Summary

There is provided an aqueous coating suspension that comprises:

a) layered double hydroxide (LDH);
b) at least one modifier; and
c) a polymer matrix.

In an aspect, there is provided an aqueous coating suspension that comprises:

a) layered double hydroxide (LDH);
b) at least one modifier, wherein the modifier comprises a silane coupling agent selected from the group consisting of (3-aminopropyl)trimethoxysilane, (3-glycidoxypropyl)trimethoxysilane, and mixtures thereof,; and
c) a polymer matrix, wherein the polymer matrix comprises at least one polymer having a hydroxyl functional group and at least one polymer having a carboxyl functional group and wherein the weight ratio of the polymer having a hydroxyl functional group and the polymer having a carboxyl functional group is 9:1 to 2:1.

Advantageously, layered double hydroxide (LDH) with well-designed composition and structure could yield advanced functional materials for new applications or studies which need homogeneous materials with well-defined sizes and shapes. Further advantageously, the synthesized LDH may have features including high purity, tunable structure and morphology and mass production, as compared to natural sourced clay.

There is provided a process of preparing the coating suspension described herein, comprising the steps of:

a. providing an aqueous suspension of layered double hydroxide (LDH); and
b. contacting the layered double hydroxide (LDH) aqueous suspension with an aqueous solution of polymer having a hydroxyl functional group followed by an aqueous solution of polymer having a carboxyl functional group.

In another aspect, there is provided a process of preparing the coating suspension as defined above, comprising the steps of:

a1) contacting an aqueous suspension of LDH with at least one modifier, wherein the at least one modifier is as defined above,
a) providing an aqueous suspension of layered double hydroxide (LDH), and
b) contacting the layered double hydroxides (LDHs) aqueous suspension with an aqueous solution of polymer having a hydroxyl functional group followed by an aqueous solution of polymer having a carboxyl functional group.

Advantageously, the aqueous solution of polymer having a hydroxyl functional group is mixed with positively charged LDH solution first to moderate the bonding strength between LDH and the polymer having a carboxyl functional group. Therefore, a stable gelatinous suspension can be produced without gel formation, and the suspension can be further applied onto substrates directly. As a result, the LDH/polymer barrier film with appropriate bonding strength show better oxygen barrier than that prepared from naturally sourced clay.

There is provided an aqueous coating suspension prepared by the process described herein.

Claims

1. An aqueous coating suspension that comprises:

a) layered double hydroxide (LDH);

b) at least one modifier, wherein the modifier comprises a silane coupling agent selected from the group consisting of (3-aminopropyl)trimethoxysilane, (3-glycidoxypropyl)trimethoxysilane, and mixtures thereof,; and

c) a polymer matrix, wherein the polymer matrix comprises at least one polymer having a hydroxyl functional group and at least one polymer having a carboxyl functional group and wherein the weight ratio of the polymer having a hydroxyl functional group and the polymer having a carboxyl functional group is 9:1 to 2:1.

2. The aqueous coating suspension according to claim 1, wherein the LDH has a chemical formula according to formula (I) shown below:

$$[M^{z+}_{1-x}M'^{y+}_{x}(OH)_2]^{a+}(X^{n-})_{a/n}\bullet bH_2O\bullet c(\text{solvent}) \qquad (I)$$

wherein

M and M' are charged metal cations and M is different from M';

z is 1 or 2;

y is 3 or 4;

$0 < x < 0.9$, preferably $0.1 \leq x \leq 0.5$

b = 0-10

c = 0-10

X is an anion

n is the charge on the anion X,

$a > 0$ and $a = z(1-x)+xy-2$ and ;

solvent is solvent with a hydrogen bond donor or acceptor function.

3. The aqueous coating suspension according to claim 2, wherein M is selected from the group consisting of lithium, zinc, magnesium, iron, calcium, tin, nickel, copper, cobalt and combinations thereof, and M is preferably magnesium, and

wherein M' is selected from the group consisting of aluminium, iron, gallium, indium, yttrium, cobalt, manganese, chromium, titanium, vanadium, lanthanum, tin, zirconium and combinations thereof, and M' is preferably aluminium, and

wherein X is selected from the group consisting of carbonate, hydroxide, fluoride, chloride, bromide, iodide, sulphate, nitrate and phosphate and combinations thereof, preferably carbonate.

4. The aqueous coating suspension according to any one of the preceding claims, wherein the LDH has a platelet morphology, wherein the LDH has an aspect ratio in the range of 3 – 1000 and/or wherein the lateral size of the platelet is in the range of 50 – 1000 nm and/or wherein the thickness of the platelet is in the range of 1 – 200 nm and/or wherein the LDH content is in the range of 2.5 to 50 wt% based on total solid weight of coating suspension.

5. The aqueous coating suspension according to any one of the preceding claims, wherein the modifier comprises a fatty acid and/or an organic phosphonic acid, and/or wherein the modifier content is in the range of 2 to 30% based on total weight of LDH.

6. The aqueous coating suspension according to claim 5, wherein the silane is a mixture of (3-aminopropyl)trimethoxysilane and (3-glycidoxypropyl)trimethoxysilane at a weight ratio selected from the range of 1:9 to 9:1.

7. The aqueous coating suspension according to claim 5, wherein the fatty acid is a saturated or unsaturated fatty acid selected from the group consisting of stearic acid, palmitic acid, oleic acid, limoleic acid, linolenic acid and combinations thereof.

8. The aqueous coating suspension according to claim 5, wherein the organic phosphonic acid is selected from the group consisting of aminotris(methylensphosphonic acid), ethylenediamine tetra(methylene phosphonic acid), and combination thereof.

9. The aqueous coating suspension according to claim 1, wherein the content of the polymer having a hydroxyl functional group in the coating suspension is in a range of 1 wt% to 15 wt% based on the aqueous coating suspension and/or wherein the content of the polymer having a carboxyl functional group in the coating suspension is in a range of 0.1 wt% to 10 wt% based on the whole suspension.

10. The aqueous coating suspension according to claim 9, wherein the polymer having a hydroxyl functional group is selected from the group consisting of a polyvinyl alcohol (PVA), polyvinyl alcohol derivatives, polyvinyl alcohol copolymers, starch, starch derivatives, chitosan, chitosan derivatives, cellulose, cellulose derivatives, cellulose ether, cellulose ester derivatives, gums, arabinans, galactans, galactomannans, proteins, and mixtures thereof and wherein the polymer having a carboxyl functional group is selected from the group consisting of a polyacrylic acid (PAA), polycarboxylic acid, polycarboxylic acid derivatives, polycarboxylic acid copolymer and mixtures thereof.

11. The aqueous coating suspension according to any one of the preceding claims, wherein the polymer matrix comprises a polyvinyl alcohol (PVA) polymer and a polyacrylic acid (PAA).

12. A process of preparing the coating suspension of any one of claims 1 to 11, comprising the steps of:

a1) contacting an aqueous suspension of LDH with at least one modifier, wherein the at least one modifier is as defined in claim 1,

a) providing an aqueous suspension of layered double hydroxide (LDH), and

b) contacting the layered double hydroxides (LDHs) aqueous suspension with an aqueous solution of polymer having a hydroxyl functional group followed by an aqueous solution of polymer having a carboxyl functional group.

13. The process according to claim 12, wherein the silane coupling agent is added into the aqueous suspension of LDH at an injection rate of 0.1 to 3.0 mL/min and at a homogenization speed of 5,000 to 20,000 rpm.

14. A film comprising a substrate and a coating layer wherein the coating layer comprises a layered double hydroxide (LDH) and a polymer matrix,

wherein the LDH is chemically coupled to the polymer matrix by a modifier or mixtures thereof to form strong interfacial bonding between the LDH and polymer matrix,

wherein the modifier comprises a silane coupling agent selected from the group consisting of (3-aminopropyl)trimethoxysilane, (3-glycidoxypropyl)trimethoxysilane, and mixtures thereof, and:

wherein the polymer matrix comprises at least one polymer having a hydroxyl functional group and at least one polymer having a carboxyl functional group and wherein the weight ratio of the polymer having a hydroxyl functional group and the polymer having a carboxyl functional group is 9:1 to 2:1,

and wherein the LDH has a hierarchical LDH structure wherein the LDH platelet stacks onto the substrate layer by layer.

15. The film according to claim 14, wherein the modifier comprises a fatty acid and/or an organic phosphonic acid

16.. The film according to claim 15, wherein the fatty acid is a saturated or unsaturated fatty acid selected from the group consisting of stearic acid, palmitic acid, oleic acid, limoleic acid, linolenic acid, and combinations thereof, and the organic phosphonic acid is selected from the group consisting of aminotris(methylensphosphonic acid), ethylenediamine tetra(methylene phosphonic acid), and combinations thereof.

17. The film according to claim 14, wherein the film has an oxygen transmission rate of 0.1 cc/(m^2.day) or less.

18. The film according to claim 14, wherein the film has an oxygen transmission rate of 0.05 cc/(m^2.day) or less.

19. The film according to claim 14, wherein the film has an oxygen transmission rate of 0.02 cc/(m^2.day) or less.

20. The film according to any one of claims 14 to 19, wherein the thickness of the coating layer is about 0.15 to 3.5 μm.

21. The film according to any one of claims 14 to 20, wherein the substrate is a plastic film.

22. The film according to any one of claims 14 to 21, further comprising a protective layer on top of the coating layer.

23. The film according to any one of claims 14 to 22, wherein the film has a light transmission rate of more than 65%.

24. A method for forming a film comprising the step of applying the coating suspension according to any one of claims 1 to 11 on a substrate.

25. The method according to claim 24, wherein the method comprises the steps of: a) applying the suspension according to any one of claims 1 to 11 on the substrate under a shearing force to form a barrier layer, and b) drying the formed barrier layer on the substrate.

26. The method according to claim 24 or 25, further comprising the step of coating a protective layer onto the coating layer.

27. Use of the film according to any one of claims 14 to 23 as an oxygen barrier for making packaging films.