

Claims

1. A substrate coated with a layered double hydroxide having the following structure (A):

$$[M^{2+}_{(1-x)}N^{3+}_x(HO^-)_2]^{x+}[(X^{n-})_{x/n}.yH_2O]^{x-} \quad (A)$$
 wherein
 - 5 M^{2+} is a divalent cation;
 - N^{3+} is a trivalent cation;
 - x is in the range of 1/6 to 1/2;
 - y is in the range of 0.5 to 4;
 - X^{n-} is an anion; and
 - 10 n is an integer selected from 1, 2 or 3;
 wherein the layered double hydroxide is surface modified with a group 10 element on the Periodic Table of Elements or a compound selected from the group consisting of: a fatty acid, a polymer, and an amino acid.
- 15 2. The substrate according to claim 1, wherein the layered double hydroxide is calcined.
3. The substrate according to claim 1 or 2, wherein the divalent cation is selected from a group 2, group 7, group 8, group 9, group 10, group 11 or group 12 element on the Periodic Table of Elements or, wherein the divalent cation is selected from the group consisting of Mg^{2+} , Zn^{2+} , Cu^{2+} , Ni^{2+} and Co^{2+} .
- 20 4. The substrate according to any one of the preceding claims, wherein the trivalent cation is selected from a group 6, group 8, or group 13 element on the Periodic Table of Elements or, wherein the trivalent cation is selected from the group consisting of Al^{3+} , Fe^{3+} and Cr^{3+} .
5. The substrate according to any one of the preceding claims, wherein the stoichiometric $M^{2+}:N^{3+}$ ratio is in the range of 1:1 to 5:1.
- 25 6. The substrate according to any one of the preceding claims, wherein X^{n-} is NO_3^- or Cl^- and n is 1, or X^{n-} is SO_4^{2-} and n is 2.
7. The substrate according to any one of the preceding claims, wherein the layered double hydroxide is vertically aligned or has a hexagonal shape.

8. The substrate according to any one of the preceding claims, wherein the layered double hydroxide has an average thickness in the range of 50 nm to 175 nm or an average spacing between each piece of adjacent LDH in the range of 300 nm to 550 nm.
9. The substrate according to any one of claims 2 to 8, wherein the calcined layered double hydroxide has an average thickness in the range of 50 nm to 100 nm.
10. The substrate according to any one of the preceding claims, wherein the fatty acid is a C₁₅ to C₂₂ fatty acid, the polymer is a polymer comprising an amine group, the amino acid is an amino acid having a charged side chain, or the group 10 element on the Periodic Table of Elements is selected from the group consisting of nickel, palladium and platinum or, wherein the fatty acid is oleic acid, the polymer is polyethyleneimine, the amino acid is L-glutamic acid or L-arginine, or the group 10 element on the Periodic Table of Elements is platinum.
11. The substrate according to any one of the preceding claims, wherein the substrate is selected from the group consisting of glass, plastic, metal or alloy, ceramic and any mixture thereof.
12. A method of preparing a substrate coated with a surface-modified layered double hydroxide, the method comprising the steps of:

providing a substrate coated with a layered double hydroxide having the following structure (A):

$$[M^{2+}_{(1-x)}N^{3+}_x(HO^-)_2]^{x+}[(X^{n-})_{x/n} \cdot yH_2O]^{x-} \quad (A)$$

wherein

M²⁺ is a divalent cation;

N³⁺ is a trivalent cation;

x is in the range of 1/6 to 1/2;

y is in the range of 0.5 to 4;

Xⁿ⁻ is an anion; and

n is an integer selected from 1, 2 or 3; and

contacting the substrate coated with a layered double hydroxide with a group 10 element on the Periodic Table of Elements or a compound selected from the group consisting of: a fatty acid, a polymer, and an amino acid.
13. The method according to claim 12, further comprising the step of calcining the layered double hydroxide before contacting the substrate with the group 10 element on the Periodic

Table of Elements or the compound selected from the group consisting of: a fatty acid, a polymer, and an amino acid.

14. The method according to claim 13, wherein the calcining step is performed in air at a temperature in the range of 400 °C to 500 °C for a duration in the range of 15 hours to 20 hours.

15. The method according to any one of claims 12 to 14, wherein the substrate coated with the layered double hydroxide is prepared by contacting a substrate with a compound having a formula $M'(X')_2 \cdot zH_2O$ and a compound having a formula $N'(X')_3 \cdot zH_2O$ in the presence of urea base,

wherein M' is a divalent cation;

N' is a trivalent cation;

z is independently in the range of 1 to 12;

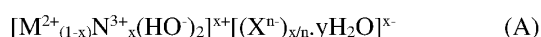
X' is independently an anion; and

heating the substrate.

16. The method according to any one of claims 12 to 15, wherein $M':N'$ is in the ratio of 2:1, and wherein $M'(X')_2 \cdot yH_2O$ is $Mg(NO_3)_2 \cdot 6H_2O$ and $N'(X')_3 \cdot yH_2O$ is $Al(NO_3)_3 \cdot 9H_2O$.

17. The method according to any one of claims 12 to 16, wherein the heating step is performed at a temperature in the range of 80 °C to 110 °C for a duration in the range of 40 hours to 60 hours.

18. Use of a layered double hydroxide as an antimicrobial, the layered double hydroxide having the following structure (A):



wherein

M^{2+} is a divalent cation;

N^{3+} is a trivalent cation;

x is in the range of 1/6 to 1/2;

y is in the range of 0.5 to 4;

X^{n-} is an anion; and

n is an integer selected from 1, 2 or 3;

wherein the layered double hydroxide is surface modified with a group 10 element on the Periodic Table of Elements or a compound selected from the group consisting of: a fatty acid, a polymer, and an amino acid.

19. The use of according to claim 18, wherein the layered double hydroxide is calcined.
- 5 20. The use according to claim 18 or 19, wherein the antimicrobial inhibits the growth of a microorganism, and the microorganism is selected from the group consisting of *E. coli*, *S. aureus*, Methicillin-resistant *S. aureus* and *C. albicans*.
21. Use of a calcined layered double hydroxide as an antimicrobial, the layered double hydroxide having the following structure (A):
- 10 $[M^{2+}_{(1-x)}N^{3+}_x(HO^-)_2]^{x+}[(X^{n-})_{x/n} \cdot yH_2O]^{x-} \quad (A)$
- wherein
- M^{2+} is a divalent cation;
- N^{3+} is a trivalent cation;
- x is in the range of 1/6 to 1/2;
- 15 y is in the range of 0.5 to 4;
- X^{n-} is an anion; and
- n is an integer selected from 1, 2 or 3.