

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 December 2007 (27.12.2007)

PCT

(10) International Publication Number
WO 2007/149091 A1

(51) International Patent Classification:
C09K 9/02 (2006.01) *G02F 1/17* (2006.01)
G02F 1/15 (2006.01)

(21) International Application Number:
PCT/US2006/024549

(22) International Filing Date: 23 June 2006 (23.06.2006)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **E.I. DU PONT DE NEMOURS AND COMPANY** [US/US]; 1007 Market Street, Wilmington, DE 19898 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **PERCEC, Simona** [US/US]; 2026 Delancey Place, Philadelphia, PA 19103 (US). **TILFORD, Susan, H.** [US/US]; 4 Wild Cherry Lane, Ewing, NJ 08638 (US).

(74) Agent: **DALICKAS, Gail, A.**; E.I. Du Pont de Nemours and Company, Legal Patent Records Center, 4417 Lancaster Pike, Wilmington, DE 19805 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, 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, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



WO 2007/149091 A1

(54) Title: ELECTROCHROMIC ELECTROLYTE BLENDS

(57) Abstract: The present invention is directed to electrochromic electrolyte polymer blends. These blends comprise an amorphous polymer and an electrochromophore component. The electrochromophore component comprises a polyalkylene polymer copolymerized with an electrochromic moiety. The blends can be used to make elastomeric films and coatings that can be used in laminates, which can be used to form manufactured articles such as architectural and vehicular glazing, eyewear, displays and signage.

TITLEELECTROCHROMIC ELECTROLYTE BLENDSFIELD OF THE INVENTION

The present invention is directed to electrochromic electrolyte
5 polymer blends. The blends comprise an amorphous polymer and an
electrochromophore component. The electrochromophore component
comprises a polyalkylene polymer copolymerized with an electrochromic
moiety. These blends can be used to make elastomeric films and coatings
that can be used in laminate structures used in manufactured articles
10 such as architectural and vehicular glazing, eyewear, displays and
signage.

BACKGROUND

Organic conducting polymers and organic electroactive polymers
have been used to make electrochromic devices. However, there remains
15 a need for elastomeric electrochromic polymers that are easily
manufactured, exhibit desired electrochromic characteristics, can be
covalently bonded to an electrode, have a long life-time, and can be used
in an all solid-state electrochromic system.

Electrochromic systems based on polymeric electrolytes are known
20 [B. Scrosati, J. Electrochem Soc., 1989, 136, 2774]. One example
comprises polyethylene oxide and lithium salts. However, the disclosed
system requires a relatively high temperature of operation (i.e., about 100
°C). This is because the conductivity is a property of the amorphous,
elastomeric phase, and the transition from the crystalline to amorphous
25 state for the PEO/Li complexes occurs above about 60 °C.

Elastomer electrolytes blended with inorganic or organic
chromophores have been reported [E. A. R. Duek, et al., Adv. Materials 5,
650, 1993].

World Patent Publication WO/2006/008776 discloses
30 electrochromic compositions obtained by blending polymers with
electrochromic molecules and plasticizers.

Blends of conducting polymers with thermoplastics or elastomers to
produce materials that exhibit the electrochromic properties of the

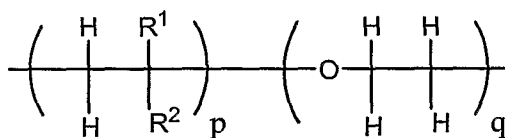
conducting polymers are also known. For example, W. A. Gazotti et al. have disclosed solid state devices using two optically complementary electrochromic blends deposited on transparent electrodes (ITO) and a polymeric electrolyte [Advanced Materials, 1998, 10, no 18, p 1522-1525].

- 5 Improvements are desirable, however, in uniformity, consistency, efficiency, and durability.

SUMMARY

One aspect of the invention is a composition comprising:

- 10 a. an amorphous (co)polymer comprising one or more repeat units, (I),



(I)

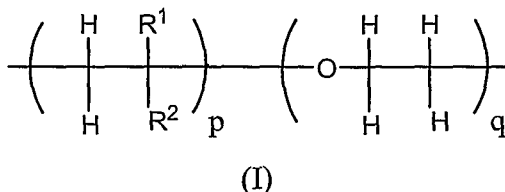
wherein

- 15 p and q are independently selected from integers from 0 to 10,000, provided that at least one of p and q is greater than 0;
 R¹ is selected from the group consisting of H and substituted and unsubstituted alkyl;
 R² is selected from the group consisting of H, OH, R¹, OR¹, OC(O)R⁴,
 20 COOR¹, and COOR³;
 R³ is selected from the group consisting of H, Na, and K;
 R⁴ is substituted or unsubstituted alkyl; and
- b. an electrochromophore component comprising polyalkyleneoxide and an electrochromic moiety; and
- 25 c. an ion source.

Another aspect of the invention is a laminate comprising:

- a. a first electrically conductive substrate; and
- b. an electrochromic layer in contact with the substrate, comprising:

- i. an amorphous (co)polymer comprising one or more repeat units, (I),



5

wherein

p and q are independently selected from integers from 0 to 10,000, provided that at least one of p and q is greater than 0;

10 R^1 is selected from the group consisting of H and substituted and unsubstituted alkyl;

R^2 is selected from the group consisting of H, OH, R^1 , OR^1 , $OC(O)R^4$, $COOR^1$, and $COOR^3$;

R^3 is selected from the group consisting of H, Na, and K;

R^4 is substituted or unsubstituted alkyl; and

15

- ii. an electrochromophore component comprising polyalkyleneoxide and an electrochromic moiety; and
- iii. an ion source.

BRIEF DESCRIPTION OF THE FIGURE

20 Figure 1 is a schematic of an all solid state electrochromic device containing an electrochromic electrolyte blend according to one embodiment of the invention.

DETAILED DESCRIPTION

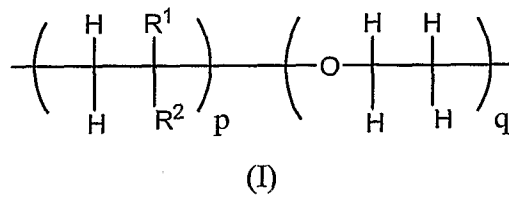
25 The blend compositions disclosed herein provide electrochromic materials that display good color uniformity and good contrast and can be used to generate a wide range of colors. Coloration efficiency and long lifetimes are achieved by the incorporation of certain functional groups in the electrochromic moiety to improve contact of the blend compositions with the electrodes of the electrochromic device.

30 Electrochromism, as used herein, is a reversible and visible change in the transmittance and/or reflectance of a material as the result of

electrochemical oxidation or reduction. Electrochromic materials can be either organic or inorganic materials that display electrochromism.

Amorphous polymers are those that display substantially no crystalline domains in the solid state.

- 5 One embodiment of this invention is a composition comprising:
- a. an amorphous (co)polymer comprising one or more repeat units, (I),



10

wherein

p and q are integers of 0 to 10,000, and at least one of p and q is greater than 0;

15 R¹ is selected from a group consisting of H, and substituted and unsubstituted alkyl;

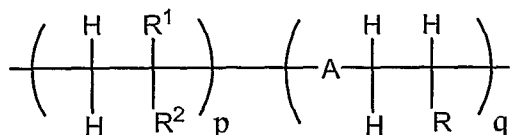
R² is selected from a group consisting of H, OH, R¹, OR¹, OC(O)R⁴, COOR¹, and COOR³;

R³ is selected from a group consisting of H, Na, and K;

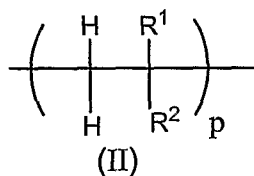
R⁴ is substituted or unsubstituted alkyl;

- 20 b. an electrochromophore component comprising polyalkyleneoxide and an electrochromic moiety; and
- c. an ion source.

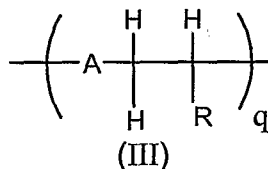
As used herein, "(co)polymer" denotes a homopolymer or copolymer. In particular, the amorphous (co)polymer can contain repeat units of



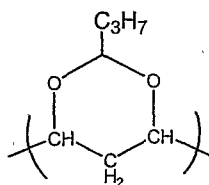
5 or



or



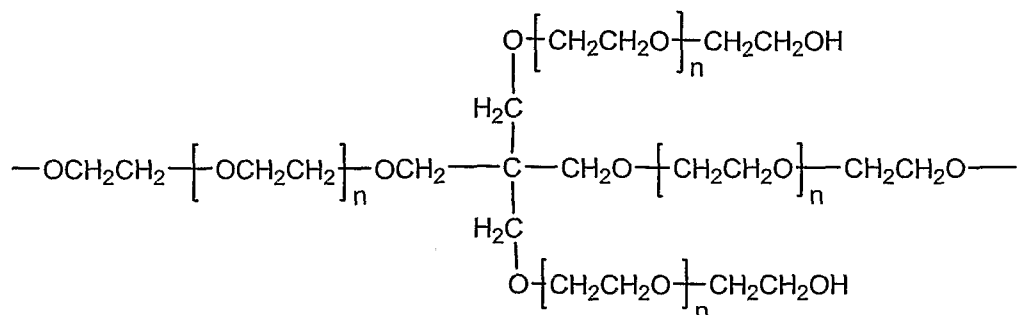
or any combination of (I), (II), and/or (III). Other repeat units can also be present, such as Structure (X):



Structure (X)

Suitable alkyl groups of the amorphous (co)polymer include C₁-C₁₀ alkyl groups. Suitable substituents on the alkyl groups include halo groups, hydroxyl, carboxyl, amino, and cyano groups.

Suitable polyalkylene oxides can be linear or branched. In one embodiment, linear polyalkylene oxide corresponds to the formula $-(\text{O}(\text{CH}_2)_r(\text{CHR})_s)-$, where r and s are integers from 0 – 10,000, with the proviso that at least one of r and s is not zero. Suitable branched polyalkylene oxides include, for example:



where each n is an integer from 0 to 1000.

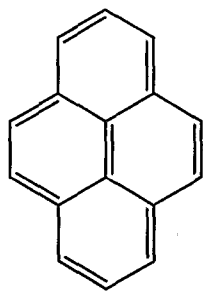
Suitable electrochromic moieties cause the blend composition to exhibit a reversible and visible change in its transmittance and/or reflectance upon electrochemical oxidation or reduction. The electrochromic moiety can be covalently attached to the polyalkylene oxide, or can be blended with the polyalkylene oxide.

Each electrochromic moiety comprises a redox-active group and an optional linker group interposed between the redox-active group and the polyalkylene oxide units. Suitable linkers include $-(\text{CH}_2)_m-$, $-\text{CH}_2-\text{OC}(\text{O})(\text{CH}_2)_n-$, and $-(\text{CH}_2\text{CH}_2\text{NH})-$, where m and n are integers from 1 to 1000.

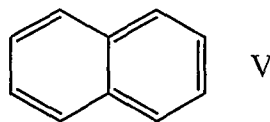
Linker groups can also comprise connecting groups such as ester $(-\text{CO}_2-)$, amide $(-\text{N}(\text{CO})-)$, ether $(-\text{O}-)$, or thioether $(-\text{S}-)$ groups, interposed between either the polyalkylene oxide backbone and the linker or between the linker and the redox-active group.

Suitable electrochromic moieties include bipyridilium systems; electroactive conducting polymers such as polyanilines, polypyrroles, polythiophenes and polythiophene copolymers, and polycarbazole; carbazoles; methoxybiphenyl compounds; quinones; diphenylamines; phenylene diamines; pyrazolines; tetracyanoquinodimethane (TCNQ); and tetrathiafulvalene (TTF).

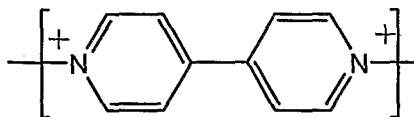
Suitable redox-active groups in the electrochromic moieties include substituted and unsubstituted aromatic and heteroaromatic groups corresponding to structures IV – IX:



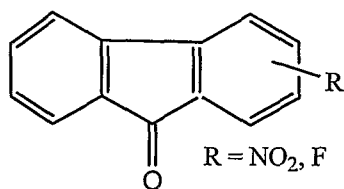
IV



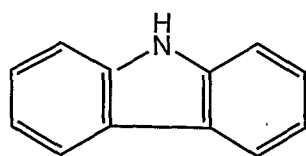
V



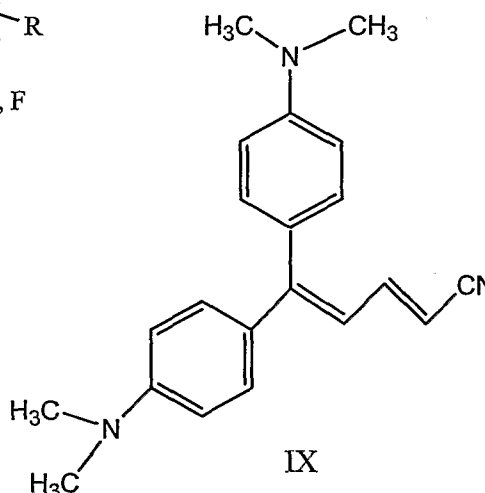
VI



VII



VIII



IX

5

Except for structure VI, the points of attachment to the polyalkylene oxide, linker or connecting group are not shown. Any point of attachment is suitable, as long as the aromatic character of the system is maintained. Structure VI has two potential points of attachment. Typically, both
 10 nitrogens of the bipyridilium system are attached to the polymer backbone, linker or connecting group. The positive charge on these quaternary nitrogens is balanced by anions such as halides. For a terminal bipyridilium group, one of the nitrogens is typically connected covalently or ionically to an alkyl group, an aryl group, a halogen, p-toluene-sulfonyl,
 15 hexafluorophosphate, trifluoromethanesulfonate (CF_3SO_3^-),

trifluoromethanesulfonimide ((CF₃SO₂)₂N-), or H, either directly or with intervening linker and/or connecting groups.

Suitable substituents on the aromatic or heteroaromatic rings of the redox-active groups include: C₁ – C₁₀ alkyl groups such as methyl, ethyl, 5 propyl, butyl, pentyl, hexyl, heptyl, octyl, and iso-pentyl; aromatic groups such as phenyl and substituted phenyl; –CN; and amines such as –N(C₂H₅)₂ and –N(CH₃)₂ groups. The substituents attached to the aromatic or heteroaromatic groups can influence the conduction properties of the composition and its response to voltage fluctuations. Different substituents 10 can be used to provide compositions of different colors. By varying the redox-active group and/or the substituents on the aromatic group of the electrochromic moiety, the compositions of this invention can be produced in a wide range of colors.

The electrochromic moieties can also comprise functional groups to 15 improve bonding to the electrodes of an electrochromic device. Suitable functional groups include –SH, pyridine, –CN, and –SCN, and can be used to promote the absorption and/or self-assembly of the electrochromophore onto electrode surfaces (e.g., Au, Cu, Pd, Pt, Ni, and Al). Other functional groups, such as –COOH and –P(O)(OH)₂, can be used to improve the 20 binding or self-assembly of the composition onto ITO (indium tin oxide) or Al₂O₃ surfaces. Alcohol and amine functionalities are useful in binding to Pt surfaces. Having direct contact and good binding between the electrochromophore and the electrodes in a solid-state system can enhance coloration efficiency.

25 The electrochromic groups can also contain functional groups such as –SO₃K or –ClO₃Li. When such compositions are used to assemble electrochromic devices, little or no additional electrolyte is required.

The electrochromic moieties that are attached to a polyalkylene oxide polymer are not pendant from the polymer backbone, but rather are 30 part of the backbone of the polymer. Each polyethylene oxide chain can contain more than one electrochromic moiety. Chains that contain more than one electrochromic moiety can contain more than one type of electrochromic moiety, e.g., electron-donors and electron-acceptors. The

density of the electrochromic moieties (i.e., the number of electrochromic moieties per unit of chain length) can be varied by controlling the length of the polyalkylene oxide segments. The distance between neighboring electrochromic moieties can also be controlled by the use of linker groups of different sizes. The electrochromic moieties can also be at the end(s) of the chain.

In one embodiment of this invention, the amorphous (co)polymer comprises predominantly repeat units of structure III, such as, for example, when the backbone comprises poly(ethylene oxide) or poly(epichlorohydrin).

In another embodiment of this invention, the amorphous (co)polymer comprises predominantly repeat units of structure II, as in polyvinyl butyral.

In another embodiment of this invention, the amorphous polymer backbone is a copolymer comprising at least one repeat unit of structure II and at least one repeat unit of structure III, such as in poly(ethylene oxide-co-epichlorohydrin) and copolymers derived from ethylene, methacrylic acid and salt forms of methacrylic acid (e.g., Surlyn® resins, available from E. I. DuPont de Nemours, Inc., Wilmington, DE).

The ion source can be an inorganic salt such as LiCl or an organic salt such as tetrabutyl ammonium bromide that is added to the co-polymer and the electrochromophore component. The polyalkylene oxide component tends to promote the dissolution of the salt, and the resulting ions increase the conductivity of the polymer. The salts also inhibit the crystallization of polyalkylene oxide. Some electrochromophore groups (e.g., viologen) are ionic and can serve as the ion source for the compositions of this invention.

The amorphous (co)polymers can be prepared by any of several different methods known to those skilled in the art. Many suitable (co)polymers are commercially available.

In some embodiments, the redox-active group itself can be directly attached to the polyalkylene oxide backbone. In other embodiments, it may be necessary or preferred, to attach a linker group to the redox-active

group to provide the desired molecular structure or to provide a more reactive group to facilitate the incorporation of the electrochromic group into the backbone. By way of illustration, Examples 1 and 2 (below) describe the preparation of a polyethylene oxide with a bipyridilium moiety
5 in the polymer backbone. Condensation reactions to form ester, amide or ether bonds are useful reactions for incorporating the linking, connecting and/or redox-active groups to each other and/or to the polymer backbone.

The amorphous polymer and the polyalkylene oxide-based polymer can be blended with additives such as plasticizers, electron mediators,
10 and/or conductive particles. An electron mediator is an auxiliary redox active compound that acts as an electron-transfer "catalyst". During the redox reaction (which is a complex process and takes place in several steps), the electron mediator accepts electrons from the electrode (is reduced) or donates electrons to the electrode (is oxidized) . In this
15 activated form, the mediator is able to transfer or take electrons from the electroactive center of the electrochromic compound. Electron mediators include ferrocene, other metallocenes, their derivatives and mixtures; and phenazine and its derivatives and mixtures. Addition of salts can significantly improve the ion-conductivity of the blend and consequently
20 enhance the electrochromic properties of the blend.

For most applications, to increase the mobility of the ions, the Tg of the amorphous polymer is desirably less than the ambient temperature in which the device made from the polymer is being used. In some
embodiments of this invention, a Tg of less than 100 °C is sufficient; under
25 some circumstances, the Tg of the amorphous polymer is desirably less than 50 °C, or less than 25 °C or less than 0 °C. The desired Tg can be achieved by the use of plasticizers and/or other additives.

Suitable plasticizers include tetraethylene glycol diheptanoate; triethylene glycol-di-2-ethyl hexanoate; 2-ethyl-1-hexanol; polyethylene
30 glycol and its derivatives; adipates such as dihexyl adipate and dioctyl adipate; phosphates such as 2-ethylhexyl diphenyl phosphate, isodecyl diphenyl phosphate, tert-butylphenyl diphenyl phosphate, triaryl phosphate ester blends, tricresyl phosphate, and triphenyl phosphate; phthalates

such as alkyl benzyl phthalate, butylbenzyl phthalate, dibutyl phthalate, and dioctyl phthalate; sebacates such as dibutyl sebacate; and sulfonamides such as toluene sulfonamide and n-ethyl sulfonamide.

Suitable conductive particles include inorganic particles formed
5 from metals, ITO, carbon nanotubes, and TiO₂. Suitable organic
conductive particles can be formed from conductive polymers such as
polyanilines, polypyrroles, polythiophenes and polythiophene copolymers.
Suitable particle sizes include those from 10 nm – 100 μm, preferably 10
nm to 1 μm.

10 The electrochromic electrolyte blends disclosed herein can be used
to make elastomeric electrochromic films by standard film-forming
techniques, and the films, in turn, can be used in laminate structures that
are useful in architectural or vehicular applications. For example, the
elastomeric electrochromic films can be laminated between layers of glass
15 coated with transparent electrodes (e.g., ITO). When a small voltage is
applied to the electrodes – typically from about 0.5 V to about 6.0 V – the
transparency and/or color of the glass-and-film laminate structure can be
altered. The type of change (e.g., color or opacity) and the degree of
change (e.g., the optical density and/or color of the transmitted light)
20 depends on the thickness of the film as well as the nature of the
electrochromic moiety. Removing the voltage source, or reversing the
polarity, will typically result in the color and/or opacity returning to their
original state. This ability to reversibly change the optical properties of the
blend composition by applying a small voltage makes it highly useful in
25 articles such as sunglasses, helmets, visors, goggles, architectural
glazing, automotive glazing, displays, signage, and mirrors.

Figure 1 is a schematic of a typical electrochromic device 100
incorporating a composition of the invention. In this embodiment, the
substrate layers 110 are coated with a conductive layer 120. Layer 130 is
30 in contact with both conductive layers and comprises the blend of an
amorphous polymer with a polyethylene oxide polymer and additives.
Color change occurs when a power source is attached to the conductive
layers and a voltage is applied.

Suitable film-forming techniques include casting, extrusion, spraying, and dip-coating. Free-standing film is preferred in some applications. Self-assembly of self-doped compositions into mono-layers or multi-layers on a substrate surface can be achieved by standard
5 methods, including microcontact printing and/or flooding the metal or ITO surfaces.

Lamination processes are well-known to those skilled in the art and can be used to make laminate structures in which an elastomeric electrochromic film is sandwiched between two substrates. Suitable
10 substrates include non-conductive substrates such as glass and polymer sheets or films. For use in electrochromic devices, electrically conductive substrates are used, such as metal sheets or foils, or non-conductive substrates coated or laminated with an electrically conductive material, such as ITO. Polymer substrates are especially useful for making flexible
15 laminate structures, and suitable substrate polymers include polyesters (e.g., poly(ethylene terephthalate), poly(ethylene naphthalate), and poly(ethylene-isosorbide terephthalate) - a high glass transition temperature (T_g) polymer comprising repeat units derived from ethylene glycol, isosorbide and a terephthalate moiety); polyimides (e.g., Kapton®
20 polyimide); polyamides (e.g., Nomex® polyamide, Kevlar®) polyamide; polycarbonate; polyphenylene oxide; polysulfones; cellulosics; and polymer blends, such as polystyrene/polyphenylene oxide.

Fabrication of articles from laminated structures or coated substrates can be carried out using standard techniques for cutting and/or
25 shaping the glass or polymer substrates.

EXAMPLES

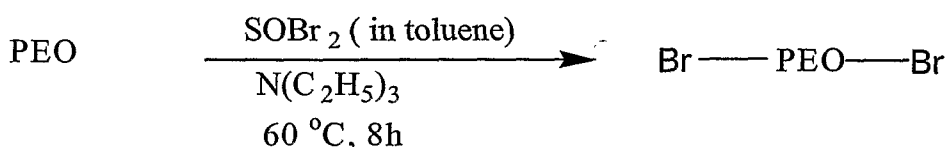
Some embodiments of the present invention are illustrated by the following Examples. It should be understood that these Examples, while representing some embodiments of the invention, are given by way of
30 illustration only. From the above discussion and these Examples, one skilled in the art can ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can

make various changes and modifications of the invention to adapt it to various uses and conditions.

All reagents were purchased from Sigma-Aldrich Co., St. Louis, MO, and used as received unless otherwise indicated.

- 5 The meaning of abbreviations used is as follows: "min" means minute(s), "hr" means hour(s), "mL" means milliliter(s), "L" means liter(s), "μL" means microliters, "mM" means millimolar, "M" means molar, "mmol" means millimole(s), "g" means gram(s), "mg" means milligram(s), "V" means volt(s), "°C" means degree Celsius.

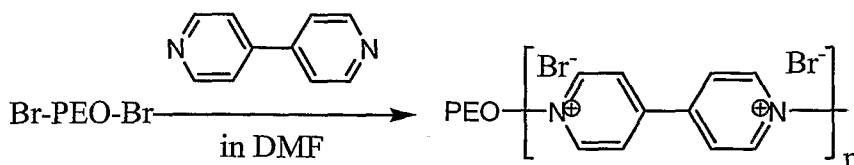
10

EXAMPLE 1Preparation of dibrominated polyethylene oxide

- 15 Dibromo-PEO was obtained by reacting thionyl bromide with polyethylene oxide (PEO). A solution of SOBr_2 (5.197 g) in toluene (132 mL) was added to polyethylene oxide (10 g, molecular weight = 200 g/mol) in the presence of triethylamine (2.53 g). The reaction mixture was then heated to 60 °C for 8 hr. After the reaction was complete, the
- 20 triethylammonium hydrogen bromide was filtered off. The toluene was then rotovaporated off to obtain the desired brominated compound.

EXAMPLE 2Copolymerization of dibrominated polyethylene oxide with 4,4'-dipyridyl

25



- 4,4'-Dipyridyl (1 g) was taken up in 20 mL of dry DMF. This solution was placed in a 100 mL 3 neck, round bottom flask connected to a N_2 bubbler. Dibrominated PEO (7.427 g, prepared as in Example 1) was
- 30 added neat to 4,4'-dipyridyl solution, with stirring. An additional 3 mL of

DMF were used to rinse the rest of the dibrominated PEO into the flask. The flask was kept under a nitrogen purge while being heated at 80 °C for 7 h and at 90 °C for 54 h. The solvent was then removed via rotoevaporation.

5

EXAMPLE 3

Preparation of Electrochromic Polyvinyl Butyral Composition

In the dry box in a 20 mL vial with magnetic stir bar a solution in 6 mL of n- propanol was made from polyvinyl butyral (330 mg), triethyleneglycol-di-2-ethyl-hexanoate (132.5 mg) viologen-polyethylene oxide copolymer (29.7 mg, prepared as in Example 2), ferrocene (3.9 mg),
10 lithium chloride (3.9 mg). This was solution number 1.

Separately, carbon nanotubes (31 mg, produced by CNI, Houston, TX, using the HiPCO process) were placed into 15 mL centrifuge vial together with 200 mg of polyvinyl butyral, triethyleneglycol-di-2-ethyl-
15 hexanoate (72 mg) and 15 mL of 1-propanol. The vial was placed into an ice bath and the ultrasonicator probe was inserted. The solution was sonicated for a total of 40 minutes. This was solution number 2.

For every milliliter of solution number 1, 10 μ L of solution number 2 were added. This solution was stirred at 50 °C for 30 min.

20

EXAMPLE 4

Preparation of the Electrochromic Device

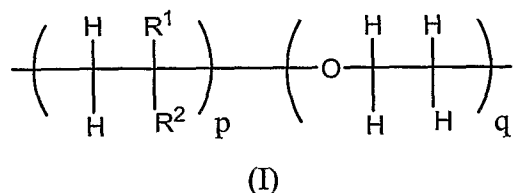
From the solution prepared as in Example 3, 0.154 mm thick films were cast using a draw bar onto two glass slides coated with ITO (40/45 mm, Thin Film Devices, Anaheim, CA). The films were cast on the ITO-
25 coated side. The two slides were placed them side by side with the two films in contact as is shown in Figure 1. On one edge of each slide, a small region of the ITO was exposed and connected to the power supply. The slide assembly was heated at 75 °C under pressure (2.6 kg) for 45 minutes. The device was then tested for electrochromic properties using a
30 voltammetric analyzer, CV-50W from Bioanalytical Systems, a DH -2000 light source (Ocean Optics, Inc., Dunedin, FL) and an HR2000 Series High Resolution Fiber Optic Spectrometer (Ocean Optics, Inc., Dunedin, FL). The % transmission of the device in the "off" state was 79.4. By

applying a voltage of -1.2 V, a reduction in light transmission to 37.4% was achieved in the "on" state in 52 sec. The change was reversible. When the voltage was removed, the light transmission increased to 75% in 135 sec and 79.4% in 200 sec. The device was tested several times over
5 a period of 8 days without observing any change in its functionality.

CLAIMS

What is claimed is:

1. A composition comprising:
- 5 a. an amorphous (co)polymer comprising one or more repeat units, (I),



- 10 wherein
- p and q are independently selected from integers from 0 to 10,000, provided that at least one of p and q is greater than 0;
- R¹ is selected from the group consisting of H, and substituted and unsubstituted alkyl;
- 15 R² is selected from the group consisting of H, OH, R¹, OR¹, OC(O)R⁴, COOR¹, and COOR³;
- R³ is selected from the group consisting of H, Na, and K;
- R⁴ is substituted or unsubstituted alkyl; and
- b. an electrochromophore component comprising
- 20 polyalkyleneoxide and an electrochromic moiety; and
- c. an ion source.
2. The composition of claim 1, further comprising an electron mediator.
3. The composition of claim 2, wherein the electron mediator is
- 25 selected from the group consisting of metallocenes and phenazines.
4. The composition of claim 1, further comprising a plasticizer.
5. The composition of claim 4, wherein the plasticizer is selected from the group consisting of polyethylene glycol and its derivatives; adipates; phosphates; phthalates; triaryl phosphate ester
- 30 blends; sebacates; and sulfonamides.

6. The composition of claim 4, wherein the plasticizer is selected from the group consisting of tetraethylene glycol diheptanoate; triethylene glycol-di-2-ethyl hexanoate; 2-ethyl-1-hexanol; dihexyl adipate; dioctyl adipate; 2-ethylhexyl diphenyl phosphate; isodecyl diphenyl phosphate; tert-butylphenyl diphenyl phosphate; tricresyl phosphate; triphenyl phosphate; alkyl benzyl phthalate; butylbenzyl phthalate; dibutyl phthalate; dioctyl phthalate; dibutyl sebacate; toluene sulfonamide and n-ethyl sulfonamide.

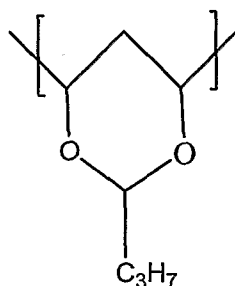
7. The composition of claim 1, further comprising conductive particles.

8. The composition of claim 7, wherein the conductive particles comprise materials selected from the group consisting of metals, ITO, carbon nanotubes, TiO_2 , polyanilines, polypyrroles, polythiophenes and polythiophene copolymers.

9. The composition of claim 8, wherein the particle size is 10 nm – 100 μm .

10. The composition of claim 1, wherein the amorphous (co)polymer comprises at least one repeat unit of $-(\text{CH}_2\text{CHOH})-$ and at least one repeat unit having the structure:

20



11 The composition of claim 1, wherein the amorphous (co)polymer comprises repeat units derived from ethylene, methacrylic acid and salt forms of methacrylic acid.

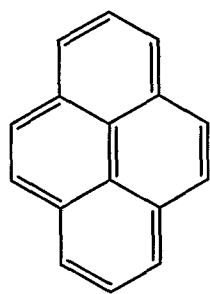
12 The composition of claim 1, wherein the polyalkylene oxide is selected from the group consisting of polyethylene oxide, poly(propylene

oxide), copolymers of poly(ethylene oxide) , poly(propylene oxide and blends thereof.

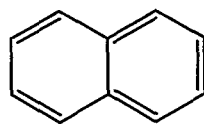
13 The composition of claim 1, wherein the electrochromic moiety is covalently attached to the polyalkylene oxide.

5 14 The composition of claim 1, wherein the electrochromic moiety is selected from the group consisting of polyanilines, polypyrroles, polythiophenes, polythiophene copolymers, polycarbazole, carbazoles, methoxybiphenyl compounds, quinones, diphenylamines, phenylene diamines, pyrazolines, tetracyanoquinodimethane, and tetrathiafulvalene.

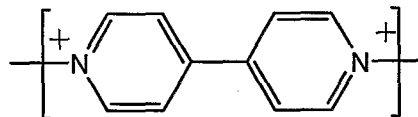
10 15 The composition of claim 1, wherein the electrochromic moiety comprises a substituted or unsubstituted aromatic or heteroaromatic group corresponding to a structure selected from the group consisting of structures IV – IX:



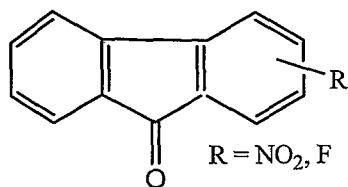
IV



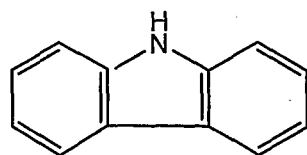
V



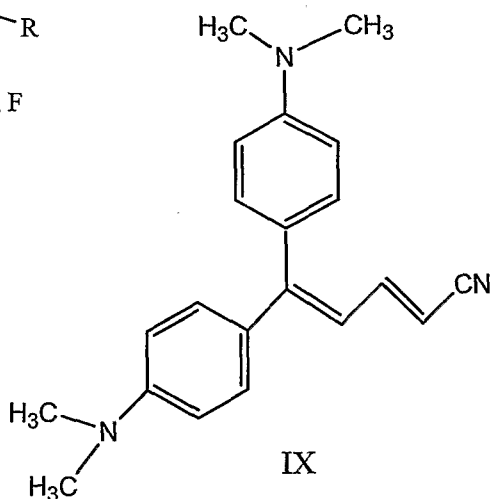
VI



VII



VIII



IX

15

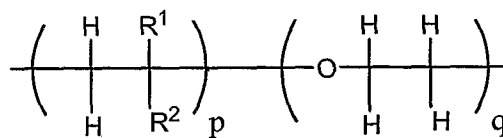
16 The composition of claim 1, wherein the electrochromic group is a derivative of 4,4'-dipyridyl.

17 The composition of claim 1, wherein the electrochromic moiety comprises a functional group selected from the group consisting of $-\text{SO}_3\text{K}$ and $-\text{ClO}_3\text{Li}$.

18 A laminate comprising:

- a. a first electrically conductive substrate; and
- b. an electrochromic layer in contact with the substrate, comprising:

10 i. an amorphous (co)polymer comprising one or more repeat units, (I),



(I)

wherein

15 p and q are independently selected from integers from 0 to 10,000, provided that at least one of p and q is greater than 0; R^1 is selected from the group consisting of H, and substituted and unsubstituted alkyl;

20 R^2 is selected from the group consisting of H, OH, R^1 , OR^1 , OC(O)R^4 , COOR^1 , and COOR^3 ;

R^3 is selected from the group consisting of H, Na, and K;

R^4 is substituted or unsubstituted alkyl; and

- ii. an electrochromophore component comprising polyalkyleneoxide and an electrochromic moiety; and
- 25 and
- iii. an ion source.

19. The laminate of claim 18, further comprising a second electrically conductive substrate in contact with the electrochromic layer.

20. The laminate of claim 19, wherein at least one electrically
30 conductive substrate comprises a transparent, non-conductive substrate

and an electrically conductive layer in contact with the electrochromic layer.

21. The laminate of claim 20 wherein the non-conductive substrate comprises a polymer selected from the group consisting of
5 polyesters, polyimides, polyamides, polycarbonate, polyphenylene oxide, polysulfones, cellulose, and polystyrene/polyphenylene oxide.

22. The laminate of claim 20, wherein the electrically conductive layer comprises material selected from the group consisting of ITO, titanium oxide, copper, aluminum, gold, platinum, silver, cobalt, palladium,
10 iridium, and rhodium.

23. A manufactured article comprising the laminate of claim 19.

24. An article of claim 23, selected from the group consisting of: architectural glazing, automotive glazing, mirrors, signage, and displays.

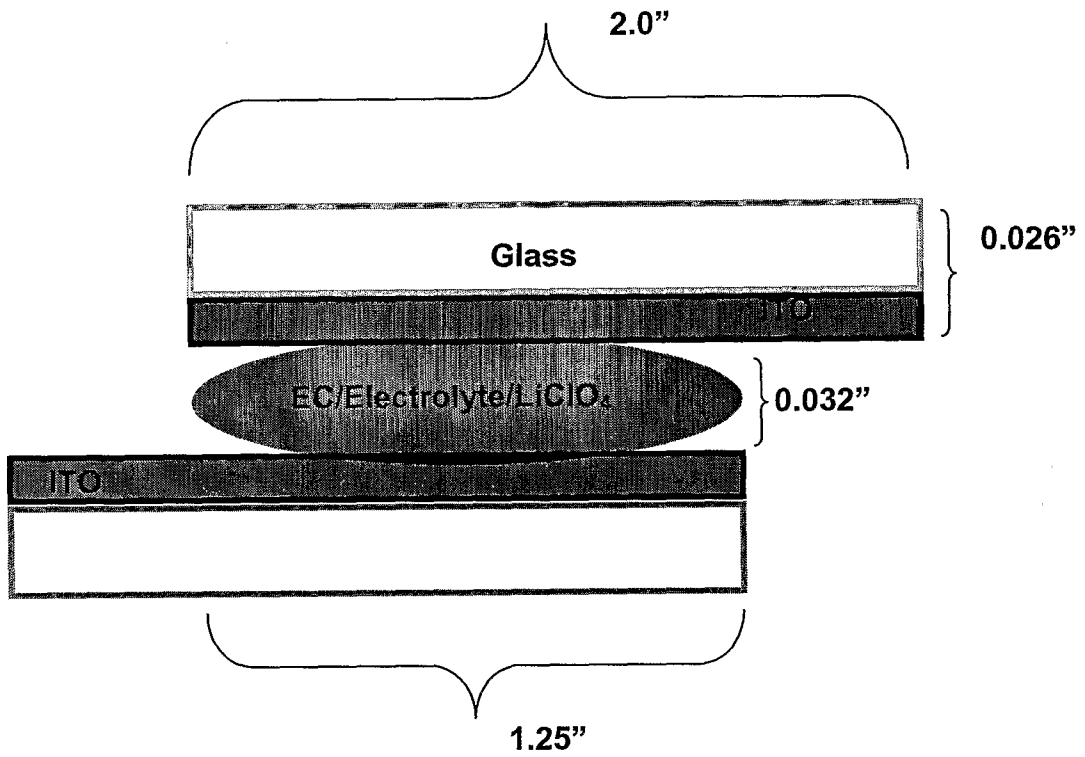


FIGURE 1

All-Solid State Electrochromic Device Using Electrochromic group-Modified Elastomer Blend

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/024549

A. CLASSIFICATION OF SUBJECT MATTER
 INV. C09K9/02 G02F1/15 G02F1/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 C09K G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
 EPO-Internal, PAJ, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 010 741 A2 (NIPPON MITSUBISHI OIL CORP [JP]) 21 June 2000 (2000-06-21)	1
Y	paragraphs [0025] - [0086]; claims 5-7	1-24
X	KOBAYASHI ET AL: "Electrochromic imaging with polymer electrolyte having high-temperature-dependent conductivity" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 90, no. 4, 6 March 2006 (2006-03-06), pages 538-545, XP005255340 ISSN: 0927-0248 page 540 pages 543-545	1

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- | | |
|---|---|
| <ul style="list-style-type: none"> *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed | <ul style="list-style-type: none"> *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *Z* document member of the same patent family |
|---|---|

Date of the actual completion of the international search <p style="text-align: center;">9 March 2007</p>	Date of mailing of the international search report <p style="text-align: center;">16/03/2007</p>
--	---

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer <p style="text-align: center;">Wengeler, Heinz</p>
---	--

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2006/024549

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 995 786 A1 (NIPPON MITSUBISHI OIL CORP [JP]) 26 April 2000 (2000-04-26)	1
Y	pages 3-26; claims 5,6	1-24
X	EP 1 045 276 A (NIPPON MITSUBISHI OIL CORP [JP]) 18 October 2000 (2000-10-18)	1
Y	pages 5-20; claim 6	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2006/024549

Patent document cited in search report	Publication date	Publication date	Patent family member(s)	Publication date
EP 1010741	A2	21-06-2000	DE 69912080 D1	20-11-2003
			DE 69912080 T2	08-07-2004
EP 0995786	A1	26-04-2000	DE 69904792 D1	13-02-2003
			DE 69904792 T2	23-10-2003
			JP 2000131722 A	12-05-2000
			US 6208452 B1	27-03-2001
EP 1045276	A	18-10-2000	WO 9932927 A1	01-07-1999
			JP 11183942 A	09-07-1999
			US 6532098 B1	11-03-2003