



(86) Date de dépôt PCT/PCT Filing Date: 2008/02/01

(87) Date publication PCT/PCT Publication Date: 2008/11/27

(85) Entrée phase nationale/National Entry: 2009/06/17

(86) N° demande PCT/PCT Application No.: US 2008/001351

(87) N° publication PCT/PCT Publication No.: 2008/143719

(30) Priorités/Priorities: 2007/02/16 (US60/901,982);
2008/01/30 (US12/011,962)

(51) Cl.Int./Int.Cl. *B32B 27/00* (2006.01)

(71) Demandeur/Applicant:
MADICO, INC., US

(72) Inventeurs/Inventors:
TEMCHENKO, MARINA, US;
AVISON, DAVID WILLIAM, US;
MANNARINO, FRANK ANTHONY, US;
LIM, SAMUEL, US

(74) Agent: OGILVY RENAULT LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : FEUILLE SUPPORT POUR MODULES PHOTOVOLTAIQUES ET SON PROCEDE DE REPARATION

(54) Title: BACKING SHEET FOR PHOTOVOLTAIC MODULES AND METHOD FOR REPAIRING SAME

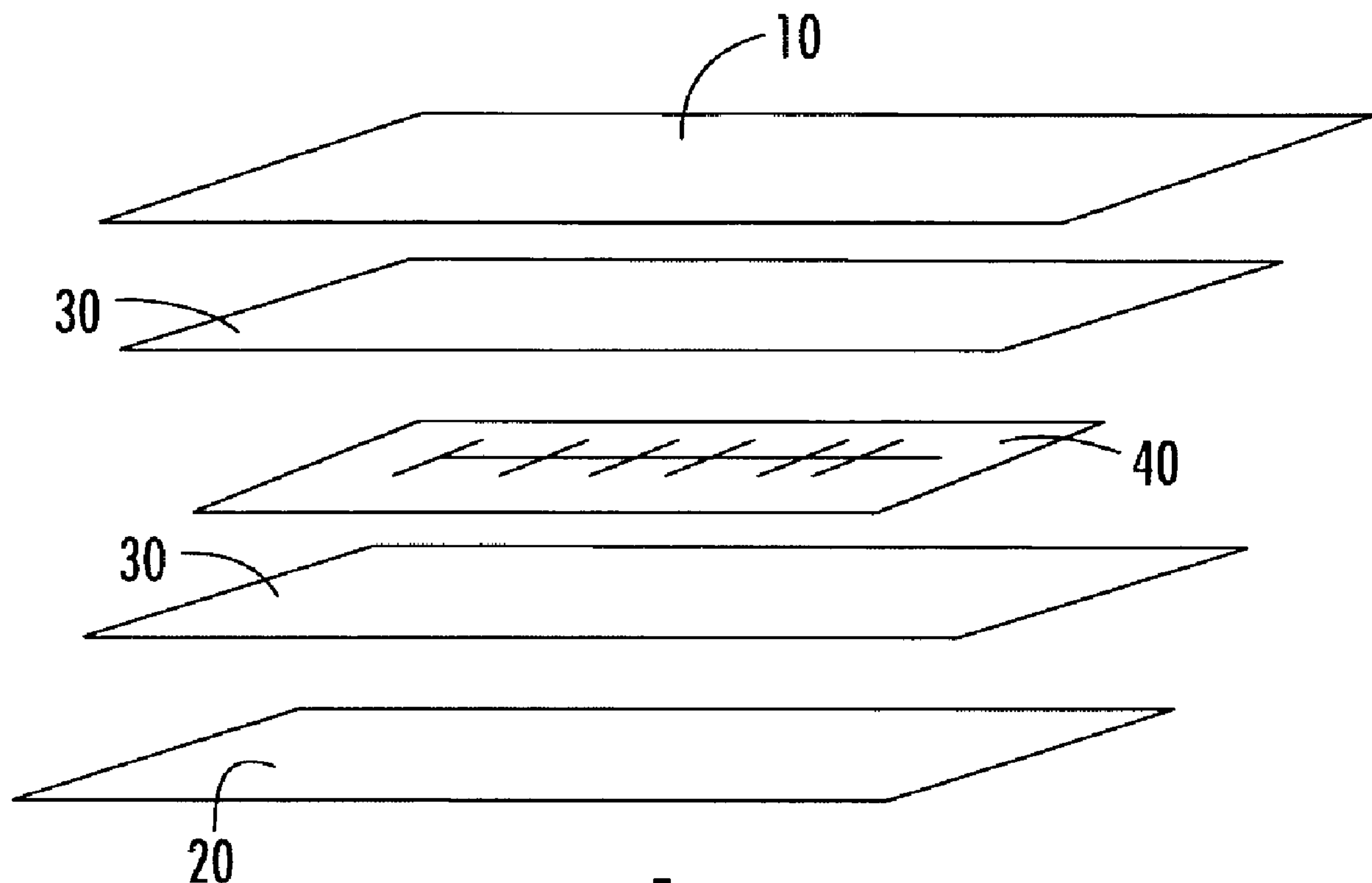


FIG. 1

(57) Abrégé/Abstract:

The present invention provides a protective backing sheet for photovoltaic modules. The backing sheets of the current invention possess excellent weather resistance, heat resistance, color retention, adhesion between layers and encapsulant, and scratch

(57) **Abrégé(suite)/Abstract(continued):**

resistance. The backing sheet can minimize the deterioration in the performance of the solar module due to moisture permeation. It also can achieve desirable photoelectric conversion efficiency over a long period of time. Additionally the described backing sheet, or alternately referred to backskin, can be made in an aesthetically pleasing form.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 November 2008 (27.11.2008)

PCT

(10) International Publication Number
WO 2008/143719 A3

(51) International Patent Classification:

B32B 27/00 (2006.01) **B32B 5/16** (2006.01)

(21) International Application Number:

PCT/US2008/001351

(22) International Filing Date: 1 February 2008 (01.02.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/901,982 16 February 2007 (16.02.2007) US

12/011,962 30 January 2008 (30.01.2008) US

(71) Applicant (for all designated States except US):

MADICO, INC. [US/US]; 64 Industrial Way, Woburn, MA 01888 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **TEMCHENKO,**

Marina [US/US]; 15 Sherwood Road, Swampscott, MA 01907 (US).

AVISON, David, William [US/US]; 17 Pheasant Ridge Road, Townsend, MA 01469 (US).

MANNARINO, Frank, Anthony [US/US]; 8 Amelia Way, Medway, MA 02503 (US).

LIM, Samuel [US/US]; 47 Harwood Street, Lynn, MA 01902 (US).

(74) Agent: **CASIERI, Christopher, S.**; Norris McLaughlin &

Marcus, P.a., 721 Route 202-206, P.o. Box 5933, Bridgewater, NJ 08807-5933 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available):

AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available):

ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: BACKING SHEET FOR PHOTOVOLTAIC AND METHOD FOR REPAIRING SAME

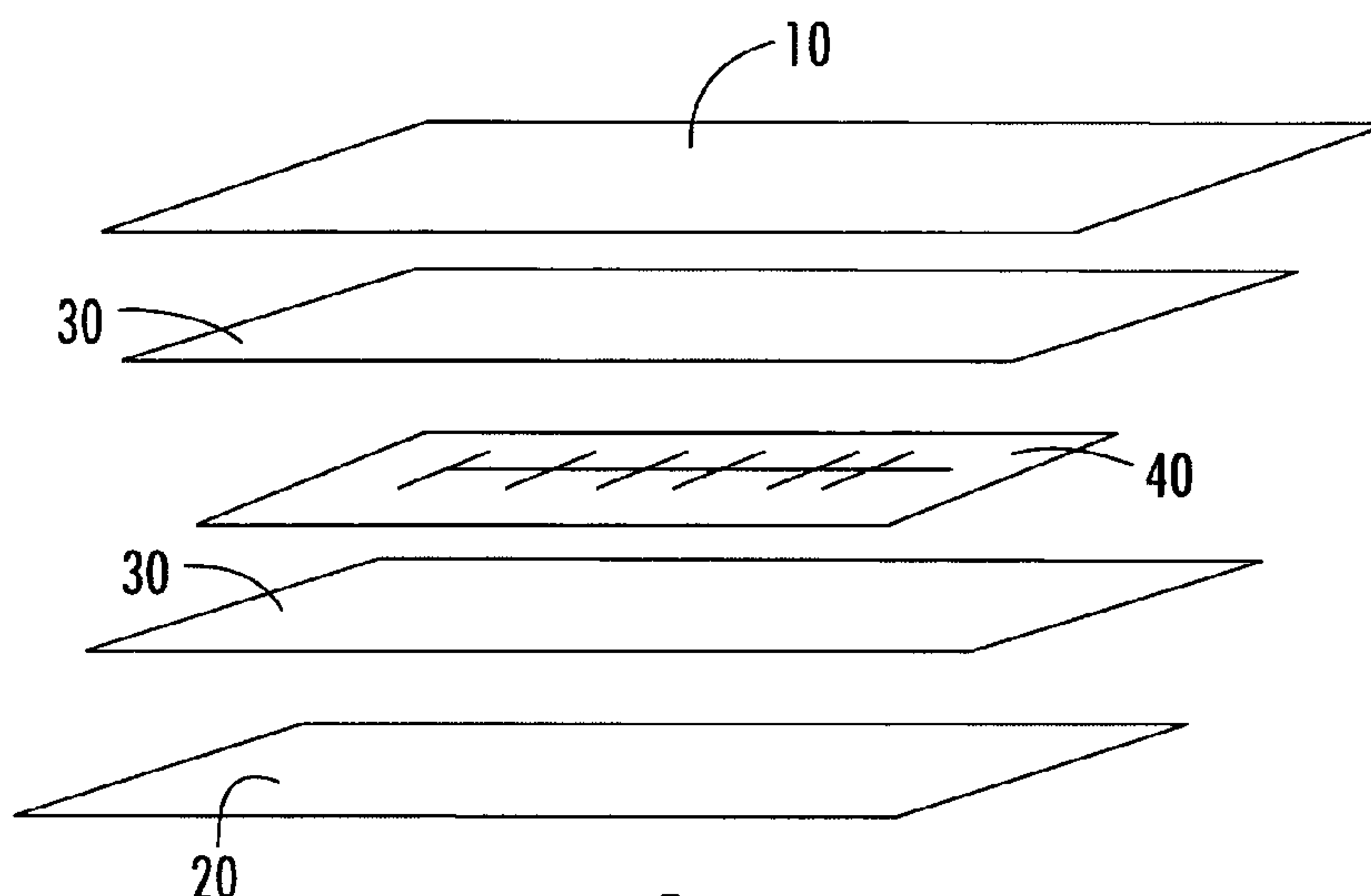


FIG. 1

(57) Abstract: The present invention provides a protective backing sheet for photovoltaic modules. The backing sheets of the current invention possess excellent weather resistance, heat resistance, color retention, adhesion between layers and encapsulant, and scratch resistance. The backing sheet can minimize the deterioration in the performance of the solar module due to moisture permeation. It also can achieve desirable photoelectric conversion efficiency over a long period of time. Additionally the described backing sheet, or alternately referred to backskin, can be made in an aesthetically pleasing form.

WO 2008/143719 A3



Published:

— *with international search report*

(88) Date of publication of the international search report:

26 February 2009

BACKING SHEET FOR PHOTOVOLTAIC MODULES AND METHOD FOR REPAIRING SAME

Background of the Invention

Field of the Invention

[0001] The present invention relates to photovoltaic modules. More specifically the present invention related to the protective backing sheets.

Description of Related Art

[0002] Solar energy utilized by photovoltaic modules is among the most promising alternatives to the fossil fuel that is being exhausted this century. However, production and installation of the photovoltaic modules remains an expensive process. Typical photovoltaic modules consist of glass or flexible transparent front sheet, solar cells, encapsulant, protective backing sheet, a protective seal which covers the edges of the module, and a perimeter frame made of aluminum which covers the seal. As illustrated in Figure 1, a front sheet 10, backing sheet 20 and encapsulant 30 and 30' are designed to protect array of cells 40 from weather agents, humidity, mechanical loads and impacts. Also, they provide electrical isolation for people's safety and loss of current. Protective backing sheets 20 are intended to improve the lifecycle and efficiency of the photovoltaic modules, thus reducing the cost per watt of the photovoltaic electricity. While the front sheet 10 and encapsulant 30 and 30' must be transparent for high light transmission, the backing sheet must have high opacity for aesthetical purposes and high reflectivity for functional purposes. Light and thin solar cell modules are desirable for a number of reasons including weight reduction, especially for architectural (building integrated PV) and space applications, as well as military applications (incorporated into the soldier outfit, etc). Additionally light and thin modules contribute to cost reduction. Also reduction in quantity of consumed materials makes the technology "greener", thus saving more natural resources.

[0003] One means to manufacture light and thin solar cells is to incorporate light and thin backing sheets. The backside covering material however, must also have some moisture resistance to prevent permeation of moisture vapor and water, which can cause rusting in underlying parts such as the photovoltaic element, wire, and electrodes, and damage solar cells. In addition, backing sheets should provide electric isolation,

mechanical protection, some UV stability, adherence to the encapsulant and ability to attach output leads.

[0004] Currently used protective backing sheets are typically laminates. Figure 2 provides an illustration of a typical laminate backing sheet 20. The laminate consists of films of polyvinylfluorides 22, which is most commonly Tedlar[®], polyesters (PET) 24, and copolymers of ethylene vinyl acetate (EVA) 26 as key components. The EVA layer 26 bonds with the encapsulant layer 30 in the module and serves as a dielectric layer and has good moisture barrier properties. It is dimensionally stable. White EVA allows significant power boost. The polyester layer 24 is very tough, has excellent dielectric properties, is dimensionally stable, and also has good moisture barrier properties. The polyvinylfluoride layer 22 serves as a very weatherable layer.

[0005] Even though these films have met performance standards in the required tests and during actual use, they exhibit certain limitations such as high cost and limited availability of the Tedlar[®] films. Another drawback of prior art materials such as PVF (Tedlar[®]), ECTFE (Halar[®]) and other fluoropolymers, is that such materials cannot be processed at ambient or moderately elevated temperatures. For example, PVF film is produced by a casting process from dispersion, using high boiling solvents (usually dimethyl acetamide for oriented Tedlar[®] and propylene carbonate for Tedlar[®] SP). The boiling point of dimethyl acetamide is 164-166°C and the boiling point of propylene carbonate is 200°C. The dispersion must be processed at 160°C and 90% of solvent content or greater to ensure adequate film formation. Higher temperatures are unacceptable due to PVF resin thermal instability: its fusion and decomposition temperatures are so close, that PVF can decompose during the baking. As a result, there is always a residual solvent in Tedlar[®] film. DuPont reports that residual amounts of dimethyl acetamide (DMAC) ranging from 0.05 to 1.0 wt% will be present in all oriented Tedlar[®] PVF films.

[0006] Alternatively, ECTFE (Halar[®]) films are produced by melt extrusion at 350°C-375°C. As a result, they cannot be easily compounded with pigments, clays, etc. and are also expensive.

[0007] U.S. Pat. No. 5,741,370 suggests that manufacturing and module mounting costs could be reduced by using, as the backskin material, a thermoplastic olefin comprising a combination of two different ionomers, e.g., a sodium ionomer and a zinc ionomer, with that combination being described as producing a synergistic effect which

improves the water vapor barrier property of the backskin material over and above the barrier property of either of the individual ionomer components. Also, the patent discloses use of an ionomer encapsulant with the dual ionomer backskin.

[0008] However, National Renewable Energy Laboratory (NREL) reports that ionomer resins contain free and bound methacrylic acid, which requires using stainless steel tooling during melt processing, thus increasing the manufacturing costs. PVMaT Improvements in the Solarex Photovoltaic Module Manufacturing Technology Annual Subcontract Report May 5, 1998 - April 30, 1999, National Renewable Energy Laboratory, January 2000 • NREL/SR-520-27643.

Summary of the Invention

[0009] The present invention provides a protective backing sheet for photovoltaic modules. The backing sheets of the current invention possess excellent weather resistance, heat resistance, color retention, adhesion between layers and encapsulant, and scratch resistance. The backing sheet can minimize the deterioration in the performance of the solar module due to moisture permeation. It also can achieve desirable photoelectric conversion efficiency over a long period of time. Additionally the described backing sheet, or alternately referred to backskin, can be made in an aesthetically pleasing form.

[0010] The backing sheets of the present invention are produced by utilizing liquid coatings application technology, followed by lamination with EVA, and can be tailored according to the application requirements. Furthermore, advantages of solar cell modules utilizing the described backskin material include a significant reduction in manufacturing costs.

[0011] The liquid coatings formulations used in the backskins overcome one or more of the deficiencies of the prior art backskins. The backskin can be made thinner than currently available backskins. The backing materials include more readily available materials which can be processed at ambient or moderately elevated temperatures. These liquid coatings can be applied directly on the second layer of laminate, thus eliminating the need for an adhesive. Additionally, they can be easily compounded with additives such as pigments, clays, etc.

[0012] In one aspect, a backing sheet for a photovoltaic module is described having a layer comprising an organic solvent soluble, crosslinkable amorphous fluoropolymers. The fluoropolymer may be a fluorocopolymer of chlorotrifluoroethylene

(CTFE) and one or more alkyl vinyl ethers, including alkyl vinyl ethers with reactive OH functionality. The backing sheet can include a crosslinking agent mixed with the fluorocopolymer.

[0013] The backing sheet may also include additional layers, such as a polyester layer. For another example, the backing sheet of may also include an EVA layer. Other optional additional layers may include one or of coextruded polyester with EVA, polycarbonate, polyolefin, polyurethane, liquid crystal polymer, aclar, aluminum, of sputtered aluminum oxide polyester, sputtered silicon oxide or silicon nitride polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon oxide or silicon nitride polycarbonate

[0014] The fluorocopolymer layer of the backing sheet can be applied to the polyester layer, or other type of layer with or without an adhesive. Also, it can be applied as a single layer or multiple layers. In one embodiment, the fluorocopolymer layer has a thickness of less than 1mil. In another aspect, the fluorocopolymer has a layer that is greater than 1mil. In another embodiment, the backing sheet includes silica.

[0015] In another aspect of the invention, a backing sheet for a photovoltaic module is described. The backing sheet has a layer comprising a copolymer of tetrafluoroethylene (TFE) and hydrocarbon olefins with reactive OH functionality. The backing sheet may further include a crosslinking agent mixed with the fluorocopolymer. In one embodiment the fluorocopolymer layer has a thickness of less than 1mil. In another embodiment, the fluorocopolymer layer has a thickness of greater than 1mil. In another embodiment, the backing sheet also has an ionomer layer.

[0016] The fluorocopolymer may be or include a terpolymer of one or more fluoromonomers. In one embodiment the terpolymer comprises vinylidene fluoride, tetrafluoroethylene, and hexafluoropropylene.

[0017] Again, the backing sheet may also include additional layers, such as a polyester layer. The fluorocopolymer layer may be applied to the polyester layer with or without adhesive. The fluorocopolymer layer may be applied as a single layer or as a combination of clear and pigmented multiple layers. The polyester film can be additionally corona or chemically treated to improve adhesion. The backing sheet of may also include an EVA layer. In another embodiment the backing sheet contains silica. Other optional additional layers may include one or of polycarbonate, coextruded polyester with EVA, polyolefin, polyurethane, liquid crystal polymer, aclar, aluminum, of

sputtered aluminum oxide polyester, sputtered silicon oxide or silicon nitride polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon oxide or silicon nitride polycarbonate, sputtered aluminum oxide Lumiflon[®], sputtered aluminum oxide Zeffle[®], sputtered silicon oxide or silicon nitride Lumiflon, sputtered silicon oxide or silicon nitride Zeffle[®].

[0018] In another aspect, a method of repairing the backing sheet of a photovoltaic module is provided. The method includes the step of applying a formulation comprising an amorphous fluorocopolymer of chlorotrifluoroethylene (CTFE) with one or more alkyl vinyl ethers, including alkyl vinyl ethers with reactive OH functionality to an area on the backing sheet in need of repair. In one embodiment the formulation is applied to the backing sheet at ambient temperature or moderately elevated temperature. In another embodiment, the formulation is comprised of a first and second component that are placed in a twin-chamber syringe equipped with static mixer and applied through an applicator attached to the syringe.

[0019] In one embodiment the first component of the formulation is comprised of a mixture of a crosslinker and a solvent, and the second component is comprised of a mixture of a solvent and a fluorocopolymer.

Brief Description of the Drawings

[0020] For a better understanding of the present invention, reference may be made to the accompanying drawings.

[0021] FIG. 1 represents an expanded view of the components of a typical photovoltaic module.

[0022] FIG. 2 represents one embodiment of the typical backing sheet.

[0023] FIG. 3 is a graph showing tensile strength as a function of exposure to "Damp Heat" for Lumiflon-based back sheet as compared to Tedlar-based back sheet.

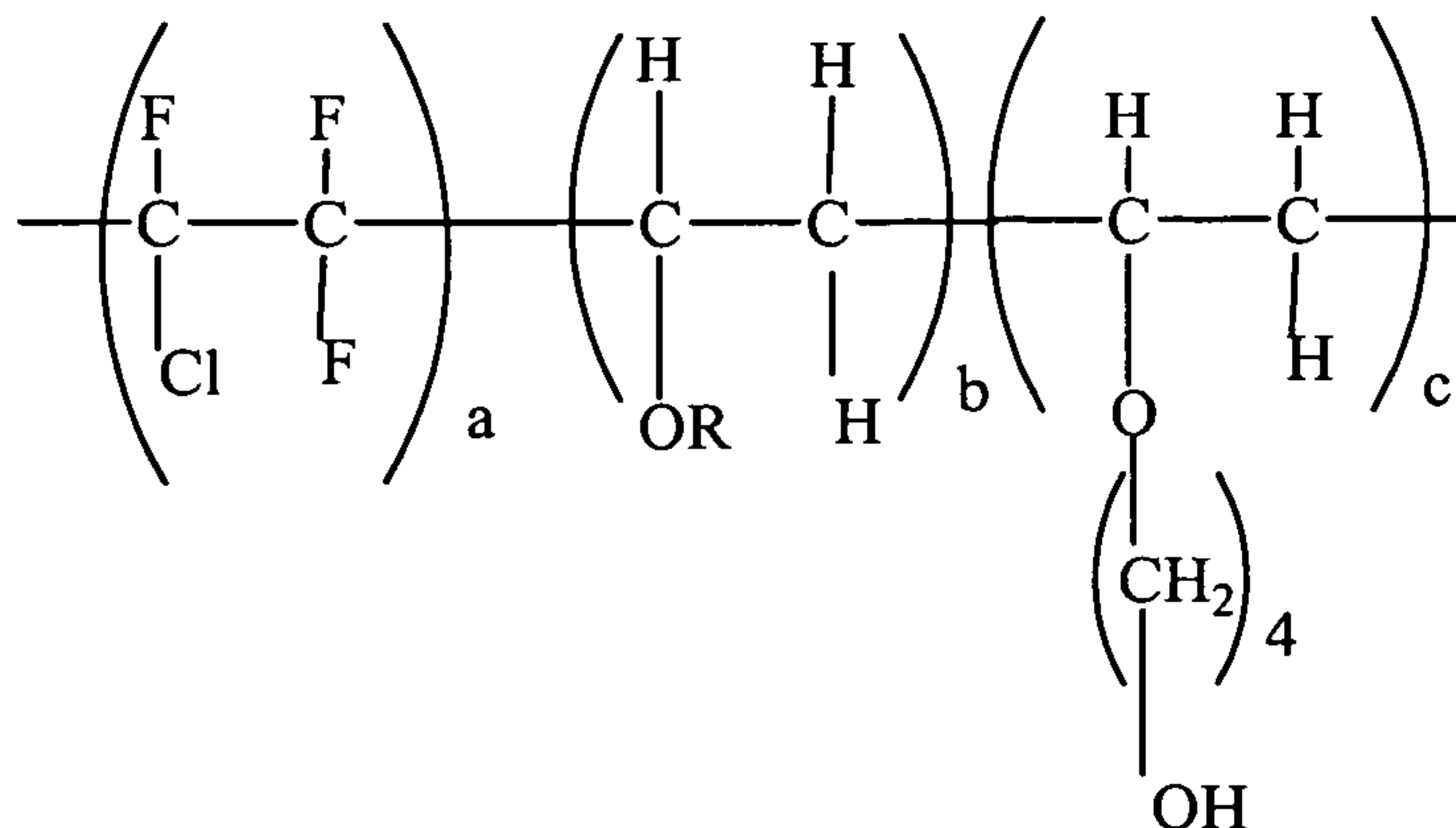
[0024] FIG. 4 is a graph showing elongation at break as a function of exposure to "Damp Heat" for Lumiflon-based back sheet as compared to Tedlar-based back sheet.

[0025] FIG. 5 is a graph showing UV stability of Lumiflon-based back sheet as compared to Tedlar-based back sheet.

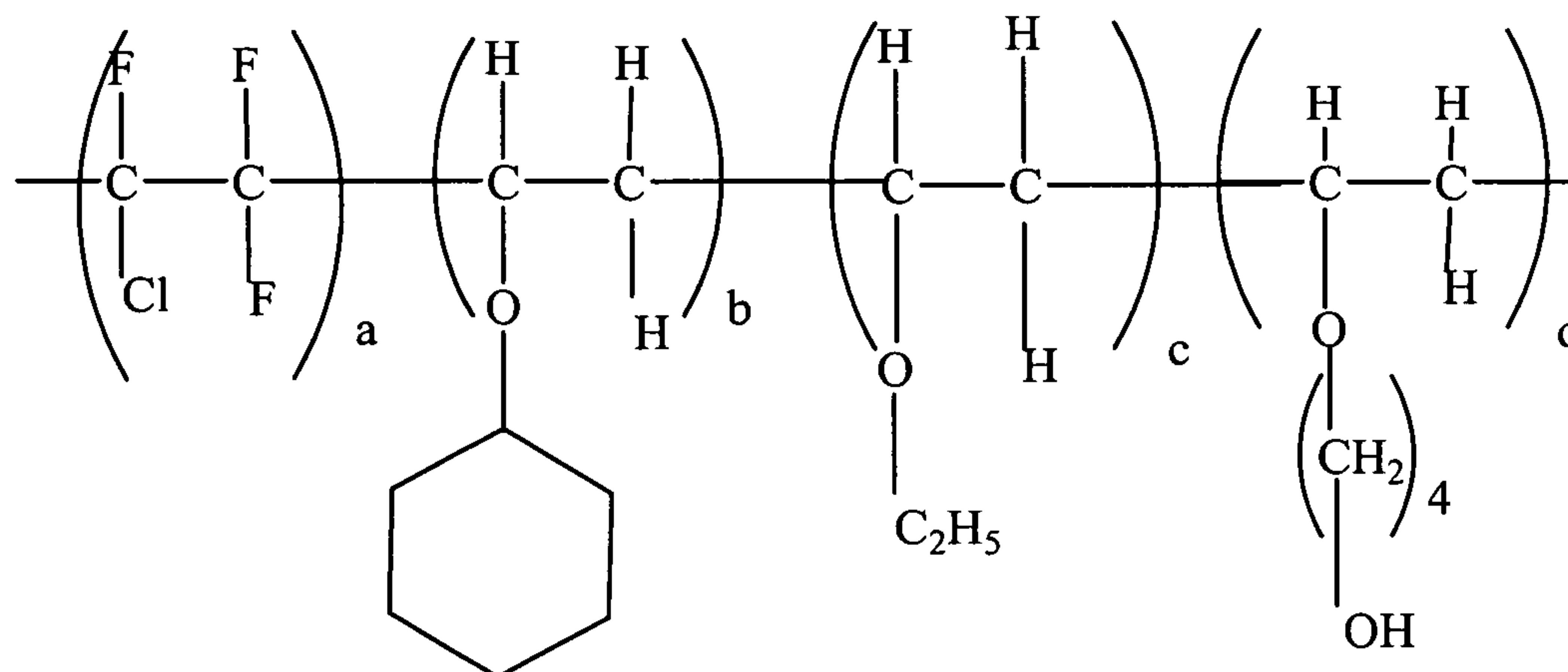
[0026] FIG. 6 illustrates an example of an applicator used with the patch kit.

Detailed Description

[0027] The present invention provides a protective backing sheet for photovoltaic modules. In one embodiment, the backing sheets are produced by utilizing liquid

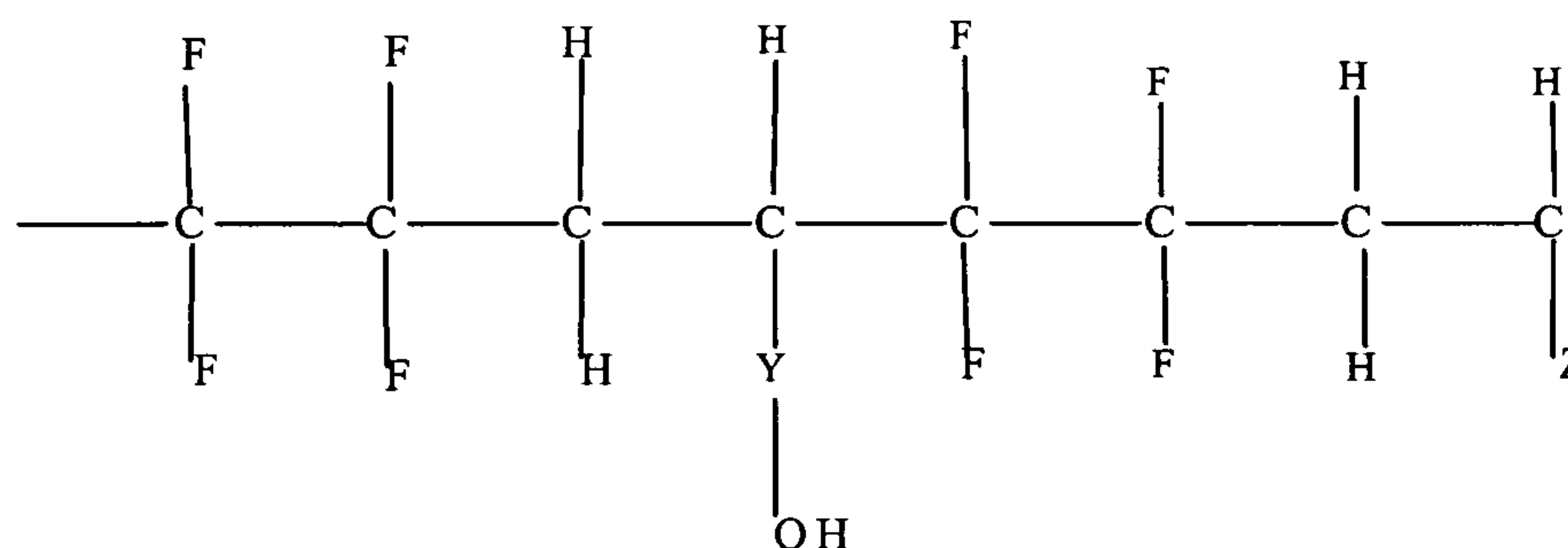


[0032]



[0033]

[0034] and



[0035]

[0036] Fluoropolymers that can be utilized in the liquid formulations include, but is not limited to, Lumiflon[®] (Asahi Glass) and Zeffle[®] (Daikin). Other materials include FluoroPel[™] and FluoroThane[™] (Cytonix Corporation), FluoroLink[™] Polymer Modifiers (Solvay Solexis). Additional components in the liquid coating formulations include crosslinking agents, catalysts, solvents, and optionally, fillers and inorganic materials such as boron nitride (Zyp Coatings).

[0037] One particularly preferred fluoropolymer is Lumiflon[®], developed by Asahi Glass in 1982. Lumiflon[®] is an amorphous fluorocopolymer of chlorotrifluoroethylene (CTFE) with several specific alkyl vinyl ethers (VE).

[0038] A combination of the alkyl vinyl ether monomers and hydroxyl groups provides the polymer with significant properties, such as solubility, compatibility to pigment, crosslinking reactivity, adhesiveness to the substrate, hardness and flexibility.

[0039] Another preferred fluoropolymer is Zeffle[®] resins (Daikin), which are copolymers of tetrafluoroethylene (TFE) and hydrocarbon olefins that are organic solvent soluble. More particularly, Zeffle[®] is a solvent-based, copolymer of tetrafluoroethylene and hydrocarbon olefins with reactive OH functionality formulated for use as a base resin in high performance paints and coatings.

[0040] In another embodiment, the fluoropolymer is a terpolymer. The terpolymer may contain one or more different fluoromonomers. For one example, the terpolymer contains vinylidene fluoride, tetrafluoroethylene, and hexafluoropropylene. Dyneon™ THV is one such terpolymer and provides a combination of performance advantages, such as low processing temperature, ability to bond to elastomers and hydrocarbon-based plastics, flexibility and optical clarity. As a clear film it can be used as a front sheet to replace glass. The addition of pigment provides a film that can be used as a backing sheet for a photovoltaic module.

[0041] Organic solvents which may be used in this invention for the formation of the liquid coating formulations include but are not limited to organic solvents such as methyl ethyl ketone (MEK), acetone, methyl isobutyl ketone (MIBK), toluene, xylene, methanol, isopropanol, ethanol, heptane, ethyl acetate, isopropyl acetate, n-butyl acetate, n-butyl alcohol or mixtures thereof. Preferred solvents include xylene, cyclohexanone and methyl ethyl ketone (MEK). The appropriate solvent is one in which all components dissolve and one in which the boiling point is low enough to minimize or remove the presence of residual solvent in the coating.

[0042] Optional pigments and fillers which may be used in this invention for the formation of the protective coatings include but are not limited to titanium dioxide, carbon black, Perylene pigments, pigments, dyes, mica, polyamide powders, boron nitride, zinc oxide, aluminum oxide, silica, UV absorbers, corrosion inhibitors, and desiccants. One preferred pigment is titanium dioxide Ti-Pure® R-105(DuPont). One preferred hydrophobically modified silica is Cab-o-sil TS 720 (Cabot). Pigments, UV absorbers and corrosion inhibitors function to impart opacity and weatherability. Orgasol® Ultrafine is a preferred polyamide powders (Arkema Inc) and can be included for gloss reduction. Carbon black, pigments and dyes can be included to alter the color of the backing sheet. Mica can be included to impart flame retardancy. Boron nitride, aluminum nitride, and/or aluminum oxide can be included to improve thermal conductivity. Cloisite® Nanoclays (Southern Clay Products), 3M™ Glass Bubbles and desiccants are preferably included to improve moisture barrier properties. Silica and/or boron nitride can be included to improve dielectric properties. Silica may also be included to reduce gloss and to impart flame retardancy

[0043] Crosslinking agents are preferably used in the formation of the protective coatings include to obtain organic solvent insoluble, tack-free film. Preferred

crosslinking agents include but are not limited to DuPont Tyzor[®] organic titanates, silanes, isocyanates, and melamine. Aliphatic isocyanates are preferred to ensure weatherability as these films are typically intended for over 30 years use outdoor.

[0044] For one example, liquid formulations for Lumiflon[®]-based coatings compositions can be prepared by mixing a Lumiflon[®] solution, pigment, crosslinker and a catalyst. Tin dibutyl dilaureate, is used to accelerate the crosslinking reaction between Lumiflon (polyol) and isocyanate in an organic solvent. Such compositions are prepared by mixing preferably 3 to 80, and even more preferably around 46 parts by weight of Lumiflon[®] solution, 5 to 60 (more preferably around 17) parts by weight of pigment, and 20 to 80 (more preferably around 32) parts by weight of organic solvent (a mixture of MEK and xylene or cyclohexanone).

[0045] The backing sheet may also include additional layers. The additional layers may be applied to the fluorocopolymer layer with or without adhesive. The optional additional layers may include, for example, one or of polyester, EVA, polycarbonate, polyolefins, polyurethanes, acrylics, polyimides, polyamides, liquid crystal polymer, aclar, aluminum, of sputtered aluminum oxide polyester, sputtered silicon oxide or silicon nitride polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon oxide or silicon nitride polycarbonate, clear fluoropolymers and clear fluorocopolymers, coextruded layer of a polymers such as polyester and EVA, and polybutadiene.

[0046] **Example 1.**

[0047] Example 1 illustrates the preparation of a Lumiflon[®]-based protective backing sheet according to the present invention. Lumiflon[®] used in this example is LF 200 grade, obtained from Asahi Glass as a 60% solution in xylene (200g). Pigment used in this example is Ti-Pure[®] R-105, obtained from DuPont (76.2g). The crosslinker is Desmodur[®] N3300, obtained from Bayer (21.4g). The pigment is mixed with Lumiflon[®] solution using high shear mixer, followed by solvent and the crosslinker addition.

[0048] The formulation is then applied. The liquid formulation is transferred from the pan to the film by applicator roll and metered off by Mayer Rod to obtain the desired coating weight. The coating is applied directly on a Mylar[®] (DuPont) (5mil) polyester film. No adhesive is required and in this example none is used. The coating is applied at a coating weight of 10 – 120 g/m², preferably 30-90 g/m², and more preferably 30 -45 g/m².

[0049] The dry coating consists of 60-65% by weight of Lumiflon® and 35% by weight of pigment. In this example, the polyester film coated with Lumiflon®-based formulation is laminated with EVA (vinyl acetate content 4%) using polyester-urethane laminating adhesive. The laminate is then vacuum laminated with an EVA encapsulant and module.

[0050] Table 1 show the properties of Lumiflon® and Zeffle® based protective backing sheets as compared to a backing sheet prepared with Tedlar® SP.

[0051] Table 1

Sample	Thickness μm	Thickness of outer layer μm	Water Vapor Transmission Test	g/(100in ² · day) 100F 100% RH	Partial Discharge Test	Voltage max, VDC
Tedlar® SP /Polyester/EVA	178	25.4	ASTM F1249	0.195	IEC 60994-1, IEC 61730	820
Lumiflon®/ Polyester/EVA	165	12.7	ASTM F1249	0.174	IEC 60994-1, IEC 61730	860
Zeffle®/Polyester /EVA	165	12.7	ASTM F1249	0.143	IEC 60994-1, IEC 61730	860

[0052] Table 2 show the properties of Lumiflon® based protective backing sheets as compared to a backing sheet prepared with oriented Tedlar®.

[0053] Table 2

Sample	Thickness μm	Thickness of outer layer μm	Water Vapor Transmission Test	g/(100in ² · day) 100F 100% RH	Partial Discharge Test	Voltage max, VDC
Tedlar® /Polyester/EVA	267	38	ASTM F1249	0.12	IEC 60994-1, IEC 61730	1020
Lumiflon®/ Polyester/EVA	241	13	ASTM F1249	0.12	IEC 60994-1, IEC 61730	1015

[0054] The results illustrate that Lumiflon® and Zeffle®-based coatings at a 0.5mil thickness demonstrate superior barrier properties (lower moisture permeability and higher voltage resistance) than non-oriented Tedlar® SP at a thickness of 1mil, which is twice the thickness of the Lumiflon® and Zeffle® layers. Additionally, the Lumiflon® based backing sheets are more cost-effective than the Tedlar® based backing sheets.

[0055] Table 3 illustrates the weatherability of Lumiflon® based protective backing sheets as compared to a backing sheet prepared with oriented Tedlar®. Samples were placed into an environmental chamber at conditions of 85°C and 85% Relative Humidity ("Damp Heat") for 2000 hrs. The weatherability of the outer layer was estimated by measuring adhesion between outer layer and polyester, tensile strength and elongation at break as a function of exposure to "Damp Heat" according to ASTM D 903-98 peel adhesion test, ASTM D 3359 cross cut tape adhesion test, and ASTM D882. The following abbreviations in Table 3 apply: TB is tear bond; 5B = 0% of coating removed; 4B = less than 5% of coating removed; 3B = 5-15 % of coating removed; 2B = 15-35% of coating removed; 1B = 35-65% of coating removed; and 0B = greater than 65% of coating removed.

[0056] Table 3

OUTER LAYER	HOURS			
	500	1000	1500	2000
Tedlar® 38 µm	TB	TB	TB	TB
Lumiflon® 13 µm	5B	5B	5B	4B

[0057] As illustrated in Table 3, the weatherability of thin Lumiflon®-based back sheet is comparable to one of oriented Tedlar®-based back sheet.

[0058] Figures 3 and 4 show that the tensile strength and elongation at break of Lumiflon®-based back sheet depreciates much less than those of Tedlar®-based back sheet as a function of exposure to "Damp Heat".

[0059] To evaluate UV stability, samples were placed into the Atlas ci 4000 Xenon Weather-Ometer, equipped with Xenon Arc Lamp for duration of 4600 hrs, measuring $L^*a^*b^*$ regularly. b^* -value represents "yellowing" of the material. As is represented in Figure 5, UV stability of Lumiflon®-based back sheet is comparable to Tedlar®-based back sheet.

[0060] Example 2

[0061] Example 2 illustrates the preparation of an alternate embodiment of a Lumiflon[®]-based protective backing sheet according to the present invention. Lumiflon[®] used in Example 2 is LF 200 grade, obtained from Asahi Glass as a 60% solution in xylene (150g). Pigment used in this example is Ti-Pure[®] R-105, obtained from DuPont (57g). Hydrophobically modified silica used in this example is Cab-o-sil TS-720 (10g) obtained from Cabot. The crosslinker used is Desmodur[®] N3300, obtained from Bayer (16 g). The catalyst used in this example is dibutyl tin dilaureate (0.15 g of 0.1% solution in MEK) obtained from Aldrich. The pigment and silica are mixed with Lumiflon[®] solution using high shear mixer, followed by solvent, crosslinker and catalyst addition.

[0062] The formulation is then applied. The liquid formulation is transferred from the pan to the film by applicator roll and metered off by Mayer Rod to obtain the desired coating weight. The coating is applied directly on a Mylar[®] (DuPont) (5mil) polyester film. No adhesive is required and in this example none is used. The coating is applied at a coating weight of 10 – 120 g/m², preferably 30-90 g/m², and more preferably 30 -45 g/m².

[0063] Table 4.

Sample	Thickness μm	Thickness of outer layer μm	Water Vapor Transmission Test	g/(100in ² · day) 100F 100% RH	Partial Discharge Test	Voltage max, VDC
Lumiflon [®] /Polyester/EVA	241	13	ASTM F1249	0.12	IEC 60994-1, IEC 61730	1015
Lumiflon [®] /silica/ Polyester/EVA	241	13	ASTM F1249	0.12	IEC 60994-1, IEC 61730	1060

[0064] As illustrated in Table 4, Example 2, which includes the addition of silica, results in 45 V (max permissible voltage) increase over the Lumiflon[®] based back sheet without silica, and in 40V increase over Tedlar[®] based back sheet.

[0065] Example 3

[0066] Example 3 illustrates the preparation of another embodiment of the present invention; a Lumiflon[®]-based "patch kit" formulation.

[0067] The Lumiflon based patch kit formulation is preferably prepared from a formulation comprising 2 separate components: A and B.

[0068] Component A comprises of a mixture of a crosslinker (Isocyanate Desmodur N3300 (2.5g, Bayer)) and a solvent (in this Example, xylene).

[0069] Component B is comprised of a mixture of a solvent, pigment and a fluorocopolymer. In this Example Component B is prepared as follows. A dispersing agent (Disperbyk 111 (0.25g, BYK- Chemie)) is mixed with xylene, 14.1 g of Lumiflon[®] LF 200, pigment Ti-Pure[®] R101 (10g, DuPont), Orgasol[®] 2002D (4.7 g, Arkema Inc) and a mixture of coloring agents (Microlith Blue, Microlith Yellow, Microlith Brown and Orasol Black). Different coloring agents can be added to match the color of the torn backing sheet.

[0070] In use, components A and B are placed into a twin-chamber syringe equipped with static mixer. The formulation is applied over damaged piece of backing sheet by using an applicator. One such applicator is available from Brandywine Associates and is illustrated in Figure 6 where 50 is the mixer, 52 is an applicator tip, and 54 is the applied patch kit formulation. However, any type of applicator, such as a brush, may be used to apply the formulation.

[0071] The patch kit is compatible with many backing sheets, such as those prepared of prior art materials such as Tedlar[®]/Polyester/EVA or backing sheet made in accordance with the present invention. The applied formulation to a Tedlar based backing sheet was subjected to partial discharge test. The results of this test are summarized in Table 5.

[0072] **Table 5. Results of Partial Discharge Test**

Laminate	Thickness mil	Outer layer thickness mil	Partial Discharge Test	Voltage max, VDC
Tedlar [®] /Polyester/EVA	10.5	1.5	IEC 60994-1, IEC 61730	1020
Tedlar [®] /Polyester/EVA patched	10.5	1.5	IEC 60994-1, IEC 61730	1020

[0073] Additionally, this formulation demonstrated excellent adhesion to underlying layers of the backing sheet material, namely, 5B, by cross-cut tape test ASTM D 3359-97.

[0074] There will be various modifications, adjustments, and applications of the disclosed invention that will be apparent to those of skill in the art, and the present

application is intended to cover such embodiments. Although the present invention has been described in the context of certain preferred embodiments, it is intended that the full scope of these be measured by reference to the scope of the following claims.

[0075] The disclosures of various publications, patents and patent applications that are cited herein are incorporated by reference in their entireties.

What is claimed is:

1. A backing sheet for a photovoltaic module comprising:
a layer comprising an organic solvent soluble and/or water dispersible, crosslinkable amorphous fluoropolymers.
2. The backing sheet of claim 1 where the fluoropolymer is a fluorocopolymer of chlorotrifluoroethylene (CTFE) and one or more alkyl vinyl ethers.
3. The backing sheet of claim 2 further comprising a crosslinking agent mixed with the fluorocopolymer.
4. The backing sheet of claim 3 further comprising a layer comprising one or more of polyester, polycarbonate, polyolefin, polyurethane, a liquid crystal polymer, acrylic, aluminum, sputtered aluminum oxide polyester, sputtered silicon dioxide polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon dioxide polycarbonate.
5. The backing sheet of claim 4 wherein the layer comprising the crosslinking agent mixed with the fluorocopolymer is applied to the polyester layer without adhesive.
6. The backing sheet of claim 5 further comprising an EVA layer.
7. The backing sheet of claim 6 wherein the fluorocopolymer layer has a thickness of less than 1mil.
8. The backing sheet of claim 6 wherein the fluorocopolymer layer has a thickness of greater than 1mil.
9. The backing sheet of claim 4 further comprising silica, titanium oxide, aluminum oxide, zinc oxide, beryllium oxide, mica, clays, boron nitride, aluminum nitride, titanium nitride, carbon black, and/or organic pigments.
10. A backing sheet for a photovoltaic module comprising:
a layer comprising a copolymer of tetrafluoroethylene (TFE) and hydrocarbon olefins with reactive OH functionality.
11. The backing sheet of claim 10 further comprising a crosslinking agent mixed with the fluorocopolymer.
12. The backing sheet of claim 11 further comprising a layer comprising one or more of polyester, polycarbonate, polyolefin, polyurethane, liquid crystal polymer, acrylic, aluminum, of sputtered aluminum oxide polyester, sputtered silicon dioxide polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon dioxide polycarbonate.

13. The backing sheet of claim 11 wherein the layer comprising the crosslinking agent mixes with the fluorocopolymer is applied to the polyester layer without adhesive.

14. The backing sheet of claim 13 further comprising an EVA layer.

15. The backing sheet of claim 13 further comprising an ionomer layer.

16. The backing sheet of claim 12 further comprising a layer of a fluorocopolymer of chlorotrifluoroethylene (CTFE) and one or more alkyl vinyl ethers.

17. The backing sheet of claim 13 wherein the fluorocopolymer layer has a thickness of less than 1mil.

18. The backing sheet of claim 13 wherein the fluorocopolymer layer has a thickness of greater than 1mil.

19. The backing sheet of claim 11 further comprising one or more of silica, titanium oxide, aluminum oxide, zinc oxide, beryllium oxide, mica, clays, boron nitride, aluminum nitride, titanium nitride, carbon black, and organic pigments.

20. A backing sheet for a photovoltaic module comprising:
a layer comprising a terpolymer of vinylidene fluoride, tetrafluoroethylene, and hexafluoropropylene.

21. The backing sheet of claim 20 further comprising a layer comprising one or more of polyester, polycarbonate, polyolefin, polyurethane, liquid crystal polymer, aclar, aluminum, of sputtered aluminum oxide polyester, sputtered silicon dioxide polyester, sputtered aluminum oxide polycarbonate, and sputtered silicon dioxide polycarbonate.

22. The backing sheet of claim 21 further comprising an EVA layer.

24. The backing sheet of claim 21 further comprising an ionomer layer.

25. The backing sheet of claim 21 further comprising a layer of fluorocopolymer of chlorotrifluoroethylene (CTFE) and one or more alkyl vinyl ethers.

26. The backing sheet of claim 25 wherein the fluorocopolymer layer has a thickness of less than 1mil.

27. The backing sheet of claim 25 wherein the fluorocopolymer layer has a thickness of greater than 1mil.

28. The backing sheet of claim 20 further comprising silica, titanium oxide, aluminum oxide, zinc oxide, beryllium oxide, mica, clays, boron nitride, aluminum nitride, titanium nitride, carbon black, and/or organic pigments.

29. A method of repairing the backing sheet of a photovoltaic module comprising:

applying a formulation comprising an amorphous fluorocopolymer of chlorotrifluoroethylene (CTFE) and one or more alkyl vinyl ethers to an area on the backing sheet in need of repair.

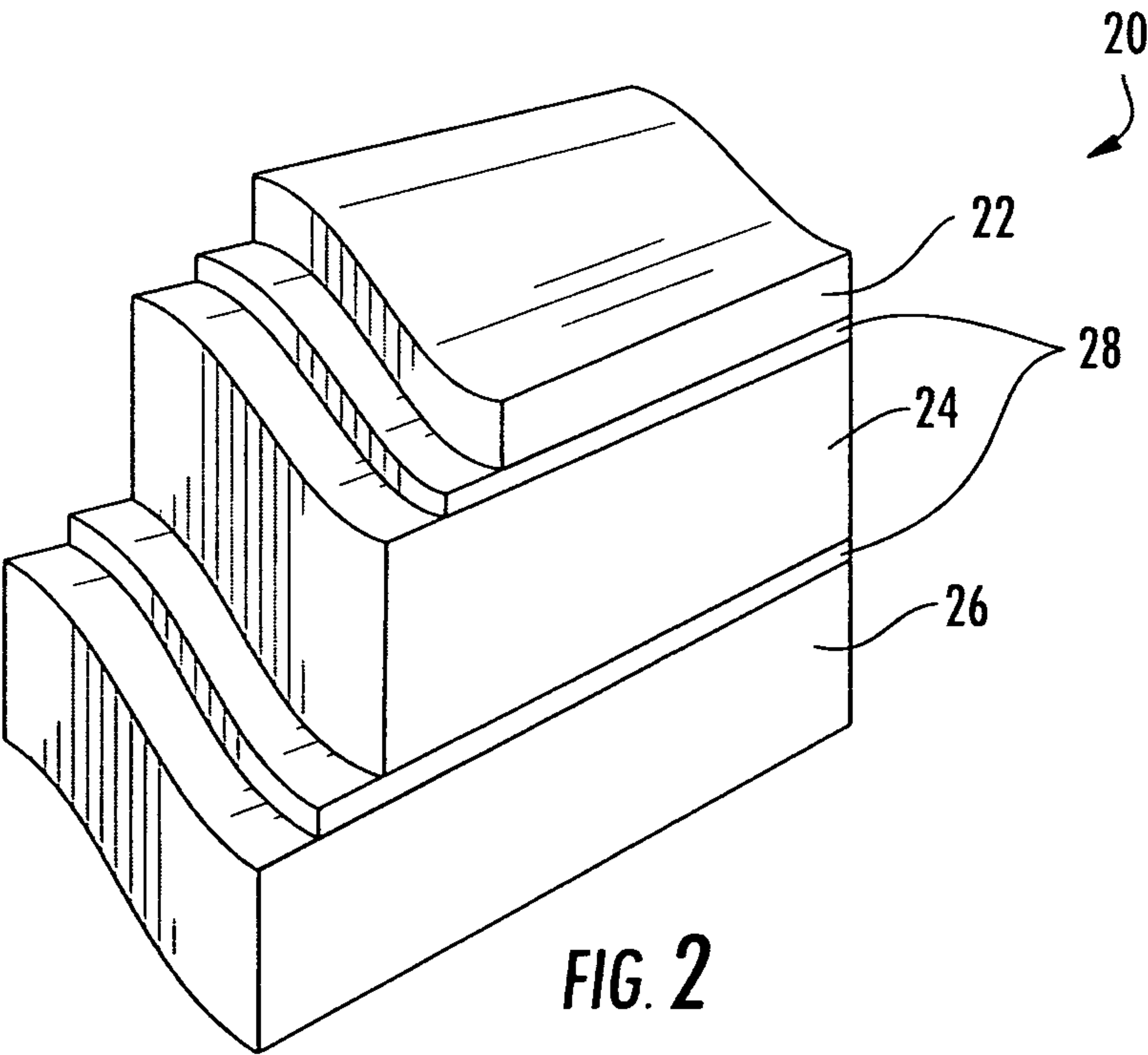
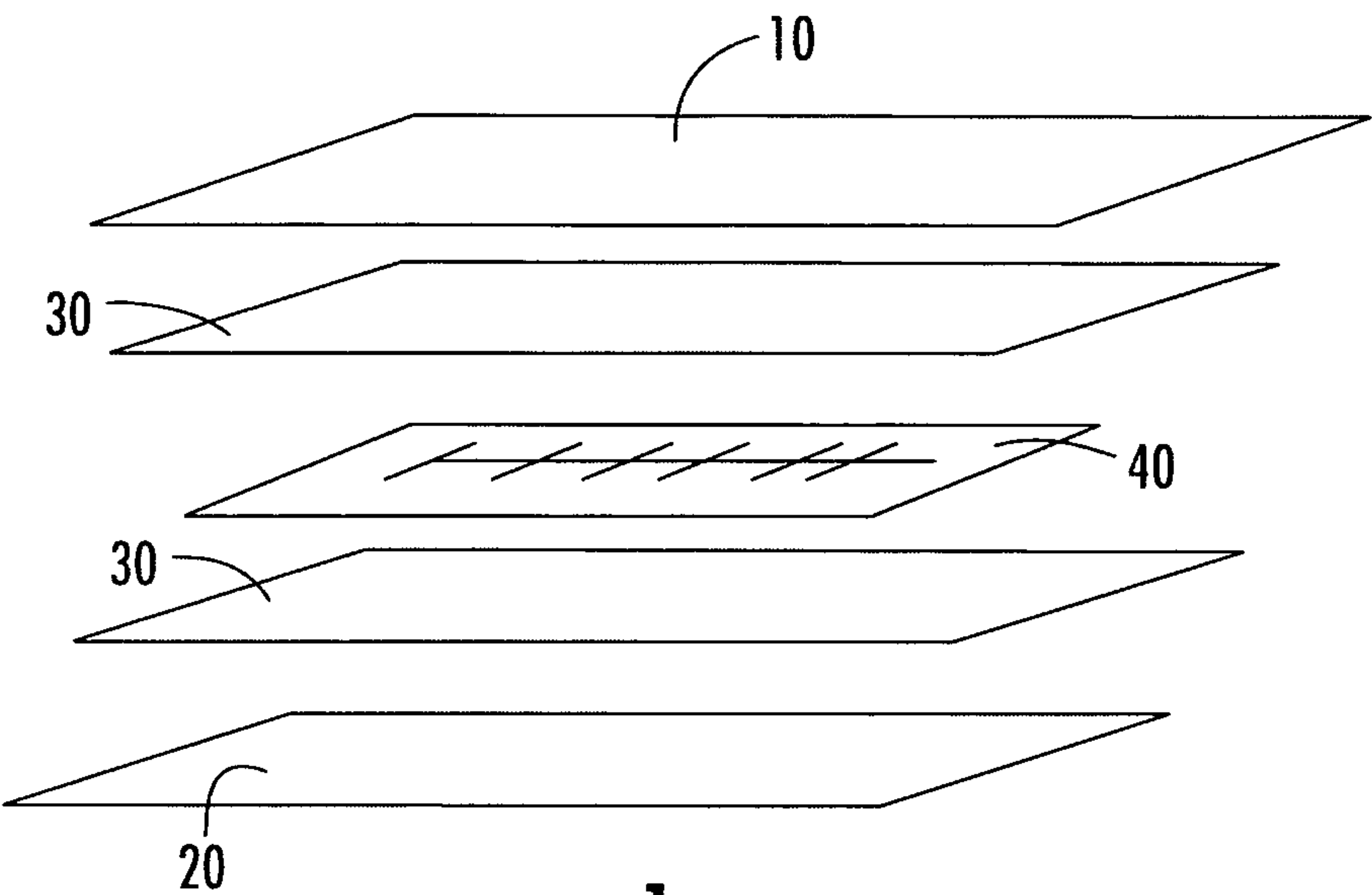
30. The method of repairing the backing sheet of claim 29 wherein the formulation is comprised of two components, wherein the first component is comprised of a mixture of a crosslinker and a solvent, and the second component is comprised of a mixture of a solvent and a fluorocopolymer.

31. The method of claim 29 wherein the formulation is applied to the backing sheet at ambient temperature or moderately elevated temperature.

32. The method of claim 29 wherein the formulation is applied to the backing sheet at ambient temperature or moderately elevated temperature by spraying.

33. The method of claim 30 wherein the first and second components are placed in a twin-chamber syringe equipped with static mixer and applied through an applicator and/or brush attached to the syringe.

1/3



2/3

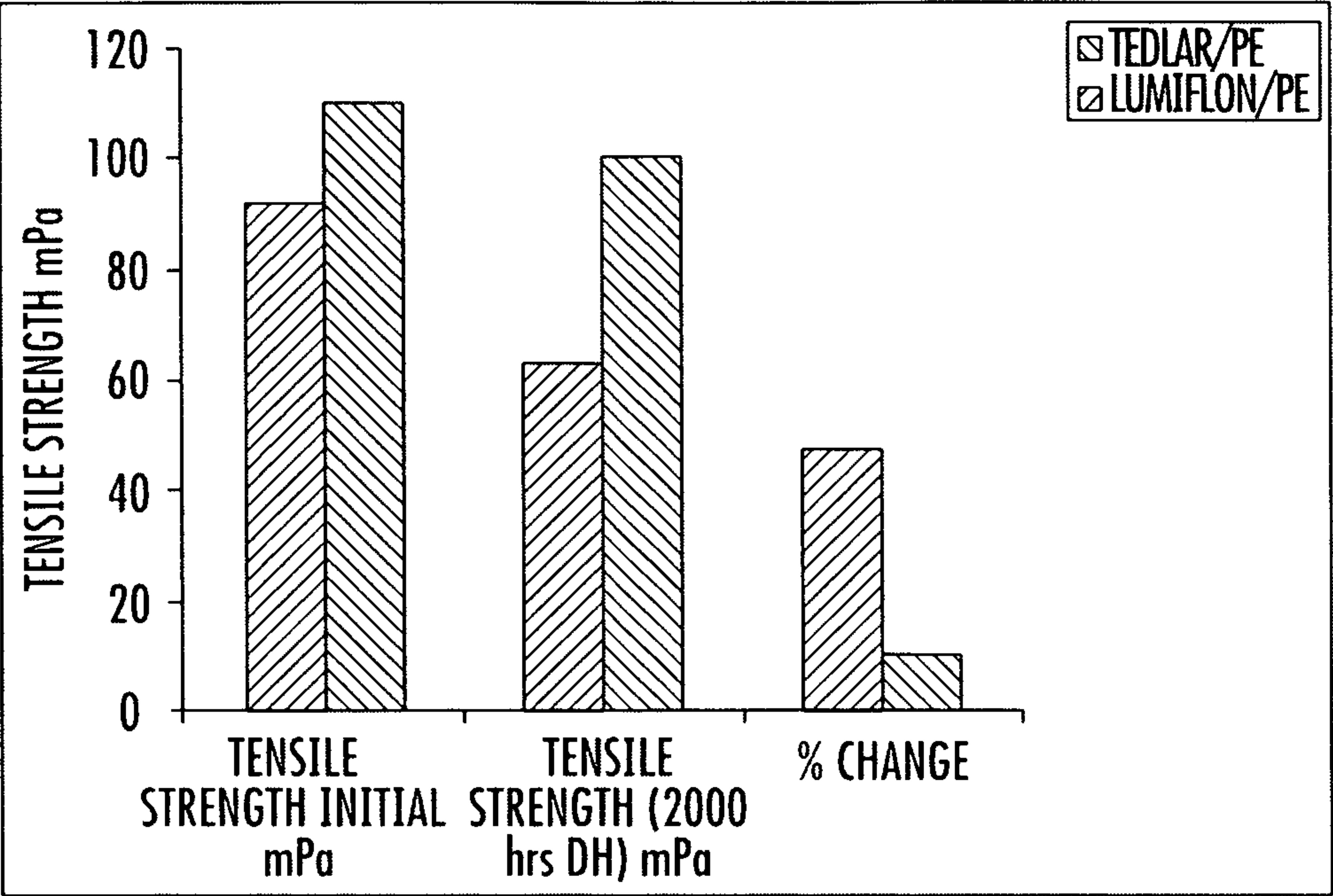


FIG. 3

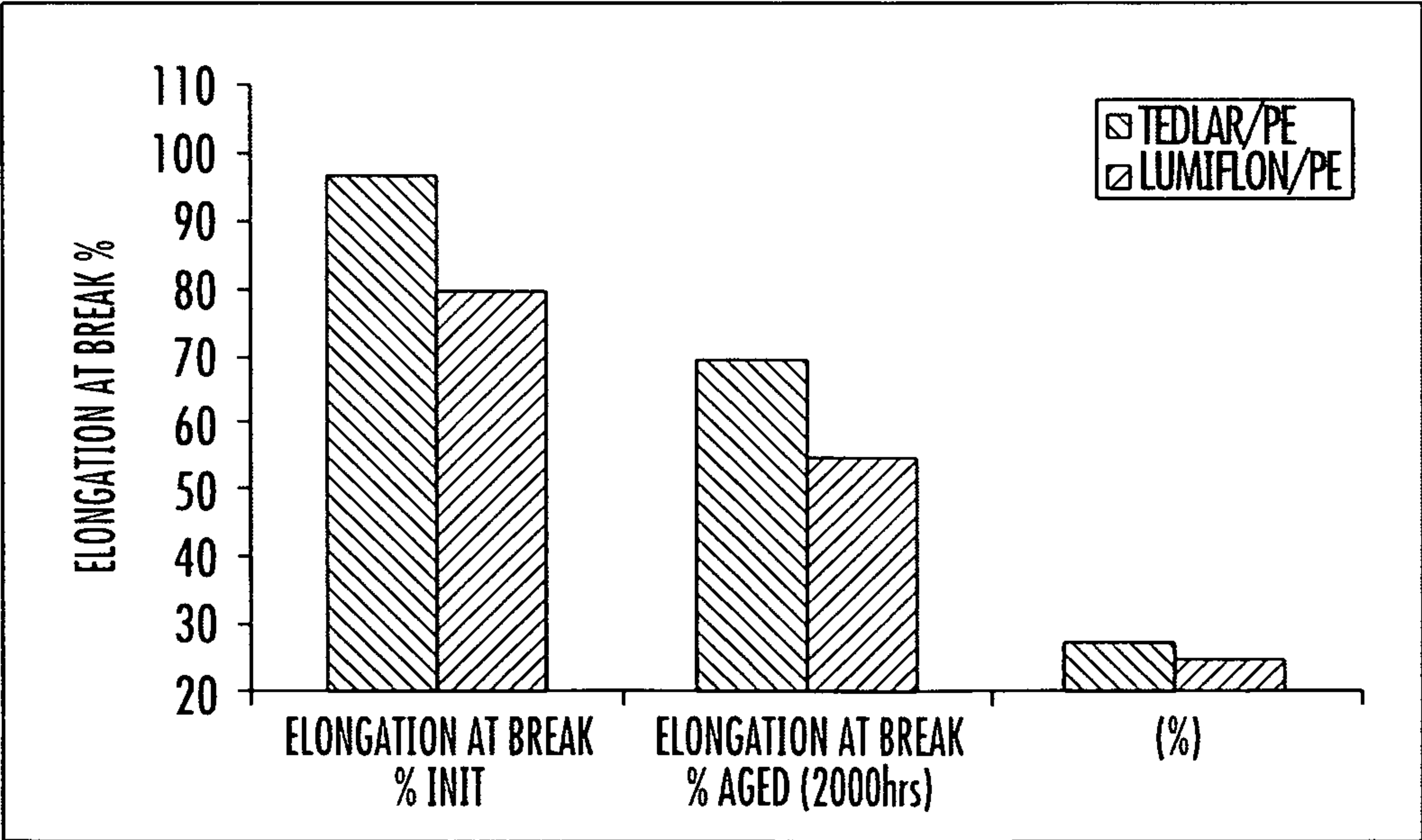


FIG. 4

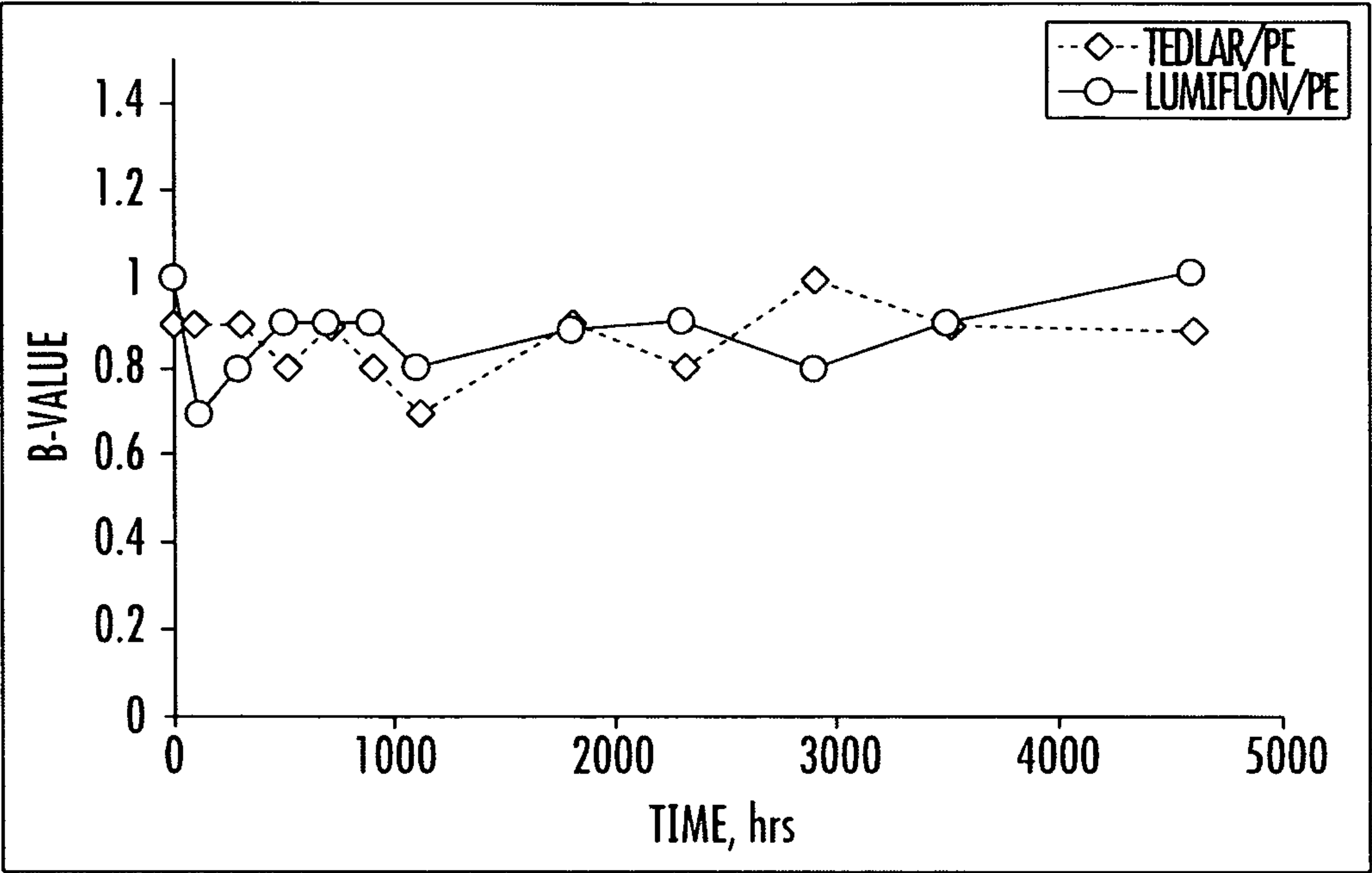


FIG. 5

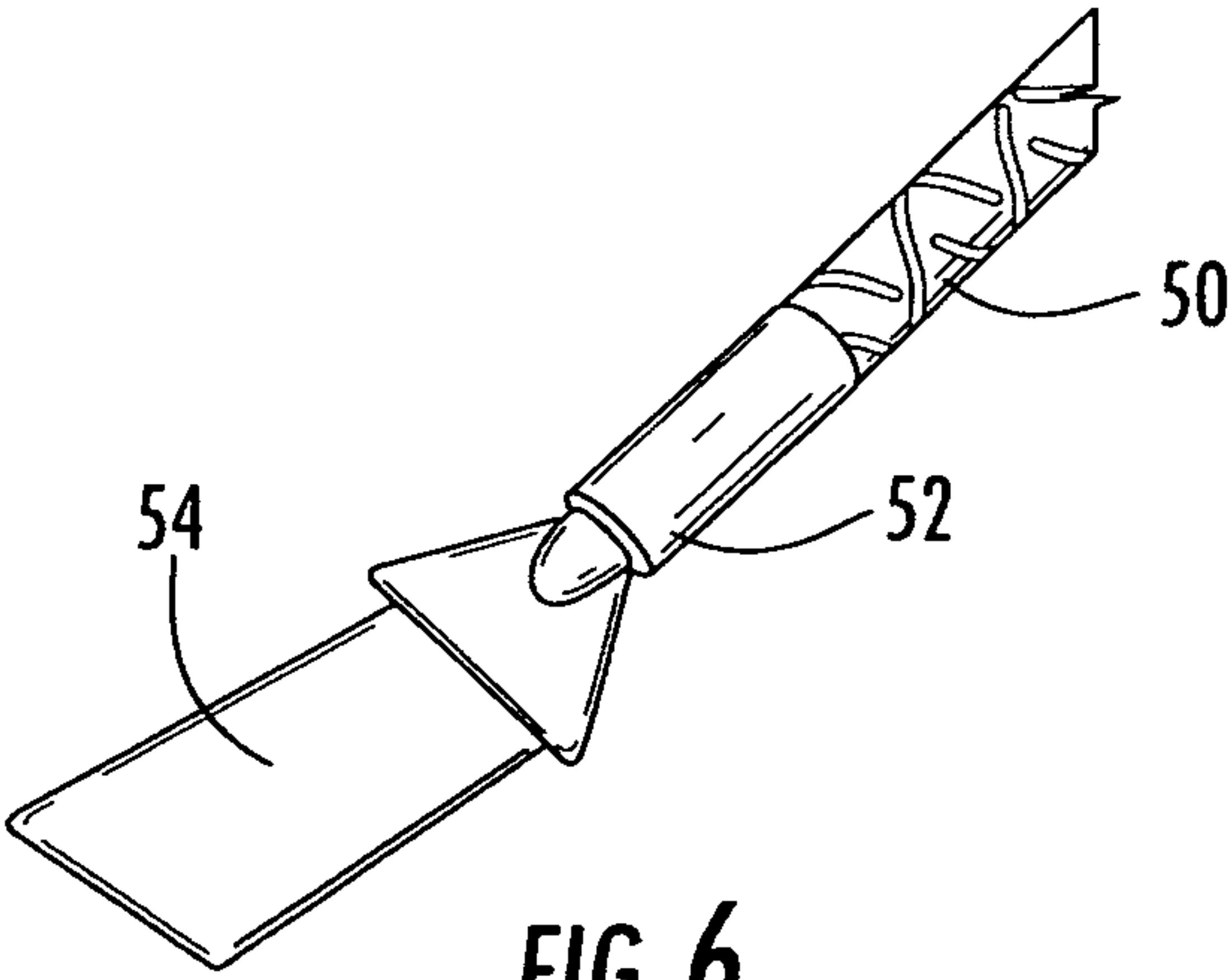


FIG. 6

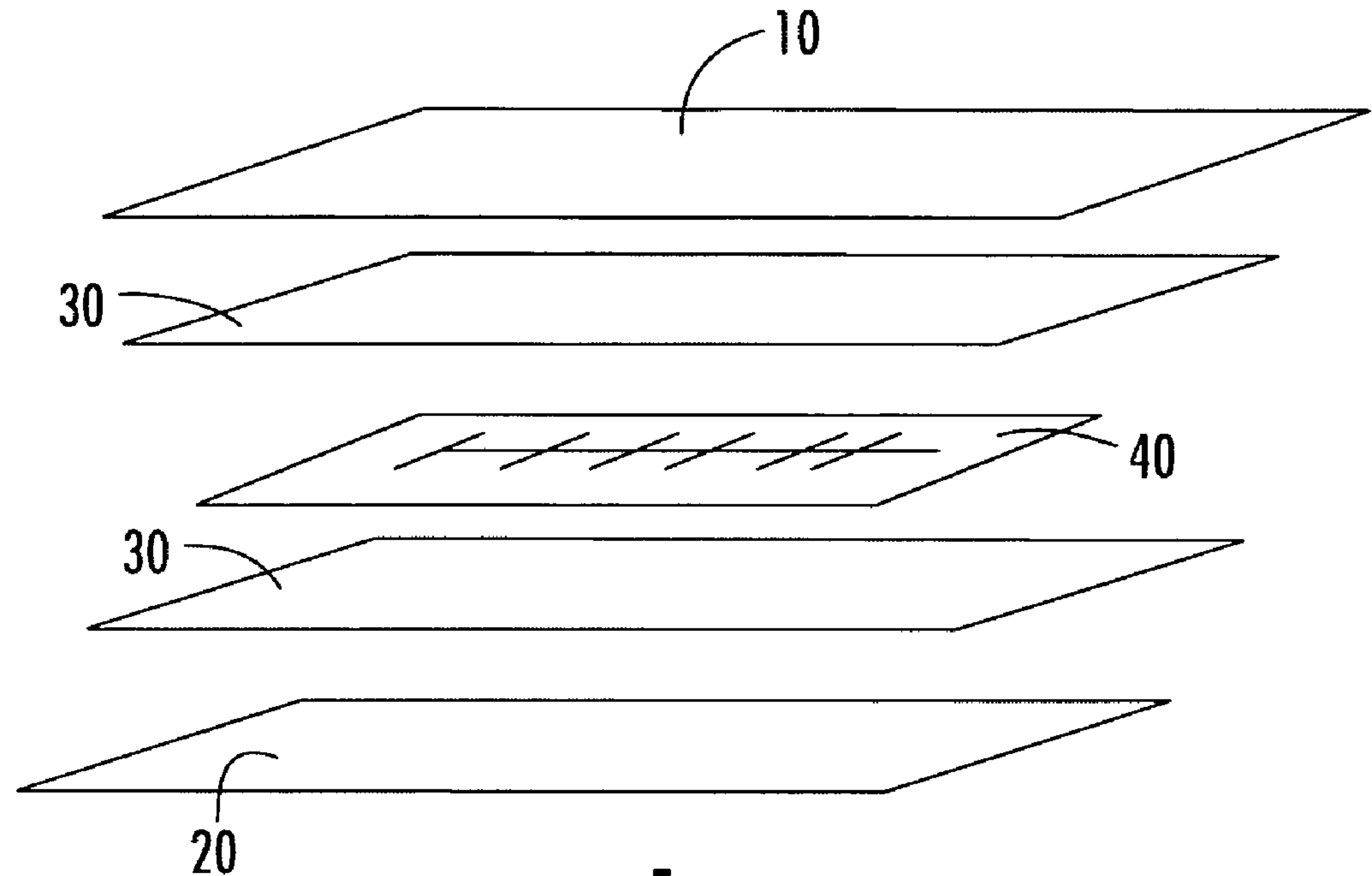


FIG. 1