Phantom Color

The invention relates to a container for holding one or more materials, comprising a non-dichroic omnidirectional structural color, said non-dichroic omnidirectional structural color, and further to a packaged product, comprising such a container and at least one material that is being held within said container, said material being selected from the group consisting of laundry and homecare compositions, cosmetic compositions, food stuffs and beverages, as well as to a method of applying color to a plastic material.

One of the biggest hurdles in recycling is that when plastic material is recycled, the recycled material preserves the original packaging color. When multiple materials are mixed for a new feed, the product takes on inconsistent and unpleasant colors. Currently the way to combat this is either to not recycle colored materials (recommended practice for transparent materials), or to add a black masterbatch to the recycling stream (recommended practice for all colored materials). These solutions are not only selective, reducing the potential amount of recycled material, but also leaves recycled packaging with either a black color or the materials natural color, considering that the material will be recycled once again. Having only two color options to choose from is not beneficial for product marketing considering the overall competitive market.

Structural colors can be made from dielectric layers and provide “brilliant” looking coatings, paints, etc. However, structural colors can also suffer from dichroic behavior, i.e., the dielectric layers can act as a color filter and two colors can appear from such a structure, one from reflectance and another from transmission. Such a property can pose a problem since the dichroism can result in the “leaking” of a background layer, e.g., a primer layer, and as such, a black background or primer is required if a single structural color appearance is desired. U.S. Patent No. US10,048,415B2 describes a structural color that can absorb or reflect incident electromagnetic radiation and prevent dichroic behavior.

As has been surprisingly discovered, application of a non-dichroic omnidirectional structural color to a plastic material, such as container plastic material commonly used for packaged products such as detergent formulations, cosmetic formulations such as shampoo, but also food stuffs and beverages, allows for recycling of the plastic material, since the structural color does not interfere with the recycling process insofar as that application of the paint is not interfered with by any residual color present in the recycled material.

In a first aspect, the invention thus provides a container for holding one or more materials, comprising a non-dichroic omnidirectional structural color, said non-dichroic omnidirectional structural color comprising

- a multilayer stack having an absorbing layer, a first layer made from a first material having a first index of refraction and a first predefined thickness extending across said absorbing layer, and a

second layer made from a second material having a second index of refraction and a second predefined thickness extending across said first layer;

- said absorbing layer is selected from the group consisting of chromium, nickel, carbon, graphite, graphene, titanium, vanadium, aluminum, cobalt, silver, molybdenum, niobium, iron, steel, tungsten and alloys thereof;
- said multilayer stack reflecting a single narrow band of visible electromagnetic radiation having a reflectance between 65-80% of incident light waves, a width of less than 200 nanometers and a center wavelength shift of less than 50 nanometers when viewed from angles between 0 and 45 degrees and exposed to a source of broadband electromagnetic radiation.

In a second aspect, the present invention further provides a packaged product, comprising a container according as herein described, and at least one material that is being held within said container, said material being selected from the group consisting of laundry and homecare compositions, cosmetic compositions, food stuffs and beverages.

Other features and aspects of the subject matter are set forth in greater detail below.

“One or more”, as used herein, relates to at least one and comprises 1, 2, 3, 4, 5, 6, 7, 8, 9 or more of the referenced species. Similarly, “at least one” means one or more, i.e., 1, 2, 3, 4, 5, 6, 7, 8, 9 or more.

“At least one”, as used herein in relation to any component, refers to the number of chemically different molecules, i.e., to the number of different types of the referenced species, but not to the total number of molecules. For example, “at least one polyethylene” means that at least one type of molecule falling within the definition for a polyethylene is used but that also two or more different molecule types falling within this definition can be present, but does not mean that only one molecule of said polyethylene is present.

“About”, as used herein in relation to a numerical value, means said value ±10%, preferably ±5%.

All percentages given herein in relation to the compositions or formulations relate to weight % relative to the total weight of the respective composition or formula, if not explicitly stated otherwise.

The present invention addresses the above-outlined issues encountered with the recycling of colored plastic materials in providing for a container for holding one or more materials, comprising a non-dichroic omnidirectional structural color is provided. The non-dichroic omnidirectional structural color can include a multilayer stack that has an absorbing layer, a first layer extending across the absorbing layer, and a second layer extending across the first layer. The first layer can be made from a first material that has a first index of refraction and a first predefined thickness and the second layer can be made from a second material that has a second index of refraction and a second predefined thickness.

The multilayer stack can reflect a narrow band of electromagnetic radiation when exposed to a source of broadband electromagnetic radiation, e.g., white light, sun light, etc. The narrow band having a width of less than 500 nanometers and a center wavelength shift of less than 200 nanometers when the multilayer stack is viewed from angles between 0 and 45 degrees. In some instances, the multilayer stack can have a third layer and a fourth layer that is present on an opposite side of the absorbing layer. The third layer and the fourth layer may or may not be made from the first material and the second material, respectively. In addition, the third layer and the fourth layer may or may not have a thickness that is equal to the first predefined thickness and the second predefined thickness, respectively.

The absorbing layer can contain chromium and, in some instances, can be a chromium layer. Furthermore, the multilayer structure can be a paint pigment that may or may not be mixed with a binder to form a paint, the paint blocking electromagnetic radiation reflected off of a primer layer that the paint is applied to. In the event that the paint contains other additives that can reflect electromagnetic radiation, the paint pigment can block such reflected electromagnetic radiation. In this manner, the multilayer stack can provide a “pure” color that is not contaminated by electromagnetic radiation that is reflected off of an underlying primer, additives within a binder, and the like.

In some instances, the narrow band of reflected electromagnetic radiation is less than 250 nanometers and the center wavelength shift is less than 150 nanometers when the multilayer structure is viewed from angles between 0 and 45 degrees. In other instances, the narrow band of reflected electromagnetic radiation has a width of less than 200 nanometers and the center wavelength shift is less than 100 nanometers when viewed from angles between 0 and 45 degrees. In still other instances, the above stated properties can be provided when the multilayer structure is viewed from angles between 0 to 50, 0 to 60 and/or 0 to 70 degrees.

The absorbing layer, first layer, and second layer can be located on a substrate and may or may not be located on both sides of a substrate that is generally planar. In addition, the substrate can be a particle that is coated with the absorbing layer, first layer, and second layer. It is appreciated that more than two layers can be present and the multilayer structure may or may not be a quarter wave design. Stated differently, the multilayer structure/stack with the absorbing layer has at least two layers that may or may not have thicknesses in accordance with a quarter wave design, so long as the multilayer structure reflects a narrow band of electromagnetic radiation with a width of less than 500, 250 or 200 nanometers and has a narrow band center wavelength shift of less than 200, 150 or 100 nanometers when the stack is viewed from angles between 0 and 45, 0 to 50, 0 to 60, or 0 to 70 degrees.

Further reference in this regard is made to US 10,048,415 B2, which is incorporated herein by reference in its entirety.

Particularly, provided herein is container for holding one or more materials, comprising a non-dichroic omnidirectional structural color, said non-dichroic omnidirectional structural color comprising a multilayer

stack having an absorbing layer, a first layer made from a first material having a first index of refraction and a first predefined thickness extending across said absorbing layer, and a second layer made from a second material having a second index of refraction and a second predefined thickness extending across said first layer; said absorbing layer is selected from the group consisting of chromium, nickel, carbon, graphite, graphene, titanium, vanadium, aluminum, cobalt, silver, molybdenum, niobium, iron, steel, tungsten and alloys thereof; said multilayer stack reflecting a single narrow band of visible electromagnetic radiation having a reflectance between 65-80% of incident light waves, a width of less than 200 nanometers and a center wavelength shift of less than 50 nanometers when viewed from angles between 0 and 45 degrees and exposed to a source of broadband electromagnetic radiation.

The omnidirectional structural color multilayer structure blocks light reflected from an underlying layer and/or additives, particles, and the like that are present in the proximity thereof. As such, the omnidirectional structural color multilayer structure has use as a paint pigment.

The omnidirectional structural color multilayer structure can have an absorbing layer, a first layer made from a first material extending across the absorbing layer, and a second layer made from a second material extending across the first layer. The first layer can have a first predefined thickness and the first material can have a first index of refraction. The second layer can have a second predefined thickness and the second material can have a second index of refraction. The at least two layers extending across the absorbing layer can reflect a narrow band of electromagnetic radiation when exposed to a source of broadband electromagnetic radiation, the narrow band having a width of less than 500, 250 or 200 nanometers and a center wavelength shift of less than 200, 150 or 100 nanometers when the multilayer structure is viewed from angles between 0 and 45, 0 to 50, 0 to 60, or 0 to 70 degrees. In addition, the multilayer structure can have a quantity defined as a range to mid-range ratio of less than 2%.

The absorbing layer can block electromagnetic radiation reflected off of a surface that is proximate to the multilayer structure. It is appreciated that the blocking of the electromagnetic radiation from the surface that is proximate to the multilayer structure can afford in the decrease or elimination of “leaking or “bleed through” of a color(s) from a surface(s) that is(are) are proximate to the multilayer structure. For example, the multilayer structure can be in the form of a paint pigment, and the paint pigment can block light that has been reflected off of an underlying primer layer that the paint has been applied to. In this manner, an underlying primer layer does not have to be a particular color, e.g. black, and the suppression or blocking of color(s) from additional additives within the paint can be provided. As such, the multilayer structure affords for a greater variety of additives, primer colors, and the like to be used in combination with paint.

The absorbing layer can have two or more dielectric layers extending there across with a first layer extending and in direct contact with the absorbing layer and a second layer extending and in direct contact with the first layer. In some instances, the absorbing layer has two sides with at least two

dielectric layers extending across both sides. In other instances, the absorbing layer can be in the form of a particle which is coated by the at least two dielectric layers. In still yet other instances, a substrate in the form of a particle can be coated by the absorbing layer and the at least two dielectric layers.

The absorbing layer can be made from any material known to those skilled in the art that defines at least 0-70% transparent of incident electromagnetic radiation of either all or certain frequency of light. Suitable materials for such an absorbing layer can be semi-opaque or opaque material such as chromium, nickel, carbon, graphite, graphene, titanium, vanadium, aluminum, cobalt, silver, molybdenum, niobium, iron, stainless steel, tungsten and various combinations of alloys of these materials such as Ni—Cr or Ni—Cr—Fe. Absorber materials also can be visually dark oxides like biotite, doped mica, doped aluminum oxide, other metal colored metal oxide such as aluminum oxide, neodymium oxide, tungsten oxide, iron oxide etc. and combinations thereof.

Regarding the at least two dielectric layers, the first layer can have a refractive index between 2 and 4 and the second layer can have a refractive index between 1 and 3. In addition, the first layer and the second layer can have a refractive index contrast between 0.2 and 1.0. In some instances, the first layer can have a refractive index between 2 and 2.5 while the second layer can have a refractive index between 1.8 and 2.2.

The multilayer structure can be in the form of a pigment, i.e., a plurality of particles that can be mixed with a binder, solvent, and the like to produce a paint that can be applied to a surface with a brush or by spraying. The solvent can be any solvent composition known to those skilled in the art, illustratively including organic solvents or water. For example, organic solvents such as aliphatics, aromatics, alcohols, ketones, white spirit, petroleum distillates, esters, glycol ethers, and the like can be used. Additives can be included within the paint composition, for example surface tension modifiers, flow modifiers, surface finish modifiers, wet edge modifiers, pigment stability modifiers, antifreeze modifiers, foam control modifiers, catalysts, thickeners, stabilizers, emulsifiers, texture modifiers, adhesion modifiers, flatteners, biocides, and the like.

In some instances, a nonstructural color pigment can also be included and dispersed throughout the binder along with the omnidirectional structural color pigment. The omnidirectional structural color pigment can make up between 1 and 20 percent of the overall composition, however this is not required. In addition, the paint can be a base coat of a two-stage paint or in the alternative the paint can be a base coat of a self-stratifying paint. It is appreciated that the paint can be applied on top of a primer layer that is used to coat and protect materials such as steels, galvanized steels, galvaluminized steels, aluminum, aluminum alloys, plastics, and the like.

In various embodiments, said multilayer stack has a third layer and a fourth layer on an opposite side of said absorbing layer.

In various further embodiments, said third layer and said fourth layer are made from said first material and said second material, respectively. In some embodiments, said third layer and said fourth layer have a thickness equal to said first predefined thickness and said second predefined thickness, respectively.

In further embodiments, the absorbing layer is selected from the group consisting semi-opaque materials and opaque materials. For instance, in various embodiments, the absorbing layer is a visually dark oxide. In some embodiments, said visually dark oxide is selected from the group consisting of biotite, doped mica, aluminum oxide, doped aluminum oxide, neodymium oxide, tungsten oxide, iron oxide and combinations thereof.

Particularly, in various embodiments, the multilayer structure described herein is a paint pigment.

In some embodiments, wherein the multilayer structure described herein is a paint pigment, the container of the present invention further comprises a binder mixed with said paint pigment to form a paint, said paint blocking electromagnetic radiation reflected off of a primer layer when said paint is applied thereto.

In various further such embodiments, wherein the container comprises a paint containing the multilayer structure in the form of a paint pigment, the container further comprises a paint additive mixed within said paint, said paint pigment blocking electromagnetic radiation reflected off of said paint additive when said paint is exposed to said source of broadband electromagnetic radiation.

In various embodiments, preferably, the non-dichroic omnidirectional structural color described herein is present on at least one surface of a substrate material, wherein the substrate material defines the shape and dimensions of the container and is fitted for holding one or more materials.

Substrate materials suitable for employment in this context are generally known in the art and particularly include plastic materials comprising recyclable materials, particularly recyclable plastic materials, more preferably plastic materials consisting of recyclable materials, such as, without limitation, PET (Polyethylene Terephthalate), HDPE (High-Density Polyethylene), PVC (Polyvinyl Chloride), LDPE (Low-Density Polyethylene), PP (Polypropylene), PS (Polystyrene), and Polycarbonate.

In various embodiments, the substrate material comprises at least one plastic material, and preferably the plastic material comprises or consists of a recyclable plastic material.

Addressing the above-outlined issues, the present invention further provides for a packaged product, comprising a container as herein described above, and at least one material that is being held within said container, said material being selected from the group consisting of laundry and homecare compositions, cosmetic compositions, food stuffs and beverages.

A process for producing a component having an omnidirectional structural color appearance generally includes providing a component to be painted, and providing a paint having a reflection band of less than 500, 250 or 200 nanometers, a reflection band center wavelength of less than 200, 150 or 100 nanometers, when a layer of the paint is viewed from angles between 0 and 45 degrees. The component can have a primer layer that does not have a color of black and the omnidirectional structural color paint can be applied on top of the primer layer and allowed to dry and/or cure. The painted component has an omnidirectional structural color appearance with a reflection band of less than 200 nanometers when viewed from an angle of between 0 and 45 degrees and a shift in the center wavelength of the reflection band of less than 200 nanometers when viewed from these angles. The paint having the multilayer structure that includes the absorbing layer prevents light reflected from the primer layer to alter or distort the color of the paint pigment.

In a further aspect, therefore, the present invention also provides for a method of applying color to a plastic material, preferably a plastic material suitable for use as a container material for holding one or more consumer product materials, the method comprising applying a non-dichroic omnidirectional structural color, as herein described above, to the plastic material.

To this end, the plastic material is part of a material or constitutes a material forming a container or vessel suitable for receiving and holding a respective consumer product, such as a detergent formulation, a hair shampoo or a beverage, and thus featuring at least one outer surface and at least one inner surface (more than one inner surface, for instance, may be present if the container comprises more than one inner compartment), and the non-dichroic omnidirectional structural color is applied to at least one surface, preferably at least one outer surface of the container-forming material. Means of applying the color herein described include, without limitation, spraying of a paint containing said color in the form of a paint pigment onto said surface, immersing the surface into such a paint, and the like.

It is understood that all embodiments disclosed herein in relation to the container are similarly applicable to the packaged products, and methods of applying color, insofar applicable, and *vice versa*.

Claims

1. A container for holding one or more materials, comprising a non-dichroic omnidirectional structural color, said non-dichroic omnidirectional structural color comprising
   - a multilayer stack having an absorbing layer, a first layer made from a first material having a first index of refraction and a first predefined thickness extending across said absorbing layer, and a second layer made from a second material having a second index of refraction and a second predefined thickness extending across said first layer;
   - said absorbing layer is selected from the group consisting of chromium, nickel, carbon, graphite, graphene, titanium, vanadium, aluminum, cobalt, silver, molybdenum, niobium, iron, steel, tungsten and alloys thereof;
   - said multilayer stack reflecting a single narrow band of visible electromagnetic radiation having a reflectance between 65-80% of incident light waves, a width of less than 200 nanometers and a center wavelength shift of less than 50 nanometers when viewed from angles between 0 and 45 degrees and exposed to a source of broadband electromagnetic radiation.

2. The container according to claim 1, wherein said multilayer stack has a third layer and a fourth layer on an opposite side of said absorbing layer.

3. The container according to claim 2, wherein said third layer and said fourth layer are made from said first material and said second material, respectively.

4. The container according to any one of claims 2 and 3, wherein said third layer and said fourth layer have a thickness equal to said first predefined thickness and said second predefined thickness, respectively.

5. The container according to any one of claims 1 to 4, wherein said absorbing layer is selected from the group consisting semi-opaque materials and opaque materials.

6. The container according to any one of claims 1 to 5, wherein said absorbing layer is a visually dark oxide.

7. The container according to claim 6, wherein said visually dark oxide is selected from the group consisting of biotite, doped mica, aluminum oxide, doped aluminum oxide, neodymium oxide, tungsten oxide, iron oxide and combinations thereof.

8. The container according to any one of claims 1 to 7, wherein said multilayer structure is a paint pigment.

9. The container according to claim 8, further comprising a binder mixed with said paint pigment to form a paint, said paint blocking electromagnetic radiation reflected off of a primer layer when said paint is applied thereto.

10. The container according to claim 8, further comprising a paint additive mixed within said paint, said paint pigment blocking electromagnetic radiation reflected off of said paint additive when said paint is exposed to said source of broadband electromagnetic radiation.

11. The container according to any one of claims 1 to 10, wherein the non-dichroic omnidirectional structural color is present on at least one surface of a substrate material, wherein the substrate material defines the shape and dimensions of the container and is fitted for holding one or more materials.

12. The container according to claim 11, wherein the substrate material comprises at least one plastic material.

13. The container according to claim 12, wherein the plastic material is recyclable.

14. A packaged product, comprising a container according to any one of claims 1 to 13, and at least one material that is being held within said container, said material being selected from the group consisting of laundry and homecare compositions, cosmetic compositions, food stuffs and beverages.