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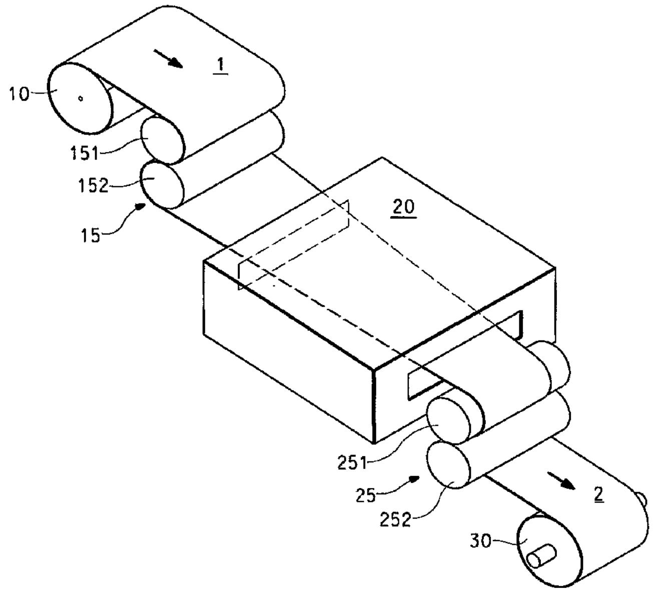
(54) Title: HYDROENTANGLED ELASTIC NONWOVEN SHEET



(57) Abstract: A method for making an elastic fabric with the steps of providing a hydroentangled precursor fabric having at least 1% by weight of binder fibers, heating the precursor fabric to a temperature above the melting point of the binder fibers and then drawing the precursor fabric in the machine direction at a ratio sufficient to reduce the width by more than 20% and at a strain rate of 10 to 800% per minute to produce an elastic fabric having a cross-directional extensibility of about 100% up to 500% and a 30-95% recovery under a 50% extension.

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TITLE OF INVENTION

HYDROENTANGLED ELASTIC NONWOVEN SHEET

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the preparation of elastic nonwoven sheets from non-elastic hydroentangled sheets.

2. Description of the Related Art

Elastic fabrics are usually made with rubber or some other elastomeric material incorporated into or attached to a precursor fabric. The precursor fabrics can be traditional textiles or nonwoven fabrics. Other methods of producing elastic nonwovens included imbedding or attaching elastomeric threads, strips, and films. These can be attached by adhesives, thermobonding, lamination, sewing, stitch bonding, etc. However, in all cases, the process is expensive.

US 5,244,482 to Hassenboehler et al and EP 1538250 A1 to Tsai et al. on the other hand have shown that thermoplastic bonded nonwoven fabrics, such as spunbond and carded webs, can be processed using heat and strain to create a web with elastic properties. These thermo-mechanical methods describe passing a thermally bonded precursor web through an oven at an elevated temperature between the softening temperature and the melting point and applying a draw in the machine direction to transversely consolidate the web, whereby the majority of the fibers are extended and aligned predominantly in the direction of the draw. Upon cooling the web, the fixation of fibers in the longitudinally extended configuration creates a position memory at the thermally bonded points; therefore, the web exhibits recovery when stretched in the transverse direction. However, these methods require precursor webs that have been subjected to thermo-mechanical bonding or calendering and the treatment temperature has to be lower than the melting point of the fibers. Otherwise, the web would be plasticized, stiff, brittle, and with virtually no elasticity, or worse would cause the web to break in the process. Furthermore, since the tensile strength of such a web totally relies on the thermal bonding and the heat and strain treatment aligns the majority of the fibers mostly in the direction of the draw, it causes serious loss of tearing strength in the resultant elastic fabric along the draw direction.

For many applications, a, softer fabric with higher tearing strength is desired and can be obtained through the use of entangled fabrics. However, traditional spunlaced and needle punched fabrics do not gain elasticity by the heat-and-strain process described in the prior art, because the "bond points" are formed by entanglement, which provides only frictional and interlocking contact points that are not permanently altered by such a process.

SUMMARY OF THE INVENTION

The invention is directed to a method for making an elastic fabric by providing a hydroentangled precursor fabric having at least 1% by weight of thermoplastic binder fibers that has lower melting temperature than that of the rest of base fibers; and while heating the precursor fabric to a temperature above the melting point of the binder fibers, drawing the precursor fabric in the machine direction at a ratio sufficient to reduce the width of the precursor by at least 20% and at a strain rate of 10 to 800% per minute, and then cooling the resultant to ambient temperature to set the resultant web.

The invention is directed to an elastic hydroentangled fabric made by the described method and having an extensibility of 100% to 500% in the cross direction and a 30-95% recovery under a 50% elongation, in the cross direction.

BRIEF DESCRIPTION OF THE DRAWING

The figure is a schematic illustration of an apparatus for performing one embodiment of the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

One object of the present method is to provide a cost-effective thermo-mechanical process of creating an elastic spunlaced fabric without the use of true elastomeric fibers as base fibers. By incorporating in non-elastomeric precursor web a low percentage of low melting point binder fibers, with or without being thermally bonded, and conducting a stretch process at temperature above the melting point of the binder fibers, the plasticized binder fibers can serve the bonding purpose in the contacting points and create the position memory for fibers fixed around the contacting points. Since the percentage of binder fibers is low, there is no significant stiffness caused by the high temperature process of this invention.

The use of spunlaced nonwoven precursor provides thicker, softer elastic fabrics with a more desirable tearing strength. The precursor fabric is made of predominantly non-elastomeric base fibers such as (poly) ethyleneterephthalate (i.e., polyester), or polyamide staple fibers or a mix of above synthetic fibers with some percentage of non-thermoplastic fibers such as wood pulp, cotton, rayon, lyocell, etc. and then blended with at least about 1% binder fibers and preferably about 5% to 30% binder fibers. The binder fibers are preferably made of thermoplastic fibers such as polypropylene, polyethylene, co-polyester, acrylic, polyamide, polyurethane, and polystryene. The binder can be a bi-component fiber, such as sheath/core, side-by-side, etc. For example, the binder fibers can be bi-component staple fibers having a co-polyester sheath and polyester core or polyethylene sheath and either a polyester or compounded elastomer core. The co-polyester composition can vary depending on the manufacturer of the fiber and the desired attributes, but is commonly composed of the copolymer of poly(ethylene terephthalate) and isophthalate. The percentage of binder fiber is by weight of the fabric. By incorporating binder fibers into the fiber web that is further processed into a spunlaced web and then activating these binder fibers in an in line dryer, we have made a fabric which can then be converted into an elastic web. The cross over points of the binder fibers with themselves and/or the base fibers act similarly to the point bonds of a spunbonded fabric.

The present invention provides a process of preparing an elastic spunlaced (hydro-entangled), nonwoven web. A precursor web of synthetic and/or wood pulp fibers blended with thermoplastic binder fibers is processed into a web by opening, carding or other suitable web forming processes followed by hydroentanglement (also referred to as spunlacing). The spunlaced web is subjected to an elevated temperature sufficient to at least partially melt the binder fibers, but not the base fibers making up the fabric. This can be accomplished by a hot air treatment or any other suitable means for achieving the desired elevated temperature. While subject to a temperature above the melting point of the binder fibers, the spunlaced fabric is subjected to a drawing treatment in the machine direction at a drawing ratio sufficient to reduce the web width by more than 20% (preferably in the range of 55-75%) with a strain rate of from 10 to 800 %/min. The drawing ratio can be 5 to 50 %, preferably 10 to 20%. This step of drawing at an elevated temperature can be accomplished either in-line with the precursor web forming process or as a separate off-line process. The method of heating the precursor web is not particularly limited as long as the heat transfer may be accomplished in as short a time as necessary to avoid damage of the web. Heating may be accomplished by radiation or convection. Radiation heating may be carried out by using infrared methods. Convection heating may be carried out by a suitable heating fluid, preferably a gas such as air.

The process of the invention can be further described with reference to the figure. Accordingly, an elastic spunlaced fabric 2 is prepared by providing a spunlaced precursor web 1 containing thermoplastic binder fibers, whereby the precursor web is supported by unwinding roll 10. Unwinding roll 10 is rotated around its longitudinal axis whereby the precursor web 1 leaves unwinding roll 10 at a speed A in the machine direction (MD) as indicated by the arrow. The precursor web travels via S-wrap 15 into a heating means 20, through the heating means and from the exit of the heating means via S-wrap 25 to the winding roll 30. S-wrap 25 and winding roll 30 are driven at a speed higher than the unwinding speed A of unwinding roll 10 and S-wrap 15 by a factor of (1+X%). S-wrap 15 comprises rolls 151 and 152. S-wrap 25 comprises rolls 251 and 252. The factor (1+X%) determines the drawing ratio of the precursor web in the process of the present invention. According to the invention, the precursor web is subjected to a drawing treatment in a machine direction at a drawing ratio sufficient to reduce the width by at least 20% and a strain rate within a range of 50 to 800 %/min, at a temperature above the melting point of the binder fibers in order to create in the resultant fabric, elongation at break in the cross direction of greater than about 100% up to 500%. Commercially useful recovery of 15-80% with 50-200% extension can be achieved with the resultant elastic fabrics. Preferably, the machinery for carrying out the process of the invention is constructed for commercial capacity with an unwinder roll and a winding roll(s) installed in a distance of from 3 to 40 m, preferably about 20-30 m, and a heating device installed between. The unwinder advantageously runs at commercial speed of more than 30 m/min and up to 300 m/min, preferably at least 100 m/min and up to 250 m/min, and a draw ratio of 1% to 30 %, preferably 10-20%, is created by increasing the speed of the winding roll. The strain rate is adjusted to 10 to 800 %/min. The draw ratio relates to the degree of width reduction of the precursor web and the strain rate relates to the speed of the treatment at a fixed draw ratio. It was found that when the speed is below the desired range, the web tends to overheat and to become stiff. On the other hand, if the speed is above the desired range, the precursor web is not sufficiently heated and either the web may break during the drawing treatment or the width reduction is not maintained after the web is released from the draw tension. The S-wraps 15 and 25 also control the movement of the nonwoven web, as well as serving as the drawing means.

The elastic spunlaced web is characterized by a width reduction of 20-75% compared to the precursor web and a cross-direction extensibility of about 100% to 500%. The draw ratio required to achieve a specific width reduction is very much dependent on the precursor web structure. Obtaining a width reduction greater than 20% is important for achieving cross-direction elongation greater than 100% in the resultant fabric and the possibility for further making the fabric elastic. Further, the cross-direction elasticity of the elastic spunlaced web is characterized by 30-95% recovery under a 50% elongation, 25-75% recovery under a 100% elongation, or 15-75% recovery under a 150% elongation. The resultant elastic spunlaced fabric has a thickness of 0.2 mm-3.5mm and a basis weight of 20 to 300 g/m^2.

The present invention further provides products containing the elastic nonwoven web of the present invention that greatly expands the scope of nonwoven substrates available for producing elastic nonwoven fabrics in a very cost effective manner. The subject invention has applications in fields such as consumer goods; cleanrooms; medical face masks, hoods and gloves; substrates for composites and laminates and coatings such as for synthetic leather substrates.

Glossary and Test Methods:

The strain rate (%/t) is generally described as a piece of fabric being drawn and extended a certain (X) percentage in a period of time. The extension percentage can be achieved by the speed ratio of winder or S-wrap (25) to unwind or S-wrap (25), and the time period of fabric run through can be calculated by dividing D over the average of unwind speed (A) and winder speed of [(1+X%) A]. Speed A is generally expressed in m/ min as follows:

$$X\% / \{D / [A + (1+X\%) A] /2\} = X\% / \{ 2D / [A + (1+X\%) A]\} = \{X\% \times [A + (1+X\%) A]\} / 2D$$

The web elasticity is defined by measuring a 5-cm wide x 10-cm long strip along the longitudinal axis as follows:
(stretched length - recovered length) / (stretched length - original length).

The melting point is the temperature where a thermoplastic fiber starts to become a liquid.

The strip tensile test is a measure of breaking strength and elongation or strain of a fabric when subjected to unidirectional stress. This testing was conducted on a constant rate of strain tester, Instron Model 1122. In the current examples, strips of fabric 2 inches (50 mm) wide and at least 5 inches (150 mm) long are cut in the machine direction and cross direction of the fabric. Ten specimens per sample were tested to compute an average value. This test is known in the art and generally conforms to the specifications of ASTM Method 5035-95. The results are expressed in pounds to break and percent of elongation before break. The term "elongation" means the increase in length of a specimen during a tensile test expressed as a percentage of the original length. The term "extensibility" used is the same as the elongation-at-break measured in the tensile test.

Tearing strength is measured by the tongue (single rip) procedure modified from the ASTM 5735 using a rectangular specimen of 2 x 2.5 inches (50 mm x 63.5 mm). Ten (10) specimens are tested per treatment and the results are expressed in pounds.

The basis weight of each specimen is computed from the average weight of 10 strip samples or 12 grab samples respectively.

Thickness is the average of 10 strip samples or 12 grab samples respectively. The strip samples are measured using a TMI automated thickness tester, with a 2 inch diameter contact area and pressure of 14.7 g/cm^2. The grab samples were measured using an Ames thickness gauge with a 1-inch diameter contact area and pressure of 7.46 g/cm^2.

EXAMPLES

In the following examples, the base fibers are polyester staple fibers, commercially available from DAK Americas identified as Dacron(R) Type 612W. The binder fibers are sheath/core co-polyester/polyester staple fibers commercially available from FIT, Incorporated and identified as Type 201. The melting point of the binder fibers is 110°C (230°F) and the precursor spunlaced fabrics contain 15% binder fibers.

Examples 1-10

Precursors A and E have a basis weight of 1.2 and 1.85 ounce per square yard, respectively. The results of longitudinal draws at ambient temperatures are presented in Table 1 below.

Table 1

Example	Draw Ratio (%)	Width (in)	Width Reduction (%)	Strain Rate %/min
Precursor A	0	76	0	–
1	10	64	16	60
2	15	52	33	87
3	18	44	42	102
4	20	40	Broke web	
Precursor E	0	60	0	–
6	10	55	8	60
7	15	46	23	87
8	18	45	25	102
9	20	43	28	113
10	25	42	Broke web	

The longitudinal draw at ambient temperatures was varied and was found to reduce the width to some degree and enhance the extensibility of the resultant webs. At a width reduction of about 20%, an extensibility of more than 100% in the cross direction of the resultant webs was achieved, however, no significant elastic recovery was observed from 50-100% elongation.

Examples 11-23

Precursors C and D had a basis weight of 0.8 ounce per square yard (27 g/m^2). The results of longitudinal draw at elevated temperatures are presented in Table 2 below.

Table 2

Example	Treatment Temperature (°F)	Draw Ratio (%)	Width (in)	Width Reduction (%)
Precursor C	77	0	75	0
11	230	10	33.5	55
12	230	18	17.5	77
13	330	9	34.5	54
14	330	12	25	67
15	330	15	19.5	74
Precursor D	77	0	75	0
16	230	6	52	31
17	230	8	44	41
18	230	10	34.5	54
19	230	18	19	75
20	330	8	42	44
21	330	10	33	56
22	330	14	22.5	70
23	330	16	19.5	74

In contrast to the results in Tables 1 and 2 above, the spunlaced precursors without binder fibers processed in the above conditions were able to achieve similar width reductions and enhancement of extensibility in the cross direction; however, no noticeable elastic recovery was found from 50-100% elongation. Further, in processing the precursors of A,B,C,D at an elevated temperature but below 230°F (the melting point of binder fibers), the resultant fabrics showed only a minor degree of elasticity.

Examples 24-28

Precursor spunlaced fabrics as described above were subjected to a draw ratio of 14% at various draw temperatures and then tested for elongation and stretch recovery. The results are presented in Table 3, below.

Table 3

	BW opsy	Draw Ratio (%)	Treatment Temperature (°F)	Width Reduction (%)	CD Elongation at break		Load at 1st elongation (lbf)		Recovery % At 1st elongation	
					%	lbf	100%	150%	100%	150%
Precursor A	1.2	0	77	0	64	56.4	N/A	N/A	N/A	N/A
24		14	230	65	282	10.32	1.300	3.035	50	34.5
25		14	270	66	319	9.20	1.227	2.095	70.6	50
26		14	310	67	317	7.24	1.290	1.960	74.8	59.4
27		14	350	69	352	7.54	1.480	2.068	78	61.1
28		14	400	73	394	4.85	1.156	1.500	77.3	67.8

The longitudinal draw at elevated temperatures was able to reduce the width up to about 75% and a draw ratio of about 10% was shown sufficient to achieve a 50% width reduction. The width reduction on the resultant example webs was found to be a function of draw and the temperature and the enhancement of the extensibility in the cross direction was also found to result from the draw and the temperature. Further, it was noticeable that the elasticity (recovery after elongation) increased with higher temperatures.

Examples 19-38

Precursor spunlaced fabrics as described above, but with basis weights of either 0.8 or 1.2 oz/yd^2 (27 or 40.7 g/m^2) were subjected to various draw ratios at various draw temperatures to achieve the desired width reduction of at least 50%. The examples were then further tested for various elongation and stretch recovery properties. With the treatment of longitudinal draw at an elevated temperature of 330°F, the physical properties of the resultant webs were significantly changed and a commercially valuable elasticity was shown by the elongation of under 300%. The results are presented in Table 4, below.

Example	Treatment Temperature (˚F)	B.W. (opsy)	Draw Ratio %	Resultant			Elongation at break (%)		Recovery at 1st CD elongation (%)				
				Width Reduction (%)	B.W. (opsy)	Thickness (mil)	MD	CD	50%	100%	150%	200%	300%
Precursor A		1.2	0	0	1.2	18.6	24.3	NA	-	-	-	-	-
29	230 ˚F		12	51	2.1	19.3	12.9	245.1	78.6	66.4	47.9	38.8	-
30	230 ˚F		18	68	3.3	20.2	10.6	469.7	78	68	60.5	51.2	36.5
31	330 ˚F		10	50	2.1	21.1	13.2	229.8	85.6	68.8	54.5	-	-
32	330 ˚F		14	65	2.9	21.7	13.7	354.6	86.7	67.2	53.9	33.8	16.4
33	330 ˚F		18	74	3.6	21.2	13.9	497.3	86.8	70.4	65.3	51.8	27.1
Precursor B		1.2	0	0	1.2	18.6	23.6	63.0	-	-	-	-	-
34	230 ˚F		12	52	2.2	19.3	13.8	263.9	82	45.2	25.7	18.6	-
35	230 ˚F		21	71	3.5	20.8	9.5	484.0	81.6	59.6	52	35.8	19.7
36	330 ˚F		10	51	2.2	22.0	13.4	240.8	88.4	50.4	28.5	-	-
37	330 ˚F		14	66	3.2	22.1	11.5	353.8	88.8	76.8	63.2	44.2	17.5
38	330 ˚F		18	75	3.6	21.5	13.0	519.0	87.8	74.4	63.5	52	21.2
Precursor C		0.8	0	0	0.8	14.6	22.8	66.7	-	-	-	-	-
39	230 ˚F		10	53	1.4	16.4	13.1	214.8	83	50.4	33.3	-	-
40	230 ˚F		18	74	2.3	19.0	8.3	485.9	83.3	70.8	61.6	50.8	27.1
41	330 ˚F		9	54	1.6	18.0	11.3	229.5	90.6	68.4	54.4	31.6	-
42	330 ˚F		12	67	1.5	18.0	11.1	314.8	91.3	80	67.2	46	-
43	330 ˚F		15	73	2.5	20.1	11.8	402.3	91.3	84	72.3	56.2	27.6
Precursor D		0.8	0	0	0.8	13.4	17.7	61.4	-	-	-	-	-
44	230 ˚F		10	49	1.4	15.1	12.6	205.0	84	53.2	27	19.6	-
45	230 ˚F		18	72	2.1	17.0	6.9	454.2	83	67.6	63.2	52.6	25.8
46	330 ˚F		10	54	1.7	18.9	11.1	287.0	91.3	67.2	49.1	22.4	-
47	330 ˚F		14	70	2.2	18.8	11.5	395.5	90.7	79.2	67.7	56.2	26.3
48	330 ˚F		16	74	2.4	18.7	11.3	423.5	89.7	80	73.1	56	33.3

WHAT IS CLAIMED IS:

1. A method for making an elastic fabric comprising the steps of

(a) providing a hydroentangled nonwoven precursor fabric containing predominantly non-elastomeric base fibers and at least 1% by weight of thermoplastic binder fibers that have a lower melting point than the base fibers

(b) heating the precursor fabric to a temperature above the melting point of the binder fibers,

(c) drawing the precursor fabric in the machine direction at a ratio sufficient to reduce the width of the precursor by at least 20% and to achieve a cross-direction elongation of above 100% in the resultant elastic fabric.

(d) cooling the stretched web before releasing the tension to create fixed bond points on binder fibers.

2. The method of claim 1, wherein the processing speed is at least 30 meters per minute and preferably 100-300 meters per minute.

3. The method of claim 2, wherein the processing strain rate is 10-800% per minute.

4. The method of claim 1, wherein the drawing step comprises the use of two sets of S-wrap rolls.

5. The method of claim 1, wherein the heating step comprises heating the precursor fabric to a temperature above the melting point of some base fibers.

6. An elastic fabric composed of non-elastomeric fibers obtained by applying a draw in the machine direction at an elevated temperature to a precursor to reduce the width of the precursor and extend the length from the precursor by more than 20% and achieve in the

elastic fabric an increase of extensibility in cross direction of more than 50% of the precursor.

7. An elastic nonwoven fabric made from an entangled precursor web containing non-elastomeric base fibers and less than 30% of non-elastic thermoplastic binder fibers that have a lower melting point than the base fibers, wherein the precursor web is drawn in the machine direction at an elevated temperature above the melting point of the binder fibers to reduce the width of the precursor by more than 20% and achieve in the elastic nonwoven fabric a cross-directional extensibility of 100% to 500% with a 30-95% recovery from a 50% elongation.

8. The elastic fabric of claim 7, having a 40-85% recovery under a 100% elongation.

9. The elastic fabric of claim 7, having a 15–75% recovery under a 150% elongation.

10. The elastic fabric of claim 7, comprising at least 1% by weight of binder fibers.

11. The elastic fabric of claim 7 in a form selected from the group consisting of apertured fabric, mesh fabric, and net fabric.

12. The elastic fabric of claim 7, comprising thermoplastic base fibers selected from the group consisting of polypropylene, polyethylene, polyester, acrylic, polystyrene ,polyamide and mixtures of thermoplastic fiber and non-thermoplastic fibers selected from the group consisting of wood pulp, cotton, rayon, and lyocell.

13. The elastic fabric of claim 7, comprising binder fibers selected from the group consisting of polypropylene, polyethylene, polyester, acrylic, polystyrene, polyamide, co-polyester, sheath/core co-

polyester/polyester, sheath/core polyethylene/polyester, and sheath/core non-elastic polyolefin/elastomer.

14. The elastic fabric of claim 7, comprising a base fiber blend of thermoplastic and non thermoplastic fibers selected from the group consisting of cotton, wood, and synthetics.

15. The elastic fabric of claim 13, wherein the synthetic is an aramid.

16. The elastic fabric of claim 7, comprising thermoplastic base fibers of polyester and sheath/core binder fibers, wherein the core is polyester.

17. The elastic fabric of claim 16, wherein the sheath is a co-polyester.

18. The elastic fabric of claim 16, wherein the sheath is polyethylene.

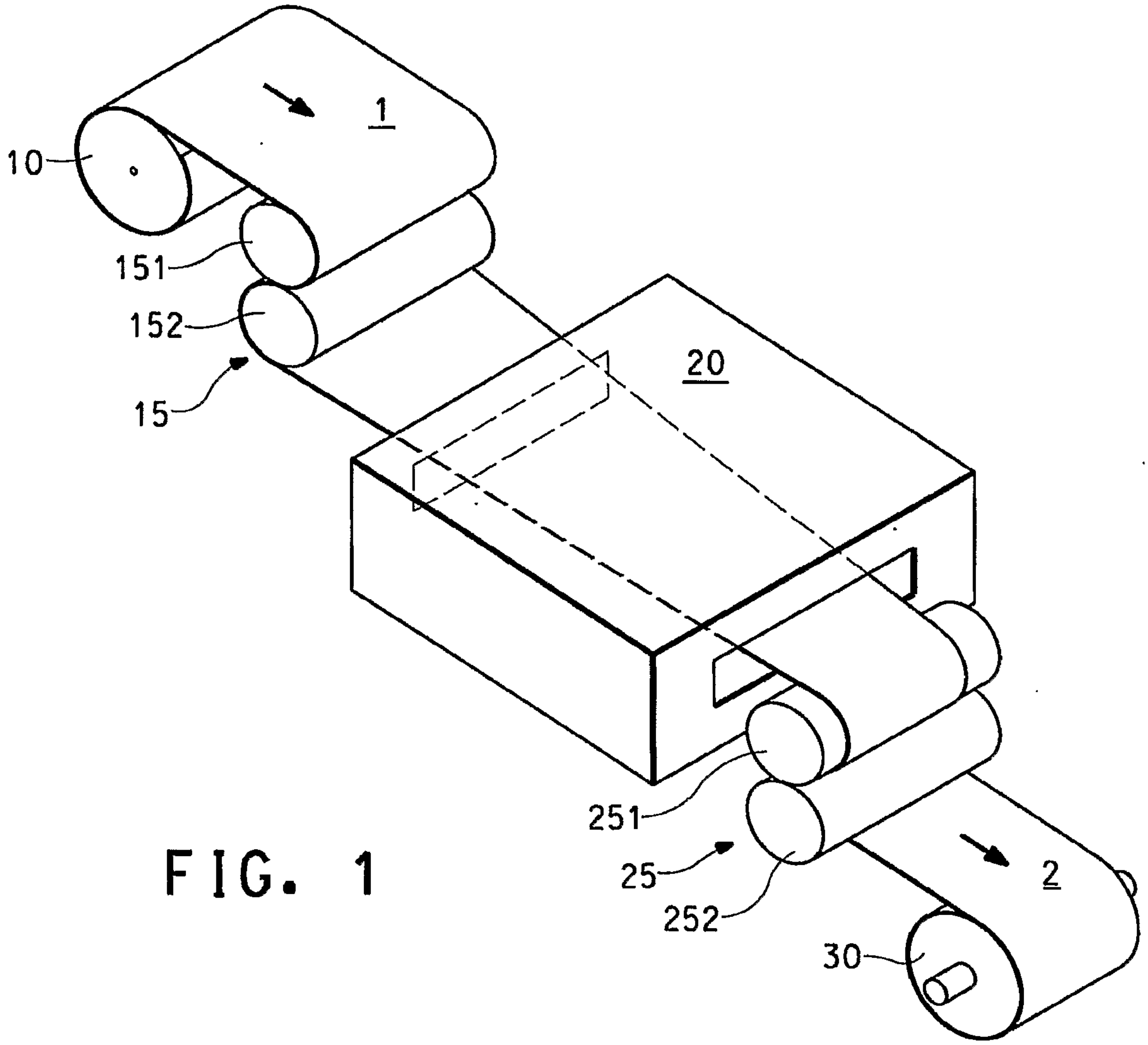

FIG. 1