

PRINTABLE HIGH BARRIER MULTILAYER FILM

This invention relates to a multilayer packaging film having good barrier resistance to the transmission of oxygen and water vapor, good printability; and the ability to receive a firmly bonded metal layer thereon.

Certain polymeric films e.g., polypropylene, employed for the packaging of foods, inherently permit the transmission of oxygen and water vapor from outside of the film to inside of a package made up of the film. Oxygen and water vapor permits rapid deterioration of foods packaged in containers made from such a film. Metal deposits on such films are desirable because of the improvement in appearance and in providing yet another layer which militates against the invasion of oxygen and water vapor.

Thus, it is a principal object of the present invention to present a film which has excellent printability, can have a metal layer firmly bonded thereto and which has significantly decreased oxygen and water vapor transmission rates.

According to one aspect of this invention, there is provided a film combination comprising:

(a) an oriented polymeric substrate which either i) comprises an intimate blend of polypropylene with maleic acid anhydride modified polypropylene or ii) is otherwise susceptible of transmitting oxygen and water vapor and has a primer coating on at least one surface;

(b) a layer of cross-linked polyvinyl alcohol on i) the intimate blend or ii) the primer coating;

(c) a layer of a polymer comprising vinyl alcohol residues which may be as defined in b) or an intimate blend of a homo- or copolymer of vinyl alcohol, with an ethylene acrylic acid copolymer; and, optionally

(d) a layer as defined in a) i).

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This invention is also concerned with a film combination comprising:

(a) an oriented polymeric substrate susceptible in its unmodified form of transmitting oxygen and water vapor;

(b) a primer coating on at least one surface of said substrate (a);

(c) a layer of cross-linked polyvinyl alcohol on said coating (b); and

(d) a layer of the blend of (1) a polyvinyl alcohol homo or copolymer and (2) an ethylene-acrylic acid copolymer.

It is preferred that the substrate layer be corona discharge treated prior to receipt of the primer coating.

The present invention also relates to a process for forming a firmly bonded film combination comprising:

(a) preparing an intimate blend of polypropylene and a maleic acid anhydride modified polypropylene and forming a cast layer thereof;

(b) forming said cast layer into a machine direction oriented film;

(c) applying a coating of poly(vinyl alcohol) containing cross-linking means to the machine direction oriented film;

(d) mating a second so-coated machine direction oriented film so that poly(vinyl alcohol) surfaces are in contact;

(e) transverse direction orienting the mated films to form a film combination of high delamination resistance.



The invention is also concerned with a film combination comprising:

(a) a pair of films each comprised of an intimate blend of polypropylene and a maleic acid anhydride modified polypropylene;

(b) coatings of poly(vinyl alcohol) containing cross-linking means having been applied to a surface of each of said pair while said pair had been in a machine direction orientation condition; and

(c) each coated film having been positioned with the poly(vinyl alcohol) layers in intimate contacting relationship while said coated contacting films had been transverse direction oriented.

The substrates contemplated herein include any polymeric film substrate which inherently permits the transmission of oxygen and water vapor and wherein the utility of such film for packaging purposes would call for a minimization of such transmission. In most cases the source of oxygen and water vapor is atmospheric oxygen and water vapor. While nylon, polyethylene terephthalate and polycarbonate films are contemplated herein, the particularly preferred class of films are the polyolefins. Within the polyolefins class, homopolymer and copolymers of propylene are preferred. Particularly preferred are isotactic polypropylenes containing at least 80% by weight of isotactic polypropylene. The preferred base substrate layer can be homopolypropylene having a melting point from 305 to 340°F, preferably from 321° to 336°F; an inherent viscosity from 1.4 to 4.0; an MFI from 0.5 to 12; an MW from 100,000 to 600,000; and a density from 0.89 to 0.91. Commercially available materials of this description include Exxon 4252 and ARCO W472. The preferred substrate can also be coextruded with a thin skin layer amounting from about 2-12% of the total



thickness of a copolymer of propylene and another olefin, e.g., ethylene, butene-1, etc. The other olefin can be present in the copolymer in an amount from about 1-7 wt%.

5 This invention encompasses polypropylene substrates comprising from (90 to 99 wt%, preferably from 92.5 to 98.5 wt%, of a polypropylene resin as described herein, compounded with or modified by from (1 to 10 wt%, preferably from 1.5 to 7.5 wt%, based on
10 the weight of the polypropylene resin of a maleated polypropylene.

 The maleated polypropylene additive may be derived from maleic acid or its anhydride, copolymerized with polypropylene. Pertinent properties of maleated
15 polypropylene marketed by Eastman Chemical are as follows:

 Ring and Ball softening 157°C;
 M.W. 4500;
 Density °C 0.934;
20 Acid Number 45;
 Brookfield Visc. 190°C.cp/370
 Color Gardner Scale 11;
 Penetration Hardness, 100 gm/5 sec./25°C
 tenths of mm.0-1.

25 In addition, the term maleic anhydride modified polypropylene homopolymer is the product resulting from the reaction between maleic anhydride and the thermal degradation product of polypropylene. Examples of this material can be found disclosed in U.S. 3,480,580.

30 In order to effectively inhibit the amount of oxygen and water vapor transmitted through the base layer, the base layer should preferably be (1) treated to a surface free energy of at least about 35 dynes/cm, (2) have a primer coating applied thereto, (3) have a
35 coating of a layer of a cross-linked polyvinyl alcohol



homopolymer or copolymer applied thereto, and (4) have a layer of a blend of a polyvinyl alcohol homo or copolymer and a ethylene-acrylic acid copolymer applied thereto.

5 The preferred substrate must be properly prepared to receive the primer layer, followed by application of the cross-linked polyvinyl alcohol. This proper treatment involves treating the surface to a surface
10 tension level of at least about 35 and preferably from 38 to 45 dynes/cm in accordance with ASTM Standard D2578-84. The treatment can be flame treatment, plasma treatment, chemical treatment or corona discharge treatment. Flame treatment and corona discharge treatment are preferred with corona discharge treatment
15 being particularly preferred.

 Commercially available corona discharge treatment equipment can be obtained from Solo Systems, Inc., Garland, Texas; Corotec Corporation, Collinsville, Connecticut; Softal Electronics, Hamburg, W. Germany;
20 and others. Using, for example, Softal Electronics equipment, a treater can have an air gap of about 0.050 in. when treating polypropylene film of about 0.9 mils. The film can be treated to 42-44 dynes/cm. After this treatment, a suitable primer material may be coated
25 onto the treated surface.

 Preferred primer materials are those disclosed in U.S. 4,564,559. These include a primer produced by condensing a monoaldehyde with an interpolymer of acrylamide or methacrylamide and at least one other
30 unsaturated monomer. Further included is a material resulting from condensing aminoaldehyde with acrylamide or methacrylamide and subsequently interpolymerizing the condensation product with at least one other unsaturated monomer in the presence of a C_1-C_6 alkanol.
35 A preferred primer coating resin of this type comprises



5 a copolymer containing up to 90% by weight of styrene,
up to 80% by weight of an alkyl alkylate, up to 15% by
weight of methacrylic acid and 5% to 25% by weight of
acrylamide which has been condensed with a solution of
formaldehyde in n-butanol containing from 0.2 to 3
equivalents of formaldehyde for each amine group in the
copolymer. Another primer resin of this type is a 50%
solid solution of a copolymer resin containing 38.5
10 parts of styrene, 44 parts of ethyl acrylate, 2.5 parts
of methacrylic acid and 15 parts of acrylamide which
has be condensed with 5.2 parts of formaldehyde in
n-butanol.

15 A particularly preferred primer material for the
structure contemplated herein has been found to be
poly(ethyleneimine). The amine primer provides an
overall adhesively active surface for thorough and
secure bonding with the subsequently applied
cross-linked polyvinyl alcohol. It has been found that
an effective coating solution concentration of the
20 poly(ethyleneimine) applied from either aqueous or
organic solvent media, such as ethanol, is a solution
comprising 0.1 to 0.6% by weight of the
poly(ethyleneimine). A commercially available material
of this type is known as Polymin P, a product of
25 BASF-Wyandotte Corporation.

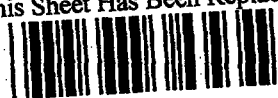
Another particularly preferred primer material is
the reaction product of an epoxy resin with an
acidified aminoethylated vinyl polymer. The
contemplated epoxy resins are glycidyl ethers of
30 polyhydroxy compounds. Typical polyhydroxy compounds
which may be used include bisphenol A, ring-substituted
bisphenol A, resorcinol, hydroquinone,
phenol-formaldehyde, Novolac resins, aliphatic diols,
such as ethylene glycol, propylene glycol,
35 1,4-butanediol, 1,6-hexane-diol, glycerol, lower alkyl



hydantoins and mixtures thereof. The preferred epoxy resins of the present invention are those made by the glycidation reaction between epichlorohydrin and bisphenol A. Epoxy resins of this type are commonly classified by their epoxy equivalent weight (EEW) which is defined by the weight of resin in grams which contains one gram equivalent of epoxy groups. Resins with an EEW ranging from 170 to 280 may be used in the present invention, but the preferred range is 180 to 210.

Although the specific structure of the epoxy resin is not critical to the primer employed in the present invention, important considerations in the selection of the epoxy resin revolve around its physical state. For example, it must be liquid and capable of being readily dispersed or dissolved with the second component or curing agent as described hereinbelow. If the epoxy resin is of low viscosity, it may be stirred directly into the second component, i.e., curing agent, however, it is preferred to employ the epoxy resin in an aqueous emulsion.

The second component in the epoxy primer composition of the present invention is an amino modified acrylic polymer which is water soluble. This polymer is a curing agent for the epoxy compound. The preferred material is described in U.S. 3,719,629. This material may be generically described as an acidified aminoethylated interpolymer having pendent aminoalkylate groups. This material is produced by polymerizing acrylate, methacrylate, styrene or other suitable monomers with sufficient methacrylic or acrylic acids to give a -COOH content of 7.5 to 12.5%. Solvent polymerization techniques are preferred. The polymer is then reacted with ethyleneimine monomer and



acidified with hydrochloric acid to render the polymer water soluble.

5 In one embodiment of the present invention, a liquid epoxy resin is emulsified in a solution of the curing agent by rapid stirring, the resultant dispersion is diluted with water to the desired concentration for coating, usually from 2 to 20% solids. When mixing the epoxy resin with the curing agent, it is generally preferred to use a stoichiometric equivalent balance of
10 epoxy and amine groups. However, it has been found that the stoichiometric ratio may be varied over a wide range, from 1 epoxy to 3 amine groups through 3 epoxy groups to 1 amine group.

15 The polyvinyl alcohol employed herein can be any commercially available material. For example, ELVANOL 71-30, an E. I. DuPont product. The polyvinyl alcohol coating solution is prepared by dissolving the polymer in hot water, cooling and mixing both with a suitable cross-linking agent and an acid catalyst. The
20 cross-linking agent can be a melamine- or urea-formaldehyde resin. Commercially available cross-linkers also would include PAREZ 613, a methylated melamine formaldehyde; CYMEL 373, a methylated melamine formaldehyde; CYMEL 401, a
25 trimethylol melamine urea formaldehyde; glyoxal, borax, etc. An acid catalyst, e.g., ammonium sulfate, ammonium chloride, sulfuric acid, nitric acid and ammonium nitrate will effectively catalyze these
30 systems.

Cross-linking is carried out to make the polyvinyl alcohol less moisture sensitive but it is essential that this does not occur before the coating weight is applied and evenly distributed. This is effected by
35 making up the aqueous solution so that the initial



concentration is too low for this to occur but, as drying occurs, the concentration increases and the rate of cross-linking is heightened.

5 Suitable concentrations have been found to be from
3 to 10, preferably from 4 to 8 wt% of the solution
being polymer plus cross-linking agent plus catalyst.
If the solids content is higher, the solution becomes
too viscous; if lower, good water resistance is not
obtained. From 10% to 30%, typically 15% cross-linking
10 agent is used with from 0.5% to 4.5%, typically 2% of
the acid catalyst. A preferred formulation comprises
the following solids content: 85.5 wt% polyvinyl
alcohol; 12.8 wt% methylated melamine formaldehyde; and
1.7 wt% ammonium chloride (NH_4Cl).

15 The aqueous polyvinyl alcohol solution was
prepared by dissolving sufficient ELVANOL 71-30 in hot
water to form an 8 wt% solution which was then cooled.
To this solution was added a 20 wt% aqueous melamine
formaldehyde solution and a 5 wt% aqueous ammonium
20 chloride solution to provide the preferred formulation
recited above.

By cross-linking the underlying layer of polyvinyl
alcohol, the moisture resistance of the polyvinyl
alcohol is dramatically improved. The over-lying blend
25 layer of polyvinyl alcohol and ethylene-acrylic acid
copolymer provides a surface that is excellently
printable and metallizable.

The final layer of the multilayer film structure
is made up of a blend of noncross-linked polyvinyl
30 alcohol homopolymer or copolymer and ethylene-acrylic
acid copolymer. The polyvinyl alcohol is the same
polyvinyl alcohol as described above. The ethylene
acrylic acid copolymer is produced by the high pressure
copolymerization of ethylene and acrylic acid. When
35 ethylene is copolymerized with acrylic acid, the



molecular structure is significantly altered by the random inclusion of bulky carboxylic acid groups along the back-bone and side chains of the copolymer. The carboxyl groups are free to form bonds and interact with any polar substrate. They can also hydrogen bond together to yield toughness. The carboxyl groups tend to inhibit crystallization which results in clarity, low melting and softening point for the film. The ethylene-acrylic acid copolymers consist essentially of about 96 mol% methylene groups, thus, their water resistance is understandably similar to that of polyethylene. The ammonium salts of the copolymers permit water dispersions of the material to be formed which facilitates ease of topical application to surfaces. These copolymers can be formed having melt indexes from 300 to 3,000. Commercially available examples of these copolymers are PRIMACOR 4983 (Dow Chemical Co.) an aqueous dispersion having 25% solids content and obtained from a reaction between approximately 15 mol% acrylic and a 5 mol% ethylene; and Michem 4983 available from Michaelman Corporation.

In preparing the blend of the polyvinyl alcohol homopolymer or copolymer and the ethylene-acrylic acid copolymer, the components can range from 1:2 to 2:1 by weight. In preparing a roughly 2:1 blend in an aqueous dispersion for example, 10 parts of Vinol 325 (a 98% hydrolyzed medium viscosity polyvinyl alcohol, obtained from Air Products) can be mixed with 90 parts by weight of Michem 4983 (an ethylene-acrylic acid copolymer obtained from Michaelman Corporation). The Michem 4983 has a solids content of about 25%. This combination, adjusted to an aqueous 5% solid solution will provide the polyvinyl alcohol to ethylene-acrylic acid copolymer mixture in a ratio of approximately 2:1.



A metal layer, for example one comprising aluminium, may be deposited on the intimate blend of layer (c).

The following Examples illustrate the invention.

5

EXAMPLE 1

A homopolymer polypropylene film with a biaxial orientation from 4 to 5 times MD and from 7 to 10 times TD was corona discharge treated to a wetting tension of about 42 dynes/cm. The treated film was precoated on both sides with 0.1 wt% poly(ethyleneimine), i.e. Polymin M, a product of BASF-Wyandotte Corp. The film was air-dried at a 100°C. This coating weight was too low to be measured but is calculated to be in the range of 0.001 grams per 1000 in². A commercially available acrylic heat seal layer is applied to one side. The opposite surface of the film structure was coated with a formulation comprising 85.5 wt% polyvinyl alcohol, 12.8 wt% methylated melamine formaldehyde and 1.7 wt% ammonium chloride. The solution was applied utilizing a reverse direct gravure coater and the coated film was passed through a dry-air oven at from 100-125°C. This produced a coating wt of 0.5 g/m². After allowing the polyvinyl alcohol 3 days to partially cross-link, the film was recoated with the polyvinyl alcohol/ethylene-acrylic acid copolymer mixture. The coating weight of this mixture was 0.05 g/msi. The following table shows oxygen transmission data and ink adhesion data.

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20

25

TABLE

	<u>Ink</u>	<u>Ink Pick-off</u>	<u>Oxygen Transmission</u>		
30	Solvent Based	0% ¹	100%RH	50%RH	0%RH
	Nulam Blue Ink		53.88 ²	0.108 ²	0.023 ²
	Water Based	0%			
	Aqualam P White				

Ink

35

¹ Used 610-3M tape

² cc/100in²/24hr

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The resulting film had high barrier properties having excellent printability.

EXAMPLE 2

5 An intimate blend of polypropylene (95 wt%) and maleated polypropylene (5 wt%) was prepared and formed into a cast layer of approximately 35 mls thick. This cast layer was then machine direction oriented to a thickness of about 1 ml thick. A coating of the above-identified poly(vinyl alcohol) was applied to one
10 surface each of a pair of the machine direction oriented polypropylene films. The poly(vinyl alcohol) coating contained 2.5 phr of ammonium chloride and 20 phr of Parex 613 maleine formaldehyde. The so-coated substrate films were mated together so that the
15 poly(vinyl alcohol) layers were in contact. This was accomplished by running the film through rollers at room temperature. The film traveled at approximately 50 fpm and was subjected to a pressure of 90 psi. Thereafter the film combination was heated to 160°C and
20 transverse direction oriented. The finished film had been machine direction oriented 7 times and transverse direction oriented 5 times.

The resulting laminated film strongly resisted delamination and was highly resistant to the
25 transmission of oxygen and water vapor during a 24 hr. period.

It is to be understood that instead of bringing together 2 separately formed coated machine direction oriented films a single poly(vinyl alcohol) coated film
30 can be folded on itself so that the poly(vinyl alcohol) faces are in contact and, after edge trimming, the film can be pressure laminated to itself, heated and transverse direction oriented before final windup for shipment to a converter.



It is to be understood that the outer surfaces of the completed lamination can have applied thereto any conventional coatings, such as, heat seal layers.

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**CLAIMS:**

1. A film combination comprising :
 - a) an oriented polymeric substrate which either i) comprises an intimate blend of polypropylene with maleic acid anhydride modified polypropylene or ii) is otherwise susceptible of transmitting oxygen and water vapor and has a primer coating on at least one surface;
 - b) a layer of cross-linked polyvinyl alcohol on i) the intimate blend or ii) the primer coating;
 - c) a layer of a polymer comprising vinyl alcohol residues which may be as defined in b) or an intimate blend of a homo- or copolymer of vinyl alcohol, with an ethylene acrylic acid copolymer; and, optionally,
 - d) a layer as defined in a)i).
2. A film combination according to claim 1 wherein the intimate blend of a)i) comprises from 92.5 to 98.5% by weight of polypropylene and from 1.5 to 7.5% by weight maleic acid anhydride modified polypropylene.
3. A film combination according to claim 1 wherein a)ii) comprises a homopolymer or copolymer of polypropylene.
4. A film combination according to any preceding claim wherein the oriented polymeric substrate has been treated to a surface free energy of at least about 35 dynes/cm.

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5. A film combination according to any preceding claim wherein the weight ratio of the intimate blend of (c) is from 2:1 to 1:2.
- 5 6. A film combination according to claim 5 wherein the intimate blend comprises polyvinyl alcohol and ethylene-acrylic acid copolymer.
7. A film combination according to any preceding claim having a metal layer deposited on the intimate blend of layer (c).
- 10 8. A film combination according to claim 7 wherein the metal comprises aluminum.
- 15 9. A film combination comprising a pair of films each comprising an oriented polymeric substrate comprising an intimate blend of polypropylene and a maleic acid anhydride modified polypropylene on which a coating of polyvinyl alcohol containing a cross-linking agent has been applied to a surface thereof while the pair of films have been monoaxially oriented in the machine direction, the
- 20 pair of films having been positioned with the polyvinyl alcohol layers in intimate contacting relationship while contacting films have been oriented in the transverse direction.
- 25 10. A film combination of claim 9 wherein the positioning is accompanied by a mating force of 30-130 psi.
11. A film combination according to any preceding claim which is oriented from 2 to 7 times MD and from 3 to 8 times TD.

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