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 compositions of matter including at least one urea (multi)-(meth)acrylate (multi)-silane compound of the formula R_S-N(R^5)-C(O)-N(H)-R_A. R_S is a silane containing group of the formula -R^1-[Si(Y_p)(R^2)$_{3-p}$]$_q$, 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. Additionally, 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 having the formula X^2-C(O)-C(R^3)=CH_2, wherein X^2 is -O, -S, or –NR^3, R^3 is H, or C_1-C_4, and n=1 to 5. R^5 is H, C_1 to C_6 alkyl or cycloalkyl, or R_S, with the proviso that at least one of the following conditions applies: n is 2 to 5, R^5 is R_S, or q is 2 to 5.

In one aspect, the present disclosure describes a composition of matter, comprising: at least one urea (multi)-(meth)acrylate (multi)-silane compound of the formula: R_S-N(R^5)-C(O)-N(H)-R_A, wherein: R_S is a silane containing group of the formula: -R^1-[Si(Y_p)(R^2)$_{3-p}$]$_q$, 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; 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; and R^5 is H, C_1 to C_6 alkyl or cycloalkyl, or R_S, with the proviso that at least one of the following conditions applies: n is 2 to 5, R^5 is R_S, or q is 2 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, at least some of the hydrolysable groups Y are chlorine.

~~In another aspect, t~~The present disclosure also 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; 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 of the foregoing urea (multi)-(meth)acrylate (multi)-silane precursor compounds of the formula R_S-N(R^5)-C(O)-N(H)-R_A, as described above.

In another aspect, the present disclosure describes 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 urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_S-N(R^5)-C(O)-N(H)-R_A, wherein: R_S is a silane containing group of the formula: -R^1-[Si(Y_p)(R^2)$_{3-p}$]$_q$, 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; 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; and R^5 is H, C_1 to C_6 alkyl or cycloalkyl, or R_S, with the proviso that at least one of the following conditions applies: n is 2 to 5, R^5 is R_S, or q is 2 to 5.

~~In yet another aspect, t~~The present disclosure also 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 of the foregoing urea (multi)-(meth)acrylate (multi)-silane precursor compounds of the formula R_{S1}-$N(R^4)$-C(O)-N(H)-R_{A1}. R_{S1} is a silane containing group of the formula -R^{1d}-$Si(Y_p)$ $(R^2)_{3-p}$, wherein R^{1d} is a divalent 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, and p is 1, 2, or 3. Additionally, R^4 is H, C_1 to C_6 alkyl or C_1 to C_6 cycloalkyl. R_{A1} is a (meth)acryl containing group of the formula R^{11d}-(A), wherein R^{11d} is a divalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, and 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, and R^3 is H, or C_1-C_4.

In another aspect, the present disclosure describes 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 urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_{S1}-$N(R^4)$-C(O)-N(H)-R_{A1}, wherein: R_{S1} is a silane containing group of the formula: -R^{1d}-$Si(Y_p)(R^2)_{3-p}$, further wherein: R^{1d} is a divalent 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, and p is 1, 2, or 3; R^4 is H, C_1 to C_6 alkyl or C_1 to C_6 cycloalkyl; and R_{A1} is a (meth)acryl containing group of the formula: R^{11d}-(A), wherein: R^{11d} is a divalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, and 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, and R^3 is H, or C_1-C_4.

In any of the foregoing articles, 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 chlorine.

In additional exemplary embodiments of any of the foregoing articles, the articles further include a multiplicity of alternating layers of the oxide layer and the protective (co)polymer layer on the base (co)polymer layer. Some exemplary embodiments of the present disclosure provide composite barrier assemblies, for example composite barrier films, Thus, in some exemplary embodiments of any of the foregoing articles, 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 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 articles further include an oxide layer applied to the protective (co)polymer layer, optionally wherein the oxide layer includes silicon aluminum oxide.

~~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 describes an electronic device incorporating the article as defined herein, wherein the substrate is a (co)polymer film and the electronic device is selected from a solid state lighting device, a display device, and combinations thereof.

~~In another 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 urea (multi)-(meth)acrylate (multi)-silane precursor compounds of the formula R_S-N(R^5)-C(O)-N(H)-R_A or R_{S1}-N(R^4)-C(O)-N(H)-R_{A1}, 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 another aspect, the present disclosure describes 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 a (co)polymer formed as the reaction product of at least one urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_S-N(R^5)-C(O)-N(H)-R_A, wherein: R_S is a silane containing group of the formula: -R^1-[Si(Y_p)(R^2)$_{3-p}$]$_q$, 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, 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}-$(A)_n$, 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)-$C(R^3)=CH_2$ wherein: X^2 is -O, -S, or $-NR^3$, where R^3 is H, or C_1-C_4 and n=1 to 5; and R^5 is H, C_1 to C_6 alkyl or cycloalkyl, or R_S, with the proviso that at least one of the following conditions applies: n is 2 to 5, R^5 is R_S, or q is 2 to 5.

In another aspect, the present disclosure provides 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 a (co)polymer formed as the reaction product of at least one urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula: R_{S1}-$N(R^4)$-C(O)-N(H)-R_{A1}, wherein: R_{S1} is a silane containing group of the formula: -R^{1d}-$Si(Y_p)(R^2)_{3-p}$ wherein: R^{1d} is a divalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, Y is a hydrolysable group, R^2 is a monovalent alkyl or aryl group, and p is 1, 2, or 3; R_{A1} is a (meth)acryl group containing group of the formula: R^{11d}-(A) wherein: R^{11d} is a divalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene groups optionally containing one or more catenary oxygen atoms, and A is a (meth)acryl group comprising the formula X^2-C(O)-$C(R^3)=CH_2$: wherein X^2 is -O, -S, or $-NR^3$, further wherein R^3 is H, or C_1-C_4; and R^4 is H, C_1 to C_6 alkyl or cycloalkyl.

In some exemplary embodiments of the process, the at least one urea (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 processes, 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 chlorine.

In some particular exemplary embodiments of any of the foregoing processes, step (a) includes (i) evaporating a base (co)polymer precursor, (ii) condensing the evaporated base (co)polymer precursor onto the substrate, and (iii) curing the evaporated base (co)polymer precursor to form the base (co)polymer layer. In certain such exemplary embodiments, the base (co)polymer precursor includes a (meth)acrylate monomer