CLAIMS

1. Use of a sol comprising a solvent, an alkoxide and a catalyst to prepare a water impermeable product.

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

~~3. Use of a sol according to claim 1 or 2,~~ wherein:

~~-~~the sol fills or partially fills one or more pore volumes or void volumes of the product; and/or~~.~~

~~4. Use of a sol according to claim 1, 2, or 3, wherein~~

~~-~~the sol acts as a binder to promote cohesion of the product.

~~5~~3. The use of a sol according to any preceding claim, wherein the product is a fibre-based product.

~~6~~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 .

~~7. Use of a sol according to any preceding claim,~~ 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.

~~8~~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~~.~~

~~9. Use of a sol according to claim 8,~~ wherein the catalyst is selected from hydrochloric acid, citric acid, nitric acid, acetic acid, sodium hydroxide, potassium hydroxide, ammonia, and any combination thereof.

~~10~~6. Use of a sol according to any preceding claim, wherein the solvent comprises water, one or more alcohols, ~~and~~ or any combination thereof, optionally~~.~~

~~11. Use of a sol according to claim 10,~~ wherein the solvent comprises methanol, ethanol, isopropanol, butanol, ethylene glycol or any combination thereof.

~~12~~7. Use of a sol according to any preceding claim, wherein the sol consists essentially of a solvent, an alkoxide and a catalyst.

~~13~~8. 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.

~~14~~9. Use of a sol according to any of claims 1 to ~~11~~ 6 wherein the sol comprises one or more functional additives, optionally~~.~~

~~15. Use of a sol according to claim 14,~~ 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.

~~16~~10. Use of a sol according to any preceding claim, wherein the sol is added as a component additive to the material of the product and/or to one or more coatings applied to the product.

~~17~~11. Use of a sol according to any preceding claim, wherein:

- the 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

- ~~.~~

~~18. Use of a sol according to any one of claims 1 to 16, wherein~~ the product is a plastic or bioplastic; or~~.~~

~~19. Use of a sol according to any one of claims 1 to 16, wherein~~ the product is an adhesive or paint.

~~20~~12. Use of a sol according to any preceding claim, wherein the sol is applied during formation of the product to prepare a water impermeable product, optionally~~.~~

~~21. Use of a sol according to claim 20, w~~ 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.

~~22~~13. Use of a sol according to any preceding claim, wherein the sol is applied following formation of the product to prepare a water impermeable product, optionally~~.~~

~~23. Use of a sol according to claim 22,~~ 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.

~~24~~14. Use of a sol according to claim ~~21~~ 12 or ~~23~~13, 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.

~~25~~15. 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

~~26. Use of a sol according to any preceding claim, wherein~~ the sol is applied to the whole of a surface of a product or only a portion of a surface of a product.

~~27~~16. 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~~.~~

~~28. Use of a sol according to claim 27,~~ wherein the base coating or top coating formed by application of a 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.

~~29~~17. Use of a sol according to any preceding claim, wherein the water impermeable product is used as primary, secondary or tertiary packaging; optionally ~~.~~

~~30. Use of a sol according to claim 29,~~ 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 ~~.~~

~~31. Use of a sol according to claim 30,~~ wherein the packaging is in the form of a container for use in the food and beverages industry.

~~32~~18. Use of a sol according to any of claims 1 to ~~11~~ 6 or ~~14~~ 9 to ~~31~~17, wherein the sol further comprises one or more biopolymers, optionally~~.~~

~~33. Use of a sol according to claim 32~~ 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.

~~34. A water impermeable fibre-based product prepared using a sol according to any of claims 1 to 33.~~

~~35~~19. A sol comprising a solvent, an alkoxide, a biopolymer, and a catalyst.

~~36~~20. A sol according to claim ~~35~~19, wherein:

- the biopolymer comprises a starch, optionally~~.~~

~~37. A sol according to claim 36,~~ wherein the starch comprises a cationic starch. optionally~~.~~

~~38. A sol according to claim 37,~~ wherein the cationic starch is selected from quaternary ammonium type cationic starch, tertiary ammonium type cationic starch, and any combination thereof; or~~.~~

~~39. A sol according to claim 35, wherein~~ the biopolymer comprises a flour.

~~.~~

~~40~~21. A sol according to claim ~~39~~20, 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~~.~~

~~41. A sol according to claim 39 or 40, wherein the flour comprises~~ 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.

~~42~~22. A sol according to ~~any of~~ claim~~s~~ 20~~38~~ or 21~~to 40~~, 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.

4323. A sol according to any of claims ~~35~~ 19 to 2242, wherein the catalyst is at least one of an acid and a base, optionally.

~~44. A sol according to claim 43,~~ wherein the catalyst is selected from hydrochloric acid, citric acid, nitric acid, acetic acid, sodium hydroxide, potassium hydroxide, ammonia, and any combination thereof.

4524. A sol according to any of claims ~~35~~ 19 to 2344, wherein the alkoxide is selected from silicon alkoxides, metal alkoxides, phosphorus alkoxides, and any combination thereof, optionally.

~~46. A sol according to any of claims 35 to 45,~~ 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.

4725. A sol according to any of claims 3519 to 2446, wherein the solvent comprises water, one or more alcohols, ~~and~~ or any combination thereof, optionally.

~~48. A sol according to claim 47,~~ wherein the solvent comprises methanol, ethanol, isopropanol, butanol, ethylene glycol or any combination thereof.

4926. A sol according to any of claims 2035 to 2548, wherein the sol comprises one or more functional additives, optionally.

~~50. A sol according to claim 49,~~ 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.

5127. A method of making a sol according to any of claims ~~35~~ 19 to 2650, 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.

~~52~~28. A method according to claim ~~51~~27, wherein the catalyst is at least one of an acid or a base.

~~53~~29. A method according to claim ~~51~~ 27 or 28~~52~~, wherein the method further comprises adding one or more functional additives and/or one or more substrates, optionally ~~.~~

~~54. A method according to claim 53,~~ wherein:

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

~~55. A method according to claim 53, wherein~~ the one or more functional additives and/or one or more substrates are added during the formation of the sol; or~~.~~

~~56. A method according to claim 53, wherein~~ the one or more functional additives and/or one or more substrates are added after the formation of the sol.

~~57~~30. A method according to any one of claims ~~51~~ 27 to 29~~56~~, further comprising centrifuging the sol and/or drying the sol to form a solid, optionally wherein the method further comprises~~.~~

~~58. A method according to claim 57, further comprising~~ grinding the solid to a desired particle size.

~~59~~31. A coated product wherein the product has been coated with a sol according to any one of claims ~~35~~ 19 to 26~~50~~.

~~60~~32. A coated product according to claim ~~59~~31, 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.

~~61~~33. A coated product according to claim ~~59~~ 31 or ~~60~~ 32 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.

~~62~~34. A coated product according to any one of claims ~~59~~ 31 to 33~~61~~ wherein the product is in the form of molecules, particles, fibres, moulded products, sheets and combinations thereof.

~~63~~35. A powder derived from a sol according to any of claims ~~35~~ 19 to ~~50~~26.

~~64~~36. A powder according to claim ~~63~~35, further comprising one or more functional additives, optionally~~.~~

~~65. A powder according to claim 64,~~ wherein the functional additive comprises photoinitiators, resins, oils, dyes, salts, mineral or other inorganic particles, surfactants, composite particles and/or metal particles.

~~66~~37. Use of a powder according to any one of claims ~~63~~ 35 ~~to~~ or ~~65~~ 36 as a component additive in the formation of one or more products or coatings applied to one or more products.