layer onto the substrate when formed into a plasma with a second gaseous species capable of etching the substrate when formed into a plasma, thereby forming a gaseous mixture, forming the gaseous mixture into a plasma, and exposing a surface of the substrate to the plasma, wherein the surface is etched and a layer is substantially simultaneously deposited on at least a portion of the etched surface, thereby forming a nanostructure comprising nano-pillars or nano-columns having features of diverse height and aspect ratio.

Further, when the substrate is a fluoropolymer, the above techniques provide exceptional adhesion to adjacent layers that may be applied by coating, laminating, or compression onto the nanostructure. Thus, in some embodiments, the disclosure provides that where the substrate is a fluoropolymer, the method may further comprise contacting the nanostructure with a film or a film-forming material so as to form a multi-layered laminate. Fluoropolymers are notoriously difficult to make adhesion to, and with the techniques of this disclosure, it is possible to form a multilayered laminate where the adhesive strength between the film and the nanostructure is greater than the cohesive strength of the film.

In another aspect, the disclosure provides a method of forming a multilayered laminate, comprising:

providing a fluoropolymer film having at least a first surface, forming a nanostructure further comprising nano-pillars or nano-columns having features of diverse height and aspect ratio on the first surface, and contacting the nanostructure with a film or a film-forming material so as to form a multi-layered laminate.

In some exemplary embodiments of the foregoing, the substrate can be a non-conductive substrate, for example a substrate including a (co)polymer (e.g. a (co)polymeric film), a fiber, a glass, a composite, a microporous membrane and combinations thereof. In certain such exemplary embodiments, the substrate can be transparent to visible light and can include (co)polymers such as poly(methyl methacrylate), poly(ethylene terephthalate), polycarbonate, cellulose, triacetate, polyamide, polyimide, a fluoropolymer, a polyolefin, a siloxane (co)polymer, a cyclic olefin (co)polymer, a polyurethane and combinations thereof.

In certain such exemplary embodiments, the first gaseous species includes a compound selected from the group consisting of organosilicon compounds, metal alkyl compounds, metal isopropoxide compounds, metal oxide compounds, metal acetylacetonate compounds, metal halide compounds, and combinations thereof. The

CLAIMS

1. A method of making a nanostructure, comprising:

providing a substrate;

mixing a first gaseous species capable of depositing a layer onto the substrate when formed into a plasma, with a second gaseous species capable of etching the substrate when formed into a plasma, thereby forming a gaseous mixture;

forming the gaseous mixture into a plasma; and

exposing a surface of the substrate to the plasma, wherein the surface is etched and a layer is substantially simultaneously deposited on at least a portion of the etched surface, thereby forming a nanostructure comprising nano-pillars or nano-columns having features of diverse height and aspect ratio.

2. A method of making a nanostructure according to claim 1, wherein the substrate comprises a (co)polymeric material, an inorganic material, an alloy, a solid solution, or a combination thereof.

3. A method of making a nanostructure according to claim 2, wherein the (co)polymeric material comprises a (co)polymer selected from poly(methyl methacrylate), poly(ethylene terephthalate), polycarbonate, cellulose, triacetate, polyamide, polyimide, a fluoropolymer, a polyolefin, a siloxane (co)polymer, a cyclic olefin (co)polymer, a polyurethane, and combinations thereof.

4. A method making a nanostructure according to claim 3, wherein the (co)polymer is a polytetrafluoroethylene fluoropolymer and the surface of the substrate is substantially colorless after exposure to the plasma.

5. A method of making a nanostructure according to claim 1, wherein the substrate comprises a transparent (co)polymer.

6. A method of making a nanostructure according to claim 1, wherein the first gaseous species comprises a compound selected from the group consisting of organosilicon compounds, metal alkyl compounds, metal isopropoxide compounds, metal oxide compounds, metal acetylacetonate compounds, metal halide compounds, and combinations thereof.

7. A method of making a nanostructure according to claim 6, wherein the organosilicon compounds comprise tetramethylsilane, trimethylsilane, hexamethyldisiloxane, tetraethylorthosilicate, a polyhedral oligomeric silsesquioxane, or a combination thereof.

8. A method of making a nanostructure according to claim 1, wherein the second gaseous species comprises oxygen, a fluorocarbon, nitrogen trifluoride, sulfur hexafluoride, chlorine, hydrochloric acid, methane, or a combination thereof.

9. A method of making a nanostructure according to claim 8, wherein the fluorocarbon is selected from tetrafluoromethane, perfluoropropane, and combinations thereof.

10. A method of making a nanostructure according to claim 1, wherein the gaseous mixture further comprises argon.

11. A method of making a nanostructure according to claim 1, wherein the nanostructure has a dimension of less than about 400 nanometers.

12. A method of making a nanostructure according to claim 11, wherein the nanostructure has a dimension of less than about 40 nanometers.

13. A method of making a nanostructure according to claim 1, performed in a substantially continuous manner.

14. An article comprising a nanostructure further comprising nano-pillars or nano-columns having features of diverse height and aspect ratio made from the method according to any of claims 1-13.

15. An article according to claim 14, having a Reflectance of less than 3% and a Haze Delta of less than 0.5%.

16. An article according to claim 15, having a Reflectance of less than 2% and a Haze Delta of less than 0.5%.

27. A method of making a nanostructure according to claim 1, wherein the substrate is a fluoropolymer, and the method further comprises contacting the nanostructure with a film or a film-forming material so as to form a multi-layered laminate.

28. A method of forming a multilayered laminate, comprising:

providing a fluoropolymer film having at least a first surface,

forming a nanostructure further comprising nano-pillars or nano-columns having features of diverse height and aspect ratio on the first surface, and

contacting the nanostructure with a film or a film-forming material so as to form a multi-layered laminate.

29. A method of forming a multilayered laminate according to claim 28, wherein the adhesive strength between the film and the nanostructure is greater than the cohesive strength of the film.

30. An article made from the method according to any of claims 28-29.