protection from moisture and oxygen. Examples of such transparent multilayer barrier coatings and processes can be found, for example, in U.S. Patent Nos. 5,440,446 (Shaw et al.); 5,877,895 (Shaw et al.); 6,010,751 (Shaw et al.); 7,018,713 (Padiyath et al.); and 6,413,645 (Graff et al.).

SUMMARY

~~In one aspect, t~~The present disclosure describes an article including a substrate selected from a (co)polymeric film or an electronic device, the electronic device further including an organic light emitting device (OLED), an electrophoretic light emitting device, a liquid crystal display, a thin film transistor, a photovoltaic device, or a combination thereof; a base (co)polymer layer on a major surface of the substrate; an oxide layer on the base (co)polymer layer; and a protective (co)polymer layer on the oxide layer, wherein the protective (co)polymer layer includes the reaction product of at least one urethane (multi)-(meth) acrylate (multi)-silane precursor compound of the formula R_S-N(H)-C(O)-O-R_A or R_S-O-C(O)-N(H)-R_A. R_S is a silane containing group of the formula -R^1-[$Si(Y_p)(R^2)_{3-p}]_q$, in which R^1 is a multivalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, each Y is a hydrolysable group, R^2 is a monovalent alkyl or aryl group; p is 1, 2, or 3, and q is 1-5. R_A is a (meth)acryl group containing group of the formula R^{11}-$(A)_n$, in which R^{11} is a polyvalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, A is a (meth)acryl group comprising the formula X^2-C(O)-C(R^3)=CH_2, in which X^2 is -O, -S, or –NR^3, R^3 is H, or C_1-C_4, and n=1 to 5.

In one aspect, the present disclosure relates to an article, comprising: a substrate selected from a (co)polymeric film or an electronic device, the electronic device further comprising an organic light emitting device (OLED), an electrophoretic light emitting device, a liquid crystal display, a thin film transistor, a photovoltaic device, or a combination thereof; a base (co)polymer layer on a major surface of the substrate; an oxide layer on the base (co)polymer layer; and a protective (co)polymer layer on the oxide layer, wherein the protective (co)polymer layer comprises the reaction product of at least one urethane (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_S-N(H)-C(O)-O-R_A or R_S-O-C(O)-N(H)-R_A, wherein: R_S is a silane containing group of the formula -R^1-$[Si(Y_p)(R^2)_{3-p}]_q$, further wherein: R^1 is a multivalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, each Y is a hydrolysable group, R^2 is a

monovalent alkyl or aryl group; p is 1, 2, or 3, and q is 1-5; and R_A is a (meth)acryl group containing group of the formula R^{11}-$(A)_n$, wherein: R^{11} is a polyvalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, A is a (meth)acryl group comprising the formula X^2-C(O)-C(R^3)=CH_2, further wherein: X^2 is -O, -S, or –NR^3, R^3 is H, or C_1-C_4, and n=1 to 5.

In any of the foregoing embodiments, each hydrolysable group Y is independently selected from an alkoxy group, an acetate group, an aryloxy group, and a halogen. In some particular exemplary embodiments of the foregoing articles, at least some of the hydrolysable groups Y are alkoxy groups.

In additional exemplary embodiments of any of the foregoing articles, the article includes a multiplicity of alternating layers of the oxide layer and the protective (co)polymer layer on the base (co)polymer layer. In other exemplary embodiments of any of the foregoing articles, the base (co)polymer layer includes a (meth)acrylate smoothing layer.

In further exemplary embodiments of any of the foregoing articles, the oxide layer includes at least one oxide, nitride, carbide or boride of atomic elements selected from Groups IIA, IIIA, IVA, VA, VIA, VIIA, IB, or IIB, metals of Groups IIIB, IVB, or VB,

rare-earth metals, or a combination or mixture thereof. In some exemplary embodiments of any of the foregoing articles, the article further includes an oxide layer applied to the protective (co)polymer layer, optionally wherein the oxide layer includes silicon aluminum oxide.

Some exemplary embodiments of the present disclosure provide composite barrier assemblies, for example composite barrier films. Thus, in some exemplary embodiments of composite barrier films, the substrate includes a flexible transparent (co)polymeric film, optionally wherein the substrate comprises polyethylene terephthalate (PET), polyethylene napthalate (PEN), heat stabilized PET, heat stabilized PEN, polyoxymethylene, polyvinylnaphthalene, polyetheretherketone, a fluoro(co)polymer, polycarbonate, polymethylmethacrylate, poly α-methyl styrene, polysulfone, polyphenylene oxide, polyetherimide, polyethersulfone, polyamideimide, polyimide, polyphthalamide, or combinations thereof. ~~In a further aspect, t~~The disclosure also describes methods of using a composite film as described above in an article selected from a photovoltaic device, a solid state lighting device, a display device, and combinations thereof. Exemplary solid state lighting devices include semiconductor light-emitting diodes (SLEDs, more commonly known as LEDs), organic light-emitting diodes (OLEDs), or polymer light-emitting diodes (PLEDs). Exemplary display devices include liquid crystal displays, OLED displays, and quantum dot displays. In another aspect, the present disclosure relates to an electronic device incorporating the article as defined herein, wherein the article is selected from a solid state lighting device, a display device, and combinations thereof.

~~In an additional aspect, t~~The disclosure also describes a process including (a) applying a base (co)polymer layer to a major surface of a substrate, (b) applying an oxide layer on the base (co)polymer layer, and (c) depositing on the oxide layer a protective (co)polymer layer, wherein the protective (co)polymer layer includes a (co)polymer formed as the reaction product of at least one of the foregoing urethane (multi)-(meth)acrylate (multi)-silane precursor compounds of the formula R_S-N(H)-C(O)-O-R_A or R_S-O-C(O)-N(H)-R_A, as previously described. The substrate is selected from a (co)polymeric film or an electronic device, the electronic device further including an organic light emitting device (OLED), an electrophoretic light emitting device, a liquid crystal display, a thin film transistor, a photovoltaic device, or a combination thereof.

In a further aspect, the present disclosure relates to a process, comprising: (a) applying a base (co)polymer layer to a major surface of a substrate selected from a (co)polymeric film or an electronic device, the electronic device further comprising an organic light emitting device (OLED), an electrophoretic light emitting device, a liquid crystal display, a thin film

transistor, a photovoltaic device, or a combination thereof; (b) applying an oxide layer on the base (co)polymer layer; and (c) depositing on the oxide layer a protective (co)polymer layer, wherein the protective (co)polymer layer comprises the reaction product of at least one urethane (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_S-N(H)-C(O)-O-R_A or R_S-O-C(O)-N(H)-R_A, wherein: R_S is a silane containing group of the formula -R^1-[Si(Y_p)(R^2)$_{3-p}$]$_q$, further wherein: R^1 is a multivalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, each Y is a hydrolysable group, R^2 is a monovalent alkyl or aryl group; p is 1, 2, or 3, and q is 1-5; and R_A is a (meth)acryl group containing group of the formula R^{11}-(A)$_n$, wherein: R^{11} is a polyvalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, A is a (meth)acryl group comprising the formula X^2-C(O)-C(R^3)=CH_2, further wherein: X^2 is -O, -S, or –NR^3, R^3 is H, or C_1-C_4, and n=1 to 5.

In some exemplary embodiments of the process, the at least one urethane (multi)-(meth)acrylate (multi)-silane precursor compound undergoes a chemical reaction to form the protective (co)polymer layer at least in part on the oxide layer. Optionally, the chemical reaction is selected from a free radical polymerization reaction, and a hydrolysis reaction. In any of the foregoing articles, each hydrolysable group Y is independently