# A Core-Shell Composite And A Process Of Preparing The Same

## References to Related Applications

This application claims priority to Singapore application number 10201808838P filed on 5 October 2018, the disclosure of which is hereby incorporated by reference.

## Technical Field

The present invention relates to a core-shell composite and a process of preparing the same.

## Background Art

Microbial infections and the development of antimicrobial resistance have received attention as one of the most critical issues facing the public health and security. The creation of clean antimicrobial surfaces with long-term stabilities and activities have tremendous applications involving almost all aspects of daily life, such as medical devices, hospital surfaces, textiles, packaging, electrical appliances, marine antifouling, filters and public surfaces.

Inorganic antimicrobial materials, especially semiconductor antimicrobial materials are less prone to chemical contamination and possess long-term stability. When these semiconductor materials are synthesized using two or more materials and multilayers result, a core-shell type material is formed, often with core-shell particles showing distinctive properties of the materials employed together. The physiochemical and structural properties of materials including particle size and concentration, morphology, presence of surface charges and conductivity, can affect their antimicrobial activity and toxicity mechanisms. Some metal or metal oxides, such as silver, zinc oxide and titanium oxide materials have been used as antimicrobial ingredients in various products or in antimicrobial surface coatings. However, these materials have various limitations, such as heavy metal contamination/ toxicity for silver-based materials and low antimicrobial efficacies due to dependence on photo irradiation and uncertain nano-toxicity for zinc oxide and titanium oxide materials.

Therefore, there is a need to provide a process and a core-shell material for antimicrobial activity that overcome or ameliorate one or more of the disadvantages mentioned above.

## Summary

The present disclosure relates to a core-shell composite comprising a core comprising a zinc metal, and a shell that at least partially encapsulates the core, wherein the shell comprises a salt of the zinc metal as a cation with a sulphur-containing anion.

In one aspect, the present disclosure relates to a core-shell composite comprising: a core comprising zinc metal; and a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion, wherein said sulphur-containing anion has the formula $[S_xO_{1-x}]^{y-}$, where $0 < x < 1$ and y is 1 or 2.

Advantageously, the core-shell composite formed in the present disclosure may be able to release reactive oxygen species without the need for activation by ultraviolet or visible light irradiation.
Further advantageously, the core-shell composite may demonstrate an antimicrobial activity in the form of antibacterial and antifungal effects. Thus, the core-shell composite can be used as an antimicrobial additive to be mixed in other systems or as part of an antimicrobial surface coating.

The present disclosure also relates to a method of forming a core-shell composite comprising the step of heating a mixture of zinc metal particle with elemental sulphur to form said core-shell composite, wherein the zinc metal particle forms the core of the core-shell composite, and

wherein the shell of the core-shell composite at least partially encapsulates said core and comprises a salt of the zinc metal as a cation with a sulphur-containing anion.

In another aspect, the present disclosure relates to a method of forming a core-shell composite comprising the step of heating a mixture of a zinc metal particle with elemental sulphur at a temperature in the range of 100 ºC to 160 ºC to form said core-shell composite, wherein the zinc metal particle forms the core of said core-shell composite, and wherein the shell of said core-shell composite at least partially encapsulates said core and comprises a salt of said zinc metal as a cation with a sulphur-containing anion.

Advantageously, the core-shell composite formed in the present disclosure may be stable and easily synthesized, thus enabling scale-up in manufacturing.

The present disclosure also relates to a method of killing or inhibiting the growth of a microbe, comprising the step of subjecting the microbe to a core-shell composite, wherein the core-shell composite comprises a core comprising zinc metal and a shell that at least partially encapsulates the core, wherein the shell comprises a salt of the zinc metal as a cation with a sulphur-containing anion.

In another aspect, the present disclosure relates to a non-therapeutic method of killing or inhibiting the growth of a microbe, comprising the step of subjecting said microbe to a core-shell composite, wherein said core-shell composite comprises: a core comprising zinc metal; and a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion

In another aspect, the present disclosure relates to the use of a core-shell composite as an anti-microbial coating on a substrate surface, wherein the core-shell composite comprises a core comprising a zinc metal, and a shell that at least partially encapsulates the core, wherein the shell comprises a salt of the zinc metal as a cation with a sulphur-containing anion.

The present disclosure also relates to the use of a core-shell composite as an additive in a composition or a formulation, wherein the core-shell composite comprises a core comprising zinc metal, and a shell that at least partially encapsulates the core, wherein the shell comprises a salt of the zinc metal as a cation with a sulphur-containing anion.

In another aspect, the present disclosure relates to the use of a core-shell composite as an additive in an antimicrobial composition or a formulation, wherein said core-shell composite comprises: a core comprising zinc metal; and a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion.

Advantageously, the core-shell composite formed in the present disclosure may be highly active against gram-positive and gram-negative bacteria and fungi without the need for activation by ultraviolet or visible light irradiation.

## Definitions

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

The term “core-shell” as used herein refers to the structural form comprising of a core of inner material and external shell of one or more layers of material.

The term “composite” as used herein refers to a material made of two or more constituent components that are of different physical and/or chemical properties such that when combined, the resulting material has characteristics different from the constituent components and the individual components remain separate and distinct within the finished structure.

The term “antimicrobial” as used herein refers to causing cell inhibition, cell injury or cell death of target bacteria and fungi microorganisms.

The term “additive” as used herein refers to a substance that is added to another substance or product in minor quantities to impart or improve certain desired performance properties.

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

# Claims

1. A core-shell composite comprising:
a core comprising zinc metal; and
a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion, wherein said sulphur-containing anion has the formula $[S_xO_{1-x}]^{y-}$, where $0 < x < 1$ and y is 1 or 2.

2. The core-shell composite of claim 1, wherein said shell comprises a plurality of layers, each layer independently comprising said salt of said zinc metal as a cation with a sulphur-containing anion.

3. A method of forming a core-shell composite comprising the step of heating a mixture of a zinc metal particle with elemental sulphur at a temperature in the range of 100 $^oC$ to 160 $^oC$ to form said core-shell composite,
wherein the zinc metal particle forms the core of said core-shell composite,
and wherein the shell of said core-shell composite at least partially encapsulates said core and comprises a salt of said zinc metal as a cation with a sulphur-containing anion.

4. The method of claim 3, further comprising the step of reacting said core-shell composite with an aqueous solution.

5. The method of claim 3 or 4, wherein said heating step is undertaken for a period of time in the range of 1 hour to 10 hours.

6. The method of claim 3, further comprising the step of, before said reacting step, cooling the core-shell composite to a temperature of 100 °C.

7. The method of claim 4, wherein said reacting step is undertaken at a temperature in the range of 90 $^oC$ to 110 $^oC$.

8. The method of claim 4 or 7, wherein said reacting step is undertaken for a period of time in the range of 1 hour to 10 hours.

9. The method of any one of claims 4, 7 or 8, wherein said aqueous solution is water.

10. A non-therapeutic method of killing or inhibiting the growth of a microbe, comprising the step of subjecting said microbe to a core-shell composite, wherein said core-shell composite comprises:
a core comprising zinc metal; and
a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion.

11. The non-therapeutic method of claim 10, wherein said core-shell composite is present as a coating on a substrate surface.

12. The non-therapeutic method of claim 11, wherein said core-shell composite is present as an additive in a composition or a formulation.

13. Use of a core-shell composite as an anti-microbial coating on a substrate surface, wherein said core-shell composite comprises:
a core comprising zinc metal; and
a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion.

14. Use of a core-shell composite as an additive in an antimicrobial composition or a formulation, wherein said core-shell composite comprises:
a core comprising zinc metal; and
a shell that at least partially encapsulates said core, said shell comprising a salt of said zinc metal as a cation with a sulphur-containing anion.