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 features an encapsulated device including a photovoltaic cell and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further including a substrate, 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.

In one aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a substrate; 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 another aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a substrate; 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 another aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a substrate; 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 another aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a substrate; 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)-urethane (meth)acrylate-silane precursor compound of the formula: R_A-NH-C(O)-N(R^4)-R^{11}-[O-C(O)NH-R_S]$_n$, wherein: R_A is a

(meth)acryl containing group of the formula R^{11}-$(A)_n$, further 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 atom, A is a (meth)acryl group comprising the formula X^2-C(O)-C(R^3)=CH_2, additionally wherein: X^2 is -O, -S, or –NR^3, R^3 is independently H, or C_1-C_4, and n = 1 to 5, R^4 is H, C_1 to C_6 alkyl, or C_1 to C_6 cycloalkyl; R_S is a silane containing group of the formula -R^1-Si(Y_p)(R^2)$_{3-p}$, wherein: R^1 is a polyvalent 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.

In another aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a composite film, comprising: a substrate; 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)-urethane (meth)acrylate-silane precursor compound of the formula: R_S-NH-C(O)-N(R^4)-R^{11}-[O-C(O)NH-R_A]$_n$, wherein: R_S is a silane containing group of the formula -R^1-Si(Y_p)(R^2)$_{3-p}$, wherein: R^1 is a polyvalent 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^4 is H, C_1 to C_6 alkyl, or C_1 to C_6 cycloalkyl; R_A is a (meth)acryl group containing group of the formula R^{11}-$(A)_n$, further wherein: R^{11} is a polyvalent alkylene, arylene, alkarylene, or aralkylene group, said alkylene, arylene, alkarylene, or aralkylene group optionally containing one or more catenary oxygen atom, A is a (meth)acryl containing group of the formula X^2-C(O)-C(R^3)=CH_2, additionally wherein: X^2 is -O, -S, or –NR^3, R^3 is independently H, or C_1-C_4, and n = 1 to 5.

In another aspect, the present disclosure features an encapsulated device comprising: a photovoltaic cell; and a composite film overlaying at least a portion of the photovoltaic cell, the composite film further comprising: a substrate; 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 some exemplary embodiments, the protective (co)polymer layer includes the reaction product of at least one urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula $R_S-N(R^5)-C(O)-N(H)-R_A$. 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. 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 $X^2-C(O)-C(R^3)=CH_2$, in which 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 other exemplary embodiments, the protective (co)polymer layer includes the reaction product of at least one urea (multi)-(meth)acrylate (multi)-silane precursor compound of the formula$R_{S1}-N(R^4)-C(O)-N(H)-R_{A1}$. R_{S1} is a silane containing group of the formula $-R^{1d}-Si(Y_p)(R^2)_{3-p}$, in which 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 $R^{11d}-(A)$, in which 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,