detect a different target material.

In addition, the composition may be used to provide information necessary for the detection of a biomaterial or the diagnosis of a disease. The disease may be cancer, an infectious disease, an inflammatory disease, or a genetic disease, and in one embodiment, the disease is preferably cancer or an inflammatory disease.

The cancer may be selected from the group consisting of breast cancer, lung cancer, liver cancer, pancreatic cancer, stomach cancer, colorectal cancer, bone cancer, skin cancer, brain tumors, sarcoma, eye cancer, bone marrow cancer, blood cancer and a combination thereof. Meanwhile, the infectious disease may be caused by an infection of any one selected from the group consisting of bacteria, fungi, viruses, parasites and a combination thereof. Here, the bacteria may be enterobacteria or enterococci. Examples of the bacteria include *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Acinetobacter baumannii*. In one

embodiment of the present invention, the bacteria are preferably *Pseudomonas aeruginosa* or *Staphylococcus aureus*.

Examples of the viruses may include a double-stranded DNA virus, a single-stranded DNA virus, a double-stranded RNA virus, a positive-sense single-stranded RNA virus, a negative-sense single-stranded RNA virus, a single-stranded RNA retrovirus and a double-stranded DNA retrovirus. In one embodiment of the present invention, the virus may be selected from the group consisting of cytomegalovirus, Dengue virus and a combination thereof.

In still another aspect, the present invention provides a method for providing information necessary for the diagnosis of a disease, the method including: mixing the composition including the quencher and the fluorescent material-conjugated probe with an isolated sample; measuring a fluorescence level of the mixture; and comparing the resulting level with a fluorescence level of a normal control sample.

The quencher and the fluorescent material-conjugated probe, which are included in the composition, are as described above. In addition, the sample may be a sample isolated and discharged from a diagnosis target, and may be cells, a cell culture medium, tissue, saliva, urine, feces, semen, blood, plasma or serum. In addition, a normal control sample refers to a sample isolated and discharged from a normal person without a disease.

The method according to the present invention may be used to detect a biomaterial such as a nucleic acid or protein, or to diagnose a disease as described above. Here, the fluorescence may be determined by measuring light emitted while being released by specifically contacting or binding a fluorescent material quenched by a nanomaterial with a target material. To measure the fluorescence level, flow

cytometry, fluorescence-activated cell sorting (FACS), or a method for analyzing a fluorescent signal or an image may be used.

In yet another aspect, the present invention provides a kit including the quencher and the fluorescent material-conjugated probe. The quencher and the
5 fluorescent material-conjugated probe, which are included in the composition, are as described above. The kit may be used to detect a biomaterial such as a nucleic acid or protein, or to diagnose a disease as described above.

Hereinafter, the present invention will be fully described with reference to the
10 following examples. However, the following examples are merely provided to exemplify the present invention, and the present invention is not limited by the examples.

I. Preparation of two-dimensional nanomaterial

Example 1. Preparation of graphene oxide nanocolloid (GON)

15 4 g of $K_2S_2O_8$ and 4 g of P_4O_{10} were added to 50 ml of H_2SO_4 and dissolved while stirring. 2 g of graphite nanofiber was added to the resulting solution, and heated at 90 °C for 16 hours. The heated mixture was cooled to room temperature, 250 ml of distilled water was added thereto, followed by filtration with a paper filter (Whatman-GE Healthcare, USA). The purified mixture was washed with distilled
20 water twice or more and dried in air.

1.5 g of the dry powder-type graphite nanofiber was added to 250 ml of H_2SO_4 , 10 g of $KMnO_4$ was slowly added thereto, and reacted while stirring. Here, a reaction temperature did not exceed 10 °C. The reaction products were warmed up in 35 °C distilled water for further reaction while stirring for 6 hours. After the

reaction, 1,000 ml of distilled water was added, and here, the temperature was maintained at 55 °C or less. 50 ml of H₂O₂ was added to the mixture to allow a reaction, and the resulting mixture was centrifuged at 10,000 rpm for 30 minutes, thereby obtaining a pellet. The obtained pellet was washed with 3.4% (w/w) HCl
5 and acetone three times or more using a centrifuge.

The acetone contained in the finally-obtained brownish supernatant was removed under vacuum, and distilled water was added to the remaining solution to adjust the final concentration to 1 mg/ml, followed by vortexing for complete suspension. The collected product was purified and neutralized using a 10,000 Da
10 dialysis membrane, and the final product was lyophilized to obtain powder-type GON. The obtained GON was observed using AFM, and the result is shown in FIG. 2. As shown in FIG. 2, GON with a size of 100 nm or less and a thickness of 2 nm or less was obtained.

Example 2. Preparation of manganese dioxide (MnO₂)

15 Distilled water was added to a solution of 32 ml of sodium dodecyl sulfate (SDS) and 1.6 ml of H₂SO₄ to adjust the final volume to 300 ml. The resulting solution was heated at 95 °C for 15 minutes, and then 3.2 ml of a KMnO₄ solution was rapidly added thereto. Afterward, heating was continued for 60 minutes, and a dark brown manganese dioxide sheet was obtained.

20 Triple distilled water and an alcohol were added at a volume ratio of 1:1 to the obtained manganese dioxide sheet, and centrifuged at 12,000 rpm, thereby obtaining a pellet. In addition, centrifugation was performed twice under the same conditions to allow the obtained product to be resuspended in triple distilled water, thereby obtaining the final product. The obtained MnO₂ was observed by STEM

and AFM, and the result is shown in FIG. 3. As shown in FIG. 3b, MnO₂ with a size of 200 nm or less and a thickness of 2 nm or less was obtained.

Example 3. Preparation of nano graphene oxide (NGO)

0.5 g of Na₂NO₃ was added to 23 ml of H₂SO₄ and dissolved while stirring.

5 0.5 g of graphite nanofiber was added to the resulting solution, and then 3 g of KMnO₄ was slowly added thereto while stirring to allow a reaction. Here, a reaction temperature did not exceed 10 °C. The reaction products were warmed up in 35 °C distilled water for further reaction while stirring for 1 hour, and then were further reacted at 90 °C for 30 minutes. After the reaction, 1 ml of distilled water

10 was added, and the temperature was maintained at 55 °C or less. 3 ml of H₂O₂ was added to the reaction products to allow a reaction, cooled to room temperature, and then 250 ml of distilled water added thereto. After the resulting solution was filtered using a paper filter, a filtrate obtained thereby was washed with distilled water twice or more and dried in air.

15 To prepare graphene oxide (GO), 50 ml of 9M NaOH was added to 10 mg/ml of a graphene oxide solution, followed by tip-sonication for 90 minutes. The graphene oxide was purified and neutralized using a 3,800 Da dialysis membrane, and the final product was lyophilized to obtain powder-type NGO. The obtained NGO was observed using AFM, and the result is shown in FIG. 4. As shown in

20 FIG. 4, NGO with a size of 200 nm or less and a thickness of 1.5 nm or less was obtained.

II. Preparation of two-dimensional nanomaterial surface-modified with polymer

Example 4. Preparation of GON surface-modified with dextran

(DReGON)

The surface of the GON obtained in Example 1 was modified with dextran. Specifically, 50 mg of the GON was suspended in 50 ml of distilled water, and a 0.1%(w/w) dextran aqueous solution was added thereto. The mixture was subjected
5 to ultrasonication for 30 minutes, and then reacted with 25 μ l of an aqueous ammonia solution at 95 °C for 3 hours while stirring. The reaction product was washed with distilled water, isolated by centrifugation at 10,000 rpm for 30 minutes, and lyophilized, thereby obtaining a final product DReGON.

Raman analysis was performed using the obtained DReGON. Specifically,
10 DReGON was put on a silicon wafer, and then the silicon wafer was mounted in a Raman spectrometer (LabRAM HR UV/vis/NIR), followed by spectrum analysis by irradiation of 514 nm CW laser.

The result of observing the obtained DReGON by AFM is shown in FIG. 5a, and the result of Raman spectrum analysis is shown in FIG. 5b. As shown in FIG.
15 5a, DReGON with a size of 100 nm or less and a thickness of 7 nm or less was obtained. Meanwhile, as shown in FIG. 5b, D and G peaks were observed at 1370 cm^{-1} and 1600 cm^{-1} , respectively, and the ID/IG ratio was 0.85.

Example 5. Preparation of NGO surface-modified with polyethylene glycol (PEG)

20 The surface of the NGO obtained in Example 3 was modified with PEG. Specifically, 5 mg of NGO was mixed with the same amount of PEG (10 kDa), followed by bath-sonication. After adding 5 mg of 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC), the bath-sonication of the mixture was further performed for 5 minutes. After being stirred for 6 hours, the mixture was

purified and neutralized using a 10,000 Da dialysis membrane, and the final product was lyophilized, thereby obtaining powder-type NGO that was surface-modified with PEG (PEG-NGO).

The obtained PEG-NGO was observed by AFM, and the result is shown in FIG. 6a. As shown in FIG. 6a, the PEG-NGO with a size of 200 nm or less and a thickness of 1 nm or less was obtained.

Example 6. Preparation of GON surface-modified with polyethylene glycol and polyethyleneimide (PEI)

The surface of the GON obtained in Example 1 was modified with PEG and PEI. Specifically, 20 mg of PEG (10 kDa) was added to 10 ml of a 2 mg/ml GON solution, followed by bath-sonication for 5 minutes. By adding 20 mg of EDC, the bath-sonication of the mixture was further performed for 5 minutes. The bath-sonication was performed for 5 minutes each after the addition of 10 mg of PEI and EDC to the reaction product, followed by stirring at room temperature for 6 hours to allow uniform reactions. Afterward, the mixture was purified and neutralized using a 12,000 Da dialysis membrane, and the final product was lyophilized, thereby obtaining powder-type GON that was surface-modified with PEG and PEI (PEG-PEI-GON).

The obtained PEG-PEI-GON was observed by AFM, and the result is shown in FIG. 6b. As shown in FIG. 6b, the PEG-PEI-GON with a size of 100 nm or less and a thickness of 10 nm or less was obtained.

III. Confirmation of preparation of composition of two-dimensional nanomaterial surface-modified with polymer for detecting target material

Experimental Example 1. Confirmation of preparation of composition of

two-dimensional nanomaterial surface-modified with polymer for detecting target material

Experimental Example 1-1. Confirmation of preparation of DReGON composition for detecting target material-(1)

5 To confirm whether the DReGON prepared in Example 4 can be used as a composition for detecting a target material, an experiment was carried out as follows. Specifically, a peptide nucleic acid (PNA) probe for detecting a target material was prepared by requesting Panagene (Korea) to label Cy5 at the 5'-end, and include two units, as linkers, in which two carbon atoms are bound to one oxygen atom between
10 Cy5 and the probe sequence. 1 μ M of the PNA probe was added to 20 μ l of nuclease-free water, and completely dissolved by being heated at 80 °C for approximately 3 minutes. 20 μ l of the dissolved PNA probe was mixed with the DReGON prepared in Example 4, and reacted at room temperature for 30 minutes. Four, eight, twelve or twenty-four hours after the reaction, a fluorescence signal was
15 measured using a fluorescence reader at Ex/Em=647/670 nm. Here, only a PNA probe was used as a control.

As a result, provided that the fluorescence signal of the PNA probe is 100%, when the PNA probe is reacted with a two-dimensional nanomaterial that is surface-modified with a polymer, the fluorescence signal is reduced to less than 5%, and
20 therefore it was confirmed that the material forms a detection composition.

Experimental Example 1-2. Confirmation of preparation of DReGON composition for detecting target material-(2)

To confirm whether the DReGON prepared in Example 4 can be used as a composition for detecting a target material, an experiment was performed under the

same conditions and in the same manner as in Experimental Example 1-1. Here, as a PNA probe, PNA-US5-2 or PNA-DENV listed in Table 2 was used. 10 pmol of the PNA probe was mixed with each of 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 or 1.6 µg of DReGON. As a result, a value of the measured fluorescence signal is shown in FIG.

5 7. As shown in FIG. 7, a reduction in the fluorescence signal is dependent on a concentration of the added PNA probe, and therefore it was confirmed that the material forms a detection composition.

Experimental Example 1-3. Confirmation of preparation of PEG-NGO composition for detecting target material

10 To confirm whether the PEG-NGO prepared in Example 5 can be used as a composition for detecting a target material, an experiment was performed under the same conditions and in the same manner as in Experimental Example 1-1. Here, 10 pmol of a PNA probe was mixed with each of 0, 0.1, 0.2, 0.5 or 1.0 µg of PEG-NGO. As the PNA probe, one in which a Cy5 fluorescent dye is bound to PNA-Sa or PNA-
15 Pa, listed in Table 1 below, was used. As a result, a value of the measured fluorescence signal is shown in FIG. 8. As shown in FIG. 8, a reduction in the fluorescence signal is dependent on a concentration of the added PNA probe, and therefore it was confirmed that the material forms a detection composition.

**Experimental Example 1-4. Confirmation of preparation of PEG-PEI-
20 GON composition for detecting target material**

To confirm whether the PEG-PEI-GON prepared in Example 6 can be used as a composition for detecting a target material, an experiment was performed under the same conditions and in the same manner as in Experimental Example 1-1. 10 pmol of a PNA probe was mixed with each of 0, 0.1, 0.2, 0.5 or 1.0 µg of PEG-PEI-

NGO. As the PNA probe, one in which an FITC fluorescent dye is bound to PNA-TS listed in Table 1 below was used. As a result, a value of the measured fluorescence signal is shown in FIG. 9. As shown in FIG. 9, a reduction in the fluorescence signal is dependent on a concentration of the added PNA probe, and therefore it was confirmed that the material forms a detection composition.

Experimental Example 2. Confirmation of stability of DReGON particles

To confirm the stability of the DReGON particles prepared in Example 4, an experiment was carried out as follows. Specifically, 0.1 mg/ml of a DReGON solution was well suspended in a PBS solution containing serum, and maintained for 0, 4, 8, 12 or 24 hours at room temperature, followed by measurement of absorbance over time. As a control, the GON prepared in Example 1 was used. As a result, as shown in FIG. 10, DReGON (b) showed more stable absorption spectra in a physiologically active environment for a long period of time than those of GON (a), and such stable dispersibility was retained for 24 hours or longer.

IV. Confirmation of target material detectability of two-dimensional nanomaterial surface-modified with polymer

Experimental Example 3. Confirmation of ability to detect cancer cell-specific nucleic acid sequence

Experimental Example 3-1. Confirmation of detectability of DReGON

To measure a detection limit of the DReGON prepared in Example 4, an experiment was carried out as follows. First, PNA21 and DReGON were mixed as probes and reacted under the same conditions and in the same manner as in Experimental Example 1-1. Thirty minutes after the reaction, a target material including a cancer cell-specific sequence, that is, miR-21, was added to the reaction

product to have a concentration of 0, 0.001, 0.01, 0.1, 1, 10, 100 or 1,000 nM, and reacted at room temperature for 2 hours. Fluorescence signals were measured using a fluorescence reader at Ex/Em=647/670 nm. The sequences of the PNA probe and the target materials used in the experiment are listed in Tables 1 and 2 below.

5 [Table 1]

Target disease	Probe	Sequence (5'→3')	SEQ ID NO:
Cancer	PNA21	TCAACATCAGTCTGATAAGCTA	SEQ ID NO: 1
	PNA31	AGCTATGCCAGCATCTTGCCT	SEQ ID NO: 2
	PNA223	ATTTGACAAACTGAC	SEQ ID NO: 3
	PNA484	GGAGGGGACTGAGCCTG	SEQ ID NO: 4
	Let-7a	AACTATACAACCTACTACCTCA	SEQ ID NO: 5
	PNA-TS	CTGCCCCAAAATGCCT	SEQ ID NO: 6
Bacterial disease	PNA-Pa	GCGGCATGGCTGGATC	SEQ ID NO: 7
	PNA-Sa	ACAGAGTTTTACGATC	SEQ ID NO: 8
Viral disease	PNA-US5-2	AGACATCGTCACACCTATCATA	SEQ ID NO: 9
	PNA-DENV	GCGTTTCAGCATATTGA	SEQ ID NO: 10

[Table 2]

Target disease	Target material	Sequence (5'→3')	SEQ ID NO:
Cancer	miR-21	UAGCUUAUCAGACUGAUGUUGA	SEQ ID NO: 11
	miR-31	AGGCAAGAUGCUGGCAUAGCU	SEQ ID NO: 12
	miR-223	GUCAGUUUGUCAAU	SEQ ID NO: 13
	miR-484	CAGGCUCAGUCCCCUCC	SEQ ID NO: 14
	Let-7a	UGAGGUAGUAGGUUGUAUAGUU	SEQ ID NO: 15
	miR-TS	AGGCAUUUUGGGGCAG	SEQ ID NO: 16
Bacterial disease	miR-Pa	GAUCCAGCCAUGCCGC	SEQ ID NO: 17

	miR-Sa	GAUCGUAAAACUCUGU	SEQ ID NO: 18
Viral disease	miR-US5-2	UAUGAUAGGUGUGACGAUGUCU	SEQ ID NO: 19
	miR-DENV	UCAAUAUGCUGAAACGC	SEQ ID NO: 20

Results derived by substituting changes in fluorescence before and after the addition of a target material into Equation 1 below are shown in FIG. 11. Here, as a control, the GON prepared in Example 1 was used.

5 [Equation 1]

$$\text{Detection Limit} = 3.3\left(\frac{SD}{S}\right)$$

*SD: Standard deviation, S: Slope of calibration line

As shown in FIG. 11, GON detected up to 230 pM of the target material, but DReGON detected up to 10 pM of the target material. From the result, it was confirmed that the two-dimensional nanomaterial that was surface-modified with a polymer according to the present invention can also detect a target nucleic acid present at a low concentration in a sample.

Experimental Example 3-2. Confirmation of detectability of PEG-NGO

The ability of PEG-NGO to detect a cancer cell-specific nucleic acid sequence was confirmed under the same conditions and in the same manner as in Experimental Example 3-1. Here, 10 pmol of the PEG-NGO prepared in Example 5, instead of DReGON, was used, and PNA21 and PNA233 as probes and miR-21 and miR-233 as target materials were used at 0, 0.002, 0.02, 0.2, 2, 20, 200 or 2,000 nM. In addition, after the target material was added, a reaction was performed for 4 hours, a fluorescence change was measured at intervals of 20 minutes, and the result

is shown in FIG. 12. As shown in FIG. 12, as the concentration of the target material was increased, the fluorescence signal became stronger, and fluorescence was restored to different levels according to the concentration and type of a probe.

Experimental Example 3-3. Confirmation of detectability of PEG-PEI-GON

The ability of PEG-PEI-NGO to detect a cancer cell-specific nucleic acid sequence was confirmed under the same conditions and in the same manner as in Experimental Example 3-1. Here, 10 pmol of the PEG-PEI-NGO prepared in Example 6, instead of DReGON, was used, and PNA-TS as a probe and miR-TS as a target material were used at 100, 200, 300 or 500 nM. In addition, after the target material was added, a reaction was performed for 4 hours, a fluorescence change was measured at intervals of 20 minutes, and the result is shown in FIG. 13. As shown in FIG. 13, as the concentration of the target material was increased, the fluorescence signal became stronger, and fluorescence was restored in a different level according to the concentration and type of a probe.

Experimental Example 3-4. Confirmation of detectability of DReGON in cancer cell lines

The ability of DReGON to detect a cancer cell-specific nucleic acid sequence was confirmed using various types of cancer cell lines. First, MCF-7, HeLa and SW620 cell lines were prepared by being cultured in a DMEM or RPMI medium. However, PNA484 or PNA31 as a probe was mixed with DReGON under the same conditions and in the same manner as in Experimental Example 1-1 to allow a reaction. The prepared cells were seeded into a 12-well plate to have a density of 1×10^5 cells per well, and after 24 hours, a reaction product of DReGON, and

PNA484 or PNA31 was added to the cells at a concentration of 80 pmol.

After 14 hours, images of fluorescence signals of cells observed using a fluorescence microscope are shown in FIG. 15. Here, as a control, images taken without addition of a probe to cells are shown in FIG. 14. As shown in FIG. 15,
5 detection of the target material by DReGON was identified through a fluorescence signal of a fluorescent material-conjugated probe.

Experimental Example 3-5. Confirmation of detectability of DReGON in blood cells

To confirm the detectability of DReGON for a specific base sequence present
10 in blood cells, an experiment was carried out as follows. Specifically, blood cells were collected from 10 ml of healthy human blood by a known method, and cultured in an RPMI medium. The cultured cells were fixed and 200 nM of a PNA probe to which 3.0 µg of DReGON and a Cy5 fluorescent dye were bound was added. Here,
as a PNA probe, PNA21, PNA223, Let-7a or a mixture thereof (scrambled) was used.
15 As a control, an untreated cell group was used.

After 4 hours, the intensity of fluorescence restored in the blood cells, detected by flow cytometry, is shown in FIG. 16. As shown in FIG. 16, it was confirmed that a target base sequence expressed in the blood cells is detected by the PNA probe.

20 Experimental Example 4. Confirmation of ability of PEG-NGO to detect bacteria-specific nucleic acid sequence

The ability of PEG-NGO to detect a *Pseudomonas aeruginosa* or *Staphylococcus aureus*-specific nucleic acid sequence was confirmed under the same conditions and in the same manner as in Experimental Example 3-1. Here, 0.2 µg

of the PEG-NGO prepared in Example 5, instead of DReGON, and 10 pmol of PNA-Pa or PNA-Sa were added, and then 0, 10, 20, 40, 70 or 100 nM of *Pseudomonas aeruginosa* or *Staphylococcus aureus* AS-DNA was added thereto as a target material. As a result, the measured fluorescence change is shown in FIG. 17. As shown in FIG. 17, the intensity of fluorescence was increased depending on the concentration of the added *Pseudomonas aeruginosa* or *Staphylococcus aureus* AS-DNA.

Experimental Example 5. Confirmation of ability DReGON to detect virus-specific nucleic acid sequence

The ability of DReGON to detect a human cytomegalovirus (HCMV) or dengue virus (DENV)-specific nucleic acid sequence was confirmed under the same conditions and in the same manner as in Experimental Example 3-1. Here, 0.5 µg of DReGON, and 20 pmol of PNA-US5-2 or PNA-DENV were added, and 20 pmol of miR-US5-2 or miR-DENV was added thereto as a target material. As a result, fluorescence changes measured over reaction time are shown in FIG. 18. As shown in FIG. 18, the intensity of fluorescence for a HCMV or DENV-specific nucleic acid sequence added depending on a reaction time was increased.

Consequently, from the results, it can be demonstrated that, unlike a microarray or RT-PCR, the composition of the present invention can easily detect a target sequence, and can be used to indirectly confirm the concentration of the target sequence.

Sequence Listing Free Text

SEQ ID NO: 1: tcaacatcag tctgataagc ta

- SEQ ID NO: 2: agctatgcca gcatcttgcc t
- SEQ ID NO: 3: atttgacaaa ctgac
- SEQ ID NO: 4: ggagggggact gagcctg
- SEQ ID NO: 5: aactatacaa cctactacct ca
- 5 SEQ ID NO: 6: ctgccccaaa atgcct
- SEQ ID NO: 7: gcggcatggc tggatc
- SEQ ID NO: 8: acagagtttt acgatc
- SEQ ID NO: 9: agacatcgtc acacctatca ta
- SEQ ID NO: 10: gcgtttcagc atattga
- 10 SEQ ID NO: 11: uagcuuauca gacugauguu ga
- SEQ ID NO: 12: aggcaaugaug cuggcauagc u
- SEQ ID NO: 13: gucaguuugu caaa
- SEQ ID NO: 14: caggcucagu cccucc
- SEQ ID NO: 15: ugagguagua gguuguauag uu
- 15 SEQ ID NO: 16: aggcauuuug gggcag
- SEQ ID NO: 17: gauccagcca ugccgc
- SEQ ID NO: 18: gaucguaaaa cucugu
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- SEQ ID NO: 20: ucaauaugcu gaaacgc

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PCB603020LMN.txt

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【CLAIMS】

【Claim 1】

A quencher comprising a water-soluble polymer-conjugated nanomaterial.

【Claim 2】

5 The quencher of claim 1, wherein the water-soluble polymer is any one selected from the group consisting of chitosan and a derivative thereof, a chitosan salt, dextran and a derivative thereof, hyaluronic acid and a derivative thereof, a hyaluronate, pectin and a derivative thereof, a pectin salt, an alginate and a derivative thereof, alginic acid, agar, a galactomannan and a derivative thereof, a
10 galactomannan salt, xanthan and a derivative thereof, a xanthan salt, β -cyclodextrin and a derivative thereof, a β -cyclodextrinate, polyethylene glycol (PEG), polyethyleneimine (PEI) and a combination thereof.

【Claim 3】

 The quencher of claim 1, wherein the nanomaterial has a particle or sheet
15 form.

【Claim 4】

 The quencher of claim 3, wherein the nanomaterial has a particle size of 0.01 to 1 μm .

【Claim 5】

20 The quencher of claim 1, wherein the nanomaterial is prepared as a carbon

nanomaterial or manganese dioxide.

【Claim 6】

The quencher of claim 5, wherein the carbon nanomaterial is any one selected from the group consisting of nano graphene oxide (NGO) and a derivative thereof,
5 reduced graphene oxide and a derivative thereof, a graphene oxide nanocolloid (GON) and a combination thereof.

【Claim 7】

The quencher of claim 1, wherein the conjugation is achieved by a chemical or physical bond.

10 **【Claim 8】**

The quencher of claim 7, wherein the chemical bond is EDC coupling.

【Claim 9】

The quencher of claim 7, wherein the physical bond is a hydrogen bond.

【Claim 10】

15 A composition comprising the quencher of claim 1 and a fluorescent material-conjugated probe.

【Claim 11】

The composition of claim 10, wherein the probe is any one selected from the group consisting of an antibody, a nucleic acid, a peptide, a protein and a
20 combination thereof.

【Claim 12】

The composition of claim 11, wherein the nucleic acid consists of 10 to 50 bases.

【Claim 13】

5 The composition of claim 11, wherein the nucleic acid is any one selected from the group consisting of DNA, RNA, mRNA, miRNA, non-coding RNA, double helix RNA, double helix DNA, a DNA-based enzyme, a deoxyribozyme, an aptamer, a peptide nucleic acid (PNA), a locked nucleic acid (LNA) and a combination thereof.

【Claim 14】

10 The composition of claim 11, wherein the nucleic acid is any one selected from the group consisting of SEQ ID NOs: 1 to 10.

【Claim 15】

The composition of claim 10, wherein the fluorescent material is selected from the group consisting of fluorescein, fluorescein chlorotriazinyl, rhodamine
15 green, rhodamine red, tetramethylrhodamine, fluorescein isothiocyanate (FITC), Oregon green, an Alex Fluor dye, carboxyfluorescein (FAM), 6-carboxy-4',5'-dichloro-2',7'-dimethoxyfluorescein (JOE), carboxy-X-rhodamine (ROX), 6-carboxy-2',4,4',5',7,7'-hexachlorofluorescein (HEX), Texas red (sulforhodamine 101
acid chloride), 6-carboxy-2',4,7',7-tetrachlorofluorescein (TET),
20 tetramethylrhodamine-isothiocyanate (TRITC), carboxytetramethylrhodamine (TAMRA), a cyanine-based dye, a thiodicarbocyanine dye, and a combination thereof.

【Claim 16】

The composition of claim 15, wherein the cyanine-based dye is any one selected from the group consisting of Cy3, Cy5, Cy5.5, Cy7 and a combination thereof.

5 **【Claim 17】**

The composition of claim 10, wherein the composition is for detection of a biomaterial or diagnosis of a disease.

【Claim 18】

10 The composition of claim 17, wherein the disease is cancer, an infectious disease, an inflammatory disease, or a genetic disease.

【Claim 19】

The composition of claim 18, wherein the infectious disease is caused by an infection of any one selected from the group consisting of bacteria, fungi, viruses, parasites and a combination thereof.

15 **【Claim 20】**

The composition of claim 19, wherein the bacteria include any one selected from the group consisting of *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Acinetobacter baumannii* and a combination thereof.

【Claim 21】

20 The composition of claim 19, wherein the viruses include any one selected from the group consisting of a double-stranded DNA virus, a single-stranded DNA

virus, a double-stranded RNA virus, a positive-sense single-stranded RNA virus, a negative-sense single-stranded RNA virus, a single-stranded RNA retrovirus, a double-stranded DNA retrovirus and a combination thereof.

【Claim 22】

5 The composition of claim 19, wherein the virus is any one selected from the group consisting of human cytomegalovirus, Dengue virus and a combination thereof.

【Claim 23】

A method for providing information necessary for the diagnosis of a disease, comprising:

- 10 1) mixing the composition of claim 10 with an isolated sample;
- 2) measuring a fluorescence level of the mixture; and
- 3) comparing the resulting level with a fluorescence level of a normal control sample.

【Claim 24】

15 The method of claim 23, wherein the disease is cancer, an infectious disease, an inflammatory disease or a genetic disease.

【Claim 25】

A kit comprising the quencher of claim 1 and a fluorescent material-conjugated probe.

20