CLAIMS

1. Use of a sol comprising a solvent, an alkoxide and a catalyst to prepare a water impermeable fibre-based product, wherein:

the solvent comprises one or more alcohols;

the alkoxide comprises Ti(isopropoxy)$_4$, Al(isopropoxy)$_3$, Al(sec-butoxy)$_3$, Zr(n-butoxy)$_4$, Zr(n-propoxy)$_4$, n-propyltriethoxysilane, tetrapropyl orthosilicate, titanium(IV) tert-butoxide, titanium(IV) isopropoxide, triethyloxysilane, methyltriethyloxysilane, tetraethoxysilane, triethoxy(octyl)silane, phenyl-triethoxysilane, titanium(iv) ethoxide, triethoxy-silylcyclopentane, (3-glycidyloxypropyl) trimethoxysilane, cyclopentyltriethoxysilane, 3-amino-propyltriethoxysilane, triethoxy-3-(2-imidazolin-1-yl)propylsilane or any combination thereof; and

the catalyst is at least one of an acid and/or a base.

2. Use of a sol according to claim 1, wherein the sol forms a coating on one or more surfaces of the water impermeable product, optionally wherein:

the sol fills or partially fills one or more pore volumes or void volumes of the water impermeable product; and/or

the sol acts as a binder to promote cohesion of the water impermeable product.

~~3. The use of a sol according to any preceding claim, wherein the product is a fibre-based product.~~

~~4. Use of a sol according to any preceding claim, wherein the alkoxide is selected from silicon alkoxides, metal alkoxides, phosphorus alkoxides, organically modified alkoxides, and any combination thereof, optionally wherein the alkoxide is selected from n-propyltriethoxysilane, tetrapropyl orthosilicate, titanium(IV) tert-butoxide, titanium(IV) isopropoxide, triethyloxysilane, methyltriethyloxysilane, triethoxy(octyl)silane, phenyl-triethoxysilane, titanium(IV) ethoxide, triethoxy-silylcyclopentane, (3-glycidyloxypropyl) trimethoxysilane, cyclopentyltriethoxysilane, 3-amino-propyltriethoxysilane, triethoxy-3-(2-imidazolin-1-yl)propylsilane, and any combination thereof.~~

~~5. Use of a sol according to any preceding claim, wherein the catalyst is at least one of an acid and/or a base, optionally wherein the catalyst is selected from hydrochloric acid, citric acid, nitric acid, acetic acid, sodium hydroxide, potassium hydroxide, ammonia, and any combination thereof.~~

~~6~~3. Use of a sol according to any preceding claim, wherein the solvent comprises ~~water, one or more alcohols, or any combination thereof, optionally wherein the solvent comprises~~ methanol, ethanol, isopropanol, butanol, ethylene glycol or any combination thereof.

~~7~~4. Use of a sol according to any preceding claim, wherein the sol consists essentially of a solvent, an alkoxide and a catalyst.

~~8~~5. Use of a sol according to any preceding claim, wherein the water impermeable product is prepared by applying the sol to a product in the absence of any functional additives.

~~9~~6. Use of a sol according to any of claims 1 to ~~6~~ 3 wherein the sol comprises one or more functional additives, optionally wherein the one or more functional additives comprise photoinitiators, resins, oils, dyes, salts, mineral or other inorganic particles, surfactants, composite particles and/or metal particles.

~~10~~7. Use of a sol according to any preceding claim, wherein the sol is added as a component additive to the material of the water impermeable product and/or to one or more coatings applied to the water impermeable product.

~~11~~8. Use of a sol according to any preceding claim, wherein:

the water impermeable product is a fibre-based product, and the water impermeable fibre-based product comprises pulp, paper, cardboard, board or combinations thereof including composite fibre-based products and biocomposite fibre-based products; or

the water impermeable product is a plastic or bioplastic; or

the water impermeable product is an adhesive or paint.

~~12~~9. Use of a sol according to any preceding claim, wherein the sol is applied during formation of ~~the~~ a product to prepare ~~a~~ the water impermeable product, optionally wherein the product is a fibre-based product, and the sol is applied during formation of a pulp slurry, wet pulp, air-laid pulp or dry pulp.

~~13~~10. Use of a sol according to any preceding claim, wherein the sol is applied following formation of ~~the~~ a product to prepare ~~a~~ the water impermeable product, optionally wherein the product is a fibre-based product, and the sol is applied to a pulp slurry, wet pulp, air-laid pulp or dry pulp following formation of the pulp slurry, wet pulp, air-laid pulp or dry pulp.

~~14~~11. Use of a sol according to claim ~~12~~ 9 or ~~13~~10, wherein the product is a fibre-based product, and the sol is applied during formation of a pulp slurry, wet pulp, air-laid pulp or dry pulp, and further wherein a water impermeable paper, cardboard, board, composite fibre-based product, or biocomposite fibre-based product is formed from the pulp slurry, air-laid pulp or dry pulp.

~~15~~12. Use of a sol according to any preceding claim, wherein:

the sol is applied to a product by spraying the sol onto the product, soaking the product in the sol, dipping the product in the sol, roller coating the sol onto the product, brushing the

sol onto the product, wiping the sol onto the product, impregnating the product with the sol by padding, exhausting the sol on the product, flowing the sol onto the product, the use of slit coating techniques, the use of blade application techniques, or any combination thereof; and/or

the sol is applied to the whole of a surface of a product or only a portion of a surface of a product.

~~16~~13. Use of a sol according to any preceding claim, wherein the sol is applied to a product to form a base coating onto which further coatings can be applied or wherein the sol is applied to a product to form a coating over an existing coating, optionally wherein the base coating or top coating formed by application of ~~a~~ the sol ~~according to the present invention~~ is optically transparent and/or gas impermeable and/or hydrophobic and/or oleophobic and/or stain resistant and/or antireflective.

~~17~~14. Use of a sol according to any preceding claim, wherein the water impermeable product is used as primary, secondary or tertiary packaging; optionally wherein the packaging is used in the food and beverages, electronics, engineering, appliances, cosmetics, medical devices, pharmaceuticals, fashion, cosmetics, personal care, household products, interior or exterior decoration, home improvement, automotive, aviation, marine, defence or construction industries, and further optionally wherein the packaging is in the form of a container for use in the food and beverages industry.

~~18~~15. Use of a sol according to any of claims 1 to ~~6~~ 3 or ~~9~~ 6 to ~~17~~14, wherein the sol further comprises one or more biopolymers, optionally wherein the biopolymer is selected from the group comprising starch, cationic starch, modified starch, flour, wheat flour, barley flour, lentil flour, bamboo flour, corn flour, oat flour, rye flour, buckwheat flour, rice flour, chickpea flour, green pea flour, chitin, cellulose, hemi-cellulose, or any combination thereof.

~~19~~16. A sol comprising a solvent, an alkoxide, a biopolymer, and a catalyst, wherein:

the solvent comprises one or more alcohols;

the alkoxide comprises Ti(isopropoxy)$_4$, Al(isopropoxy)$_3$, Al(sec-butoxy)$_3$, Zr(n-butoxy)$_4$, Zr(n-propoxy)$_4$, n-propyltriethoxysilane, tetrapropyl orthosilicate, titanium(IV) tert-butoxide, titanium(IV) isopropoxide, triethyloxysilane, methyltriethyloxysilane, tetraethoxysilane, triethoxy(octyl)silane, phenyl-triethoxysilane, titanium(iv) ethoxide, triethoxy-silylcyclopentane, (3-glycidyloxypropyl) trimethoxysilane, cyclopentyltriethoxysilane, 3-amino-propyltriethoxysilane, triethoxy-3-(2-imidazolin-1-yl)propylsilane or any combination thereof;

the biopolymer comprises a starch-based polymer, hemi-cellulose-based polymer, cellulose-based polymer, lignin-based polymer and/or chitosan-based polymer; and

the catalyst is at least one of an acid and/or a base.

~~20~~17. A sol according to claim ~~19~~16, wherein:

the biopolymer comprises a starch, optionally wherein the starch comprises a cationic starch. optionally wherein the cationic starch is selected from quaternary ammonium type cationic starch, tertiary ammonium type cationic starch, and any combination thereof; or

the biopolymer comprises a flour.

~~21~~18. A sol according to claim ~~20~~17, wherein the biopolymer comprises a flour, and the flour comprises:

5 to 85% starch, 0 to 30% hemi-cellulose, 0 to 50% cellulose, 0 to 25% lignin, 0 to 35% protein and 0 to 25% ash; or

45 to 85% starch, 0 to 15% hemi-cellulose, 0 to 10% cellulose, 0 to 7% lignin, 10-15% protein and 0 to 5% ash.

~~22~~19. A sol according to claim ~~20~~ 17 or ~~21~~18, wherein the biopolymer comprises a flour, and the flour is selected from the group comprising wheat flour, barley flour, lentil flour, bamboo flour, corn flour, oat flour, rye flour, buckwheat flour, rice flour, chickpea flour, green pea flour, or any combination thereof.

~~23~~20. A sol according to any of claims ~~19~~ 16 to ~~22~~19, ~~wherein the catalyst is at least one of an acid and a base, optionally~~ wherein the catalyst is selected from hydrochloric acid, citric acid, nitric acid, acetic acid, sodium hydroxide, potassium hydroxide, ammonia, and any combination thereof.

~~24. A sol according to any of claims 19 to 23, wherein the alkoxide is selected from silicon alkoxides, metal alkoxides, phosphorus alkoxides, and any combination thereof, optionally wherein the alkoxide is selected from n-propyltriethoxysilane, tetrapropyl orthosilicate, titanium(IV) tert-butoxide, titanium(IV) isopropoxide, triethyloxysilane, methyltriethyloxysilane, triethoxy(octyl)silane, phenyl-triethoxysilane, titanium(iv) ethoxide, triethoxy-silylcyclopentane, (3-glycidyloxypropyl) trimethoxysilane, cyclopentyltriethoxysilane, 3-amino-propyltriethoxysilane, triethoxy-3-(2-imidazolin-1-yl)propylsilane, and any combination thereof.~~

~~25 A sol according to any of claims 19 to 24, wherein the solvent comprises water, one or more alcohols, or any combination thereof, optionally wherein the solvent comprises methanol, ethanol, isopropanol, butanol, ethylene glycol or any combination thereof.~~

~~26~~21. A sol according to any of claims ~~20~~ 16 to ~~25~~20, wherein the sol comprises one or more functional additives, optionally wherein the one or more functional additives comprise photoinitiators, resins, oils, dyes, salts, mineral or other inorganic particles, surfactants, composite particles and/or metal particles.

~~27~~22. A method of making a sol according to any of claims ~~19~~ 16 to ~~26~~21, the method comprising:

a) dispersing a biopolymer in a solution comprising a catalyst and then adding an alkoxide; or

b) dispersing an alkoxide in a solvent, adding a catalyst and then adding a biopolymer; or

c) dispersing an alkoxide in a solution comprising a catalyst and then adding a biopolymer.

~~28. A method according to claim 27, wherein the catalyst is at least one of an acid or a base.~~

~~29~~23. A method according to claim ~~27~~ 22~~or 28~~, wherein the method further comprises adding one or more functional additives and/or one or more substrates, optionally wherein:

the one or more functional additives and/or one or more substrates are added before formation of the sol; or

the one or more functional additives and/or one or more substrates are added during the formation of the sol; or

the one or more functional additives and/or one or more substrates are added after the formation of the sol.

~~30~~24. A method according to ~~any one of~~ claim~~s~~ ~~27~~ 22 ~~to~~ or ~~29~~23, further comprising centrifuging the sol and/or drying the sol to form a solid, optionally wherein the method further comprises grinding the solid to a desired particle size.

~~31~~25. A coated product wherein the product has been coated with a sol according to any one of claims ~~19~~ 16 to ~~26~~20.

~~32~~26. A coated product according to claim ~~31~~25, wherein the coating is water impermeable and/or optically transparent and/or gas impermeable and/or anti-microbial and/or hydrophobic and/or oleophobic and/or anti-fouling and/or anti-biofouling and/or stain resistant and/or adhesion promoting and/or antireflective.

~~33~~27. A coated product according to claim ~~31~~ 25 or ~~32~~ 26 wherein the product comprises wood, textiles, leather, metal (including alloy), concrete, cardboard, paper, plastic, bioplastic, glass, ceramics, sand, electronic circuitry, brick, marble, soil, painted surfaces and combinations thereof, wherein combinations thereof includes composite products and biocomposite products.

~~34~~28. A coated product according to any one of claims ~~31~~ 25 to ~~33~~ 27 wherein the product is in the form of molecules, particles, fibres, moulded products, sheets and combinations thereof.

~~35~~29. A powder derived from a sol according to any of claims ~~19~~ 16 to ~~26~~21.

~~36~~30. A powder according to claim ~~35~~29, further comprising one or more functional additives, optionally wherein the functional additive comprises photoinitiators, resins, oils, dyes, salts, mineral or other inorganic particles, surfactants, composite particles and/or metal particles.

~~37~~31. Use of a powder according to ~~any one of~~ claims ~~35~~ 29 or ~~36~~ 30 as a component additive in the formation of one or more products or coatings applied to one or more products.