

1

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PROCESS FOR PRODUCING A NONWOVEN FABRIC WEB FROM A SUSPENSION OF POLYOLEFIN FIBERS AND A HYDROPHILIC COLLOIDAL POLYMERIC ADDITIVE

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ABSTRACT OF THE DISCLOSURE

A mass of polyolefin fibers having a dispersibility index of less than about 300. The polyolefin fibers are rendered water dispersible for use in papermaking by adding from about 0.5 to about 20% by weight of the fibers of a hydrophilic colloidal polymeric additive selected from the group consisting of anionic-cationic complexes and starch. The preferred hydrophilic colloidal polymeric additive is potato starch. The polyolefin fibers employed have a surface area greater than 1 square meter/gram.

BACKGROUND OF THE INVENTION

Many efforts have been made over the years to employ synthetic polymeric fibers in papermaking. The use of synthetic fibers in a conventional papermaking process employing deposition of these fibers upon a foraminous support from an aqueous slurry presents numerous problems. Amongst these problems are obtaining a good dispersion of the fibers in water due to their hydrophobic character, obtaining a good drainage rate of water from the highly diluted aqueous slurry upon a foraminous forming surface, ease of removing the web from the foraminous forming surface, and obtaining sufficient strength so that the wet web will hold together upon removal from the foraminous forming surface.

There has recently been disclosed in U.S. patent applications Ser. No. 874,687, filed Nov. 6, 1969, now abandoned; Ser. No. 27,053, filed Apr. 9, 1970, now abandoned; and Ser. No. 69,194, filed Sept. 3, 1970, now abandoned. Three processes of forming polyolefin fibers of extremely high molecular weight which have a gross morphology similar to natural cellulosic papermaking fibers.

Because of the fact that polyethylene and polypropylene fibers have a specific gravity less than water, in distinction to the most commonly employed prior art staple synthetic fibers which have a specific gravity greater than water, there is presented a serious problem of water dispersibility. For example, when a mass of these polyolefin fibers are placed into a body of water, they immediately float to the top and "cream" up on the upper surface thereof.

Therefore, it is the primary object of this invention to provide a method of treating these polyolefin fibers to render them water dispersible.

SUMMARY OF THE INVENTION

The present invention relates to treating polyolefin fibers of the type formed by the processes described in the aforementioned copending patent applications Ser. No. 874,687; 27,053; and 69,194 to render them water dispersible by incorporating therein an amount of a hydrophilic colloidal polymeric additive selected from the group consisting of anionic-cationic complexes and starch.

2

DESCRIPTION OF PREFERRED EMBODIMENTS

The polyolefin fibers employed in this invention may be any of those formed by the processes of the aforementioned three copending patent applications, preferably linear polyethylene and polypropylene. Generally speaking, these fibers are of papermaking size, i.e., about 0.2 to 3 millimeters in length or larger; are formed from a polyolefin having an extremely high viscosity average molecular weight, which in the case of linear polyethylene and polypropylene is preferably between about 500,000 and 20,000,000 or above; and have a surface area as measured by gas adsorption techniques of from 1 to about 100 square meters/gram or greater, and generally greater than about 25 square meters/gram.

The fibers as produced by any of the aforementioned three processes are, as obtained from the process, dispersed in the reaction medium, such as cyclohexane. The reaction medium is removed and solvent exchanged through an appropriate solvent, such as isopropanol, to water and stored in wet cake form. The fibers may be refined in a disc refiner prior to solvent exchange. Alternatively, the reaction medium may be removed by steam distillation.

The anionic-cationic complex employed on the present invention may be formed from any combination of water soluble anionic and cationic polymeric materials which will form a hydrophilic colloidal suspension in water. By "colloidal" is meant that the particles of the additive are of colloidal size, generally from about 10 angstroms to 2 microns.

Exemplary of suitable anionic polymers are ethylene-acrylic acid, carboxymethyl cellulose, anionic urea-formaldehyde and polyacrylic acid.

Exemplary of suitable cationic polymers are polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gum. The preferred anionic-cationic complexes are ethylene-acrylic acid/polyethyleneimine and carboxymethyl cellulose/melamine-formaldehyde.

The additive components may be prepared in an aqueous medium in the manner conventional for the particular component. Most of the anionic-cationic complex components may be obtained from the manufacturer in a form suitable for simple addition to water. Some components may require special preparation. For example, ethylene-acrylic acid is obtained in pellet form, added to water in an amount of 22 grams per 73 ml. of water, heated to 70° C., 4.7 grams of 28% aqueous NH₄OH added, heated to 95–98° C., stirred for one hour, and cooled. Starches are cooked in the conventional manner at 90–95° C. for about 20 minutes prior to use.

The fibers and additive are mixed together in water and agitated. Where the additive is an anionic-cationic complex, it is preferred to form the complex in the presence of the fibers. However, this is not necessary and the complex may be performed and added to an aqueous suspension of the fibers.

With this treatment, the polyolefin fibers are rendered water dispersible. However, it has been found that if the water is drained from the aqueous slurry and the fibers subsequently redispersed in water, the dispersibility is further improved. Further improvement is noticed with additional drainage and redispersion, although after the third or fourth such treatment the improvement becomes minimal. While the reason for this improvement is not completely understood, it is believed that due to the high surface area of the polyolefin fibers employed, they act as a filter to catch the colloidal dispersant from the water as it passes through the web. This intimate physical contact between the colloidal dispersant and

the polyolefin fiber is apparently sustained during reslushing so as to give a more easily dispersible material.

The degree of water dispersibility of the polyolefin fibers of this invention is measured by a parameter called the "dispersibility index." This quantity is easily determined by adding 4 grams (oven dry weight) of fiber to 400 milliliters of water and agitating for 10 seconds in a Waring Blendor. The 400 milliliters of fiber slurry is then poured into a 1,000 ml. graduated cylinder and water added to the 800 ml. level. The cylinder is shaken four times with the open end of the cylinder covered. One up-and-down motion is considered to be one shake. The cylinder is then placed on a level surface and a stop watch started. At periodic intervals, the milliliters of clear water visible from the bottom of the cylinder is recorded. This recording is made at the end of 10 seconds, 20 seconds, 30 seconds, 40 seconds, 50 seconds, 60 seconds, 80 seconds and 120 seconds. The milliliter of clear water visible from the bottom is divided by 8 which gives the percent fiber floatation rate. The sum of all 8 fiber floatation rates is the dispersibility index. The test is repeated by shaking the cylinder four times and repeating the remaining steps. The average of two tests is employed. A completely nonwetttable fiber would have a dispersibility index of 800, whereas a completely dispersed slurry would give an index of 0. Wood fiber has a dispersibility index of approximately 10. For use on a Fourdrinier paper machine, the dispersibility index of the fibers should be less than about 300, and preferably is less than about 100.

In addition to providing dispersibility, a successful additive for these polyolefin fibers must also not interfere to any great extent with the drainage rate of water from the slurry on a formaminous forming surface. The drainage rate is determined by dividing the same slurry employed in the dispersibility test into two portions, each portion being about 400 ml. and containing two grams of fibers, and adding one portion to a British sheet machine. The mold of the British sheet machine is filled to the standard mark with water. The slurry is stirred four times and the suction lever released. The time it takes for the water to drain through the 150-mesh stainless steel screen of the mold is measured and recorded as the drainage rate in seconds. The termination of drainage is indicated by the sound of suction. The

sheets formed from the treated fibers is determined by forming handsheets having a 37 pounds/3,000 sq. ft. basis weight on a British sheet machine using the 150-mesh stainless steel screen in accordance with TAPPI Test T205 M-58. The sheets are couched from the screen or wire in the standard manner previously described for the wire release test and subjected to a 15-second cold (70° F. press at 100 p.s.i. against a polished caul. The sheets are given a second identical press after turning them over on the caul so that both sides of the handsheet are given a smooth finish. The final drying is done on a rotary dryer at 220° F. The sheets are then treated for strength and optical properties in accordance with standard TAPPI testing methods.

Example 1

This example illustrates the effect of the various additives upon the dispersibility index, drainage rate and ease of wire release.

The polyolefin fibers employed were linear polyethylene prepared by the process of aforementioned patent application Ser. No. 27,053. These fibers had the following properties:

Viscosity average molecular weight	-----	1.2×10 ⁶
Crystallinity (differential scanning calorimetry)	percent--	32
Surface areas (m. ⁻² /gm.)	-----	40
Fiber length	-----mm.	0.2-2.0
Polymer density	-----	0.94

These fibers were refined in cyclohexane at a consistency of 2% by weight in a Sprout Waldron double disc refiner having 12-inch discs. The refining was performed in two passes, one at 0.005 inch refiner plate separation disc force and the second at 0.003 inch. The moving disc operated at 2700 r.p.m. The other disc was stationary. The refined fibers were then solvent-exchanged twice with isopropanol to remove the cyclohexane, once with 50-50 isopropanol-water, and washed twice with water to remove the isopropanol. The fibers were stored in wet cake form. The moisture content was 90% by weight.

The wet fiber cake was then added to water in an amount to form a slurry of 0.5% consistency. The various additives were added to the aqueous slurry in the amounts reported in Table 1 below.

Table 1 below reports the results of this example.

TABLE I

Additive	Percent fiber basis	Dispersibility index		Drainage rate (sec.)	East of wire release
		Primary	Secondary		
No additive	0	506	500	5.0	V. poor.
EAA/PEI	5/5	6	0	13.5	V. good.
Cationic starch	5	7	0	19.0	Do.
Potato starch	5	8	0	21.0	Do.
MF/CMC	5/2.5	8	0	11.0	Do.
Wood pulp (100%)	-----	-10	-----	16.5	Excellent.

test is repeated for the other 400 ml. portion and an average of the two tests employed.

In addition, the additive employed for these polyolefin fibers must not interfere with the wire release properties of the sheet formed therefrom. The wire release is a qualitative measure determined by taking one of the 6.25-inch diameter sheets formed on the 150-mesh stainless steel screen during the drainage rate test, placing two dry blotters over the wet sheet and placing a standard TAPPI round metal plate over the blotters. A 28.6-pound TAPPI standard couching roller is then rolled over the stack five times in a back-and-forth motion starting from the center of the sheet. The sheet is then peeled or couched off the 150-mesh sheet mold screen and the release therefrom (called "wire release") described as excellent, good, fair or poor. The test is repeated with the other sheet formed during the drainage rate test, and a qualitative average of the two employed.

The effect of the additive upon the strength of hand-

The EAA above refers to ethylene-acrylic acid, and is Bakelite EAA-9500. The PEI above refers to polyethyleneimine and is Tydex 12. The cationic starch is Cato 15. The potato starch was obtained from Western Starch Co. The MF above refers to melamine-formaldehyde and was obtained from Pacific Resins. The CMC above refers to carboxymethyl cellulose and is CMC 4LF of Hercules.

The dispersibility index in the foregoing Table 1 is reported as "primary" or "secondary." The "primary" value given for the dispersibility index is the value obtained before handsheet making. The "secondary" value of dispersibility index reported is that obtained with a reslushed handsheet. The lower values for the secondary dispersibility index indicates that reslushing the treated fibers will provide even greater improvement in dispersibility.

The negative values for wood pulp given in Table 1 is due to the difference in specific gravity, i.e., cellulose fibers fall, whereas polyolefin fibers rise in water.

It is seen by reference to foregoing Table 1 that treatment with the additives of this invention improves the dispersibility index and the ease of wire release to a value comparable to ordinary wood pulp. This permits their use in a conventional paper machine in making nonwoven webs, either alone or in conjunction with other fibers such as cellulose.

Example 2

This example shows the effects of various amounts of additive on the web-forming properties of polyolefin fibers. In this example, the additive was ethylene-acrylic acid/polyethyleneimine. The polyolefin fibers employed were the same as those employed in Example 1. The ethylene-acrylic acid and polyethyleneimine were the same as Example 1.

TABLE 2

Run:	Percent EEA/ percent PEI (fiber basis)	Dispersibility index		Drainage rate (sec.)	Ease of wire release
		Primary	Secondary		
1-----	5/5	6	0	13.5	V. good.
2-----	2.5/2.5	16	7	14.6	Do.
3-----	2.5/2.5	28	4	21	Do.
4-----	2.5/2.5	64	11	13	Do.
5-----	1.0/1.0	457	52	9.2	Good.
6-----	0.5/0.5	473	258	9.0	Do.
7-----	10/10	52	0	29	V. good.
8-----	2.5/0.5	468	92	9.8	Good.

NOTE.—In runs 1, 2 and 5-8 the EEA was added first. In run 3, PEI was added first, and in run 4 the EEA and PEI were premixed.

With reference to the foregoing Table 2, it is seen that dispersibility is improved with as low as 1% by weight total colloid (0.5/0.5) but the effect continues up to at least 20% by weight total colloid. Best results are obtained when the ethylene-acrylic acid component is added first, but the differences in the order of addition are probably not significant.

Example 3

This example compares various optical and strength properties of handsheets prepared from treated and untreated polyethylene fibers. These fibers are the same as in Example 1.

Table 3 below compares optical and strength properties of handsheets prepared from treated and untreated fibers prior to heat pressing. In Table 3 below the very low tensile strength of the untreated web may be due in part to the poor formation noticed. The lowering of the brightness of the web with treated fibers may be due to impurities in the water and/or oxidation of amine groups in the melamine component. The MF/CMC was used in an amount (based on fibers) of 5%/2.5% by weight.

TABLE 3.—COMPARISON OF HANDSHEETS PRIOR TO HEAT PRESSING

[37-lb./3000 sq. ft. Sheets]

	Untreated fiber web	Fibers of web treated with MF/CMC
Caliper ¹ -----	12.9	9.1
Opacity ² (percent)-----	98.3	98.5
Brightness ³ (percent)-----	94.1	88.1
Tensile ⁴ (lbs./inch)-----	0.14	1.55
Stretch ⁵ (percent)-----	1.3	5.5
Tear ⁶ (grams)-----	5	21

¹ TAPPI test—T 411 OS-68.² TAPPI test—T 425 M-60.³ TAPPI test—T 452 OS-58.⁴ TAPPI test—T 494 OS-70.⁵ TAPPI test—T 494 OS-70.⁶ TAPPI test—T 414 TS-65.

Table 4 below is a similar comparison to that of Table 3, except that the sheet was lightly heat pressed at 265° F. and 31 p.s.i. for 15 seconds.

TABLE 4.—COMPARISON OF OPAQUE HEAT PRESSED HANDSHEETS

[37-lb./3,000 sq. ft. sheets]

	Untreated fiber web	Fibers of web treated with MF/CMC (5%/2.5%)
Caliper-----	8.4	7.3
Opacity-----	98.9	97.4
Brightness-----	92.5	89.5
Tensile-----	1.02	2.74
Stretch-----	1.5	5.1
Tear-----	18	24

Example 4

This example compares the result obtained employing a hydrophilic colloid complex as the additive to the results obtained employing the individual components by themselves. Table 5 below sets forth the results. The fibers were the same as employed in Example 1.

TABLE 5

Additive	Percent fiber basis	Dispersibility index		Drainage time (sec.)	Ease of wire release
		Primary	Secondary		
EAA-----	5	468	462	7.2	V. poor.
PEI-----	5	413	410	8.2	Poor.
EAA/PEI-----	2.5/2.5	16	7	14.6	V. good.
PEI/EAA-----	2.5/2.5	28	4	21	Do.
MF-----	5	491	110	10	Do.
CMC-----	5	519	247	8	Poor.
MF/CMC-----	5/2.5	8	0	11	V. good.
CMC/MF-----	2.5/2.5	309	34	13	Good.

It is seen by reference to foregoing Table 5 that the polyethyleneimine or ethylene-acrylic acid components separately do not provide the good dispersibility and wire release that the combination of the two provides. Also, it is seen that the carboxymethyl cellulose and melamine-formaldehyde components do not provide the good dispersibility index that the combination of the two provides.

Example 5

This example illustrates why potato starch is the preferred colloidal additive. Table 6 below shows the tensile strength obtained in sheets made from 50% polyethylene fiber (same as used in Example 1) and 50% bleached kraft. As is seen, potato starch is the most effective additive in terms of generating additional tensile strength.

TABLE 6

Additive	Tensile (lb./in.)		
	100% RF	50% RF/50% bleached kraft	100% bleached kraft
No additive-----	0.14	6.0	-----
EAA/PEI-----	1.74	10.8	-----
MF/CMC-----	1.53	10.2	-----
Cationic starch-----	1.27	12.4	-----
Potato starch-----	1.48	15.0	-----
No additive-----	-----	-----	28.6

Example 6

In this example, staple fibers of high density polyethylene are treated with 5% potato starch and compared to the same treatment applied to the polyethylene

7

fibers of Example 1. The polyethylene staple fibers employed were 3 denier, 6 mm. in length, had a surface area of 0.2 square meter/gram and were washed in cyclohexane to remove lubricant.

TABLE 7

Run:	Dispersibility index		Drainage rate (sec.)	Ease of wire release
	Primary	Secondary		
1-----	391	334	5.3	Poor.
2-----	238	174	5.4	Do.
3-----	506	500	5.0	V. poor.
4-----	8	0	21.0	V. good.

NOTE.—Run 1 is staple fiber, no starch treatment; Run 2 is staple fiber. 5% potato starch treatment; Run 3 is the polyethylene fiber of Example 1 with no treatment; Run 4 is the polyethylene fiber of Example 1 treated with 5% potato starch.

It can be seen by reference to Table 7 that while starch treatment does provide some improvement of staple fiber dispersibility, it is not improved to the extent high surface area polyethylene fibers are improved. This is believed to be due to the fact that high surface area polyolefin fibers act as though they were a hydrophobic colloid which, when combined with a hydrophilic colloid, provides a protective colloid effect which gives excellent water dispersibility, whereas staple fibers, because of their low surface area, do not act as a hydrophobic colloid. Also, it can be seen by reference to Table 7 that the ease of wire release of the treated staple fiber sheet is not good, whereas with the high surface area polyethylene fibers the wire release is very good.

Example 7

In this example, polypropylene fibers prepared in accordance with the teachings of Ser. No. 69,194 were treated with 5% by weight potato starch by the procedure described in Example 1. The primary dispersibility index was 285, the secondary dispersibility index was 12, the drainage rate was 8.1 seconds and the wire release was good.

In the treatment described herein, the amount of hydrophilic colloidal polymeric additive retained by the polyolefin fibers is between about 0.1% to 20% by weight of the fibers. For example, when 5% potato starch is mixed with polyethylene fibers as in Example 1, 0.8% by weight is retained at the end of the second wash.

While in the foregoing description high surface area polyolefin fibers are treated with the hydrophilic colloidal polymeric additive by mixing them together in water, alternative methods may be employed. For example, the additive may be contacted with the fibers during steam distillation of residual reaction solvent. This is done by mixing the additive and the fibers containing solvent as obtained from the mechanical refining stage, and then sparging in live steam with agitation to remove the reaction solvent.

Another alternative is to mix the hydrophilic colloidal polymeric additive to the fiber during the solvent exchange treatment. For example, if the fibers are solvent exchanged from cyclohexane to water through isopropanol, the additive can be mixed with the fiber during the isopropanol wash.

We claim:

1. A mass of polyolefin fibers comprising polyolefin fibers having a surface area greater than about 1 square meter/gram and containing an amount of hydrophilic colloidal polymeric additive selected from the group consisting of starch and anionic-cationic colloidal complexes wherein the anionic component of the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid, carboxymethyl cellulose, polyacrylic acid, and anionic urea-formaldehyde, and the cationic component is selected from the group consisting of polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gums sufficient to impart

8

to the mass of fibers a dispersibility index in water of less than 300.

2. The mass of fibers of claim 1 wherein said polyolefins are selected from the group consisting of polyethylene and polypropylene having a viscosity average molecular weight greater than about 500,000.

3. The fibers of claim 1 wherein said colloidal additive is present in an amount of about 0.1 to about 20% by weight of the fibers.

4. The mass of fibers of claim 1 wherein said fibers have a drainage rate, through a 150-mesh screen from an aqueous slurry having a consistency of about 0.5%, of less than about 25 seconds.

5. The fibers of claim 1 wherein the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid/polyethyleneimine and melamine-formaldehyde/carboxymethyl cellulose.

6. The fibers of claim 1 wherein the hydrophilic colloidal polymeric additive is potato starch.

7. A process for producing a nonwoven fabric web comprising mixing an aqueous suspension of a hydrophilic colloidal polymeric additive selected from the group consisting of starch and anionic-cationic colloidal complexes wherein the anionic component of the anionic-cationic colloidal complex is selected from the group consisting of ethyleneacrylic acid, carboxymethyl, cellulose, polyacrylic acid, and anionic urea-formaldehyde, and the cationic component is selected from the group consisting of polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gum and polyolefin fibers having surface area greater than 1 square meter/gram, said hydrophilic colloidal polymeric additive being present in an amount sufficient to impart to the fibers a dispersibility index in water of less than 300, and feeding the resulting aqueous slurry to a paper machine.

8. The process of claim 7 wherein the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid/polyethyleneimine and melamine-formaldehyde/carboxymethyl cellulose.

9. The process of claim 7 wherein the hydrophilic colloidal polymeric additive is potato starch.

10. A process for producing a nonwoven fiber web comprising mixing an aqueous suspension of a hydrophilic colloidal polymeric additive selected from the group consisting of starch and anionic-cationic colloidal complexes wherein the anionic component of the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid, carboxymethyl cellulose, polyacrylic acid, and anionic urea-formaldehyde, and the cationic component is selected from the group consisting of polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gum and polyolefin fibers having a surface area greater than 1 square meter/gram, said hydrophilic colloidal polymeric additive being present in an amount sufficient to impart to the fibers a dispersibility index in water of less than 300, agitating the colloidal additive and fiber slurry, removing most of the water from the slurry, redispersing said mass of fibers in water, and feeding the resulting aqueous slurry to a paper machine.

11. The process of claim 10 wherein the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid/polyethyleneimine and melamine-formaldehyde/carboxymethyl cellulose.

12. The process of claim 10 wherein the hydrophilic colloidal polymeric additive is potato starch.

13. A process for producing a mass of polyolefin fibers having a dispersibility index less than about 300 comprising mixing together a hydrophilic colloidal polymeric additive selected from the group consisting of starch and anionic-cationic colloidal additive wherein the anionic component of the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic

acid, carboxymethylcellulose, polyacrylic acid, and anionic urea-formaldehyde, and the cationic component is selected from the group consisting of polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gum, and polyolefin fibers, having a surface area greater than 1 square meter/gram, in liquid medium, said hydrophilic colloidal polymeric additive being present in an amount sufficient to impart to the fibers a dispersibility index in water of less than 300.

14. The process of claim 13 wherein the colloidal additive and fibers are mixed together in water.

15. The process of claim 13 wherein the colloidal additive is mixed with the fibers in an organic solvent, and the organic solvent is removed by steam distillation.

16. The process of claim 13 wherein the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid/polyethyleneimine and melamine-formaldehyde/carboxymethyl cellulose.

17. The process of claim 13 wherein the hydrophilic colloidal polymeric additive is potato starch.

18. A nonwoven sheet material containing polyolefin fibers having a surface area greater than 1 square meter/gram and containing from about 0.1 to about 20% by weight of said fibers of a hydrophilic colloidal polymeric additive selected from the group consisting of starch and an anionic-cationic colloidal complex wherein the anionic component of the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid, carboxymethyl cellulose, poly-acrylic acid, and anionic

urea-formaldehyde, and the cationic component is selected from the group consisting of polyethyleneimine, melamine-formaldehyde, polyvinylpyrrolidone, cationic urea-formaldehyde, polyamide-epichlorohydrin and cationic guar gum.

19. The sheet material of claim 18 wherein the anionic-cationic colloidal complex is selected from the group consisting of ethylene-acrylic acid/polyethyleneimine and melamine-formaldehyde/carboxymethyl cellulose.

20. The sheet material of claim 18 wherein the hydrophilic colloidal polymeric additive is potato starch.

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162—175, 182