

LOW COEFFICIENT OF FRICTION ORIENTED FILM

This invention relates to low-coefficient of friction oriented films; more particularly, this invention relates to a oriented multi-layer polypropylene films having a low film-to-film coefficient of friction (COF).

5 Highly crystalline polypropylene film is an excellent packaging material, but it has a high film-to-film COF which makes it difficult or impossible for it to be successfully utilized in automatic packaging equipment. The film will not respond to the packaging
10 speed capability of the system and, as a consequence, jamming results.

 In the past, the COF characteristics of polypropylene film have been beneficially modified by the inclusion in the polypropylene of COF-improving additives;
15 for example, fatty acid amides. The effectiveness of an amide to reduce COF depends upon its ability to migrate to the surface of the film. While such amides can improve the COF of the film, the value of the COF is, however, subject to wide variation depending upon the thermal
20 history of the film during storage, shipping and certain converting processes. The presence of such amides on the film surfaces can, furthermore, adversely affect the film's appearance as manifested by an increase in haze, a decrease in gloss and the presence of streaks. The
25 presence of such amides on the surface can also adversely affect their wettability and the adhesion of solvent and water base inks, coatings, adhesives; and of metals.

 In an effort to improve the COF of polypropylene film without adversely affecting the film's
30 appearance, wetting and adhesion, it has been proposed in US 4578316





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to prepare a polypropylene film having on at least one surface thereof a layer of a blend of (1) a member selected from the group consisting of a medium density polyethylene (MDPE), a high density polyethylene (HDPE) or a blend thereof, and (2) polypropylene. This document further discloses that the two materials in the surface layer can be blended in an amount from 2% by weight to 60% by weight of the medium or high density polyethylene with the remainder being the polypropylene. The document also suggests that at percentages of 60 to 100% MDPE or HDPE, the surface layers are too soft and too hazy. That such high MDPE or HDPE content films would have comparatively inferior optical properties is not unexpected, because MDPE and HDPE films are known to be hazy and opaque.

This invention seeks to provide polypropylene film having a low COF which is stable with respect to thermal history; and good optical, wetting and adhesion properties.

This invention provides an oriented multi-layer film which comprises at least a first surface layer of a polymeric material comprising high density polyethylene (HDPE) and a second layer of a polymeric material comprising polypropylene wherein the film has been oriented by stretching it at a temperature above the melting point of the high density polyethylene but below the melting point of the polypropylene, preferably without added prior COF or antiblock agents; for example, fatty acid amides.

The polypropylenes which can be used to prepare the film of this invention are well known in the art. They are generally formed by polymerizing propylene in the presence of stereospecific catalyst systems. These polypropylenes can have a melt flow rate from 1 to 25, preferably from 1 to 8. The crystalline melting point of these materials is from 160°C (320°F) to 169°C (336°F).

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The number average molecular weight ranges from 25,000 to 100,000 while their specific gravity ranges from 0.90 to 0.91. Although it is preferred to use a pure polypropylene layer in the films of this invention, the polypropylene may also be modified; for example, by copolymerization with small amounts of another monomer or by blending with another material, so long as the melting point of the resulting material is sufficiently above that of the HDPE layer to allow for orientation of the film at a temperature between the melting points of the materials of the two layers.

The comparatively low COF material of which the surface layer is comprised is high density polyethylene (HDPE). For the purposes of this invention, the HDPEs have specific gravity from 0.941 to 0.965 and a melt index from 0.5 to 18. It is preferred that at least one surface layer of the film consist solely of HDPE; however, the HDPE may be blended with other materials; for example, polypropylene or MDPE, so long as the melting point of the blend is sufficiently below that of the polypropylene layer to allow for orientation of the film at a temperature between those two melting points.

The preferred oriented multi-layer films of this invention are two or three layer films having the configuration A/B, A/B/A or A/B/C where A is the HDPE layer, B is the polypropylene layer, and C is one or more of any number of functional layers (e.g. sealant). Additional layers of polymeric material may be incorporated in these films, however. For example, tie layers of adhesives may be used to add other functional or cost reduction layers. An example of a preferred third layer is a layer comprising a copolymer of ethylene with propylene; a terpolymer of ethylene, propylene and a further olefin (for example 1-butene) or a blend thereof. Such copolymers and/or terpolymers generally contain from 2 to 7 weight % ethylene and 2 to 7 weight % 1-butene.



Each surface or skin layer or HDPE generally comprises from 2 to 15%, preferably from 2 to 5%, of the overall thickness of the film although thicker layers could be used to prepare a stiffer film or a film with better water barrier properties.

The oriented multi-layer film of this invention may be prepared by coextrusion, extrusion coating or casting methods known in the art. The coextrusion of HDPE with polypropylene, like other coextrusions, requires the proper matching of polymer viscosities and flow velocities in the die. It has been found that this can be accomplished by pairing low melt flow (1.9 to 2.5) polypropylene resins with comparable melt index (1 to 3.0) HDPE resins. It is also possible to improve the flow compatibility of the two resins through extrusion condition changes. It has been found that the HDPE/polypropylene coextrusion can be most successfully cast onto a cast roll having a temperature from 60°C (140°F) to 72°C (160°F).

The multi-layer film structures of this invention are oriented, generally biaxially, for added strength and enhanced properties. Generally, the films are stretched from 300 to 700% in the machine direction and from 500 to 900% in the transverse direction. As indicated previously, it has been found to be critical, for preparing a film with low haze and high gloss, to orient the film structure at a temperature above the melting point of the HDPE layer and below the melting point of the polypropylene layer. To achieve best results, the film should also be rapidly quenched after orientation. Orientation of a HDPE/polypropylene film according to this invention has been successfully achieved at over temperatures from 125°C (260°F) to 160°C (320°F).



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The process of the present invention is illustrated in greater detail as follows: polypropylene homopolymer resin (melt flow 3 to 4) is fed into the main extruder of an A/B coextrusion system while HDPE resin (melt index 3.0) is fed into the satellite extruder. The ratio of these materials is 95/5. The melt temperature of the polypropylene is 254°C (490°F) while that of the HDPE is 257°C (495°F). The molten materials are joined in a multicavity die and cast onto a polished chrome chill roll with a set point of 60°C (140°F). The cast sheet is 30 mils thick and enters a water bath 38°C (100°F). Following this initial quench, the sheet is reheated to 132°C (270°F) and stretched in the machine direction five times. The thinned sheet is then fed into a tenter frame where it is preheated at a temperature of 168°C (335°F) and stretched eight times in the transverse direction. It is heat set at 149°C (300°F), trimmed and wound into a roll.

Multi-layer film structures can be prepared according to this invention which exhibit coefficients of friction of below 0.40, generally from 0.30 to 0.40, good gloss (greater than 80) and low haze (less than 3.0) without the use of migratory or non-migratory additives to the polypropylene or its surface. These films possess the unique ability to develop weld bonds between the film and laminate when used in extrusion lamination with low density polyethylene. They also offer a unique slip surface for metallization as well as a surface which accepts water and solvent based inks when surface treated in a manner known to the art.



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The following Examples illustrate the invention. In these examples, the polypropylene resins used are designated as follows:

- 5 PP-1 = Melt flow 4
- PP-2 = Melt flow 6
- PP-3 = Melt flow 2.5
- PP-4 = Melt flow 1.95
- PP-5 = Melt flow 3

The HDPE resins used are designated as follows:

- 10 HDPE-1 = Melt index 1.1
- HDPE-2 = Melt index 3.0

The oriented polypropylene film used as a comparison in several of the examples, PP, is Bicolor (R) LQM-W Oriented Polypropylene Film, available from Mobil Chemical Company, 1150 Pittsford-Victor Road, Pittsford, N.Y.

Test results presented in the examples were obtained using the following test procedures:

- 20 Haze - ASTM D1003
- Gloss - ASTM D2457
- Film to Film Coefficient of Friction (COF)
- ASTM D1894
- 25 Film to Steel Coefficient of Friction
(COF) - ASTM D1894
- Force-over-the-forming-collar (FOFC) - A
packaging structure is pulled through a
MIRA-PAK vertical form fill and seal
machine over a polished 11-1/2" forming
collar. The film is attached to a Hanson
30 gauge while pulling which has a 0 - 50 lb.
scale with 1 lb. increments.



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Bond Strength - During lamination, a paper sheet is inserted between layers. These separated layers are used as the tails to be gripped in the Instron where the actual strength is measured.

Dyne Solution Test - ASTM D2378

EXAMPLES 1 TO 17

Biaxially oriented multi-layer HDPE/polypropylene film structures were prepared by coextruding the polymers and orienting the cast film at a temperature above the melting point of the HDPE and below that of the polypropylene as described above. The optical characteristics for a number of these films are presented in TABLE 1.

TABLE 1

Ex.	Structure	Layer		Haze	Gloss
		Thicknesses			
1	HDPE-1/PP-1/HDPE-1	5/90/5		1.7	81.5
2	"	"		3.0	84.8
3	"	"		1.8	90.1
4	"	"		2.6	86.4
5	HDPE-1/PP-2/HDPE-1	"		6.2	9.3
6	HDPE-1/PP-1/HDPE-1	"		1.0	79.2
7	"	"		0.9	93.6
8	HDPE-1/PP-3/HDPE-1	"		0.9	93.2
9	PP-5/HDPE-1	95/5		2.4	94.8
10	"	"		2.3	96.7
11	"	"		1.9	85.5
12	"	"		2.4	78.0
13	"	"		3.7	84.6
14	"	"		1.7	85.7
15	PP-3/HDPE-1	"		1.9	87.5
16	PP-4/HDPE-1	"		1.0	89.6
17	"	"		1.6	92.6



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EXAMPLE 18

Coextruded biaxially oriented PP/HDPE film structures according to this invention were extrusion laminated to other films and tested for machinability and bond strength as well as coefficient of friction. The film structures of this invention which were tested are identified as follows:

- Film A = HDPE-1/PP-1/HDPE-1
- Film B = HDPE-1/PP-1/HDPE-1
- 10 Film C = HDPE-1/PP-3/HDPE-1
- Film D = PP-5/HDPE-1
- Film E = PP-5/HDPE-1
- Film F = PP-5/HDPE-1
- Film G = PP-5/HDPE-1
- 15 Film H = HDPE-2/PP-5/(ethylene/propylene
copolymer)

In the A/B or A/B/C film structures, Films A-C and H, the HDPE layer comprises from 2 to 5% of the overall thickness of the film. In the A/B/A structures, the total HDPE layers comprise from 5 to 10% of the overall thickness of the film. Although a number of the film structures comprise the same polymer layers (e.g., Films A and B), they are designated separately because they were prepared at different times in different runs.

25 The coextruded film structures of this invention or, for purposes of comparison, a biaxially oriented polypropylene film (PP), were extrusion laminated with low density polyethylene films (LDPE) to either glassine or PXS, optionally being coated with polyethylene imine primer. The results of machinability and bond strength tests are presented in TABLE 2.

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TABLE 2

	<u>Structure</u>	FOFC	COF		Bond Strgth
		<u>lbs.</u>	<u>Film-Film</u>	<u>Film-Steel</u>	<u>g/in</u>
	Trial 1				
5	1) Film A/LDPE/PXS**	-	0.31	-	82.6
	2) PP/LDPE/Primer/ Glassine	-	-	-	6.5
	Trial 2				
10	3) Film B/LDPE/ Primer/Glassine	41	0.51	0.23	350*
	4) Film A/LDPE/ Primer/Glassine	20	0.52	0.19	348*
	5) PP/LDPE/Primer/ Glassine	50	0.31	0.22	51
15	Trial 3				
	6) Film C/LDPE/ Glassine	20	0.39	-	-
	7) Film D/LDPE/ Glassine	18	0.37	-	-
20	8) Film E/LDPE/ Glassine	17	0.34	-	-
	9) Film F/LDPE/ Glassine	15	0.36	-	-
	10) Film F/LDPE/ Glassine	38	0.33	-	-
25	11) Film G/LDPE/PXS**	14	0.40	-	-
	12) PP/LDPE/PXS	17	0.34	-	-
	Trial 4				
30	13) Film H/LDPE/ Primer/Glassine (HDPE out)	18	0.37	0.17	Inseparable
	14) Film H/LDPE/ Primer/Glassine (HDPE buried)	38	0.45	0.22	Inseparable
35	15) PP/LDPE/Primer/ Glassine (HDPE buried)	40	0.31	0.22	142

* Paper tore at this strength, so bond was stronger than this.



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5 The data presented in TABLE 2 indicate that in all cases, the oriented HDPE/PP film structures of this invention outperformed the oriented PP film structures in the force-over-the-forming-collar (FOFC) test. In all but one test, the film structures of this invention produced FOFC of 20 lbs. or less. FOFC of 25 lbs. or less is considered to be good machinability. The PP film performed in its usual range of 38 to +50 lbs. The HDPE/PP film structures performed as well in the PXS lamination as the PP films. The reason for the poor performance of Film Structure 3 is not known but may be due to uneven skin distribution experienced during parts of the early run.

15 The other test for machinability, film-to-film COF, indicated slightly higher coefficients of friction for the film structures of the invention than for the PP film laminations.

20 The data in TABLE 2 also show that the HDPE skins of the films of this invention have excellent bonds in LDPE extrusion laminations. In Trial 1, the extrusion temperatures were low, resulting in poor bond strengths. The PP lamination, which would normally have a bond of 25-40 g/in., had a bond strength of only 6.5 g/in. Other variables run during that trial had similarly low bond strengths. Despite the poor processing conditions, the HDPE skin film had a bond strength of 82.6 g/in.

25 In Trial 3, normal lamination conditions were run and a slightly higher than normal PP bond of 51 g/in. was measured compared to the 350 g/in. bonds for the HDPE skin films. In addition, the 350 g/in. was the strength of the face of the glassine tearing with the actual film to poly bond strength being even greater.

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The extrusion temperatures were run hot in Trial 4 which, it is believed, is why the bond strengths were higher for all variables.

EXAMPLE 19

5 A film structure according to this invention, a coextrusion of PP-5/HDPE-1 (Film G), was tested in adhesive laminations to PXS and compared to laminations with oriented PP film. For these laminations, the HDPE
10 side of the film structure was buried. To test for bond strength, two substrates were joined together at a nip point under pressure and heat. The first substrate was coated with adhesive and then dried. The coated substrate was then joined to the second substrate at a high pressure heated nip. Bond strengths were measured initially and
15 after aging. The adhesives used were either a polyvinylidene chloride (PVdC) a urethane, or Duro-Flex 56 (composition unknown, available from National Starch and Chemical Corporation, Bridgewater, NJ). The results are presented in TABLE 3.

20

TABLE 3

	<u>Structure</u>	<u>Bond Strength (g/in.)</u>	
		<u>Initial</u>	<u>2 Week Aged</u>
	Film G/PVdC/PXS	186	147
	PP/PVdC/PXS	122	120
25	Film G/Urethane/PXS	458	357
	PP/Urethane/PXS	482	Tear
	Film G/Duro-Flex 56/PXS	262	198
	PP/Duro-Flex 56/PXS	293	107

30 The results in TABLE 3 indicate that the PVdC bond strengths of the HDPE skin film of this invention are



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5 better than those of the PP film. The urethane bonds were slightly lower on the HDPE skin films, but they were still well within the fitness-for-use range. Duro-Flex 56 bonds were very good.

EXAMPLE 20

10 High density polyethylene has a reputation for being an easy to treat substrate. This was verified by tests on A/B film structures or polypropylene (melt flow 2.25)/HDPE (melt index 1.1). The results are presented in TABLE 4.

15

TABLE 4

	Power Setting	Dune Sol. Test (dyne/cm)	Contact Angle		Block ¹	Ink Block ²
			Advan.	Reced.		
	Not treated	31	99.5	92.0	1.6	6.2
20	60V., 2a.	33+	80.8	73.8	1.5	24.8
	105V., 4.4a.	39	61.0	43.3	25.2	33.1
	150V., 6.4a.	42	62.3	31.0	35.7	31.4
	185V., 12a.	54-	58.0	14.0	46.0	24.1

¹ One hour block test at 750 psi, 140°F

25 ² Three day ink block test at 100 psi, 125°F

30 The data in TABLE 4 illustrate that a level of 42 dyne/cm was achieved at a power setting of 150V., 6.4a., the same power setting normally used to treat oriented homopolymer polypropylene film to 36-37 dynes/cm. A value as high as 54- was measured on one sample.



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EXAMPLE 21

Several film structures according to this invention were evaluated for waterbased ink blocking using the following test. Ink (CZ Aqualam P waterbased ink) was placed on the film and drawn down using a Meyer Rod metering system and then dried thoroughly. The sample was then placed in a standard 3-day blocking test at 100 psi, 125°F. The test was run treated side to printed treated side. Separation bond strength was measured using an Instron machine. The results are presented in TABLE 5.

TABLE 5

	<u>Film Structure</u>	<u>Ink Blocking (g/in.)</u>	<u>Comments</u>
	PP-5/HDPE-1	24.8	33+ dyne/cm
	"	33.1	39 dyne/cm
15	"	31.4	42 dyne/cm
	"	24.1	54- dyne/cm
	"	6.2	31 dyne/cm
	PP	55.7*	36 dyne/cm
	PP	58/5**	36 dyne/cm
20	PP-1/HDPE-1	33.1	N.A.
	PP-1/HDPE-1	18.8	N.A.

* Avg. of 2 tests

** Avg. of 10 tests

The data in TABLE 5 show the HDPE films of this invention to having a blocking force of 24-33 g/in. compared to PP films with an average of 58.5 g/in. This is a 50% decrease in blocking force.



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CLAIMS

1. An oriented multi-layer film which comprises at least a first surface layer of a polymeric material comprising high density polyethylene (HDPE) and a second layer of a polymeric material comprising polypropylene wherein the film has been oriented by stretching it at a temperature above the melting point of the high density polyethylene but below the melting point of the polypropylene.
2. A film according to claim 1 wherein the first surface layer consists essentially of HDPE.
3. A film according to claim 1 or 2 wherein the HDPE has a melt flow index from 0.5 to 18.
4. A film according to any preceeding claim wherein the surface layer comprises from 2 to 15% of the total thickness of the oriented multi-layer film.
5. A film according to claim 4 wherein the first surface layer comprises from 2 to 5% of the total thickness of the oriented multi-layer film.
6. A film according to any preceeding claim wherein the second layer consists essentially of polypropylene.
7. A film according to any preceeding claim wherein the polypropylene has a melt flow index from 1 to 8.

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8. A film according to any preceeding claim which further comprises a second surface layer comprising HDPE.

9. A film according to any preceeding claim which further comprises a second surface layer comprising a copolymer of ethylene with propylene; a terpolymer of ethylene, propylene and a further olefin; or a blend thereof.

10. A film according to any preceeding claim which is biaxially oriented.

11. A film according to any preceeding claim which exhibits a coefficient of friction of less than 0.40.

12. A film according to any preceeding claim which exhibits gloss of greater than 80 and haze of less than 3.0.

13. A process for preparing an oriented multi-layer film having low coefficient of friction and good optical properties, which process comprises stretching a multi-layer film comprising at least a first surface layer of a polymeric material comprising high density polyethylene and a second layer of polymeric material comprising polypropylene at a temperature above the melting point of the high density polyethylene but below the melting point of the polypropylene.

14. A process according to claim 13 wherein the stretching is effected at a temperature from 125°C (260°F) to 160°C (320°F).

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15. A process according to claim 13 or 14 wherein the multi-layer film is stretched from 300 to 700% in the machine direction.

16. A process according to any of claims 13 to 15 wherein the multi-layer film is stretched from 500 to 900% in the transverse direction.

17. A process according to any of claims 1 to 16 wherein the multi-layer film is defined in any of claims 1 to 12.

18. Use, in a multi-layer film as defined in any of claims 1 to 12, of a stretching temperature above the melting point of the polymeric material comprising the surface layer but below the melting point of the polypropylene.

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