CLAIMS

1. A method to create a colored surface, comprising the steps of:

   (a) anodizing a substrate in an anodizing bath comprising phosphoric acid, at a constant temperature and a constant voltage for a first time period to develop an anodizing layer having main pores; wherein each of the main pores includes side pores; wherein the anodizing layer includes a barrier layer;
   (b) reducing the constant voltage applied to the anodizing bath for a second time period to change a thickness of the barrier layer and change a width of the main pores in the anodizing layer;
   (c) plating the substrate in a plating bath to partially fill the main pores and the side pores and develop a plasmonic surface at a first current that is increased over a third time period in accordance with a current profile of the plating bath;
   (d) plating the substrate in the plating bath at a second current for a fourth time period to partially fill the main pores and the side pores with metal nanorods; and
   (e) applying a sealing layer over the main pores of the anodizing layer and forming an air gap between the metal nanorods and the sealing layer.

2. The method of claim 1, wherein the substrate comprises an aluminum alloy.

3. The method of claim 1, wherein in step (a) the constant temperature is a temperature between 20 degrees Celsius and 40 degrees Celsius.

4. The method of claim 1, wherein in step (a) the constant voltage is a voltage between 60 Volts and 280 Volts, with a maximum current density of 2 amperes per square decimeter.

5. The method of claim 1, wherein in step (b) the constant voltage is reduced by 50%, and the second time period comprises between 2 and 10 minutes and then reduced by a further 50% for a third time period of between 2 and 10 minutes.

6. The method of claim 1, wherein in step (b) the voltage applied to the anodizing bath is reduced to (i) reduce the thickness of the barrier layer, and (ii) to increase the width of the main pores in the anodizing layer.

7. A method to create a plasmonic colored surface, comprising the steps of:

(a) anodizing an aluminum alloy substrate in an anodizing bath comprising phosphoric acid, at a constant temperature and a constant direct or pulsed current and/or voltage for a first time period to develop an anodizing layer of between 2 and 10 microns thick having main pores; wherein the main pores include side pores; wherein the anodizing layer includes a barrier layer;

(b) reducing the constant direct or pulsed current and/or voltage applied to the anodizing bath for a second time period to change a thickness of the barrier layer and change a width of the main pores in the anodizing layer;

(c) plating the aluminum alloy substrate in a plating bath at a first current that is increased over a third time period in accordance with a direct current (DC) plating current profile of the plating bath;

(d) plating the aluminum alloy substrate in the plating bath at a second current for a fourth time period to partially fill the main pores and the side pores in the anodizing layer and develop a plasmonic surface; and

(e) sealing the main pores of the anodizing layer resulting in an air gap formed between the main pores and a sealing layer.

8. The method of claim 7, wherein in step (a) the anodizing bath comprises 50-600 milliliters per liter (ml/L) of phosphoric acid, 1-15 ml/L of sulfuric acid, and 1-10 grams per liter (g/L) of oxalic acid.

9. The method of claim 7, wherein in step (a) the anodizing bath further comprises 1 to 5 weight percent of copper sulfate and ethylenediaminetetraacetic acid (EDTA).

10. The method of claim 7, wherein in step (c) the plating bath comprises a semi-bright

nickel bath with a nominal plating current of between 2 amperes per square decimeter (A/dm^2) and 4 A/dm^2.

11. The method of claim 7 wherein in step (d) the plating of the substrate partially fills the pores in the anodizing layer with metal nanorods.

12. A method, comprising the steps of:

(a) pre-treating an aluminum alloy substrate;
(b) activating the aluminum alloy substrate;
(c) anodizing the aluminum alloy substrate in an anodizing bath comprising phosphoric acid, at a constant temperature and a constant voltage for a first time period, to develop an anodizing layer having main pores; wherein the main pores include side pores; that includes a barrier layer;
(d) reducing the constant voltage applied to the anodizing bath for a second time period to change a thickness of the barrier layer and change a width of the main pores in the anodizing layer;
(e) plating the aluminum alloy substrate in a plating bath via multiple plating stages to deposit metal nanorods into the main pores and the side pores of the anodizing layer; and
(f) sealing the main pores of the anodizing layer resulting in an air gap formed between the main pores and a sealing layer.

13. The method of claim 12, wherein the pre-treating step (a) modifies the average roughness (Ra) of the aluminum alloy substrate and comprises:
degreasing the aluminum alloy substrate in an alkaline bath;
roughening the aluminum alloy substrate in a solution of phosphoric acid, polyethylene glycol, sulfuric acid, and hydrofluoric acid; and
etching the aluminum alloy substrate in a nitric acid solution to develop an Ra of between 0.4 and 1.8.

14. The method of claim 12, wherein in step (e) the multiple plating stages comprise: a first plating stage that applies a first current that is increased over a third time period

in accordance with a current profile of the plating bath; and

a second plating stage that applies a constant second current for a fourth time period.

15. The method of claim 12 wherein in step (f) the step of sealing the pores of the anodizing layer, the air gap is maintained between the pores and a sealing layer by a nanoparticle configured to plug the pores.

16. A method to create a plasmonic colored surface, comprising the steps of:

(a) anodizing a substrate in an anodizing bath comprising phosphoric acid, at a constant temperature and a constant voltage for a first time period to develop an anodizing layer having main pores; wherein each of the main pores include side pores; wherein the anodizing layer includes a barrier layer;

(b) reducing the constant voltage applied to the anodizing bath for a second time period to change a thickness of the barrier layer and change a width of the main pores in the anodizing layer;

(c) plating the substrate in a plating bath to fill or partially fill the main pores and the side pores and develop a plasmonic surface, at a first current that is increased over a third time period in accordance with a current profile of the plating bath;

(d) plating the substrate in the plating bath at a second current for a fourth time period; and

(e) sealing the main pores of the anodizing layer resulting in an air gap formed between the main pores and a sealing layer.