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(54) Strong discontinuous polyethylene fibres.

(57) Strong discontinuous fibres formed from polyethylene are disclosed. The fibres have a length of 1-25 mm, a fibre diameter of less than 30 microns and a handset zero span strength of greater than 3 kg/15 mm. The fibres may be in the form of a polyethylene pulp having a surface area of at least 4 m^2/g, a Pulmac defect value of less than 3% and a handsheet zero span value of at least 3 kg/15 mm. Polyethylene sheet may be formed from the strong discontinuous fibres. The fibres and sheet may be used in blends with cellulose fibres, fillers, thixotropic agents and as synthetic paper.

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The present invention relates to strong as-spun discontinuous polyethylene fibres, especially strong discontinuous plexifilamentary film-fibril strands formed directly from fibre-forming polyethylene. Such as-spun discontinuous fibres may be formed in a flash spinning process.

As used herein, "discontinuous" means that the strands have a length of not more than 100 mm.

As used herein, "plexifilamentary film-fibril strands of polyethylene" means strands which are characterized as a three dimensional integral network of a multitude of thin, ribbon-like film-like elements of random length and of a thickness in the range of about 1-20 microns, with an average thickness of less than about 10 microns, generally coextensively aligned with the longitudinal axis of the strand. The film-fibril elements intermittently unite and separate at irregular intervals in various places throughout the length, width and thickness of the strand to form the three dimensional network. Such strands are known, being described in further detail in Blades and White, US Patent 3 081 519 which issued 1963 March 19.

Blades and White describe a flash-spinning process for producing continuous plexifilamentary film-fibril strands from fibre-forming polymers. A solution of polymer in a liquid that is a non-solvent for the polymer at or below its normal boiling point, is extruded at a temperature above the normal boiling point of the liquid and at autogenous or higher pressure through a spinneret into a medium of lower temperature and substantially lower pressure. This flash spinning causes the liquid to vaporize and form a continuous plexifilamentary film-fibril strand. Commercial spunbonded products have been made from polyethylene plexifilamentary film-fibril strands obtained by flash-spinning using trichlorofluoromethane as solvent, but that halocarbon has been implicated in the depletion of the earth's ozone.

It is known that the spinneret and tunnel used in flash spinning a polymer solution are important with respect to properties of flash spun continuous fibres, e.g. tenacity and elongation to break. For instance, US Patent 4 352 650 of Marshall, which issued 1982 October 05, discusses optimization of the tunnel for increasing fibre tenacity e.g. from 4.2 to 5.2 grams/denier, of flash spun continuous fibres. In general, fibre tenacity can be increased by as much as 1.3 to 1.7 times by using a tunnel at the exit to the spinneret. Various methods for making discrete fibres are known e.g. as discussed in the copending patent application of S. Cloutier, L.M. Manuel (formerly L.M. Morin) and V.G. Zboril filed concurrently herewith.

US Patent 5 043 108 of S. Samuels, which issued 1991 August 27, discloses flash spinning of a mixture of organic solvent, polyethylene and a non-solvent or spin aid, especially water or an alcohol, or mixtures thereof, in which the amount of water is less than the saturation limit of water in the organic solvent, to produce continuous as-spun fibres. A process for the manufacture of a polyolefin pulp in which strands are formed and shredded is disclosed in US Patent 5 093 060 of S. Samuels and V.G. Zboril, issued 1992 March 03. However, while it is possible to produce continuous filaments using a flash spinning process and to subsequently shred the continuous filaments by mechanical means to form discontinuous filaments, such mechanical shredding tends to fuse the ends of the shredded filaments, even if the shredding is carried out under water. Fused ends make it difficult or impossible to open up the resultant web of fibres, as well as reducing fibre orientation and strength. For these reasons, processes that produce discontinuous fibres without requiring use of mechanical shredding means would be preferred.

While a variety of discrete fibres have been produced, discrete fibres of improved properties are still required. Improved discontinuous as-spun plexifilamentary film-fibril strands, especially fine, strong, oriented and discontinuous fibrils, and polyethylene pulp have now been found.

Accordingly, the present invention provides fine, strong, as-spun discontinuous fibres formed from polyethylene, said fibres having a length of 1-25 mm, a fibre diameter of less than 30 microns and a handsheet zero span strength of greater than 3 kg/15 mm.

In a preferred embodiment of the fibres of the present invention, the handsheet zero span strength is greater than 6 kg/15 mm.

The present invention also provides a polyethylene pulp formed from as-spun discontinuous fibres having a surface area of greater than 4 m^2/g, a Pulmac defect value of less than 3%, a handsheet zero span value of at least 3 kg/15 mm and with the fibres of the pulp having a Kajaani coarseness of less than 0.30 mg/m.

In a preferred embodiment of the pulp of the present invention, the pulp has a Pulmac defect value of less than 2%.

In another embodiment, the fibre length is less than about 2 mm and with an average length in the range of 0.80-1.20 mm.

In a further embodiment, the fibres have a fineness such that the fibres have a Kajaani coarseness of less than 0.20 mg/m.

In yet another embodiment, the pulp has a surface area in the range of 6-8 m^2/g.

In embodiments of the fibre and of the pulp, the polyethylene has a melt index of less than 15 dg/min, especially less than 7 dg/min and in particular less than 2 dg/min.

The measurements of handsheet zero span strength and surface area are described below.

The fibre is in the form of plexifilamentary film-fibrils in a discontinuous form. The average length of the fibre is in the range of 1-100 mm and especially in the range of 1-25 mm. The fibres of the present invention have a handsheet zero span strength of greater than 3 kg/15 mm and especially greater than 6 kg/15 mm.

The diameter of the fibre is preferably less than 30 microns and more particularly less than 20 microns. The fibres are referred to as "as-spun" fibres, which have "free" ends in contrast to the fused ends that tend to result from mechanical cutting of polyethylene fibres, especially at commercial rates. The as-spun fibres are characterized by an absence of fused ends. This freeness of the fibres contributes to improved processing of the fibres, which usually includes a step of opening up of the fibres or separation of fibre bundles into individual fibres.

The fibres of the present invention are short fibres, in comparison to the fibres produced in the aforementioned Blades and White and Samuels processes.

The fibres of the present invention may be manufactured in a flash spinning process, particular examples of which are described in the aforementioned copending patent application of S. Cloutier, L.M. Manuel and V.G. Zboril. In such an embodiment of a process of manufacture, polyolefin is dissolved in an organic solvent. The polyolefin may be in the form of pellets or powder, or other forms known in the art, having been previously polymerized from monomers. Alternatively, the polyolefin is already dissolved in an organic solvent e.g. it is a solution of polymer in organic solvent from a process for the polymerization of monomers.

The polyolefin may be a high molecular weight homopolymer of ethylene or copolymer of ethylene and at least one C_4-C_{10} hydrocarbon alpha-olefin e.g. butene-1, hexene-1 and/or octene-1. The polyolefin may also be a homopolymer of propylene or copolymer of propylene with a minor amount of ethylene. A wide variety of such polymers, including by type of monomer(s) used, molecular weight, molecular weight distribution and other properties are commercially available. In preferred embodiments in which the polyolefin is a homopolymer of ethylene or copolymer of ethylene and at least one C_4-C_{10} hydrocarbon alpha-olefin, the density is in the range of 0.930 to 0.965 g/cm^3, especially in the range of 0.940 to 0.960 g/cm^3. The melt index of the polyolefin is preferably less than 15 dg/min i.e. in the range of from so-called "no-flow" e.g. less than about 0.01 dg/min, to 15 dg/min, especially in the range of 0.50 to 7.0 dg/min; melt index is measured by the method of ASTM D-1238 (condition E).

A variety of organic solvents may be used in the process, examples of which include pentane, hexane, cyclohexane, heptane, octane, methyl cyclohexane and hydrogenated naphtha, and related hydrocarbon solvents, and mixtures of solvents.

The polyolefin may contain additives e.g. antioxidants, ultra violet stabilizers, wetting agents, surfactants and other additives known for use in polyolefins, provided that the additives are capable of passing through the orifice used in the process and not otherwise adversely affecting the process.

The solution of polyolefin in organic solvent is at an elevated temperature and pressure, the solution being at a pressure that is at least the autogenous pressure and at a temperature sufficient to maintain the polyolefin in solution. In preferred embodiments, the solution also contains a non-solvent e.g. water, as a spinning aid, as described in the aforementioned patent of Samuels. The spinning aid may contain wetting agents, surfactants or the like. The temperature and pressure used, and the composition of the solution especially the percent of polymer in the solution, affect the properties of the film-fibril strands obtained on spinning and consequently the fibrous material subsequently formed in the process. For instance, the temperature, pressure and solution composition may be selected so that highly oriented fibres are obtained, such fibres being preferred.

The solution is fed through a feed section to a spinneret exit to form plexifilamentary film-fibril strands, the strands being formed as the polymer solution passes from the spinneret exit. A mixture of steam and water is contacted with the solution passing from spinneret exit substantially simultaneously with the passage of the solution from the spinneret exit. The mixture of steam and water may be fed as a stream to the tunnel or, preferably, a stream of hot high pressure water is flashed through an orifice into the tunnel, where the mixture of steam and water is formed. The temperature and pressure of the stream are selected so as to produce the required ratio of steam to water in the tunnel.

In a preferred embodiment, the ratio of steam to water is in the range of 20:80 to 80:20 on a weight basis, especially in the range of 35:65 to 65:35. The temperature of the inert fluid is 2-40°C lower than the melting point of the polymer.

It is to be understood that the surfaces of pipes, vessels and the like used in the process of the invention should be free of snag points or other obstructions that might prevent or retard the passage of the film-fibrils or fibrous material.

The fibre may be converted to a polyethylene pulp, which has a variety of uses. For instance, the pulp may be used as part of blends with cellulose for use in e.g. diapers, disposable wipes, feminine hygiene products and incontinence products, as a filler e.g. in polymers, cement and the like, thixotropic agent in paints and as synthetic paper. In some end-uses, fibres especially longer fibres with lengths in the range of about 5-25 mm, may be used, without refining, to produce sheet structures using either wet-lay or dry-lay sheet forming technologies.

Pulp may be obtained by feeding the fibres to a refining process that reduces the length of the fibres to less than about 2 mm and with an average length in the range of about 0.80-1.20 mm as well as opening up the fibre structure. The fibres are fed to the refiner in the form of a slurry e.g. about 2% by weight, with polyvinyl alcohol added as surfactant; other surfactants may be used in combination with or instead of polyvinyl alcohol. The fibres must be of a length of not more than about 10 mm, preferably with an average length of about 6 mm in order to produce an acceptable slurry. The refining process may be carried out in a pulp and paper-type refiner. Suitable refiners include single disk, twin-flow and conical refiners.

Synthetic pulp is synthetic fibre having a very short length. As used herein, the pulp preferably has an average length of less than about 2 mm, especially in the range of 0.8-1.2 mm, and preferably about 1 mm. In addition, the pulp preferably has a surface area of greater than 4 m^2/g, especially than 6 m^2/g and in particular in the range of 6-8 m^2/g. Pulp has a handsheet zero span value of at least 3 kg/15 mm, especially at least 5 kg/15 mm. In use, it is preferred that the pulp have a low percentage of long fibres and a low percentage of agglomerates. Long fibres are measured by Clark 14 mesh, and acceptable values are less than 12% and especially less than 7%. Agglomerates are measured by Pulmac defects, and acceptable values are less than 3% and especially less than 2%. The fineness of the fibres may be characterized using, a coarseness test viz. the Kajaani test. As used herein "fine fibres" have a coarseness of less than 0.3 mg/m and preferably less than 0.2 mg/m.

In the examples, the following test methods were used:

Handsheet zero span is a measurement of fibre strength, and is obtained using the procedures of TAPPI T205 om and a Pulmac Troubleshooter, using the method suggested by the manufacturer. Handsheets with a basis weight of 60 g/m^2 are made in a handsheet mould, by forming a slurry of fibres in water and then depositing the fibres on a screen using vacuum. Handsheet zero span is the force required to break a strip measuring 2.54 cm x 10 cm, using a jaw width of 15 mm and a jaw separation of 0 mm. The results are expressed in kg/15 mm;

Surface area is a measure of the degree of fineness and fibrillation of the product, and is measured by the Strohlein nitrogen adsorption method. Nitrogen is adsorbed on the fibres at liquid nitrogen temperature. The amount adsorbed is measured as a pressure difference between sample and reference flask. Because of the small size of nitrogen molecules, small differences in surfaces can be detected. In effect, the method is a one-point measurement using the principles of the BET nitrogen adsorption of S. Brunauer, P.H. Emmett and E. Teller, J. Amer. Chem. Soc., vol 60, p 309-319 (1938). The results are reported in m^2/g;

Linear Shrinkage is measured by immersion of fibre bundles in ethylene glycol at 155°C for 5 seconds, and is expressed as the ratio of the initial length to the shrunken length. Linear shrinkage is an indication of the orientation imparted to the fibres during the spinning process;

Average fibre length and coarseness was measured using Kajaani apparatus in which a very dilute slurry of fibres in distilled water is drawn through a small orifice using a vacuum. The length and size of the fibres are detected by a diode array detector as the fibres pass through the orifice. A distribution of fibre lengths and sizes is obtained. For unrefined samples, where the fiber length is greater than 2 mm, a very dilute slurry of 0.0078g of fibre in water is prepared, deposited onto a screen and then pressed into a plastic slide measuring 12.7 x 12.7 cm; a visual estimate of the length distribution and average length of the sample is then made;

A Clark classifier is used to measure the proportion of long fibres (mostly longer than 2 mm) in a sample; samples that have not been refined completely will have unacceptably high Clark values e.g. greater than 12%. The procedure used is TAPPI T233 os and TAPPI T261 pm. Fibres are dispersed in water, and then circulated through a series of different mesh screens. For refined fibres, only the amount collected on the 14 Mesh screen (1.19 mm openings) is reported; and

Pulmac defects is a measure of agglomeration in which a slurry is passed through a slot opening that is 0.1 mm or 0.15 mm wide at a given flow rate. The fibres or agglomerates which do not make it through the slot after two passes are considered defects.

The present invention is illustrated by the following examples.

Example I

Fibrous material was manufactured using semi-works scale apparatus equipped with a spinneret and die having a venturi tunnel, such a tunnel being shown in Fig. 1 of the copending application of S. Cloutier, L.M. Manuel and V.G. Zboril filed concurrently herewith. The solution of polymer fed to the spinneret was a solution of ethylene/butene-1 copolymer dissolved in cyclohexane and containing 7% (w/w) of water as a spin aid. Water was introduced at high temperature and pressure into the zone immediately adjacent the spinneret so that a mixture of steam and water contacted the fibres exiting from the spinneret.

In the spinning vessel, the product was in the form of a slurry of fibres in water at a 0.5% consistency (w/w). The fibre slurry was conveyed, using a water-driven venturi, through a large smooth pipe to a vessel where live steam was injected to boil off residual traces of cyclohexane. The slurry, free of solvent, was further conveyed, using a water-driven venturi, through a large smooth pipe to a belt filter press where water was removed. The product was collected in the form of a loose cake with an approximately 50% solids content.

Further details of the polymer used and the conditions in the flash spinning process are given in Table I.

Table I

Run No.	1	2	3
POLYMER PROPERTIES:			
Melt Index (dg/min)	0.28	0.33	0.43
Density (g/cm^3)	0.937	0.942	0.958
SPINNING CONDITIONS:			
Solution Temperature (°C)	249	232	237
Let-down Chamber Pressure (kPa)	6690	6310	6345
Solution flow (kg/hr)	291	315	225
Polymer in Solution (%)	14.8	14.9	15.6
SPIN SHATTERING CONDITIONS:			
Water flow rate (kg/hr)	220	210	240
Water temperature (°C)	300	298	302
Water Pressure (kPa)	10760	13730	10030
Water flashing to steam (%)*	42	42	43
Water to polymer ratio (kg/kg)	5.1	4.5	6.9
FIBRE PROPERTIES:			
Linear shrinkage	10.5	10.5	10.1
Handsheet zero span (kg/15 mm)	6.3	8.1	9.0
Fibre lengths (mm)	18-25	18-25	4-10

Note: Solution flow = polymer plus solvent
* - assumes that pressure in tunnel is 104 kPa and the temperature is 100°C

In this example, polymers of low melt index i.e. high molecular weight, were spun into discontinuous fibres. The fibres were all strongly oriented, with linear shrinkages slightly above 10. Fibre length was in the range of 18-25 mm for Runs 1 and 2, in which the melt index was 0.28 and 0.33 dg/min respectively. However, in Run 3 in which the polymer melt index was higher viz. 0.43 dg/min, the fibre length was shorter, generally below 10 mm.

The largest effect of increasing polymer density was an increase in fibre strength, as measured by handsheet zero span. Fibre strength was 6.3 kg/15 mm at a polymer density of 0.937 g/cm^3 (Run 1), 8.1 kg/15 mm at a polymer density of 0.942 g/cm^3 (Run 2) and 9.0 kg/15 mm at a polymer density of 0.958 g/cm^3 (Run 3).

The fibres of this example were strong and discontinuous, with combinations of the unique properties described herein.

Example II

The procedure of Example I was repeated using polymers of differing melt index. Polymers having a melt indices in the range of 0.79 to 7.6 dg/min were spun into fibres.

Further results are given in Table II.

Table II

Run No.	4	5	6	7	8
POLYMER PROPERTIES:					
Melt Index (dg/min)	0.79	1.16	1.90	3.8	7.6
Density (g/cm^3)	0.955	0.956	0.938	0.947	0.959
SPINNING CONDITIONS:					
Solution Temperature (°C)	262	260	237	229	234
Let-down Chamber Pressure (kPa)	7165	6675	8550	8080	8240
Solution flow (kg/hr)	235	220	284	264	224
Polymer in Solution (%)	15.4	15.4	14.9	16.9	20.1
SPIN SHATTERING CONDITIONS:					
Water rate (kg/hr)	280	265	250	250	268
Water temperature (°C)	299	300	301	302	299
Water Pressure (kPa)	-	10070	10000	9890	10510
Water flashing to steam (%)*	42	42	42	43	42
Water to polymer ratio (kg/kg)	7.8	7.8	6.0	5.6	6.0
FIBRE PROPERTIES:					
Linear shrinkage	-	9.9	-	-	-
Handsheet zero span (kg/15 mm)	8.5	8.4	5.0	4.3	3.8
Fibre lengths (mm)	2-8	2-6	1-4	1-4	1-3

Note: Solution flow = polymer plus solvent
* - assumes that pressure in tunnel is 104 kPa and the temperature is 100°C

Polymer melt index (or polymer molecular weight) had an effect on both the fibre length and fibre strength. All the fibres were strong and discontinuous, with the unique combination of properties described herein.

For the polymer with the lowest melt index (0.79 dg/min, in Run 4), the individual fibres lengths ranged from 2 to 8 mm. In contrast, for the polymer of highest melt index (7.6 dg/min, in Run 8), the individual fibre lengths ranged from 1 to 3 mm. Fibres with the lengths reported in this Example are short enough to be dispersed into a slurry in a well agitated vessel, preferably a pulper, and refined to pulp length. In contrast, some of the fibres obtained in Example 1 had lengths of up to 25 mm, which would be expected to cause entanglement problems in a pulping and refining process.

Polymers with lower melt index (higher molecular weight) give fibres with higher strength, as measured by handsheet zero span, than fibres with higher melt index. The polymer with a melt index of 0.79 dg/min had a handsheet zero span of 8.5 kg/min (Run 4), whereas the polymer with a melt index of 7.6 dg/min had a handsheet zero span of less than half that value (Run 8). In Run 3 of Example I, the polymer had the same density and a melt index of 0.42 dg/min; the handsheet zero span was 9.0 kg/15 mm.

Example III

The procedure of Example I was repeated, with the fibres obtained being refined to a pulp length viz. approximately 1 mm.

Refining was conducted by first dispersing the fibres in water in an agitated tank, at a fibre consistency of 1.5-2%. A surfactant (polyvinyl alcohol, 2% by weight of fibres) was used in order to make the fibres more wettable. Two different single disk refiners were used, with a 30 cm plate diameter in Runs 9 and 10 and with a one metre plate diameter in Run 11. The plate gap setting was between 0.05 and 0.15 mm, with the larger gap settings being used on the smaller refiner. The samples were refined until the average fibre length was 1 mm.

Further details and the results obtained are given in Table III.

Table III

Run No.	9	10	11
POLYMER PROPERTIES:			
Melt Index (dg/min)	0.78	1 .04	7.5
Density (g/cm^3)	0.962	0.956	0.958
SPINNING CONDITIONS:			
Solution Temperature (°C)	237	249	245
Let-down Chamber Pressure (kPa)	7115	7320	8255
Solution flow (kg/hr)	250	219	231
Polymer in Solution (%)	15.4	15.1	19.0
SPIN SHATTERING CONDITIONS:			
Water rate (kg/hr)	280	245	283
Water temperature (°C)	300	301	302
Water Pressure (kPa)	10855	9510	-
Water flashing to steam (%)*	42	42	43
Water to polymer ratio (kg/kg)	7.2	7.4	6.4
UNREFINED Fibre PROPERTIES:			
Linear shrinkage	9.7	6.9	-
Handsheet zero span (kg/15 mm)	7.5	7.4	3.6
Fibre lengths (mm)	6-12	4-8	1-3
REFINED Fibre PROPERTIES:			
Average fibre length (mm)	0.97	1.02	0.98
Average fibre coarseness (mg/m)	0.171	0.219	0.26
Surface area (m2/g)	6.22	6.61	5.97
Pulmac defects (%)	0.2	0.9	1.2
Clark 14 mesh (%)	1.1	1.8	1.4
Canadian standard freeness (ml)	402	432	525
Handsheet zero span (kg/15 mm)	5.7	5.7	3.1

Note: Solution flow = polymer plus solvent
* - assumes that pressure in tunnel is 104 kPa and the temperature is 100°C

This Example compares the properties of refined fibres (pulp) to the unrefined fibres. Most applications of the fibres are expected to be in the form of pulp. In addition, certain fibre properties cannot be measured on unrefined fibres.

The fibre samples were obtained by spinning high density polymers with varying melt indices viz. from 0.78 to 7.5 dg/min. For Run 9, in which the melt index was 0.78 dg/min, the handsheet zero span for unrefined fibres was 7.5 kg/15 mm and the individual fibre lengths ranged between 6 and 12 mm. For Run 11, in which the melt index was 7.5 dg/min, the handsheet zero span was 3.6 kg/15 mm and the individual fibres lengths ranged between 1 and 3 mm.

The fibres were refined to an average length of 1 mm viz. 0.97 mm for Run 9, 1.02 mm for Run 10 and 0.98 mm for Run 11. The Pulmac defect test, which measures long fibres and agglomerates, gave results of less than 2% for the fibres of all three runs. The Clark 14 mesh test, which measures the proportion of long fibres, was also less than 2% for all three runs.

Fibre strength as measured by the handsheet zero span test was lower for the refined fibres than for the unrefined fibres. For the lower melt index polymer of Run 9, the handsheet zero span decreased from 7.5 kg/15 mm before refining to 5.7 kg/15 mm after refining. In Run 11, the decrease was from 3.6 to 3.1 kg/15 mm. Nonetheless, fibre strength was still acceptable.

Fibre size and surface area are typically measured only on refined fibres, because refining opens up the fibre structure. Average fibre coarseness as measured by the Kajaani method increased with increasing melt index, from 0.171 mg/m in Run 9 to 0.260 in Run 11. This shows that finer, more oriented fibres may be obtained with lower melt index polymers. Surface area measured by nitrogen adsorption was between 6 and 7 m^2/g for all three runs.

Claims

1. Fine, strong, as-spun discontinuous fibres formed from polyethylene, said fibres having a length of 1-25 mm, a fibre diameter of less than 30 microns and a handsheet zero span strength of greater than 3 kg/15 mm.

2. The fibres of Claim 1 in which the handsheet zero span strength is greater than 6 kg/15 mm.

3. The fibres of Claim 1 or Claim 2 in which the polyethylene has a melt index of less than 15 dg/min.

4. The fibres of Claim 3 in which the melt index of the polyethylene is less than 7 dg/min.

5. The fibres of Claim 3 in which the melt index of the polyethylene is less than 2 dg/min.

6. The fibres of any one of Claims 1-5 in which the polyethylene is a high molecular weight homopolymer of ethylene or copolymer of ethylene and at least one C_4-C_{10} hydrocarbon alpha-olefin.

7. The fibres of Claim 6 in which the polyethylene is a copolymer and the alpha-olefin is selected from butene-1, hexene-1 and octene-1, and mixtures thereof.

8. The fibres of Claim 6 in which the density of the polyethylene is in the range of 0.930 to 0.965 g/cm^3.

9. The fibres of Claim 8 in which the melt index of the polyolefin is less than 15 dg/min.

10. A polyethylene pulp formed from as-spun discontinuous fibres having a surface area of greater than 4 m^2/g, a Pulmac defect value of less than 3%, a handsheet zero span value of at least 3 kg/15 mm and with the fibres of the pulp having a Kajaani coarseness of less than 0.30 mg/m.

11. The polyethylene pulp of Claim 10 in which the Pulmac defect value is less than 2%.

12. The polyethylene pulp of Claim 10 or Claim 11 in which the fibre length is less than about 2 mm and with an average length in the range of 0.80-1.20 mm.

13. The polyethylene pulp of any one of Claims 10-12 in which the polyethylene has a melt index of less than 15 dg/min.

14. The polyethylene pulp of Claim 13 in which the melt index of the polyethylene is less than 7 dg/min.

15. The polyethylene pulp of Claim 13 in which the melt index of the polyethylene is less than 2 dg/min.

16. The polyethylene pulp of any one of Claims 10-15 in which the polyethylene is a high molecular weight homopolymer of ethylene or copolymer of ethylene and at least one C_4-C_{10} hydrocarbon alpha-olefin.

17. The polyethylene pulp of Claim 16 in which the polyethylene is a copolymer and the alpha-olefin is selected from butene-1, hexene-1 and octene-1, and mixtures thereof.

18. The polyethylene pulp of Claim 16 in which the density of the polyethylene is in the range of 0.930 to 0.965 g/cm^3.

19. The polyethylene pulp of Claim 18 in which the melt index of the polyolefin is less than 15 dg/min.

20. The polyethylene pulp of any one of Claims 10-19 in which the pulp has a surface area in the range of 6-8 m^2/g.

21. The polyethylene pulp of any one of Claims 10-20 in which the fibres have a fineness such that the fibres have a Kajaani coarseness of less than 0.20 mg/m.

22. The polyethylene pulp of Claim 10, formed from fibres of any one of Claims 1-9.

23. A polyethylene sheet formed from strong discontinuous fibres of any one of Claims 1-9.

24. A sheet of Claim 23 in which the fibres have lengths in the range of 5-25 mm.

25. A sheet of Claim 23 or Claim 24 which is an air-laid sheet.

26. A sheet of Claim 23 or Claim 24 which is a wet-laid sheet.

27. Strong discontinuous fibres formed from polyolefin, said fibres having a length of 1-25 mm, a surface area of greater than 5 m^2/g and a handsheet zero span strength of greater than 3 kg/15 mm.

28. A polyolefin pulp having a surface area of at least 5 m^2/g, a Pulmac defect value of less than 3% and a handsheet zero span value of at least 3 kg/15 mm.