

A Composite Powder Material

Technical Field

5 The present invention relates to a composite powder material for generating negative ions and radiation, a paint formulation, an article, methods of preparing the above and use of the composite powder material as an antimicrobial additive.

Background Art

10 Negative ions have been found to have various beneficial properties, which have been verified in recent years by medical experts from various countries in clinical practice and experimental studies. The value of negative ion materials has been actively explored for commercial applications.

15 The negative ions are helpful for improving air quality, and on the other hand, positively charged ion constantly worsens the quality of air. The concentration of negative ions is closely related to air quality in an environment. Generally, there is large amount of negative ions in places such as forests, beaches and waterfalls, which can be hundred times more than seriously-polluted urban areas. People can feel happy, relaxed and joyful by breathing the air which has high amount of negative ions.

20 The negative ions have also shown biological significance by having good sterilizing function. They can destroy bacterial cytolemma or enzymatic activities after combining with the bacteria. They can also change the structure of bacteriophage to inhibit formation of new bacteria, thereby achieving the purpose of antibiotic and sterilizing.

25 At present, the applications of negative ion materials have been mainly focused on air purification or healthcare for humans. However, there are limited focus and studies on the antibacterial properties of the negative ion materials. Use of the negative ion material as an additive which can be added in a product to give the product antimicrobial properties is still lacking.

30 Therefore, there is a need to provide a composite powder material for generating negative ions and radiation, a method for preparing the same and use of the composite powder material as an antimicrobial additive that overcome or ameliorate one or more of the disadvantages mentioned above.

35 Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taking in conjunction with the accompanying drawing and this background of the disclosure.

Summary

40 In one aspect, the present disclosure relates to a composite powder material for generating negative ions and radiation comprising:

- 45 a) tourmaline particles;
b) rare-earth mineral particles;
c) silicate mineral particles;
d) metal oxide particles; and
e) a binder,
wherein the sizes of the (a) tourmalines particles, the (b) rare earth mineral particles, the (c) silicate mineral particles and the (d) metal oxide particles are 5 μm or less.

50 Advantageously, the half-life of the radiating materials such as the tourmaline particles and the rare-earth mineral particles are in the range of thousands of years. Therefore, the composite powder material

has effectively life-long antibacterial properties. The rare-earth mineral particles may enhance the effect of the radiating materials. The silicate mineral particles may be used as inert materials for making up the required quantity of the composite powder material. The silica mineral particles may be porous materials with the function of absorbing smells.

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Further advantageously, the composite powder material is very stable, light resistant and temperature resistant. It can be effectively incorporated into objects, panels and structures during manufacturing process and does not change color. As the objects, panels and structures have inherent antibacterial properties for the duration of their life, there is no need for replenishment and labour-intensive spraying or coating.

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Still advantageously, the composite powder material has good slow-release property and can be prepared by a simple producing process. The good slow-release property can avoid excessive amount of negative ions and/or radiation over their entire duration of usage.

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Still advantageously, by having the particle size less than 5 μm , better transparency and clarity can be achieved when the composite powder material is incorporated in an end product, such as a film. By having particle size less than 5 μm , the anti-bacteria effect will be better due to the increase of surface area.

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In another aspect, the present disclosure relates to a method for preparing the composite powder material as described herein, comprising the steps of

a) grinding a mixture of tourmaline, rare-earth mineral, silicate mineral, and metal oxide particles with particle sizes of 5 μm or less;

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b) adding a binder to the ground mixture; and

c) drying the mixture to obtain the composite powder material.

In another aspect, the present disclosure relates to a paint formulation comprising the composite powder material as described herein.

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In another aspect, the present disclosure relates to a method for preparing a paint formulation for generating negative ions and radiation, comprising the steps of

a) mixing water, dispersing agent, defoamer, preservative, propylene glycol, pigment, and the composite powder material as described herein in a first container.

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b) mixing emulsion, water, defoamer, coalescent, thickener in a second container; and

c) pouring the mixture in the second container into the first container and further mixing to obtain the paint formulation.

In another aspect, the present disclosure relates to an article comprising the composite powder material as described herein.

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In another aspect, the present disclosure relates to a method for preparing a film for generating negative ions and radiation, comprising the steps of

a) mixing the composite powder material as described herein with a first polymer to obtain a first mixture;

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b) extruding the first mixture in a twin screw compounder to obtain a master batch;

c) mixing the master batch with a second polymer to obtain a second mixture; and

d) extruding the second mixture by blowing process to obtain the film.

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In another aspect, the present disclosure relates to a suspension comprising the composite powder material as described herein.

In another aspect, the present disclosure relates to a method for preparing a suspension for generating negative ions and radiation, comprising the step of mixing a solvent, a dispersing agent, a polymer and the composite powder material as described herein in a container.

In another aspect, the present disclosure relates to use of the composite powder material as described herein as an antimicrobial additive.

Advantageously, the use of the composite powder material as an antimicrobial additive can kill the bacteria remotely using a radiative process. Therefore, there is no need for the composite powder material to be in direct contact with the bacteria as the radiation range is a few centimetres.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "negative ion" as used herein represents negatively charged ions generated by combining air molecules with free electrons. The free electrons may be generated by radiation and ionization of neutral gas molecules. Examples of the negative ions are, but not limited to, negative oxygen ions.

The term "negative ion material" as used herein represents a material that is capable of generating negative ions.

The term "radiation" or "radiating" as used herein represents radioactive radiation, electrostatic radiation, or infrared radiation that are capable of generating negative ions.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Certain embodiments may also be described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the disclosure. This includes the generic description of the embodiments with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

Detailed Description of Embodiments

Exemplary, non-limiting embodiments of a composite powder material will now be disclosed.

- 5 The present disclosure relates to a composite powder material for generating negative ions and radiation comprising
 - a) tourmaline particles;
 - b) rare-earth mineral particles;
 - c) silicate mineral particles;
 - 10 d) metal oxide particles; and
 - e) a binder,wherein the sizes of the (a) tourmalines particles, the (b) rare earth mineral particles, the (c) silicate mineral particles and the (d) metal oxide particles are 5 μm or less.
- 15 The negative ions may be produced by Jules-Renard effect and utilizing tourmaline or the natural energy of other negative ion mineral materials to excite air ionization to produce the negative ions. Utilizing natural negative ion generating material to obtain negative ions has the advantage of low cost as an economical production method.
- 20 The sizes of the (a) tourmalines particles, the (b) rare earth mineral particles, the (c) silicate mineral particles and the (d) metal oxide particles may be in the range of about 0.01 μm to about 5 μm , about 0.05 μm to about 5 μm , about 0.1 μm to about 5 μm , about 0.5 μm to about 5 μm , about 1 μm to about 5 μm , about 3 μm to about 5 μm , about 0.01 μm to about 3 μm , about 0.01 μm to about 1 μm , about 0.01 μm to about 0.5 μm , about 0.01 μm to about 0.1 μm , or about 0.01 μm to about 0.05 μm .
- 25 The tourmaline particles may be in the range of about 20 wt% to about 60 wt%, about 25 wt% to about 60 wt%, about 30 wt% to about 60 wt%, about 35 wt% to about 60 wt%, about 40 wt% to about 60 wt%, about 45 wt% to about 60 wt%, about 50 wt% to about 60 wt%, about 55 wt% to about 60 wt%, about 20 wt% to about 55 wt%, about 20 wt% to about 50 wt%, about 20 wt% to about 45 wt%, about 30 wt% to about 40 wt%, about 20 wt% to about 35 wt%, about 20 wt% to about 30 wt%, about 20 wt% to about 25 wt based on the total weight of the composite powder material.
- 30 The rare earth mineral particles may be in the range of about 20 wt% to about 40 wt%, about 25 wt% to about 40 wt%, about 30 wt% to about 40 wt%, about 35 wt% to about 40 wt%, about 20 wt% to about 35 wt%, about 20 wt% to about 30 wt%, about 20 wt% to about 25 wt% based on the total weight of the composite powder material.
- 35 The rare-earth mineral particles may be selected from the group consisting of monazite, bastnaesite, xenotime and their mixtures thereof.
- 40 The silicate particles may be in the range of about 20 wt% to about 50 wt%, about 25 wt% to about 50 wt%, about 30 wt% to about 50 wt%, about 35 wt% to about 50 wt%, about 40 wt% to about 50 wt%, about 45 wt% to about 50 wt%, about 20 wt% to about 45 wt%, about 20 wt% to about 40 wt%, about 20 wt% to about 35 wt%, about 20 wt% to about 30 wt%, about 20 wt% to about 25 wt based on the total weight of the composite powder material.
- 45 The silicate particles may be muscovite. The silicate particles may further comprise zeolite, diatomite, bentonite or other silicate particles to make up the required quantity for the composite materials. The silicate particles may further comprise zeolite.
- 50 The metal oxide particles may be in the range of about 1 wt% to about 30 wt%, about 1 wt% to about 30 wt%, about 3 wt% to about 30 wt%, about 5 wt% to about 30 wt%, about 7 wt% to about 30 wt%, about 10 wt% to about 30 wt%, about 15 wt% to about 30 wt%, about 20 wt% to about 30 wt%, about 25 wt% to about 30 wt%, about 1 wt% to about 25 wt%, about 1 wt% to about 20 wt%, about 1 wt% to

about 15 wt%, about 1 wt% to about 10 wt%, about 1 wt% to about 7 wt%, about 1 wt% to about 5 wt%, or about 1 wt% to about 3 wt% based on the total weight of the composite powder material.

5 The metal oxide may be zinc oxide, copper oxide, titanium oxide or zinc peroxide. The metal oxide may be an enhancer of the antibacterial property of the composite powder material. The tourmaline particles and the rare-earth mineral particles can kill bacteria without physical contact. The metal oxide can kill bacteria upon physical contact. These types of antibacterial effect are complementary to each other. The metal oxide may also be binding agent and photocatalyst for air purification. The metal oxide may further comprise rare-earth oxide selected in the group consisting of cerium oxide, ytterbium oxide, 10 lanthanum oxide, neodymium oxide, holmium oxide, thulium oxide, lutetium oxide and their mixtures thereof. The rare-earth oxide may also be an enhancer of the antibacterial property of the composite powder material.

15 The binder may be in the range of about 1 wt% to about 20 wt%, about 1 wt% to about 20 wt%, about 3 wt% to about 20 wt%, about 5 wt% to about 20 wt%, about 10 wt% to about 20 wt%, about 15 wt% to about 20 wt%, about 1 wt% to about 15 wt%, about 1 wt% to about 10 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 3 wt based on the total weight of the composite powder material.

20 The binder may be selected from the group consisting of acrylic acid, poly-vinylpyrrolidone (PVP), acrylates, acrylamides, and their copolymers/mixtures thereof. Any other polymer that can be used as a binder may also be applicable. The binder may be film forming agent. The composite powder material may further comprise other mineral particles, such as silicon dioxide, germanium oxide, arsenic oxide, boron oxide. The other mineral particles may act as support for making up the component of the composite powder material. The composite powder material may further 25 comprise silicon dioxide.

The composite powder material may further comprise silver particles or other antibacterial particles known in the art.

30 The composite powder material may comprise
 20 to 60 wt% of tourmaline particles;
 20 to 40 wt% of monazite;
 20 to 40 wt% of muscovite;
 1 to 10 wt% of zeolite;
 35 1 to 10 wt% of silicon dioxide
 1 to 10 wt% of zinc oxide; and
 1 to 20 wt% of acrylic acid.

40 Exemplary, non-limiting embodiments of a composite powder material will now be disclosed.

The present disclosure relates to a method for preparing the composite powder material as described herein, comprising the steps of

- 45 a) grinding a mixture of tourmaline, rare-earth mineral, silicate mineral, and metal oxide particles with particle sizes of 5 μm or less;
 b) adding a binder to the ground mixture; and
 c) drying the mixture to obtain the composite powder material.

50 The particle sizes of step a) may be in the range of about 0.01 μm to about 5 μm , about 0.05 μm to about 5 μm , about 0.1 μm to about 5 μm , about 0.5 μm to about 5 μm , about 1 μm to about 5 μm , about 3 μm to about 5 μm , about 0.01 μm to about 3 μm , about 0.01 μm to about 1 μm , about 0.01 μm to about 0.5 μm , about 0.01 μm to about 0.1 μm , or about 0.01 μm to about 0.05 μm .

55 The binder may be selected from the group consisting of acrylic acid, poly-vinylpyrrolidone (PVP), acrylates, acrylamides, and their copolymers/mixtures thereof.

The binder may be about 30 wt% to about 50 wt%, about 35 wt% to about 50 wt%, about 40 wt% to about 50 wt%, about 45 wt% to about 50 wt%, about 30 wt% to about 45 wt%, about 30 wt% to about 40 wt% or about 30 wt% to about 35 wt in water.

- 5 The present disclosure also relates to a paint formulation comprising the composite powder material as described herein.

The present disclosure also relates to a method for preparing a paint formulation for generating negative ions and radiation, comprising the steps of

- 10 a) mixing water, dispersing agent, defoamer, preservative, propylene glycol, pigment, and the composite powder material as described herein in a first container.
 b) mixing emulsion, water, defoamer, coalescent, thickener in a second container; and
 c) pouring the mixture in the second container into the first container and further mixing to obtain the paint formulation.

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Non limiting examples of the dispersing agent include polyacrylic acid, polyurethanes, polyacrylates, modified fatty acids, phosphoric acid esters, sodium hexametaphosphate, and combinations thereof.

- 20 Non limiting examples of the defoamer include mineral oil, vegetable oil, white oil, ethylene bis stearamide (EBS), paraffin waxes, ester waxes, fatty alcohol waxes, silica, cement, plaster, detergents, polyethylene glycol and polypropylene glycol copolymers, alkyl polyacrylates, polydimethylsiloxanes and other silicones, alcohols, stearates, glycols, and combinations thereof.

- 25 Non limiting examples of the preservative include zinc oxide, silver, Methylisothiazolinone, chloromethylisothiazolinone, benzisothiazolinone, octylisothiazolinone, dichlorooctylisothiazolinone, butylbenzisothiazolinone, formaldehyde-releasing biocides, 1,2-Benzisothiazolin-3-one, and combinations thereof.

- 30 Non limiting examples of the coalescent include glycols or water-soluble glycol ethers, such as PB (propylene glycol butyl ether) and DPB (dipropylene glycol butyl ether), TPiB (2,2,4-trimethyl-1,3-pentane diol mono-isobutyrate, propylene glycol mono esters of C6/ C10-aliphatic acids, and their combinations thereof.

- 35 Non limiting examples of the thickener include polyurethanes, acrylic polymers, latex, styrene/butadiene, polyvinyl alcohol, clays, cellulosic, sulfonates, gums, saccharides, proteins, modified castor oil, organosilicones, and their combinations thereof.

- 40 The present disclosure also relates to an article comprising the composite powder material as described herein. The article may be a film or plate.

- The present disclosure also relates to a method for preparing a film for generating negative ions and radiation, comprising the steps of

- 45 a) mixing the composite powder material as described herein with a first polymer to obtain a first mixture;
 b) extruding the first mixture in a twin screw compounder to obtain a master batch;
 c) mixing the master batch with a second polymer to obtain a second mixture; and
 d) extruding the second mixture by blowing process to obtain the film.

- 50 The first polymer and the second polymer can be the same or different. The first polymer and the second polymer may be independently selected from the group consisting of low-density polyethylene (LDPE),

linear low-density polyethylene (LLDPE), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and their mixtures thereof. The first polymer in step a) and the second polymer in step c) can be different types of the same polymer, i.e. polyethylene (PE). For example, the first polymer in step a) may be low-density polyethylene (LDPE) and the second polymer in step c) may be linear low-density polyethylene (LLDPE).

The present disclosure also relates to a suspension comprising the composite powder material as described herein.

The present disclosure also relates to a method for preparing a suspension for generating negative ions and radiation, comprising the step of mixing a solvent, a dispersing agent, a polymer and the composite powder material as described herein in a container.

Non limiting examples of the dispersing agent include polyacrylic acid, polyurethanes, polyacrylates, modified fatty acids, phosphoric acid esters, sodium hexametaphosphate, polyethylene glycol (PEG), fish oil, and combinations thereof. A criteria for choosing the dispersing agents is that they should have a surface tension so that particles can bind onto the dispersing agent. The dispersing agent may preferably be sodium hexametaphosphate.

The polymer may be selected from the group consisting of poly(acrylic acid) (PAA), low-density polyethylene (LDPE), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and their mixtures thereof.

The present disclosure also relates to use of the composite powder material as described herein as an antimicrobial additive.

The composite powder material may be used as an antimicrobial additive which can efficiently and stably release negative ions at 2200-4000/s.cm.

Brief Description of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1

[Fig. 1] shows the photos of the films prepared for antimicrobial testing, with the additives of A) silver; B) silver + zinc; and C) the composite powder material.

Fig. 2

[Fig. 2] shows the photos in comparison of the films prepared with 5 μ m and 20 μ m particle size of the composite powder material. Fig. 2A shows the transparency comparison of the films on a substrate. Fig. 2B and 2C show the comparison of the free-standing films at a distance from the background.

Fig. 3

[Fig. 3] shows the transmittance profiles of the films with 20 μ m particle size and 5 μ m particle size.

Examples

Non-limiting examples of the invention will be further described in greater detail by reference to specific Examples, which should not be construed as in any way limiting the scope of the invention.

Materials

Tourmaline was purchased from Lingshou Teyuan Minerals Processing Plant in China. Monazite was purchased from Broad Vision Enterprise Co., Ltd in Taiwan. Muscovite was purchased from Tianjin Yandong Mining Co., Ltd. in China. Zinc oxide, silicon dioxide, acrylic acid and cerium oxide were purchased from Sigma Aldrich (Singapore).

Example 1: Preparation of the Composite Powder Material

40 grams of tourmaline, 30 grams of monazite, 30 grams of muscovite, 5.5 grams of zeolite, 5.5 grams of zinc oxide and 5.5 grams of silicon dioxide were mixed and grinded in a ball mill machine (Simoloyer CM08) until the particle sizes were less than 5 μm . Zirconia was used as grinding media. The mixture was grinded for 8 to 12 hours and powders were removed off from bottle wall every 2 hours as the powders would stick to bottle wall. Total usage amount of zirconia beads was 28 to 35% of volume ratio of tank. The proportion of 80 mm beads was 80 to 100% and the proportion of 20 mm beads was 20 to 0%.

26.25 mL of 40 wt% acrylic acid in water was added.

The mixture was dried at 80 °C for 120 minutes to obtain the composite powder material.

Example 2: Preparation of Paint Formulation

23.6 mL of water was prepared in a first container and was stirred at 300 rpm. 0.8 grams of dispersing agent (0.8 mL of 0.034 g/mL TEGOMER DA640 in water), 0.2 grams of defoamer (0.2 mL of 0.008 g/mL evonik TEGO-Antifoam 1-85 in water), 0.2 grams of preservative (0.19 mL of 0.008 g/mL Benzoisothiazolinone in water) and 1.4 grams of propylene glycol (1.35 mL of 0.059 g/mL propylene glycol in water) were slowly poured in the first container. The mixture was stirred for 30 minutes. Then, 15.8 grams of pigment (3 mL of 0.67 g/mL titanium dioxide or ferric oxide in water) and 2.4 grams of the composite powder material were slowly poured in the first container. The mixture was stirred for 60 minutes.

46.4 grams of emulsion (Acronal PS608 ap, BASF) was prepared in a second container and was stirred at 300 rpm. 6.1 mL of water, 0.3 grams of defoamer (evonik TEGO-Antifoam 1-85), 2.0 grams of coalescent (Rhodoline CL3101, Solvay) and 0.8 grams of thickener (Acrysol RM-12W, DOW) were slowly poured in the second container. The mixture was stirred for 30 minutes.

The mixture in the second container was poured into the first container. The mixture was stirred for 30 minutes to obtain the paint formulation.

The paint formulation may have the ranges of the components as shown in Table 1 below.

Table 1. Components of the paint formulation.

Content	amount (%)	
	minimum	maximum
A) water	24.5	26.5
B) Dispersing agent for water based application.	0.7	1.1
C) Defoamers for emulsion paints.	0.2	0.3
D) Preseverative	0.15	0.2
E) Pigment	14	20

F) Negative ion powder	0.1	5
G) Propylene glycol	1	2
Letdown		
H) Defoamers for emulsion paints.	0.1	0.5
I) Emulsion	45	55
J) Coalescent	1.9	2.5
K) thickener.	0.5	1.2
L) water	6	7.25

Example 3: Preparation of film/plate

12.5 grams of the composite powder material was mixed into 87.5 grams of polyethylene (PE) solid resin. The mixture was mixed in a tumbler for 60 minutes.

The mixture was extruded in a twin screw compounder as the master batch with the parameters of a) barrier temperature 150 to 250°C; b) speed 300 to 400 rpm; and c) orifice diameter 2 mm.

17.5 grams of the master batch was further mixed with 82.5 grams of polyethylene (PE) solid resin for 60 minutes.

The mixture was extruded by blowing process as a film at a temperature of 150 to 200°C and with an extrusion speed of 200 rpm.

Polymers such as low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET) can also be used to prepare the film/plate.

The paint formulation may have the ranges of the components as shown in Table 2 below.

Table 2. Components of the film/plate.

Content	amount (%)	
	minimum	maximum
Master batch		
A) Negative ion powder	5	20
B) LDPE/PE/PP/PET	95	80
Film		
C) master batch	25	10
D) LDPE/PE/PP/PET	75	90

Example 4: Preparation of negative ion material suspension in water

64.4 grams of water was prepared in a container and stirred at 300 rpm.

0.5 grams of sodium hexametaphosphate (0.2 mL of 0.0078 g/mL sodium hexametaphosphate in water) and 0.1 grams of component poly(acrylic acid) (0.09 mL of 0.0015 g/mL poly(acrylic acid) in water) were slowly poured into the container. The mixture was stirred for 30 minutes.

35 grams of the composite powder material was slowly poured into the container and the mixture was stirred for 60 minutes.

The negative ion material suspension may have the ranges of the components as shown in Table 3 below.

Table 3. Components of the negative ion material suspension.

Content	amount (%)	
	minimum	maximum
A) Water	50	79
B) Sodium hexametaphosphate	0.1	1
C) poly(acrylic acid) (PAA)	0.01	0.1
D) the composite powder material	20	50

5 Example 5: Characterization of negative ion generation

The release of negative ion was characterized with IT-10 ion Tester (ONETEST). The composite powder material components and their negative ion generation are listed in Table 4 below.

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Table 4. Components of the composite powder material

Tourmaline	Monazite	Muscovite	Zeolite	Silicon dioxide	Zinc oxide	Acrylic acid	Negative ion generation
20 g	30 g	30 g	5.5 g	5.5 g	5.5 g	10.5 g	2200ion/cm ³
40 g							3600ion/cm ³
60 g							4000 ion/cm ³
40 g					0		3600 ion/cm ³
40 g				0	5.5 g		3600 ion/cm ³
40 g			0	5.5 g	5.5 g		4000 ion/cm ³

The composite powder material can efficiently and stably release negative ions at 2200-4000/s.cm.

Example 6: Characterization of antibacterial properties

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Antibacterial film

The sample of negative ion material was prepared according to the method in Example 3 using polyethylene (PE) as the polymer. The sample was a colorless transparent film on a flat substrate as shown in Fig. 1.

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As control, the other membranes containing silver or silver and zinc oxide were also prepared by the extrusion method.

The three samples tested as named as Resi-J1F (silver), Resi-J2F (silver + zinc), and Resi-NF (the composite powder material).

The antimicrobial properties were measured according to ISO 22196 using Escherichia Coli CGMCC 1.2385 as the testing strain.

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At the beginning of the test ("0 hour"), the average number of live bacteria was 1.2×10^4 CFU/cm². After 24 hours, the average number of still viable bacteria increased to 7.4×10^5 CFU/cm². The average numbers of live bacteria in the three samples were counted and it was found that the sample with the negative ion material showed the least average number of live bacteria of 1.3×10^3 . The average numbers of live bacteria in the sample of silver and the sample of silver and zinc were counted as 2.6×10^4 and 5.6×10^4 respectively.

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The antibacterial rates were calculated using the formula below:

$$\text{Antibacterial rate} = (C_t - T_t) / C_t$$

$$\text{Antibacterial Performance Value} = \log C_t - \log T_t$$

- 5 C_t = 24 hour average number of still viable bacteria in samples (CFU / cm²)
 T_t = 24 hour average number of live bacteria in samples (CFU / cm²)

The antibacterial performance values of the samples were calculated using the formula below:

- 10 The results are summarized in Table 5 below.

Table 5. Antibacterial properties of the antibacterial films

Sample Name	Test strains	"24 hour" Average number of still viable bacteria (CFU/cm ²)	"24 hour" Average number of live bacteria in samples (CFU/cm ²)	Antibacterial Performance Value	Antibacterial rate (%)
Resi-J1F(silver)	Escherichia Coli CGMCC 1.2385	7.4×10^5	2.6×10^4	1.5	96
Resi-J2F(silver + zinc oxide)			5.6×10^4	1.2	92
Resi-NF (the composite powder material)			1.3×10^3	2.8	99

- 15 Therefore, the film prepared by the negative ion material of the present disclosure showed better antibacterial performance as compared to the control samples.

Antibacterial paint

- 20 The antibacterial properties of the paint prepared in Example 2 was also characterized and is shown in the table below. Glass was used as the substrate material. It was shown that the paint with 1% negative ion composite powder material had improved antibacterial properties as compared to the paint without the negative ion composite powder material.

Table 6. Antibacterial properties of the antibacterial paint

Sample Type	Description of Sample	Substrate material used	Negative ion composite powder material	Antibacterial activity/ Anti-viral Activity (E.Coli)	% Reduction of microbes	Antibacterial activity/ Anti-viral Activity (S. aureus)	% Reduction of microbes
Paint	Paint with no negative ion composite powder material	Glass	0	1.8	>90%	1.79	>90%
Paint INF	Paint with 1 wt% negative ion composite powder material	Glass	1%	3.79	>99.9%	3.72	>99.9%

Comparative Example 1: Particle size effect

The composite powder materials with different particle sizes, i.e. 5 μm and 20 μm , were prepared according to the method of Example 1. Films with 5 μm and 20 μm particle sizes of the composite powder materials were prepared according to the method of Example 3. Both films have 1% of the negative ion composite powder material. The comparison of the films with 5 μm and 20 μm particle sizes on a substrate is shown in Fig. 2A and the comparison of the free-standing films with two particle sizes at a distance from the background is shown in Fig. 2B and 2C. It can be seen that the film with 5 μm particle size has more transparency and luster as compared to the film with 20 μm particle size. The transmittance profiles of the films with 20 μm particle size and 5 μm particle size are shown in Fig. 3, which also showed the film with 5 μm particle size has higher transmittance than the 20 μm particle size.

The antibacterial property of the films with 5 μm and 20 μm particle sizes of the composite powder materials were also characterized and shown in the table below. By reducing the particle size from 20 μm to 5 μm the antibacterial rate was increased from 65% to 99%.

Table 7. Comparison of antibacterial properties of particle sizes 5 μm and 20 μm

Particle size	Antibacterial rate (<i>Escherichia coli</i> ATCC 8739)
5 μm	99%
20 μm	65%

Industrial Applicability

In the present disclosure, the composite powder material may be used as antimicrobial additive which can be incorporated into building materials, glass panels and laminates, paints and coatings, panels, veneers, wall paper, all parts of a toilet seats, home appliances, textiles, ceramic tiles and objects, plastic containers and objects, cutlery and crockery, hospital appliances and structures.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A composite powder material for generating negative ions and radiation comprising
 - a) tourmaline particles;
 - b) rare-earth mineral particles;
 - c) silicate mineral particles;
 - d) metal oxide and
 - e) a binder,
 wherein the sizes of the (a) tourmalines particles, the (b) rare earth mineral particles, the (c) silicate mineral particles and the (d) metal oxide or rare-earth oxide particles are 5 μm or less.
2. The composite powder material of claim 1, wherein the tourmaline particles are in the range of 20 to 60 wt% based on the total weight of the composite powder material.
3. The composite powder material of claim 1 or 2, wherein the rare earth mineral particles are in the range of 20 to 40 wt% based on the total weight of the composite powder material.
4. The composite powder material of any of the preceding claims, wherein the rare-earth mineral particles are selected from the group consisting of monazite, bastnaesite, xenotime and their mixtures thereof.
5. The composite powder material of any of the preceding claims, wherein the silicate particles are in the range of 20 to 50 wt% based on the total weight of the composite powder material.
6. The composite powder material of any of the preceding claims, wherein the silicate particles are muscovite.
7. The composite powder material of claim 6, wherein the silicate particles further comprise zeolite.
8. The composite powder material of any of the preceding claims, wherein the metal oxide particles are in the range of 1 to 30 wt% based on the total weight of the composite powder material.
9. The composite powder material of any of the preceding claims, wherein the metal oxide is zinc oxide, copper oxide, titanium oxide or zinc peroxide.
10. The composite powder material of any of the preceding claims, wherein the metal oxide further comprises cerium oxide.
11. The composite powder material of any of the preceding claims, wherein the binder is in the range of 1 to 20 wt% based on the total weight of the composite powder material.
12. The composite powder material of any of the preceding claims, wherein the binder is acrylic acid.
13. The composite powder material of any of the preceding claims, further comprising silicon dioxide particles.
14. The composite powder material of any of the preceding claims, further comprising silver particles.
15. The composite powder material of claim 1, comprising
 - 20 to 60 wt% of tourmaline particles;
 - 20 to 40 wt% of monazite;
 - 20 to 40 wt% of muscovite;
 - 1 to 10 wt% of zeolite;
 - 1 to 10 wt% of silicon dioxide;

1 to 10 wt% of zinc oxide; and
1 to 20 wt% of acrylic acid.

16. A method for preparing the composite powder material of claims 1 to 15, comprising the steps of
 - a) grinding a mixture of tourmaline, rare-earth mineral, silicate mineral, and metal oxide particles with particle sizes of 5 μm or less;
 - b) adding a binder to the ground mixture; and
 - c) drying the mixture to obtain the composite powder material.
17. The method of claim 16, wherein the binder is acrylic acid.
18. The method of claim 16 or 17, wherein binder is 30 to 50 wt% in water.
19. A paint formulation comprising the composite powder material of any one of claims 1 to 15.
20. A method for preparing a paint formulation for generating negative ions and radiation, comprising the steps of
 - a) mixing water, dispersing agent, defoamer, preservative, propylene glycol, pigment, and the composite powder material of any one of claims 1 to 13 in a first container.
 - b) mixing emulsion, water, defoamer, coalescent, thickener in a second container; and
 - c) pouring the mixture in the second container into the first container and further mixing to obtain the paint formulation.
21. An article comprising the composite powder material of any one of the claims 1 to 15.
22. The article of claim 21, wherein the article is a film or plate.
23. A method for preparing a film for generating negative ions and radiation, comprising the steps of
 - a) mixing the composite powder material of any one of claims 1 to 15 with a first polymer to obtain a first mixture;
 - b) extruding the first mixture in a twin screw compounder to obtain a master batch;
 - c) mixing the master batch with a second polymer to obtain a second mixture; and
 - d) extruding the second mixture by blowing process to obtain the film.
24. The method of claim 23, wherein the first and the second polymer are independently selected from the group consisting of low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and their mixtures thereof.
25. A suspension comprising the composite powder material of any one of claims 1 to 15.
26. A method for preparing a suspension for generating negative ions and radiation, comprising the step of mixing a solvent, a dispersing agent, a polymer and the composite powder material of any one of claims 1 to 15 in a container.
27. The method of claim 26, wherein the dispersing agent is sodium hexametaphosphate.
28. Use of the composite powder material of any one of claims 1 to 15 as an antimicrobial additive.