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(54) Title: **SUPERABSORBENT POLYMER COMPOSITE COMPRISING A SUPERABSORBENT POLYMER AND CELLULOSIC NANOFIBRILS**

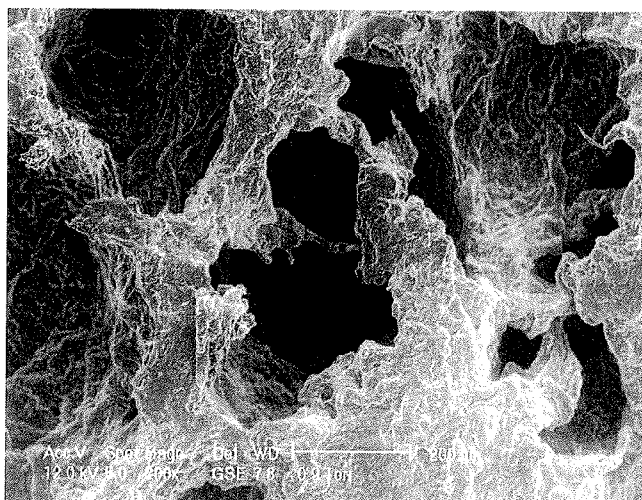


FIG. 4B

(57) Abstract: The invention provides a superabsorbent polymer composite comprising superabsorbent polymers and cellulosic nanofibrils having a diameter equal to or less than 100nm. The composite may be in the form of particles or a foam. Methods for producing the composite and absorbent articles comprising the superabsorbent polymer composite are also provided.



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SUPERABSORBENT POLYMER COMPOSITE COMPRISING A SUPERABSORBENT POLYMER AND CELLULOSIC NANOFIBRILS

TECHNICAL FIELD

- 5 The present invention relates to a superabsorbent polymer composite comprising a superabsorbent polymer and cellulosic nanofibrils. The invention further refers to a method of producing the superabsorbent polymer composite according to the invention and an absorbent article comprising the superabsorbent polymer composite.

10 BACKGROUND OF THE INVENTION

Advances in absorbent article technology have stimulated the search for absorbent (often superabsorbent) materials with desirable properties such as high absorption, high storage capacity and high gel and mechanical strength.

- 15 The absorbent materials may comprise two or more layers such as liquid acquisition layers, storage layers and distribution layers.

In order to obtain good liquid acquisition capacity it is important that the absorbent material has a high momentaneous liquid acquisition capacity. Open, bulky structures with
20 large capillaries have a high momentaneous liquid acquisition capacity and examples of such materials are cellulosic fluff pulp of thermomechanic or chemithermomechanic (CTMP) type, chemically stiffened cellulosic fibres, waddings of synthetic fibres and porous foam materials.

- 25 In order to obtain a good liquid storage capacity it is common that the absorbent structure contains superabsorbent materials. Superabsorbent materials are crosslinked polymers with the capacity to absorb liquid many times their own weight. Organic materials suitable for use as a superabsorbent material can include natural materials such as polysaccharides (particularly modified polysaccharides such as CMC:
30 carboxymethylcellulose), polypeptides and the like, as well as synthetic materials such as synthetic hydrogel polymers. Such hydrogel polymers include, for example, polyacrylates (particularly alkali metal salts of polyacrylic acids), polyacrylamides, polyvinyl alcohol, polyacrylamides, polyvinyl pyridines, and the like. Other suitable polymers include

polyvinylamine, hydrolyzed acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The absorption mechanism of such superabsorbents is thought to be based on the fact that the polymer chain contains a plurality of charged groups, which make it possible for the polymer
5 network to absorb aqueous liquids by means of osmotic forces.

The superabsorbent material in an absorbent structure, i.e. a diaper core, is often in the form of small particles, which are arranged and contained in a fibrous matrix. The fibrous matrix usually consists of cellulosic fluff pulp of thermomechanic, chemical or
10 chemithermo-mechanical type, but a certain amount of synthetic fibres are also common.

One problem with absorbent structures containing superabsorbent material is that it is difficult to distribute and maintain the superabsorbent material in the desired location in the absorbent structure, both during storage and during use of the article. Another
15 problem with absorbent structures containing superabsorbent material is so-called gel blocking. This problem occurs by the fact that the liquid-containing superabsorbent particles swell and form a gel. The gel blocks the liquid transport and gives rise to an accumulation of liquid in certain portions of the absorbent structure while other portions of the structure become more-or-less non-utilized.

20

In order to obtain a superabsorbent material with high mechanical strength, the degree of crosslinking of the polymer is crucial. The more crosslinking in a polymeric structure, the more the mechanical strength increases. However, a high degree of crosslinking within a structure restricts the swelling capacity of the material, and highly-crosslinked
25 superabsorbent materials are brittle and break easily. The performance of superabsorbent materials in different applications is highly dependent on the elastic modulus, the resistance to fracture and the water absorbance capacity among other properties. These properties are strongly affected by the degree of crosslinking. It has been shown that for polyacrylic acid (PAA) the equilibrium degree of swelling decreases
30 and the elastic modulus increases with an increasing degree of crosslinking, as expected from theory.

Absorbent web composites comprising a superabsorbent polymer component and fibrous material, such as cellulose fibres and processes for their production are known.

35

An example of this type of material is described in US 2003/0111163, which describes a process for making an absorbent fibrous web composite including a stable and controllable dispersion of superabsorbent polymer. Two polymer precursors, for example, acrylic acid or methacrylic acid, are added in separate stages to form a superabsorbing
5 polymer on or in a pre-formed fibrous web, which includes a plurality of hydrophilic fibres, e.g. microfibrillar cellulose or microcrystalline cellulose.

Similarly, US 2003/0111774 describes a process for making an absorbent fibrous composite nonwoven web including e.g. superabsorbent polymers and plurality of
10 hydrophilic fibres. The polymerization of the superabsorbent polymer is integrated into the process of forming the absorbent composite nonwoven web.

EP 1 207 914 further discloses an absorbent structure comprising an open-cell foam structure wherein the pore walls of the structure comprise a liquid-storing material, e.g.
15 polyacrylate. The absorbent structure is characterized in that the pores of the foam structure contain hydrophilic fibres, e.g. cellulose fibres, at which at least the main part of the hydrophilic fibres are firmly anchored in the pore walls of the foam structure, and that the fibre amount is at least 10 % by weight of the total weight of the open-cell foam in dry condition.

20

Foam materials made of traditional superabsorbent polymers (e.g. polyacrylic acid/polyacrylate polymers) are usually hard and stiff when dry, and inelastic when wet – they tend to fall apart under pressure. For these reasons, superabsorbent materials are usually included in absorbent articles in granular form.

25

It would therefore be advantageous to design a new absorbent material comprising superabsorbent polymers and cellulosic fibres with improved mechanical and gel properties in a swollen condition, and at the same time retain absorbent, spreading and storage properties. In particular, it would be useful to provide an absorbent material which
30 has improved strength, yet which – at the same time – does not suffer from lack of flexibility and brittleness.

SUMMARY OF THE INVENTION

The invention thus provides a superabsorbent polymer composite comprising a superabsorbent polymer and cellulosic fibrils. The cellulosic fibrils are nanofibrils having a diameter equal to or less than 100 nm.

- 5 Suitably, the composite does not contain cellulosic fibres having an average diameter greater than 100 μm .

The superabsorbent polymer composite may further comprise cellulosic microfibrils having a diameter greater than 100 nm but less than or equal to 100 μm , preferably a diameter greater than 100 nm but less than or equal to 10 μm .

- 10 Suitably, the superabsorbent polymer composite has a nanofibril content of 0.1-20 wt % of the superabsorbent polymer preferably 0.5-15 wt %, more preferably 0.5-5 wt %. Additionally, the composite may have a microfibre content of 0.1-20 wt % of the superabsorbent polymer and preferably 0.5-15 wt %.

- The superabsorbent polymer may comprise a repeating unit derived from the group
15 consisting of acrylic acid and its salts, methacrylic acids and its salts and combinations thereof.

The superabsorbent polymer composite may comprise an organic cross-linker. The organic cross-linker content may be 0.1-20 wt % of the superabsorbent polymer, preferably 0.5-15 wt %, more preferably 0.5-5 wt %.

- 20 The composite may be in the form of particles or a foam. If in the form of a foam, the nanofibrils may be incorporated into the pore walls of the foam. The foam may have a pore size gradient. Additionally, the foam may comprise a one or more substances selected from the group consisting of; plasticizers, surfactants and blowing agents.

- The invention also provides an absorbent article having an absorbent structure comprising
25 the superabsorbent polymer composite of the invention. The absorbent article may be a diaper, a pant diaper, an incontinence guard, a sanitary napkin or the like and of the kind comprising a liquid pervious topsheet, a liquid impervious backsheet, said absorbent structure arranged therebetween.

- The invention also relates to a method for making a superabsorbent polymer composite
30 according to the invention, said method comprising the steps of:

- a. providing cellulosic nanofibrils having a diameter equal to or less than 100 nm suspended in a solvent,
- b. optionally, adding microfibers having a diameter greater than 100 nm but less than or equal to 100 μm suspended in a solvent,
- 5 c. adding one or more monomers
- d. adding a neutralizer,
- e. adding a crosslinker,
- f. adding an initiator, and
- h. polymerizing the monomers and crosslinker to form a superabsorbent polymer
- 10 composite comprising superabsorbent polymers, cellulosic nanofibrils and optionally microfibers

wherein the steps a), b), c), d), e) and f) can take place in any order.

The initiator may be selected from the group consisting of oxidizing initiators, azo initiators, photoinitiators and/or thermal initiators.

- 15 If particles are to be formed, the above method may further comprise the step of (i) forming the composite into particles. If a foam is to be formed, the above method may further comprise the step of (g) forming the composite into a foam; wherein step (g) takes place after steps (a) – (f), but before step (h) of the above method.

- The method for making the foam may further comprise the steps of adding one or more
- 20 substances selected from the group consisting of; plasticizers, surfactants and blowing agents. An additional step may be to add a viscosity control agent.

The invention provides a method for making an absorbent structure, said method comprising; carrying out the method set out above, and incorporating the resulting superabsorbent polymer composite, foam or particles into said absorbent structure.

- 25 The invention also provides the use of cellulosic nanofibrils for increasing the gel strength of a superabsorbent polymer.

DEFINITIONS

The term "nanofibrils" means individual fibrils having a diameter equal to or less than 100 nm at all points along the nanofibril. The diameter may vary along its length. The nanofibrils may exist as individual fibres and/or as clusters of nanofibrils. The term
5 "nanofibrillated cellulose (NFC)" is used interchangeably with the term "nanofibrils".

The term "microfibres" means individual fibres having a diameter greater than 100 nm but less than or equal to 100 μ m at all points along the microfibre. More specifically, the microfibrils may have a diameter greater than 100 nm but less than or equal to 10 μ m or a
10 diameter greater than 100 nm but less than or equal to 1 μ m. The diameter may vary along its length. The microfibrils may exist as individual microfibrils and/or as clusters of microfibrils in the composite. The term MFC (microfibrillated cellulose) is used interchangeably with the term "microfibers".

15 The term "cellulosic" refers to fibrils or fibres from natural sources such as woody and non-woody plants, regenerated cellulose and the derivatives from these fibres by means of chemical, mechanical, thermal treatment or any combination of these. Further, "cellulosic" also refers to cellulosic or cellulose-containing fibres produced by microorganisms.

20

The term "porous" is used herein to describe a material that has pores and, which admits the passage of gas or liquid through these pores.

The term "superabsorbent polymer composite" (also called herein simply "*composite*")
25 means a structure made up of at least two distinct components: superabsorbent polymer and cellulosic fibrils. These components remain separate and distinct on a microscopic level in the composite. Other components may also be present in the composite.

The term "polymers" includes, but is not limited to, homopolymers, copolymers, such as
30 for example, block, graft, random and alternating copolymers, terpolymers, etc. and blends and modifications thereof. Furthermore, unless otherwise specifically limited, the term "polymer" shall include all possible configurational isomers of the material. These configurations include, but are not limited to isotactic, syndiotactic and atactic symmetries.

“Superabsorbent polymers” are water-swellaable, water-insoluble organic or inorganic materials capable of absorbing at least about 20 times their own weight in an aqueous solution containing 0.9 weight percent (wt %) of sodium chloride. Organic materials suitable for use as a superabsorbent material can include natural materials such as polysaccharides (including modified polysaccharides such as CMC: carboxymethyl cellulose), polypeptides and the like, as well as synthetic materials such as synthetic hydrogel polymers. Such hydrogel polymers include, for example, alkali metal salts of polyacrylic acids (pAA), polyacrylamides, polyvinyl alcohol, polyacrylates, polyvinyl pyridines, and the like. Other suitable polymers include hydrolyzed acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The hydrogel polymers are preferably lightly crosslinked to render the material substantially water insoluble. Preferred superabsorbent materials may be further surface crosslinked so that the outer surface or shell of the superabsorbent particle, fibre, flake, sphere, etc. possesses a higher crosslink density than the inner portion of the superabsorbent.

The term “absorption under load (AUL)” denotes a method used herein to measure the absorption under load of a superabsorbent polymer composite in the form of particles or foam in an aqueous solution of 0.9 % NaCl or defibrinated sheep blood.

20

The term “crosslinked” is used herein to describe a material in which particles or regions of a first component of the material are interlinked by means of a second component. Generally, covalent chemical bonds are formed between the first and second components. Increased crosslinking in a material provides it with increased strength and increased stiffness (and hence lower flexibility).

25

The term “particles” includes the composite in the form of for example powder, granules, flakes, spheres, and the like.

The term “foam” is used herein to describe one form of the composite wherein the composite comprises gas bubbles. Foams are materials that are formed by trapping gas bubbles in a liquid or solid. Solid foams form an important class of lightweight cellular materials. Foams can be classified into two types based on their pore structure. The first type of foam is called an open-cell foam. These foams contain pores that are connected

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to each other and form an interconnected network. The second type of foams does not have interconnected pores and are called closed-cell foams.

A "surfactant" is a component, which, when present in small amounts, facilitates the
5 formation of a foam, or enhances its colloidal stability by inhibiting the coalescence of bubbles.

A "blowing agent" is a substance which is capable of producing a cellular structure in a variety of materials that undergo hardening or phase transition (such as polymers,
10 plastics, metals). They are applied when the blown material is in liquid stage.

The term "absorbent article" includes diapers, incontinence guards, sanitary napkins, wound dressings, bed protectors and the like.

15 The term "defibrinated sheep blood" includes sheep blood from which substantially all fibrin has been removed. Sufficient fibrin has been removed so that coagulation of the blood is avoided during storage for at least two weeks.

The term "z-direction" is used herein as the direction being generally out of plane as
20 compared to the generally planar configuration of an absorbent structure, i.e., through the thickness of the absorbent structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail with reference to the enclosed Figures,
25 in which:

Fig. 1 shows optical microscopy images of a suspension of nanofibrillated (NFC) and microfibrillated (MFC) cellulose. (a) Image of wet 2X diluted suspension using a 10X objective. The scale line in Figure 1a corresponds to 50µm. Insert is 25X diluted using a
30 100X objective. The scale line in the insert in Figure 1a corresponds to 5µm. (b) Image of filtered and dried suspension using a 10X objective. Insert is captured using a 50X objective. The scale line in Figure 1b corresponds to 50µm, while the scale line in the insert in Figure 1b corresponds to 10µm.

Fig. 2 shows AFM images of a suspension of nanofibrillated (NFC) and microfibrillated (MFC) cellulose. (a) 10X diluted and subsequently dried, recorded in an area where no macroscopic aggregate was observed using light microscope. z-displacement (range 20 nm) to the left, phase image to the right. (b) and (c) z-displacement images (range 30 nm) of filtered and subsequently dried nanofibrillated cellulose. The images have been digitally enhanced for clarity. All scale lines in Figure 2 correspond to 100nm.

Fig. 3 shows an ESEM picture wherein the pore gradient of sample F2 is visible. The scale lines in Figure 3 correspond to 500µm.

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Fig. 4A shows an ESEM picture of an open cell composite foam (sample F3). The scale line in Figure 4A corresponds to 1mm.

Fig. 4B shows an ESEM picture and a schematic picture of a cell wall containing nanofibrils and microfibrils (sample F3). The scale line in Figure 4B corresponds to 200µm.

Figure 5 shows how the Elastic Modulus, G , ($G=P/(\alpha-\alpha^2)$) after swelling of a composite containing 0.5mol% cross-linker (CL), varies according to the total amount of NFC and MFC (per dry weight %) in said composite.

Figure 6 shows the swelling degree (Q in g/g) for a composite containing 0.5mol% cross-linker in relation to the total amount of NFC and MFC per dry weight %.

25 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Superabsorbent Polymer Composite

The present invention provides a superabsorbent polymer composite of certain materials. The composite comprises two main components: superabsorbent polymers, and cellulosic fibrils that are nanofibrils. The nanofibrils have a diameter equal to or less than 100 nm.

Suitable superabsorbent polymers for the invention can include natural materials such as polysaccharides (including modified polysaccharides such as CMC: carboxymethyl cellulose), polypeptides and the like. Other suitable polymers include hydrolyzed

acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The SAP can be CMC.

Synthetic materials can also be used as superabsorbent polymers according to the present invention. In particular, superabsorbent polymer comprising repeating units derived from the group consisting of acrylic acid (AA) monomers and its salts, methacrylic acids and its salts and combinations thereof can be used. Acrylonitrile, acryloylchloride, acrylic esters (e.g. tert-butyl- or methylacrylic acid ester), unsaturated lactones, anhydrides, acrylamide monomers, secondary or tertiary acrylamides, or other alkenes, monomers having at least one alkene (olefin) group and at least one sulfonate or sulfonic acid group, ethylene sulfonate esters, ethylene sulfonic halides and heterocyclic monomers containing sulphonamide linkages are suitable monomers. Combination of these monomers with each other, and with other monomers, is possible when forming the polymers according to the invention. Other superabsorbent polymers may be polymeric sulfonic acids such as styrene sulfonic acid, sodium styrene sulfonate and/or similar compounds. If neutral monomers are used these must be hydrolysed in order to achieve a charged polymer.

Hydrolysis of polyacrylamide gels to polyacrylic acid gels may be carried out using aqueous acidic solution, see G. Smets, A. M. Hesbain, J. Polymer Science, Vol.11, p.217-226 (1959).

The acidic monomers of the superabsorbent polymers need to be neutralized in order to increase their osmotic pressure. Suitable neutralisers comprise lithium hydroxide, sodium hydroxide, potassium hydroxide, lithium carbonate, sodium carbonate, potassium carbonate, lithium bicarbonate, sodium bicarbonate, potassium bicarbonate, and ammonia. The carboxylic acid group of the acidic monomer can be partially neutralized into lithium, sodium, potassium, or ammonium salt, or the mixtures of two or more thereof. The degree of neutralisation of the acid group is 10-95 %, preferably 30-80 % and more preferably 55-75 %.

The superabsorbent polymer composite of the invention may comprise an organic cross-linker. The superabsorbent polymer composite may have an organic cross-linker content of 0.1-20 wt % of the superabsorbent polymer preferably 0.5-15 wt %, more preferably 0.5-5 wt %. Organic cross-linking agents may have more than one (e.g. 2) polymerisable

functional groups which can be incorporated into a growing polymer in the polymerisation reaction. They act to bridge polymer chains, providing strength to the resultant gel. Known cross-linking agents are e.g. triallylisocyanurate, triallylcyanurate, N,N'-bisacrylylcystamine, N,N'-diallyltartardiamide, 1,3-diacryloylethyleneurea, ethylenediacrylate, N,N'-methylenebisacrylamide (MBA), N,N'-propylenebisacrylamide, di(acrylamindemethyl)-ether, N,N'-dimethylol(methylenebis(acrylamide)), 1,2-diacrylamide ethyleneglycol and 1,3-diacryloylethyleneurea.

Other crosslinking agents can cross-link polymers after their formation. Examples of these are formaldehyde, methylolated nitrogen compounds such as dimethylolurea, dimethylolethyleneurea and dimethylolimidazolidone, dicarboxylic acids for example maleic acid, dialdehydes such as glyoxal, diepoxides, diisocyanates, divinyl compounds such as divinyl sulfone, dihalogen containing compounds such as dichloroacetone and 1,3-dichloropropan-2-ol, halohydrins such as epichlorohydrin, bis(epoxypropyl)ether, dichloroethane, divinylsulfone, epichlorohydrin, ethylene glycol-bis(epoxypropyl)ether, vinylcyclohexene dioxide, 1,3-dichloro-2-propanol, 1,3-bis(β -hydroxy-1-chloropropoxy)-2-propanol, 1,3-bis(β -hydroxy-1-chloropropoxy)ethane, 1,2:3,4-diepoxybutane, 1,2:5,6-diepoxyhexane, 2,3-dibromo-1-propanol, 2,3-dichloro-1-propanol, 2,2-dichloroethyl ether, methylenebis(acrylamide), trisacrylohexahydrotriazine, acrylamidomethylene chloroacetamide, 2,4,6-trichloropyrimidine, 2,4,5,6-tetrachloropyrimidine, cyanuric chloride, triallyl cyanurate, dichloroacetic acid and phosphorous oxychloride.

According to the present invention, individual nanofibrils and/or clusters of nanofibrils fully separated from the cellulose fibre are used. The individual nanofibrils typically have a diameter equal to or below 100 nm at all points along the nanofibril. The diameter may vary along its length. Further, the length of the nanofibrils should not be too short in order to give the composite the desired effect. Preferably, the nanofibrils have a length greater than 1 μ m.

The presence of nanofibrils (NFC) in the composite is crucial to obtain the improved mechanical strength as well as good absorbing, liquid spreading and liquid storage properties. The nanofibrils stabilize the polymer network of the superabsorbent polymer composite and do not interfere with the absorption. Because of the improved gel strength, a high degree of crosslinking is not necessary. This fact also diminishes the risk for gel blocking. These properties give better controlled swelling and this can be utilized in

designing an absorbent structure. Without wishing to be bound by theory, it may be that the nanofibrils act as crosslinking agents, but without forming strong chemical bonds within the composite. The composite therefore gains strength, but is more flexible in terms of expansion, so thus does not become so brittle. The flexibility of the composite in
5 turn allows the composite to expand more freely and absorb more liquid.

A preferred wt % of nanofibrils compared to the amount of superabsorbent monomer in the superabsorbent polymer composite lies within the range of 0.1-20 wt % and preferably 0.5-15 wt % more preferably 0.5-5 wt %.

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Further, as well as nanofibrils and superabsorbent polymers, the superabsorbent polymer composite of the present invention can also comprise microfibers (MFC), in order to adjust the absorption capacity of the composite. For example, by adding microfibres in addition to nanofibrils a sample with higher liquid distributing capacity can be created.

15

Microfibres, according to the present invention mean individual microfibres and/or clusters of microfibres fully separated from the cellulose fibre. Suitable diameters for the cellulosic microfibres are greater than 100 nm but less than or equal to 100 μm , preferably greater than 100 nm but less than or equal to 10 μm . It is possible that the diameter varies along
20 its length.

A preferred wt % of microfibre compared to the amount of superabsorbent monomer in the superabsorbent polymer composite lies within the range of 0.1-20 wt % and preferably 0.5-15 wt %.

25

The composite may comprise nanofibrils and microfibres. Preferred wt % of microfibres compared to superabsorbent monomer lies within the range of 0.1-20 wt % and preferably 0.5-15 wt % and the preferred wt % of nanofibrils compared to superabsorbent monomer lies within the range of 0.1-20 wt % and preferably 0.5-15 wt %.

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Suitably, the composite does not contain cellulosic fibres having an average diameter greater than 100 μm .

The superabsorbent polymer composites of the present invention optionally comprise a
35 plasticizer. By plasticising agent/plasticizer is meant a chemical substance that is used

together with a polymeric material to change its mechanical properties from hard and stiff to soft and flexible. Plasticising agent/plasticizers embed themselves in between the polymer chains, spacing them apart thereby increasing the free volume, and thus significantly lowering the glass transition temperature of the polymer and making it softer.

5

Plasticizing agents selected for use in the present invention possess a range of properties. Generally, the plasticizing agents can be liquid or a solid and have a range of molecular weights and architectures and are compatible with the superabsorbent polymer composite. They could be low molecular weights substances or polymers and are non-
10 volatile and non-reactive. Generally, liquid plasticizing agents are chosen to be miscible with the monomers which are used in the polymerization. Typically, low molecular weight plasticizing agents are derived from low molecular weight acids or alcohols; examples are glycerol and citric acid. The low molecular weight acids or alcohols could also be esterified with respectively a monofunctional alcohol or monofunctional acid. Examples of
15 such plasticising agents are esters of mono- and multibasic acids, such as isopropyl myristate, dibutyl phthalate, diisooctyl phthalate, dibutyl adipate, dibutylsebacate and the like. Typically polymeric plasticizing agents include polyalkylene oxides having weight average molecular weights of about 150 to about 1500, such as polyethylene oxides, polypropylene oxides, polyethylene glycols and copolymers thereof.

20

Water will act as a plasticising agent/plasticizer together with the composites of the present invention. However, water is not considered a plasticising agent/plasticizer in the present application since the function of absorbent products is to absorb water. Relying on water as a plasticising agent/plasticizer will impair the function of the product. Other
25 parameters that hinder the use of water as a plasticising agent/plasticizer include potential microbial growth. Before using the superabsorbent polymer composite in an absorbent article, any water present from the synthesis is dried off (e.g. to constant weight in an oven).

30 The invention also provides a method for making a superabsorbent polymer composite as described above. The method comprises the steps of:

- a. providing cellulosic nanofibrils having a diameter equal to or less than 100 nm suspended in a solvent,

- b. optionally, adding microfibers having a diameter greater than 100 nm but less than or equal to 100 μm suspended in a solvent,
 - c. adding one or more monomers
 - d. adding a neutralizer,
 - 5 e. adding a crosslinker,
 - f. adding an initiator, and
 - h. polymerizing the monomers and crosslinker to form a superabsorbent polymer composite comprising superabsorbent polymers, cellulosic nanofibrils and optionally microfibers
- 10 Steps a), b), c), d), e) and f) can take place in any order.

The method of preparing the superabsorbent polymer composite of the invention may therefore involve adding one or more monomers (precursors to superabsorbent polymer) to a suspension of cellulosic nanofibrils, or vice-versa. Optionally, suspended microfibrils having a diameter greater than 100 nm but less than or equal to 100 μm are added.

15

A neutralizer, a crosslinker and an initiator are added to the reaction mixture. Neutralizers and crosslinkers are described above. The method involves a crosslinker in order for the polymer chains and crosslinker to take the form of a three-dimensional network.

- 20 The polymerization usually requires an initiator to start and propagate the reaction. Any common polymerisation initiators and/or polymerisation catalysts known in the art may be used. Oxidizing initiators (e.g. peroxides or persulphates) and azo initiators (e.g. 2,2'-azobis[2-(2-imidazolin-2-yl)propane] dihydrochloride (VA-044) may be used. Other initiators include thermal initiators and photo initiators.
- 25 The preferred solvent for the polymerisation reaction is water. However, other solvents such as alcohols, ethers or amide solvents (e.g. DMF) may be used, alone or in combination with water. The polymerisation reaction can take place at a temperature between -40°C and 100°C , and the reaction temperature can be used to control the reaction rate (polymerisation reactions are generally exothermic).

30

If the resultant superabsorbent polymer composite is to be used in an absorbent article, it should be dried.

The composite of the invention may be used in various forms, including gels, fibres, 5 particles and foams. Particles or foams are particularly of relevance. Generally, one characteristic that is evident when the composite is in the form of foam or particles is the irregularity of the surface structure, thus creating a larger surface area.

Particles

10

The invention provides superabsorbent polymer composite as above, wherein the composite is in the form of particles.

The particles are suitably surface crosslinked. The performance of the composite 15 particles can be improved by surface crosslinking in addition to the ordinary (bulk) crosslinking, thus creating a higher crosslinking density at the surface of the particles and consequently increasing the absorption properties of the particle. Suitable surface crosslinkers are for example metal salts; polyols such as glycerol, sorbitol, alkylene carbonate and quaternary ammonium compounds.

20

When the composite is in the form of particles, the nanofibrils may be completely incorporated within the particles.

The method described above for making the superabsorbent polymer composite may 25 therefore further comprise the step of (i): forming the composite into particles. This step should take place after step (h) in the above method. The composite may be made into particles via gelling. Gelling of the superabsorbent polymer composite takes place by exposing the composite to an elevated temperature until gelling occurs, e.g. at least 10 minutes. The container containing the superabsorbent polymer composite gel is then 30 closed, the heat source is turned off and the container is allowed to stand for some time. Thereafter the gel is washed in water for a period (e.g. three days) and the water is changed regularly (e.g. every day) to remove extractable material. Then the gels are dried until a constant weight is reached. Thereafter the dried gels are ground and sieved to form particles of a certain size. Other methods of drying the composites (e.g. freeze-drying) 35 may be used prior to grinding and sieving the particles.

Foam

The invention also provides a superabsorbent polymer composite, wherein the composite is in the form of a foam. A typical mean pore size of the foam composite is below 1000
5 μm .

Suitably, the foam comprises one or more substances selected from the group consisting of; plasticizers, surfactants and blowing agents. Any plasticizer mentioned above in relation to the superabsorbent polymer composite itself is suitable for use in the foam composite of the invention. Surfactants such as e.g. SDS or Tween 80 may be used.
10 Blowing agents include compressed gases that expand when pressure is released, soluble solids that leave pores when leached out, liquids that develop cells when they change to gases, and chemical agents that decompose or react under the influence of heat to form a gas. Chemical blowing agents range from simple salts to complex nitrogen releasing agents. Examples of blowing agents/porogens are sodium bicarbonates and
15 ammonium bicarbonates which produce carbon dioxide gas when submitted to acidic conditions. Other examples are isocyanate-groups which produce carbon dioxide when submitted to water or azo-groups which produce nitrogen gas when submitted to heat. Other possible components of the foam are viscosity control agents.

To make a foam according to the invention, the method described above for making the
20 superabsorbent polymer composite may be carried out, including the step of (g): forming the composite into a foam; wherein step (g) takes place after steps (a) – (f), but before step (h) of the above method. This step (g) should be carried out before the polymerizing step (h), as the polymerized mixture may be difficult to form into a foam.

The method for forming the foam may further comprise the steps of adding one or more
25 substances selected from the group consisting of; plasticizers, surfactants and blowing agents. Additionally, the method may further comprise the steps of adding a viscosity control agent.

In effect, foams according to the invention may be made by:

- foaming the mixture of nanofibrils and/or microfibres, one or more monomers and
30 optionally plasticizer, and

- polymerising the monomers and crosslinkers to form a foam composite comprising superabsorbent polymers, cellulosic nanofibrils and optionally microfibres

Solid foams can be prepared by various methods, which are generally divided into two main steps; 1. Bubble initiation and growth and 2. Solidifying.

5

1. Bubble initiation and growth.

Several options are possible, e.g.

- a. Whipping gas into a liquid.
- 10 b. Injecting gas into a liquid.
- c. Bubbles can also form spontaneously in a liquid when the vapour pressure of the gas becomes higher than the ambient pressure.
- d. Nucleation of gas bubbles by either chemical methods or physical methods.
- e. A two phase system could also be achieved in a solid/liquid system. The solid
- 15 phase will then be removed after the solidifying process.

Chemical methods are often associated with using blowing agents or porogens. Blowing agents are additives which – as above – are able to evolve gas through well-defined chemical reactions and produce foam structure in polymeric materials. Although the

20 terms “blowing agents” and “porogens” are often used to mean the same thing, porogens are sometimes defined as those blowing agents which do not decompose through well-defined chemical reactions, but that, at very high temperatures, fall randomly apart in all kinds of molecular fragments.

25 Bubbles could also be produced by emulsions and microemulsions which include changing physical conditions to ensure a cellular structure. Examples are making emulsions or microemulsions with hydrocarbons with a low vaporization temperature (for instance heptane or acetone). Supercritical fluids, like supercritical carbon dioxide could also be used to produce a cellular structure

30

In the bubble initiation and growth phase there are several components that could be used to facilitate this process. Examples are surface active components, so called surfactants. Proteins could also be used as surface active materials. Some particulates or fibres could also be used as nucleation sites for bubbles. The cellular structure could be

35 stabilized using a viscosity control agent in the liquid phase, or in the air-liquid interface.

2. Solidifying process

A solid foam is produced in the solidifying process which often is a polymerization of monomers in the liquid phase. The polymerization could be by a radical mechanism. Step-
5 growth polymerization is also plausible. The polymerization temperature could be ambient or over or below room-temperature. Polymerization which takes place in a two phase system, in which water, at temperatures below its freezing point is one of the phases, produces so-called cryogels. When water is removed, a foam is produced

10 It is also plausible that the solidifying process could occur by a physical change of the liquid phase for instance gelation and/or drying.

The method of making a foam of the superabsorbent polymer composite may include the step of extracting the water with 99.95 % ethanol. The most preferred method for forming
15 foams according to the present invention is by whipping.

Foam with Pore Gradient

By controlling the nature of the bubble initiation and growth process it is possible to produce cellular structures with different pore sizes, pore structures and/or pore gradients.

20 Therefore, the foam may have a pore size gradient, see Fig. 3. The foam can comprise different pore sizes and pore gradients in different regions thereof.

The pore gradient can be in the z-direction with largest pores in the upper part leading to smaller and smaller pores as the lower part is reached. One advantage of using such a
25 structure in absorbent articles is that the upper part of the absorbent structure located closest to the wearer can be provided with a higher liquid distributing capacity than the lower liquid storage portion of the absorbent structure. Furthermore, the lower part of the foam has a higher capillary pressure and thereby empties the upper part, allowing further wetting and giving a dry upper surface.

30

In order to obtain such a pore size gradient, different layers of foam are manufactured and placed on top of each other. By applying the different layers on top of each other before they are dry, an integrated structure will be obtained, where the layers partly penetrate into each other. One advantage of such an integrated structure – as compared to an
35 absorbent structure consisting of separate layers – is that a subsequent joining step is

eliminated. Such a structure is thus cheaper to manufacture since the need for an adhesive and/or energy supply for joining the layers is eliminated. Another advantage with an integrated structure is that the function of the structure is improved in such a way that the liquid transport does not risk deterioration at the transition from a first layer to a
5 second layer due to insufficient contact between the layers.

When the composite is in the form of a foam, the nanofibrils of the present invention may be completely incorporated within the pore walls of the composite, see Fig. 4A and 4B. This phenomenon occurs mainly due to the small size of the nanofibrils. The nanofibrils
10 can be seen lying parallel to each other as well as entangled within the pore walls of the composite. They may be evenly distributed or gathered in several separated groups. Shorter and longer nanofibrils are distributed throughout the composite.

By incorporating nanofibrils, the ability of the foam composite to withstand both tensile
15 and shearing stresses is improved. Further the foam is more easily compressed, i.e. it can be compressed to higher densities and yet expand when wetted, without exhibiting much of the brittleness associated with the foams of the prior art.

Absorbent article

20 The superabsorbent polymer composite according to the present invention is advantageously used in absorbent articles, due to its beneficial absorbing, storage and gel strength properties. The invention therefore provides an absorbent article having an absorbent structure comprising the superabsorbent polymer composite disclosed herein.

The absorbent article according to the invention may be a feminine product, such as
25 sanitary napkins and pantyliners, as well as baby diapers and incontinence guards. In other words, the invention provides an absorbent article, wherein said absorbent article is a diaper, a pant diaper, an incontinence guard, a sanitary napkin or the like and of the kind comprising a liquid pervious topsheet, a liquid impervious backsheet and said absorbent structure arranged therebetween. Most suitably, the absorbent structure
30 comprises the superabsorbent polymer composite of the present invention. The absorbent structure may further comprise additional material such as fibrous material, e.g. cellulose fibres, tissue layers or non-woven materials in combination with the superabsorbent polymer composite.

The absorbent structure in the liquid acquisition portion (where liquid initially contacts the absorbent structure) may be more crosslinked than the liquid storage portion (where liquid is ultimately stored). A very highly crosslinked superabsorbent material can not receive so much liquid as a superabsorbent material having a lower degree of crosslinking. A
5 superabsorbent material with a high degree of crosslinking has lower risk for gelblocking. Such an absorbent structure may be made by preparing two or more composite layers, in which a higher amount of crosslinking agent is added to the polymer solution which is going to form the liquid acquisition layer and a smaller amount of crosslinking agent is added to the polymers solution that is going to form the liquid acquisition portion. After
10 forming of particles or foam and crosslinking, but before drying, the different layers are placed on top of each other, at which the layers will partly integrate with each other and a continuous structure is achieved.

One advantage of the superabsorbent polymer composites of the present invention is that the amount of nanofibrils in the polymer composite can be varied, instead of varying the
15 degree of crosslinker. As shown in the appended Examples, the gel strength of the superabsorbent polymer composites of the invention can be varied by varying the amount of nanofibrils and microfibrils, without greatly affecting the absorption capacity. The maximum swelling is affected by the amount of NFC and MFC added to the composite, in the same way as adding a crosslinker, but with the advantage that the gels become less
20 brittle (see Table 1 below).

An absorbent article e.g. diaper, pantyliner, incontinence guard, sanitary napkin or the like can comprise the superabsorbent polymer composite in the form of particles or foam as set out above. In particular, the absorbent structure of the absorbent article may comprise the superabsorbent polymer composite of the invention in the form of a foam, in which the
25 foam has a pore gradient, as described above. The foam is placed with the largest pores in the upper part (i.e. closest to the wearer) leading to smaller and smaller pores as the lower part is reached (i.e. furthest from the wearer).

The absorbent structure of an absorbent article may also comprise particles of the superabsorbent polymer composite of the invention, arranged in layers such that particles
30 nearer the wearer-facing surface of the structure are larger than those nearer the garment-facing surface thereof.

The invention also provides a method for making an absorbent structure. The method comprises; making the superabsorbent polymer composite as above, suitably in the form

of a foam or particles, and incorporating the resulting superabsorbent polymer composite into said absorbent structure.

The invention also provides the use of cellulosic nanofibrils for increasing the gel strength of a superabsorbent polymer. All details regarding the superabsorbent polymer and the
5 cellulosic nanofibrils given above are also relevant to this aspect of the invention.

The present invention should not be considered as limited by the above embodiments and the Figures, but rather the scope of protection should be determined by the enclosed claims. Combinations of features and elements as described for various embodiments above should also fall within the scope of the invention.

10

EXAMPLES

Two studies were carried out.

In the first study (Section I) nanofibrils and microfibres were prepared (Section I-a).
15 Superabsorbent polymer composites in the form of particles and foams were formed (Section I-b and I-c), the composites were characterised (Section I-d), the liquid absorbency properties of the foams were tested (Section I-e) and the mechanical properties of the foams were tested (Section I-f).

20 In the second study (Section II), suspensions containing a mixture of nanofibrillated cellulose (NFC) and microfibrillated cellulose (MFC) were characterized (Section II-a), hydrogels were synthesized (Section II-b) and mechanical measurements and swelling analyses were carried out (Section II-c).

25 Section I

I-a. Preparation of nanofibrils and microfibres

Preparation of nanofibrils

30 One way of preparing nanofibrils is described in WO2009/069641. Cellulosic pulp/fibres are suspended in water and 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO) and NaBr are added. By adding 12% NaClO solution with pH 10 to the cellulosic fibre suspension during stirring at 500 rpm, TEMPO-oxidation is initiated. The pH is maintained at 10 by adding

NaOH during stirring. The TEMO-oxidised cellulose is washed with water by filtration and stored at 4°C before further treatment. The oxidized cellulose is agitated using a magnetic stirrer bar at 1500 rpm in an airtight container for 6 h to 10 days at 4°C. As a result, individual nanofibrils and/or clusters of nanofibrils are prepared.

5

Preparation of microfibrils

Microfibrils can be produced by different mechanical and chemical treatments. The microfibrils used in the following examples were produced at SCA's CMC mill Nyhamn, Sweden. These fibres had a degree of substitution of 0.28 and were sold under the trade name Aquasorb. The carboxymethylated fibres were dispersed in distilled water to a concentration of 5 %. The dispersion was kept over night in order to fully swell the fibres. It was then mechanically treated in a Hobart mixer, model N50, at maximum intensity for 2h. The dispersion was then treated in an ultrasonic bath; model Elma transonic 700, for 30 min

15

Samples

Sample S1: 0 wt % nanofibrils, reference (high crosslinking degree)

Sample S2: 12 wt % nanofibrils to wt acrylic acid monomer (low crosslinking degree)

Sample S3: 0 wt % nanofibrils to wt acrylic acid monomer, reference (low crosslinking degree)

Sample F1: 14.6 wt % microfibre to wt acrylic acid monomer

Sample F2: 2.16 wt % nanofibril and 6.6 wt % microfibre to wt acrylic acid monomer

Sample F3: 5.1 wt % nanofibril and 5 wt % microfibre to wt acrylic acid monomer

25 *Preparation of the samples – Superabsorbent polymer composite particles and foams based on polyacrylic acid cellulose microfibrils and nanofibrils.*

Raw material

All chemicals were used as received. All syntheses were performed with Ultra Pure Elga water (resistivity = 18 MΩ), Elga Maxima HPLC.

Acrylic acid monomer (AA), Tween 80 and NaOH were purchased from Merck. NN'-methylenebis(acrylamide) (MBA) and 2,2'-azobis[2-(2-imidazolin-2-yl)propane] dihydrochloride(VA-044) and Sodium dodecyl sulfate (SDS) were purchased from Sigma-Aldrich.

35 Cellulose fibres as a 5% microfibre solution and as a 1.5 % nanofibril solution in deionised water were used.

I-b. Synthesis of SAP particles

All samples were prepared in glass vials with an inner diameter of 29 mm.

The pure SAP and SAP containing nanofibrils were synthesized via a thermally-initiated
5 free radical polymerization, MBA was used as the cross-linker and VA-044 was used as
the initiator.

The content of the reaction vessel was purged with N₂ during all steps in the following
examples to exclude oxygen from the solution. The N₂ source was removed before
10 addition of the initiator.

Example 1 - Sample S1: 0 wt % nanofibrils, reference (high crosslinking degree)

A cooling bath (cold water + ice) was placed on a magnetic stirrer. 5.24 g NaOH (67 %
neutralization of the acid groups) was dissolved in 17.009 g Ultra Pure Elga water.

15 A vial was charged with 13.255 g Ultra Pure Elga water, 13.8 g acrylic acid monomer
(0.192 mol) and placed in the cooling bath. After 10 minutes of mixing, the NaOH solution
was added to the vial drop by drop. The vial was placed in a water bath preset to 42 °C
and 0.242 g crosslinker MBA (0.85 mol% to mol monomer) was added; the stirring speed
was raised to ensure incorporation of the powder onto the solution. After 10 minutes the
20 initiator VA-044 (0.1 mol% to monomer, 0.059 g) was added with a syringe as a 10%
solution in Ultra Pure Elga water. The temperature of the bath was raised to 50 °C and the
reaction was allowed to proceed at 50 °C. 10 minutes after formation of the network the
vial was sealed, the heat source was turned off and the vial was allowed to cool and stand
in the water bath overnight at 22°C; a rubbery gel was obtained.

25

Example 2 - Sample S2: 12 wt % nanofibrils to wt acrylic acid monomer (low crosslinking degree)

To increase the nanofibril concentration of the solution, a certain amount of nanofibril
solution (1.5% in deionised water) was filtered to remove a part of water. The nanofibrils
30 were still wet and contained water after this step.

An E-flask was charged with 17.863 g nanofibril solution (0.62 g nanofibrils) and then the
flask was introduced in a cold water bath. 3.705 g NaOH (67 % neutralization of the acid
groups) was added in small increments to the E-flask and the solution was mixed well
35 until all NaOH pellets were dissolved.

A cooling bath (cold water + ice) was placed on a magnetic stirrer. The nanofibril-NaOH solution was transferred to a vial, then 19.5 g nanofibril solution (0.60 g nanofibrils) was added and the vial was placed in the cooling bath. Mixing of the solution was performed
5 for ca 15 min, thereafter 10 g acrylic acid monomer (0.139 mol) was added to the vial drop by drop. Then 0.089 g crosslinker MBA (0.42 mol % to mol monomer) was added to the vial and the stirring speed was raised to ensure incorporation of the powder onto the solution. The vial was placed in a water bath preset to 42 °C. After 10 minutes the vial was sealed and the initiator VA-044 (0.1 mol% to mol monomer, 0.047 g) was added with
10 a syringe as a 10% solution in Ultra Pure Elga water. The vial was turned up and down a couple of times and shaken to mix the solution well, the temperature of the bath was raised to 50 °C and the reaction was allowed to proceed at 50 °C. 10 minutes after formation of network, the heat source was turned off and the vial was allowed to cool and stand in the waterbath over night at 22°C. A rubbery gel was obtained
15 Total amount nanofibrils = 1.2 g (12 wt % to wt monomer)

Example 3 – Sample S3: 0 wt % nanofibrils, reference (low crosslinking degree)

A cooling bath (cold water + ice) was placed on a magnetic stirrer. A vial was charged with 25.53 g Ultra Pure Elga water, 10 g acrylic acid monomer (0.139 mol) and placed in
20 the cooling bath. 14.98 g NaOH solution (as 25 % solution in Ultra Pure Elga water, 67 % neutralization of the acid groups) was added to the vial drop by drop.

The vial was placed in a water bath preset to 42 °C and 0.089 g crosslinker MBA (0.42 mol % to mol monomer) was added to the vial; the stirring speed was raised to ensure
25 incorporation of the powder onto the solution. After 10 minutes the initiator VA-044 (0.1 mol% to mol monomer, 0.045 g) was added with a syringe as a 10% solution in Ultra Pure Elga water. The temperature of the bath was raised to 50 °C and the reaction was allowed to proceed at 50 °C. 10 minutes after formation of network the vial was sealed, the heat source was turned off and the vial was allowed to cool and stand in the water bath over
30 night at 22°C. A rubbery gel was obtained.

I-c. Preparation of SAP foams

The SAP foams were prepared via a thermally-initiated free radical polymerization, MBA was used as the cross-linker and VA-044 was used as the initiator.

Example 4 - Sample F1: 14.6 wt % microfibre to wt acrylic acid monomer

N₂ gas was used as the inert gas during all steps. A hand blender type Bosch MSM6600 (2008) was used for mixing and whipping of the mixture. The whipping speed of the blender has two positions; one defined as turbo speed and one for lower speed. The lid of the reaction vessel had one inlet for CO₂ gas, one for N₂ and addition of solutions and one for the balloon whip. The reaction vessel was placed in a cooling bath (cold water + ice) and purged with N₂ gas a couple of minutes. The vessel was charged with 37.04 g microfibre solution (5 % in deionised water, 1.85 g microfibres) and the blender was started at low speed. 7.3 g NaOH (51.7 % neutralization of the acid groups) was added in small increments to the vessel and the solution was mixed until all NaOH pellets were dissolved. 19.05 g acrylic acid monomer was added to the mixture drop by drop in two increments. After the first addition, 3.4 g surfactant (SDS) was added and after a mixing time of 2 minutes the addition of the acrylic acid was continued.

0.1976 g crosslinker MBA (0.36 mol % to the total mol monomer) was dissolved in 6.35 g acrylic acid monomer. The solution was added to the vessel in two increments. Whipping was performed at turbo speed for 15 minutes and thereafter the initiator VA-044 (0.13 g, 0.11 mol% to mol monomer) was added as a 3.8 wt % solution in Ultra Pure Elga water; mixing at lower speed was performed for 5 minutes. Thereafter, 37.04 g microfibre solution (5 % in deionised water, 1.85 g microfibres) was added and whipping was continued for 5 minutes; a monomer foam structure was obtained. The reaction vessel was removed from the cooling bath and the monomer foam was carefully transferred to a rectangular plastic jar (10x10 cm). A lid was used to close the jar and the polymerisation was performed in a heating oven at a temperature of 55°C for 1 ½ hours. Then the lid was opened but not removed from the jar and the reaction was allowed to proceed over night at a temperature of 30 °C.

Example 5 - Sample F2: 2.16 wt % nanofibril and 6.6 wt % microfibre to wt acrylic acid monomer

N₂ gas was used as the inert gas during all steps. A hand blender type Bosch MSM6600 (2008) was used for mixing and whipping of the mixture. The whipping speed of the blender has two positions one defined as turbo speed and one for lower speed. The lid of the reaction vessel had one inlet for CO₂ gas, one for N₂ and addition of solutions and one for the balloon whip.

An E-flask was charged with 36.095 g nanofibril solution (1.5 % in deionised water, 0.541 g nanofibrils) and 7.3 g NaOH (51.7 % neutralization of the acid groups) was added in small increments to the E-flask; mechanical stirring was performed until all NaOH pellets were dissolved.

5

The reaction vessel was placed in a cooling bath (cold water + ice) and purged with N₂ gas a couple of minutes. The vessel was charged with 16.8 g acrylic acid monomer and the nanofibril-NaOH solution was added drop by drop; a magnetic stirrer was used for mixing of the solution. Thereafter the bar magnet was removed and the balloon whip was used for mixing and whipping. 3.3 g surfactant, SDS, was added to the mixture and after a couple of minutes MBA-acrylic acid monomer solution, 0.198 g MBA (0.4 mol % to total mol acrylic acid monomer)/ 8.2 g acrylic acid, was added in two increments. Whipping was performed at turbo speed for 10 minutes and thereafter 15.04g microfibre solution (5 % in deionised water, 0.752 g fibres) was added. After 5 minutes whipping, the initiator VA-044 (0.125 g. 0.11 mol% to mol monomer) was added as a 3.8 wt % solution in Ultra Pure Elga water and mixing at lower speed was performed for 5 minutes. Then 18.0 g microfibre solution (5 % in deionised water, 0.9 g microfibrils) was added and whipping was continued for 5 minutes at turbo speed. The vessel was removed from the cooling bath and the monomer foam was carefully transferred to a rectangular plastic jar (10x10 cm). A lid was used to close the jar and the polymerisation was performed in a heating oven at a temperature of 65 °C for 1 hour. Thereafter, the lid was open but not removed from the jar and the reaction was allowed to proceed 4 hours at a temperature of 65°C.

Example 6 - Sample F3: 5,1 wt % nanofibril and 5 wt % microfibre to wt acrylic acid monomer

25

Both CO₂ and N₂ were used in this synthesis. CO₂ was used as a physical foaming agent and was inlet at the bottom of the reaction mixture to allow gas flow into the mixture from below while N₂ was used to avoid gas escape from the top of the mixture during the foaming process.

30

To be able to increase the amount of nanofibrils without increasing of the amount water, a certain amount of nanofibril solution (1.5% in deionised water) was filtered. For this aim an E-flask, a funnel and filter paper was used. The nanofibrils were still wet and contained water after filtration. For efficient mixing/whipping of the mixture, a reaction vessel just large enough to allow free rotation of the balloon whip was used in this example. The lid

35

of the reaction vessel had one inlet for CO₂ gas, one for N₂ and addition of solutions and one for the balloon whip. The balloon whip was permanently fixed on a metallic bar which could be attached directly to an electrical motor.

- 5 An E-flask was charged with 25.354 g nanofibril solution (0.683 g nanofibrils) and 9.07 g NaOH (65.3 % neutralization of the acid groups) was added in small increments to the E-flask; magnetic stirring was performed until all NaOH pellets were dissolved. The E-flask was introduced in a cooling bath and 16.25 g acrylic acid monomer was added drop by drop.

10

- The reaction vessel was placed in a cooling bath (cold water + ice) and purged with CO₂ gas (6 B) a couple of minutes to exclude the air. The vessel was charged with 19.05 g nanofibril solution (0.594 g nanofibrils) and 0.25 g PEG 200 (1 wt % to total amount acrylic acid monomer). Mixing was performed at 300 rpm for 3 minutes and then the nanofibril-
- 15 NaOH solution was added. At this step the N₂ gas was also introduced into the system but just on the surface of the mixture. Thereafter MBA-acrylic acid monomer solution, 0.196 g MBA (0.4 mol % to total mol acrylic acid monomer) / 8.8 g acrylic acid, was added in two increments. Then 2.25 g surfactant, Tween 80, was added and the speed of the motor was raised to 500 rpm for 15 minutes; then 25.01 g microfibre solution (5 % in deionised
- 20 water, 1.25 g microfibrils) and 0.66 g Tween 80 were added and whipping was continued for 5 minutes at 500 rpm. The initiator VA-044 (0.127 g, 0.11 mol% to mol acrylic acid monomer) was added as a 3.8 wt % solution in Ultra Pure Elga water and mixing at 240 rpm was performed for 3 minutes. The monomer foam was carefully transferred to a rectangular plastic jar (20x12 cm). The vessel was covered with a lid (not closed) and the
- 25 polymerisation was performed in a heating oven at a temperature of 65°C for 2 hour. Total nanofibril amount 2.527 (10 wt % to wt monomer).

I-d. Characterisation of the superabsorbent polymer composites

30 *Measurement of nanofibril and microfibre diameter*

- Freeze-dried samples were used when measuring the diameter of the nanofibrils and the microfibrils. The freeze dried samples were characterised using a FEI Quanta 200 environmental scanning electron microscope (ESEM) equipped with a field emission gun (FEG). Small pieces of the samples were cut with a scalpel and put on a piece of carbon
- 35 tape on a standard aluminium stub. The ESEM was operated at an acceleration voltage of

10 kV and at a pressure of 0.98 torr in the low vacuum mode in order to avoid charging effects during imaging. The diameter of the nanofibrils and microfibres were measured from images acquired at a magnification of 40 000x or higher.

- 5 The ESEM picture was then used to estimate the nanofibril and microfibre diameter. The procedure was as follows:

Open image with Optimas 6.51

Calibration spatial to get the active calibration

Visual measuring of nanofibrils and microfibres

10

Optimas 6.51 software was obtained from PARAMETER Box 27186, 102 52 Stockholm. One should note that our image is a combination of individual nanofibrils/microfibres and/or clusters of nanofibrils/microfibres.

- 15 An ESEM image has been used. To improve the estimation of the diameter one can use an atomic force microscope (AFM). The AFM or scanning force microscope (SFM) is a very high-resolution type of scanning probe microscope, with demonstrated resolution of fractions of a nanometer.

20 *Characterization of the morphology of SAP particles and SAP foam*

The surface and cross section morphology of the prepared materials were studied with Environmental Scanning Electron Microscopy, Philips ESEM XL-30 TPM.

I-e. Measurements of absorption properties

- 25 An aqueous solution of 0.9 % NaCl and defibrinated sheep blood were used as test liquids. The defibrinated sheep blood was purchased from the National Veterinary Institute (Statens Veterinärmedicinska Anstalt, 751 89 Uppsala, Sweden).

Prior to measuring absorption properties, gels were washed in deionised water for three
30 days and the water was changed every day to remove extractable materials. Then the samples were dried in a heating oven at 40 °C until a constant weight was reached. Thereafter the samples were ground and sieved to cover the common size interval used for hygiene absorbent articles 140-850 µm.

- 35 1. Absorption under load (AUL) in an aqueous solution of 0.9 % NaCl.

The test was performed according to the standard test WSP 242.2 (05), Gravimetric determination of absorption under pressure. A glass filter plate is placed in a Petri dish and NaCl solution is added until the surface of the liquid reaches the same level as the surface of the glass filter. A filter paper of same dimension as the glass filter was placed
5 on it and was allowed to be totally wetted.

0.9 g SAP particles of size 140-850 μm are distributed onto the filter screen of a Plexiglas cylinder. The Plexiglas piston is placed in the cylinder and the complete assemble is weighed. The cylinder assemble is placed on the filter paper and at the same time the
10 weight (2.5 kPa) was placed into the piston. After 60 minutes the cylinder assembly is lifted from the filter paper, the weight is removed and the cylinder assembly is reweighed. In this test some of the samples were analysed after 60 minutes.

The AUL per gram dry polyacrylic acid was calculated according to the equation:
15

$$AUL = \frac{(m_w - m_d)}{m_s}$$

Eqn. 1

where:

m_w = weight of cylinder assembly with sample after absorption

m_d = weight of cylinder assembly with dry sample

20 m_s = weight of dry sample

Each of the results presented below are mean values of three measurements.

The following table indicates AUL values (gram absorbed liquid per gram dry polyacrylic
25 acid) of particles measured in an aqueous solution of 0.9 % NaCl.

abs	
Sample	(after 60 min)
S1	20.6
S2	19.7
S3	9.4

Sample S2 shows a slightly lower AUL value measured in an aqueous solution of 0.9 % NaCl than sample S1 and a substantially higher value than sample S3. The presence of

nanofibrils in sample S2 increases the AUL value compared to sample S3. The presence of nanofibrils in sample S2 may compensate for the lower crosslinking degree compared to sample S1 in terms of AUL.

5 *2. Absorption under load (AUL) in defibrinated sheep blood*

A crystallization bowl (75 mm inner diameter) is charged with 40 ml defibrinated sheep blood. 0.15 g SAP particles of size 140-850 μm are distributed onto the filter screen of a Plexiglas cylinder (25 mm inner diameter). The weight (2 kPa) is placed into the cylinder, the whole assemble is weighed and placed on a perforated metallic cylinder holder and
 10 then immersed into the sheep blood. After 20 minutes of absorption, the apparatus is lifted from the blood and allowed to drop for 10 minutes; then the assembler is reweighed.

The AUL per gram dry polyacrylic acid was calculated according to Eqn. 1. Each of the results presented below are mean values of three measurements.

15

The following table indicates AUL values (gram absorbed liquid per gram dry polyacrylic acid) of particles measured in defibrinated sheep blood.

abs	
Sample	(after 20 min)
S1	4.0
S2	8.0
S3	5.0

20 As can be seen sample S2 indicates the highest AUL value measured in defibrinated sheep blood compared to sample S1 and S3. The presence of nanofibrils gives sample S2 the most advantageous absorption under load value regardless of crosslinking degree.

I-f. Measurements of mechanical properties

25

Swelling of dry foam samples for determination of mechanical strength of the foams

The dry samples were weighed. Then the dry weight of the samples was multiplied with the same factor to get samples with the same swelling degree.

30 Example:

$$m_{\text{dry foam}} = 0.230 \text{ g}$$

$$V_{\text{H}_2\text{O}} = 0.230 \times 71 = 16.33 \text{ g}$$

The dry sample was placed in a small vessel, 16.33 g deionised water was added and the vessel was covered to avoid evaporation of liquid. The sample was allowed at room
5 temperature for 8 hours and then subjected to uniaxial mechanical compression analysis. All samples were swelled to 71 times the dry weight. The cross-sectional area of each swelled sample was measured as $22.1 \pm 0.9 \text{ cm}^2$.

The mechanical properties of the foams in the swollen states have been evaluated with a
10 Lloyd LRX tensile tester. The tensile tester is connected to a computer equipped with Ondio V4.0 software for automatic control of the machine, programming of test set-ups and to record the load-deformation curve (load, extension/compression).

The probe was comprised of one fixed Plexiglas plate and one mobile Plexiglas plate,
15 each having a surface area of 19.7 cm^2 .

The compression test was carried out with a load cell (50 N; 101.1% accuracy) at $23 \pm 1^\circ\text{C}$ and R.H. $50 \pm 10 \%$. The measurement was carried out at a constant crosshead speed of 50 mm/min.

20 The swollen foam was carefully positioned between the parallel Plexiglas plates of the instrument. A preload force of 0.05 N was used for auto-measurement of the initial high of the swollen foams and 50 % compression of the sample's initial high was performed at the constant crosshead speed. The compression was monitored as force (N) vs. extension.

25 The following values of force at 50 % compression of the initial height of the swollen foam were found. All samples were swelled to a water content of 71 times the dry weight of the sample.

Test	Sample	load after 50% compression (N)
1	F3	22.4
2	F2	2.3
3	F1	1.8

Sample F3 shows the highest load after compression values compared to the other foam samples. Thus, the higher content of nanofibrils in the sample the higher values of load after 50 % compression.

5 SECTION II

II-a. Characterisation of a suspension of nanofibrillated (NFC) and microfibrillated (MFC) cellulose

10 **Materials**

The following chemicals were of analytical grade and were used as received; acrylic acid [AA] (Fluka, Belgium), N,N'-methylenebisacrylamide [MBA] (Sigma-Aldrich, Germany), sodium chloride (Sigma-Aldrich, Germany), sodium hydroxide (Sigma-Aldrich, Germany), potassium persulfate [KPS] (Sigma-Aldrich, Germany). Suspensions of Nanofibrillated
15 cellulose [NFC] and microfibrillated cellulose (MFC) was bought from the Paper and Fibre Research Institute PFI, Norway. Used H₂O was of Milli-Q grade.

Both untreated and filtered NFC+MFC suspension was characterized using light microscope and AFM. Filtered suspension was further characterised by transmittance
20 analysis.

Filtered suspension of NFC and MFC was prepared using a 25 mm syringe filter with 0.2 µm nylon membrane (VWR), previously washed with 30 ml of H₂O.

25 For the light microscopy analysis an Olympus BH2 research microscope with a Microscope digital camera system DP12 (Olympus) was used in transmission mode. For untreated NFC + MFC suspension, images were recorded for concentrations of 0.03 and 0.8 % w/v, placed between a standard microscope glass slide and a cover slip. For filtered suspension images were recorded on samples dried at room temperature on a standard
30 microscopy glass slide, utilizing filtered and dried H₂O as controls.

Untreated NFC + MFC suspension, samples to be analysed in AFM were prepared by diluting the suspension to fibre concentrations of 0.16, 0.016 and 0.0016 % w/v. For both untreated and filtered NFC + MFC one drop of sample was added to a freshly cleaved
35 mica chip and was allowed to dry at room temperature; for the filtered sample filtered

water was used as control. The AFM analysis was performed using a Digital Instrument Nanoscope IIIa with a type G scanner (Digital Instrument Inc.). The cantilever used was a Mikro Masch silicon cantilever NSC 15. The AFM was operated at a resonance frequency of about 330 kHz in tapping mode, the scan rate was 1 Hz and the measurements were
5 performed in air.

For transmittance analysis of filtered NFC + MFC suspension the extinction of light passed through the sample in a quartz cuvette was recorded as a function of wavelength in the interval 200-800 nm using a Cintra 40 spectrophotometer (GBC), filtered H₂O was
10 used as a control.

During the visual inspection of the untreated suspension it was noted that small amounts of fibrous structures could be detected with the naked eye and that the suspension appeared opaque. The filtered suspension appeared completely transparent.
15

Optical microscopy of wet suspension of NFC and MFC revealed a highly heterogeneous suspension on the detectable length scale, as can be seen in the exemplifying images in Fig. 1a. Filtered and subsequently dried suspension of NFC and MFC left a film-like aggregate over the whole area covered by the drop prior to drying. In the aggregate area
20 structures of varying size could be seen, many with clear directionality and even fractal like structures. It was found that extent, size and shape of the structures varied between samples. This was probably due to different concentrations and size distributions of MFC and NFC in the samples after filtration and due to variations in drying between samples. Exemplifying images can be seen in Fig. 1b. The controls with filtered water did not show
25 any observable structures and only negligible aggregate, probably being an artefact from the filtration or the drying. The large aggregate formation and the formed structures from NFC + MFC suspension filtered through a 0.2 µm filter clearly indicates the presence of structures with sizes on the nano-scale.

30 AFM analysis of the wet suspension of NFC and MFC revealed that they contained a large amount of nanoparticles, though to be cellulose nanocrystals, as well as larger fibers and fibrous structures. An exemplifying image showing individual nanoparticles, fibers and larger fibrous structures is given in Fig. 2a. Typical dimensions in the z-direction were found to be about 2-5 nm for nanoparticles and individual fibers and about 30-60 nm for
35 fiber bundles. However, the structure observed varies greatly between location and

preparation procedure, as such there will be structures present falling outside the mentioned intervals. The observed nanoparticles had diameters in the xy-plane of 10's of nanometers; this being similar to diameters reported by others for spherical cellulose nanocrystals. The exact diameters of the nanoparticles are not speculated upon. This
 5 since the AFM tip is known to give artifacts in the xy-plane. However, the AFM has very high precision in the z-direction, and it can be concluded that the structure of the presumed cellulose nanocrystals is somewhat flattened.

AFM analysis of the filtered suspension of NFC and MFC and the filtered water control
 10 revealed that the filtered suspension of NFC and MFC contained nanoparticles and fibers (Fig. 2b and c). The dimensions in the z-direction ranged from about 1–20 nm for the nanoparticles and 1-2 nm for the fibers. As stated earlier, structures falling outside the mentioned intervals could also be present. The AFM analysis of the water control revealed that a thin film with pores had been formed upon drying of the sample (result not
 15 shown). Thus, the dark areas corresponding to cavities in Fig. 2b and c are derived from this film, and are not an effect of the filtered suspension.

The transmittance analysis of the filtered suspension showed an increasing extinction with decreasing wavelength. The transmittance through a medium containing particles can be
 20 described by the Beer Lambert law, replacing the extinction coefficient with a scattering coefficient, with the current notation:

$$A = \alpha_{sca} l \quad (3)$$

where A is the absorbance, l is the distance through the medium and α_{sca} is the scattering coefficient, which for Rayleigh scattering from small size particles is inversely proportional
 25 to the fourth power of the wavelength.

Taking into account the results from optical microscopy of filtered suspension, AFM and transmittance studies, it is concluded that the suspension of NFC and MFC contains a rather large amount of structures having sizes on the nano scale. The differences in the
 30 structures observed in the AFM analysis of the 10, 100 and 1000 times diluted samples, as well as the structures observed for filtered and dried NFC + MFC using optical microscopy, indicates that upon drying, the nanoparticles aggregate into larger structures in a concentration-dependent manner. Based on the characterisation it is recognized that the NFC/MFC mixture is highly heterogenous, containing structures ranging from
 35 nanometers to hundreds of micrometers.

II-b. Synthesis of hydrogels

Hydrogels containing 25 % w/v AA with degree of crosslinking ranging from 0 to 5 mol% relative to AA and concentrations of MFC + NFC ranging from 0 to 0.75 % w/v were synthesized by free radical copolymerization as follows: AA was drop wise neutralized to 60 mol% with NaOH. The neutralized AA was mixed with MBA, KPS, H₂O and NFC suspension (1.6 % w/v). KPS was used in a concentration of 21 mM, the amounts of MBA and NFC + MFC suspension were added according to desired final concentrations and H₂O was added to reach the final volume. All of the mixing was performed on ice during stirring. After mixing the samples were bubbled with N₂ gas under stirring while kept on ice for 30 minutes, this to remove O₂ from the samples. The samples were then immediately transferred to 7x40 mm autosampler vials (NTK KEMI), which were placed in a water bath at 70 °C for 6 h for the synthesis solution to polymerize. Finally the samples were allowed to settle over night at room temperature before breakage of the vials and further analysis.

II-c. Mechanical Measurements and Swelling Analysis

In order to evaluate the effect of the NFC + MFC on the mechanical and swelling properties of the hydrogels, a series of samples were studied. To evaluate the effect of the amount of NFC + MFC on the properties in a fixed surrounding matrix, this series of samples contained hydrogels with a crosslinking degree of 0.5 mol% N,N'-methylenebisacrylamide (MBA) crosslinker relative to acrylic acid (AA) and NFC + MFC concentrations ranging from 0 to 2.5 % per dry weight of the samples.

Equilibrium Swelling and Elastic Modulus

In order to establish the effect of NFC + MFC on equilibrium swollen gels the samples were submerged in 0.9 % NaCl solution. The specified ionic strength was chosen because of the biological relevance and because superabsorbents swollen in de-ionized water commonly fracture during swelling.

The swelling studies revealed, that the equilibrium swelling decreased with increasing total content of NFC + MFC (Figure 5).

The elastic modulus after swelling of the samples displayed an increase with increasing mass of NFC + MFC, shown in Fig. 6.

Studies also showed that, for samples containing NFC + MFC, the stress at fracture (compressive strength) σ_f was increased without decreasing the strain at fracture, compared to corresponding samples without NFC + MFC (see Table 1 below).

5

Mechanical Measurements

The gels were cut into cylinders intending an aspect ratio > 1.5 . However, on rare occasions a smaller aspect ratio was acquired due to removal of rough sample ends. Uniaxial compression tests were performed in order to determine the elastic modulus G of the different samples. The samples were compressed at $0.1 \text{ mm} \cdot \text{s}^{-1}$ and the resulting force was recorded using a TA-HDi® (Stable Microsystems), with a load cell capacity of 5 kg. The compression probe used was a 25 mm cylindrical aluminium probe (Stable Microsystems). Measurements were performed at $20 \pm 0.5 \text{ }^\circ\text{C}$. For the uniaxial compression of Gaussian chains the following equation is valid:

$$P = G(\alpha - \alpha^{-2}) \quad (5)$$

where P is the pressure, G is the elastic modulus and α is the ratio deformed length to initial length.

For deformation ratios up to 20 % the elastic modulus was determined as the slope of the linear region in the graph P versus $(\alpha - \alpha^2)$. The non linear data for low strains was discarded as it is derived from imperfect geometries of the sample ends.

The compressive strength of the samples was calculated as:

$$\sigma = F / A \quad (6)$$

where F is the force at fracture and A is the area at fracture, calculated based on the assumption of constant volume as:

$$A = \frac{A_0}{\alpha_f} \quad (7)$$

where A_0 is the initial area and α_f is the deformation ratio at fracture.

Data for the fracture properties of gels after synthesis and after equilibrium swelling are given in Table 1.

Table 1 Fracture properties of gels after synthesis and after equilibrium swelling. ε_f denotes the strain at fracture, σ_f the compressive strength and G the elastic modulus of the gels. $\pm$ indicates min / max values for samples after synthesis ($n = 2$) and one standard deviation for samples after equilibrium swelling ($n = 6$).

5

Sample	MBA (mol%)	NFC+MFC (mass%)	ε_f	σ_f / kPa	G / kPa
After synthesis					
1	5	0	0.37 ± 0.011	298 ± 5.0	249 ± 3.9
2	2.5	0	0.454 ± 0.0091	180 ± 17	120 ± 10
3	5	1.2	0.377 ± 0.0031	409 ± 7.0	301 ± 7.6
4	2.5	1.2	0.54 ± 0.047	440 ± 78	159.1 ± 0.71
After Swelling					
1	5	0	0.21 ± 0.023	190 ± 52	400 ± 27
2	2.5	0	0.34 ± 0.040	170 ± 35	166 ± 6.1
3	5	1.2	0.24 ± 0.034	340 ± 55	550 ± 20
4	2.5	1.2	0.32 ± 0.022	220 ± 36	247 ± 5.8

Swelling analysis

The samples were prepared for swelling by cutting off and discarding the uppermost part
 10 of the cylinders and recording their weights w_0 . The swelling experiments were conducted
 in 900 ml of 0.90 % w/v NaCl at 20 ± 0.5 °C. After one week the samples were considered
 to have reached equilibrium swelling, as no further mass uptake could be detected. The
 equilibrium weight w_{eq} was recorded. Assuming a yield of 100% from the synthesis, as
 done by others, the dry weights of the samples were calculated from the masses of the
 15 components in the synthesis mixture and the weight ratio between the initial weight w_0 of
 the samples and the synthesis mixture, so that:

$$m_{dry} = m_{AA} + m_{NaA} + m_{MBA} + m_{MFC} \quad (8)$$

where m_{dry} is the theoretical dry weight of the sample, m_{AA} is the mass of AA, m_{NaA} is the
 mass sodium acrylate, m_{MBA} is the mass MBA and m_{NFC} is the mass of cellulose fibrils
 20 (NFC + MFC) in the sample. The swelling degree Q was then calculated as:

$$Q = \frac{(w_{eq} - m_{dry})}{m_{dry}}$$

CLAIMS

1. A superabsorbent polymer composite comprising a superabsorbent polymer and cellulosic fibrils, **characterized in that** the cellulosic fibrils are nanofibrils having a diameter equal to or less than 100 nm.
- 5 2. A superabsorbent polymer composite according to claim 1, wherein the composite does not contain cellulosic fibres having an average diameter greater than 100 μm .
3. A superabsorbent polymer composite according to any of claims 1-2, further comprising cellulosic microfibrils having a diameter greater than 100 nm but less
10 than or equal to 100 μm , preferably a diameter greater than 100 nm but less than or equal to 10 μm .
4. A superabsorbent polymer composite according to any of the preceding claims, wherein the composite has a nanofibril content of 0.1-20 wt % of the superabsorbent polymer preferably 0.5-15 wt %, more preferably 0.5-5 wt %.
- 15 5. A superabsorbent polymer composite according to anyone of claims 3-4, wherein the composite has a microfibre content of 0.1-20 wt % of the superabsorbent polymer and preferably 0.5-15 wt %.
6. A superabsorbent polymer composite according to any of the preceding claims, wherein the superabsorbent polymer comprises CMC (carboxymethyl cellulose) or
20 a repeating unit derived from the group consisting of acrylic acid and its salts, methacrylic acids and its salts and combinations thereof.
7. A superabsorbent polymer composite according to any one of the preceding claims, comprising an organic cross-linker.
8. A superabsorbent polymer composite according to claim 7, wherein the
25 superabsorbent polymer composite has an organic cross-linker content of 0.1-20 wt % of the superabsorbent polymer, preferably 0.5-15 wt %, more preferably 0.5-5 wt %.
9. A superabsorbent polymer composite according to any of the preceding claims, wherein the composite is in the form of particles.

10. A superabsorbent polymer composite according to any of the preceding claims, wherein the composite is in the form of a foam.
11. A superabsorbent polymer composite according to claim 10, wherein the nanofibrils are incorporated into the pore walls of the foam.
- 5 12. A superabsorbent polymer composite according to any of claims 10-11, wherein the foam has a pore size gradient.
13. A superabsorbent polymer composite according to any of claims 10-12, wherein the foam comprises one or more substances selected from the group consisting of; plasticizers, surfactants and blowing agents.
- 10 14. An absorbent article having an absorbent structure comprising the superabsorbent polymer composite of any of claims 1-13.
- 15 15. An absorbent article according to claim 14, wherein said absorbent article is a diaper, a pant diaper, an incontinence guard, a sanitary napkin or the like and of the kind comprising a liquid pervious topsheet, a liquid impervious backsheet and said absorbent structure arranged therebetween.
16. A method for making a superabsorbent polymer composite according to any of claims 1-13, said method comprising the steps of:
- a. providing cellulosic nanofibrils having a diameter equal to or less than 100 nm suspended in a solvent,
 - 20 b. optionally, adding microfibers having a diameter greater than 100 nm but less than or equal to 100 μ m suspended in a solvent,
 - c. adding one or more monomers
 - d. adding a neutralizer,
 - e. adding a crosslinker,
 - 25 f. adding an initiator, and

h. polymerizing the monomers and crosslinker to form a superabsorbent polymer composite comprising superabsorbent polymers, cellulosic nanofibrils and optionally microfibers

wherein the steps (a), (b), (c), (d), (e) and (f) can take place in any order.

- 5 17. A method according to claim 16, wherein the initiator is selected from the group consisting of oxidizing initiators, azo initiators, photoinitiators and/or thermal initiators.
18. A method according to claims 16-17, further comprising the step of (i) forming the composite into particles.
- 10 19. A method according to claims 16-17, further comprising the step of (g) forming the mixture of one or more monomers with nanofibrils and/or microfibers into a foam; after steps (a) – (f), but before step (h) of claim 16.
20. A method according to any of claims 18-19, further comprising the steps of adding one or more substances selected from the group consisting of; plasticizers, surfactants and blowing agents.
- 15 21. A method according to any of claims 18-20, further comprising the steps of adding a viscosity control agent.
22. A method for making an absorbent structure, said method comprising; carrying out the method of any of claims 16-21, and incorporating the resulting superabsorbent polymer composite, foam or particles into said absorbent structure.
- 20 23. Use of cellulosic nanofibrils for increasing the gel strength of a superabsorbent polymer.

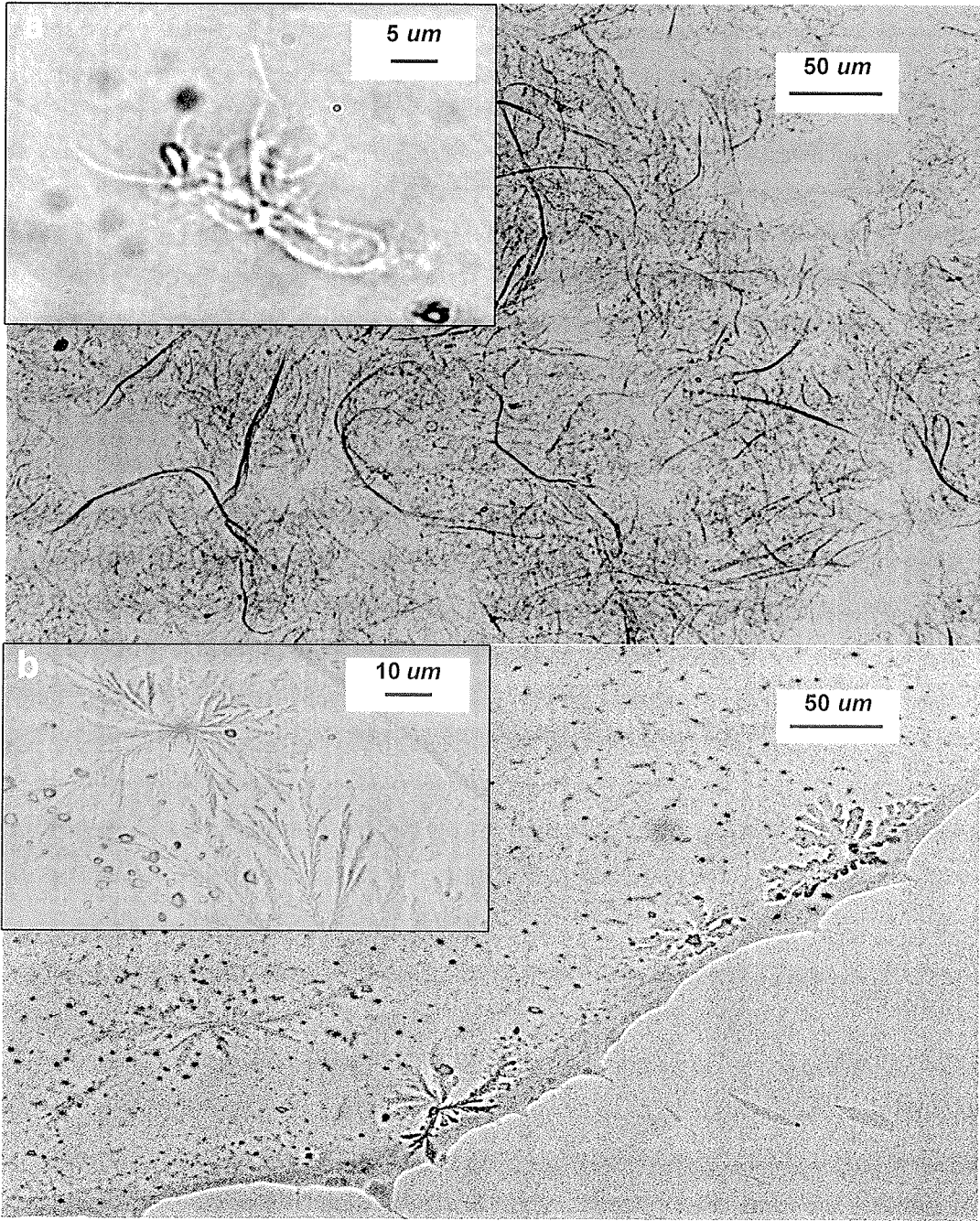


FIG. 1

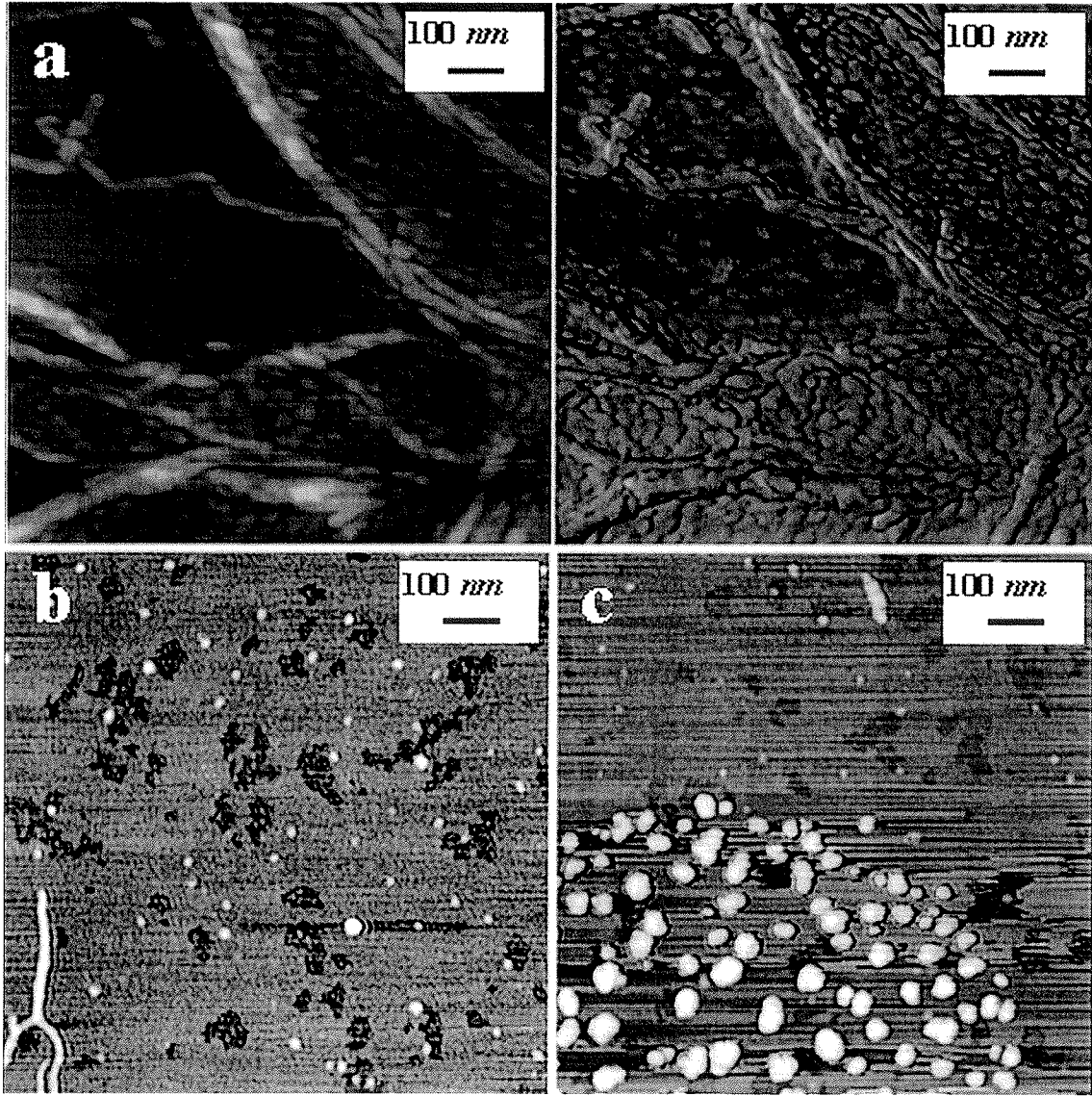


FIG. 2

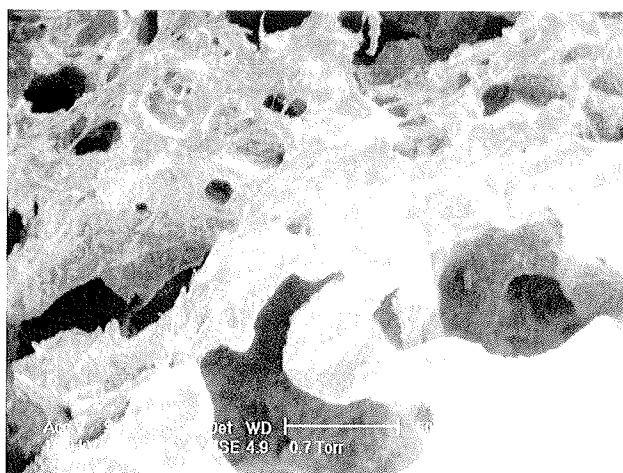
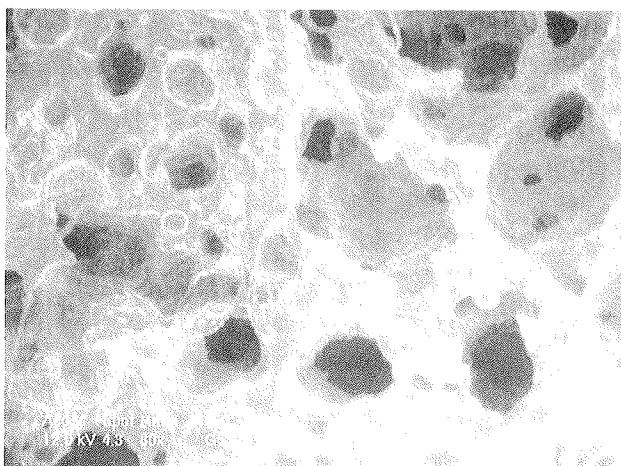
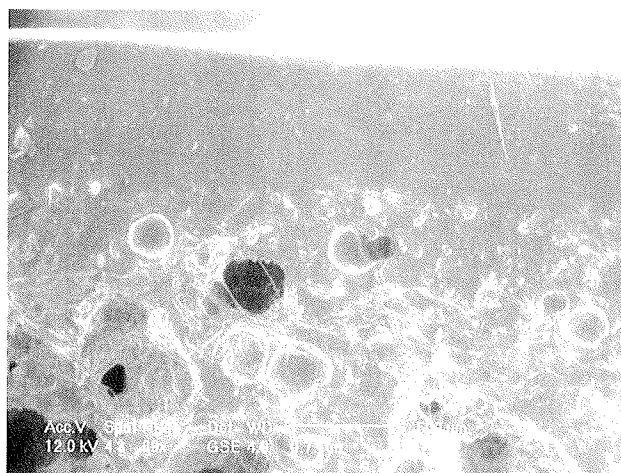


FIG. 3

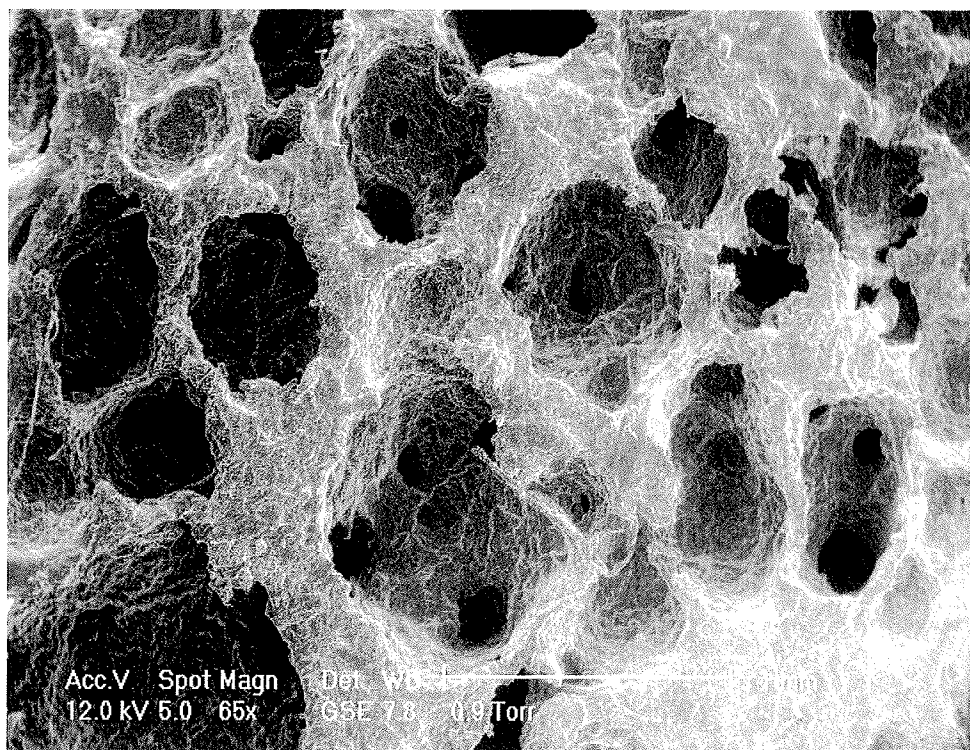


FIG. 4A

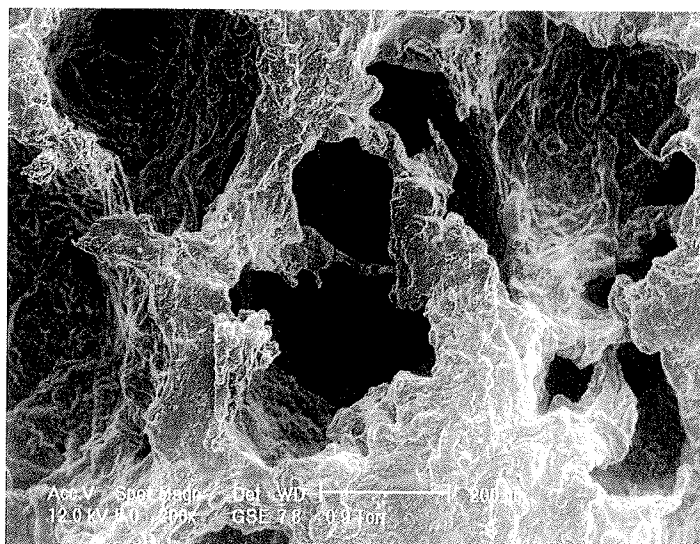


FIG. 4B

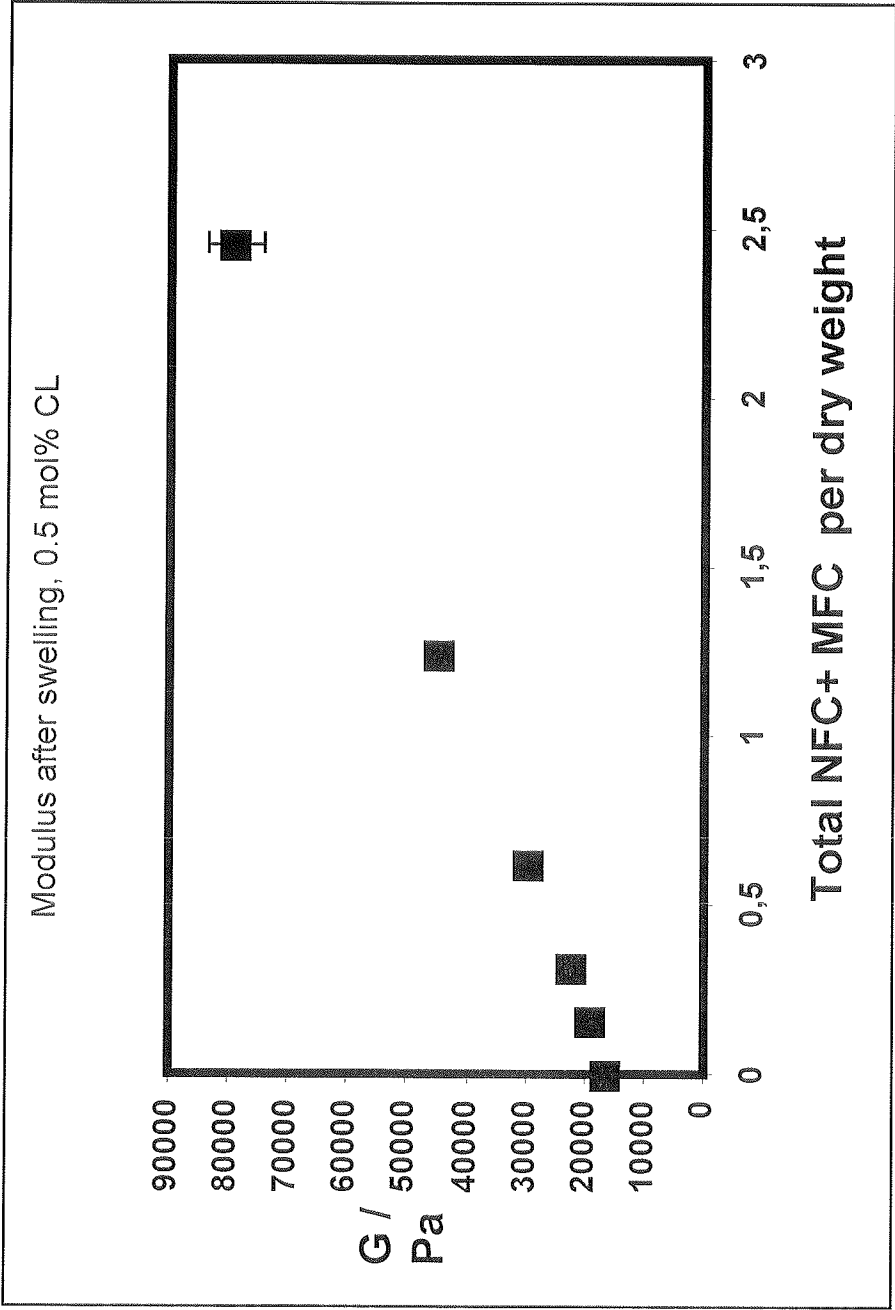


FIG. 5

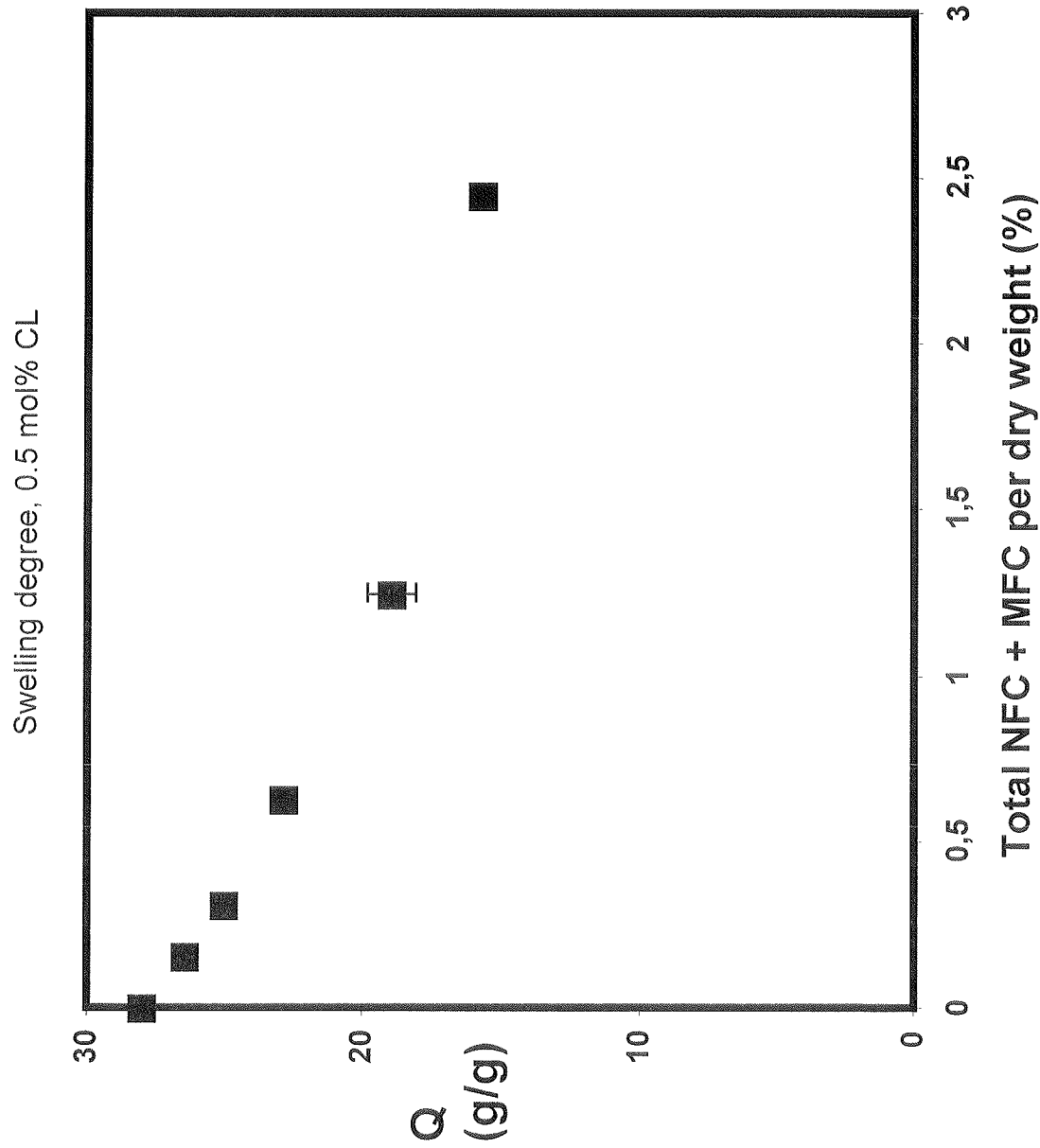


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/051446

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: A61L, A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, TXTE, COMPD, EMBASE, PUBCHEM

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006049664 A1 (KIMBERLY-CLARK WORLDWIDE, INC.), 11 May 2006 (11.05.2006), paragraphs [0030], [0042],[0045],[0083]-[0085],[0092],[0098],[0106] --	1,3,14-15
X	WO 2008113021 A2 (DONALDSON COMPANY, INC.), 18 Sept 2008 (18.09.2008), page 4, line 12 - line 17; page 52, line 28 - page 53, line 4; page 31, line 13 - line 17, page 15, line 25 - line 30; page 16, line 7 - line 8, claims 1,4, 19,21, abstract --	1,3,6

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2009/051446

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0947549 A1 (JAPAN ABSORBENT TECHNOLOGY INSTITUTE), 6 October 1999 (06.10.1999), paragraphs [0049],[0052]-[0053],[0127]	1,3,6,14-15
Y	--	1-23
Y	EP 1207914 B1 (SCA HYGIENE PRODUCTS AB), 6 August 2003 (06.08.2003), claims 1,7,9, paragraphs [0005],[0012],[0015]-[0016],[0022]	1-23
Y	--	
Y	US 5350370 A (JACKSON, DAVID M. ET AL), 27 Sept 1994 (27.09.1994), column 3, line 28 - line 40; column 4, line 19 - line 20; column 4, line 51 - line 54, page 5, line 5 - line 52, claims 1-2,9, abstract	1-23
Y	--	
Y	WO 9958091 A1 (SCA HYGIENE PRODUCTS AB), 18 November 1999 (18.11.1999), page 2, line 11 - line 19; page 3, line 20 - line 30; page 4, line 1 - line 9, claims 1-3	1-23
Y	--	
A	US 20030111163 A1 (KO, YOUNG C. ET AL), 19 June 2003 (19.06.2003), paragraphs [0033]-[0034],[0016],[0050]-[0051],[0070], abstract	1-23
A	--	
A	US 20030111774 A1 (KELLENBERGER, STANLEY R. ET AL), 19 June 2003 (19.06.2003), paragraphs [0015],[0054],[0069],[0083], abstract	1-23
A	--	
A	US 6046377 A (HUNTOON, ANDREW EDESEL ET AL), 4 April 2000 (04.04.2000), claims 1,13,16, abstract	1-23
A	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2009/051446

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20060160452 A1 (MIRLE, SRINIVAS KRISHNASWAMY ET AL), 20 July 2006 (20.07.2006), paragraph [0091], abstract --	1-23
A	DE 202005020566 U1 (SCHILL + SEILACHER AKTIENGESELLSCHAFT), 11 May 2006 (11.05.2006), paragraph [0032] --	1-23
A	EP 0598833 B1 (THE PROCTER & GAMBLE COMPANY), 29 October 1997 (29.10.1997), the whole document --	1-23
A	US 3598742 A (JAMISON, SAUNDERS ELIOT), 10 August 1971 (10.08.1971), claims 1-3, abstract -- -----	1-23

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/051446

WO	2006049664	A1	11/05/2006	EP	1834019 A	19/09/2007
				KR	20070073851 A	10/07/2007
				US	7390760 B	24/06/2008
				US	20080160856 A	03/07/2008

WO	2008113021	A2	18/09/2008	NONE		
----	------------	----	------------	------	--	--

EP	0947549	A1	06/10/1999	AU	731439 B	29/03/2001
				AU	5412098 A	03/07/1998
				CA	2264153 A	18/06/1998
				CN	1244881 A	16/02/2000
				CN	1279097 C	11/10/2006
				CN	1506119 A	23/06/2004
				CN	100355462 C	19/12/2007
				HK	1024494 A	09/02/2007
				ID	22845 A	09/12/1999
				IL	130178 A	31/08/2005
				NZ	336395 A	23/02/2001
				RU	2186797 C	10/08/2002
				TR	9901328 T	22/04/2002
				US	20100062165 A	11/03/2010
				US	20100062934 A	11/03/2010
				US	20100063470 A	11/03/2010
				WO	9825999 A	18/06/1998

EP	1207914	B1	06/08/2003	SE	1207914 T3	
				AT	246521 T	15/08/2003
				AU	6885400 A	24/04/2001
				CO	5170425 A	27/06/2002
				DE	60004375 D,T	24/06/2004
				DK	1207914 T	24/11/2003
				ES	2204677 T	01/05/2004
				JP	2003509167 T	11/03/2003
				MX	PA02001640 A	06/08/2002
				PL	354267 A	29/12/2003
				RU	2248219 C	20/03/2005
				SE	514713 C	09/04/2001
				SE	9903073 A,L	01/03/2001
				SK	992002 A	09/05/2002
				US	6657101 B	02/12/2003
				WO	0121227 A	29/03/2001

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/051446

US	5350370	A	27/09/1994	AU	674413	B	19/12/1996
				AU	6637994	A	21/11/1994
				CA	2101835	A	31/10/1994
				CN	1125391	A	26/06/1996
				CN	1191802	C	09/03/2005
				DE	69420963	D,T	31/05/2000
				EP	0703764	A,B	29/09/1999
				SE	0703764	T3	
				FR	2704563	A,B	27/10/1995
				WO	9424975	A	10/11/1994

WO	9958091	A1	18/11/1999	AU	4402899	A	29/11/1999
				CO	5111019	A	26/12/2001
				DE	69902584	D,T	24/04/2003
				DK	1079786	T	23/12/2002
				EP	1079786	A,B	21/08/2002
				SE	1079786	T3	
				JP	2002514468	T	21/05/2002
				PL	343996	A	10/09/2001
				SE	515235	C	02/07/2001
				SE	9801694	A,L	13/11/1999
				TW	530631	Y	01/05/2003
				US	6399854	B	04/06/2002

US	20030111163	A1	19/06/2003	NONE
----	-------------	----	------------	------

US	20030111774	A1	19/06/2003	NONE
----	-------------	----	------------	------

US	6046377	A	04/04/2000	ZA	9409297	A	12/01/1996
----	---------	---	------------	----	---------	---	------------

US	20060160452	A1	20/07/2006	NONE
----	-------------	----	------------	------

DE	202005020566	U1	11/05/2006	NONE
----	--------------	----	------------	------

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/051446

EP	0598833	B1	29/10/1997	SE	0598833	T3	
				AT	159730	T	15/11/1997
				AU	670244	B	11/07/1996
				AU	2475592	A	16/03/1993
				BR	9206375	A	30/05/1995
				CA	2114958	A,C	31/03/1998
				CN	1070922	A	14/04/1993
				CN	1128641	C	26/11/2003
				CN	1168292	A	24/12/1997
				CZ	290198	B	12/06/2002
				CZ	9400304	A	13/07/1994
				DE	69222945	D,T	12/03/1998
				DK	0598833	T	22/12/1997
				EG	19703	A	30/09/1995
				ES	2110518	T	16/02/1998
				FI	940649	A	11/02/1994
				GR	3025224	T	27/02/1998
				HK	1004337	A	20/11/1998
				HU	71537	A	28/12/1995
				HU	218260	B	28/06/2000
				JP	3231320	B	19/11/2001
				JP	6510075	T	10/11/1994
				KR	100257417	B	15/05/2000
				MA	22622	A	01/04/1993
				MX	9204671	A	01/03/1993
				NO	305637	B	05/07/1999
				NO	940450	A	11/04/1994
				NZ	243903	A	26/09/1995
				PL	170808	B	31/01/1997
				PT	8581	T	31/03/1993
				PT	101759	A,B	31/10/1997
				RU	2127102	C	10/03/1999
				SK	18294	A	05/10/1994
				TR	27268	A	22/12/1994
				US	5260345	A	09/11/1993
				WO	9304092	A	04/03/1993

US	3598742	A	10/08/1971	NONE
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