simulation system, one or more input properties, wherein each of the one or more input properties is indicative of a property of an array of nanoparticles; providing, to the processor, one or more input parameters for an optical simulation; performing, by the processor, the optical simulation by applying a stochastic model of the array of nanoparticles according to the input parameters; and determining, by the processor, and from the optical simulation, an output optical parameter indicative of structural color.

[0004a] In an aspect, there is provided a computer-implemented method for producing a bulk material and determining a color thereof, the computer-implemented method comprising:

providing, to a processor of a simulation system, one or more input properties, wherein each of the one or more input properties is indicative of a property of one or more arrays of nanoparticles, and wherein each of the arrays of nanoparticles is contained within one of a plurality of microspheres, and wherein the plurality of microspheres is contained within the bulk material;

providing, to the processor, one or more input parameters for an optical simulation;

performing, by the processor, the optical simulation by applying a stochastic model of an array of the one or more arrays of nanoparticles according to the input parameters, wherein the optical simulation accounts for properties of light as applied to the bulk material and microspheres thereof, wherein stochastic model comprises a Monte Carlo model or a two-tiered stochastic model, and wherein the one or more input properties affect the optical simulation by affecting a phenomena of light including a boundary condition for light scattering; and

determining, by the processor, and from the optical simulation, an output optical parameter indicative of structural color of the bulk material.

[0005] In another example, there is a simulation system for determining structural color. The system may include a processor configured to execute machine readable instructions that cause the processor to: receive one or more input properties, wherein each of the one or more input properties is indicative of a property of an array of nanoparticles; receive one or more input parameters for an optical simulation; perform the optical simulation by applying a stochastic model of the array of nanoparticles according to the input parameters; and determine from the optical simulation an output optical parameter indicative of structural color.

[0005a] In another aspect, there is provided a system for determining structural color, the system comprising a processor configured to execute machine readable instructions that cause the processor to:

receive one or more input properties, wherein each of the one or more input properties is indicative of a property of an array of nanoparticles, the array of nanoparticles being part of a bulk material, the bulk material including at least one microsphere containing the array of nanoparticles;

receive one or more input parameters for an optical simulation;

perform the optical simulation by applying a stochastic model of the array of nanoparticles according to the one or more input parameters, wherein the optical simulation accounts for properties of light as applied to the bulk material, wherein stochastic model comprises a Monte Carlo model or a two-tiered stochastic model, and wherein the one or more input properties affect the optical simulation by affecting a phenomena of light including a boundary condition for light scattering; and

determine from the optical simulation an output optical parameter indicative of structural color of the bulk material.

[0006] In yet another example, there is a method for determining one or more properties of an array of nanoparticles according to desired target properties. The method may include: providing, to a processor, one or more target properties, wherein each of the one or more target properties is indicative of a desired optical property of an array of nanoparticles; providing, to the processor, one or more input parameters for an optical simulation; performing, by the processor, an evolutionary algorithm according to the input properties and input parameters, and wherein the evolutionary algorithm employs an optical simulation of the array of nanoparticles; and determining, by the processor, and from the evolutionary algorithm, an output design parameter indicative of one or more properties of the array of nanoparticles.

In still another example, there is an optimization system. The optimization system may include a processor configured to execute machine readable instructions that cause the processor to: receive one or more target properties, wherein each of the one or more target properties is indicative of a desired optical property of an array of nanoparticles; receive one or more input parameters for an optical simulation; perform an evolutionary algorithm according to the input properties and input parameters, and wherein the evolutionary algorithm employs an optical simulation of the array of nanoparticles; and determine an output design parameter from the evolutionary algorithm, the output design parameter being indicative of one or more properties of the array of nanoparticles.

CLAIMS

What is claimed is:

1. A computer-implemented method for producing a bulk material and determining a color thereof, the computer-implemented method comprising:

providing, to a processor of a simulation system, one or more input properties, wherein each of the one or more input properties is indicative of a property of one or more arrays of nanoparticles, and wherein each of the arrays of nanoparticles is contained within one of a plurality of microspheres, and wherein the plurality of microspheres is contained within the bulk material;

providing, to the processor, one or more input parameters for an optical simulation;

performing, by the processor, the optical simulation by applying a stochastic model of an array of the one or more arrays of nanoparticles according to the input parameters, wherein the optical simulation accounts for properties of light as applied to the bulk material and microspheres thereof, wherein stochastic model comprises a Monte Carlo model or a two-tiered stochastic model, and wherein the one or more input properties affect the optical simulation by affecting a phenomena of light including a boundary condition for light scattering; and

determining, by the processor, and from the optical simulation, an output optical parameter indicative of structural color of the bulk material.

2. The computer-implemented method of claim 1, wherein the one or more input properties comprise one or more of (i) a structural property of the one or more arrays of nanoparticles or (ii) an optical property of the one or more arrays of nanoparticles.

3. The computer-implemented method of claim 2, wherein the structural property of the one or more arrays of nanoparticles comprises one or more of a nanoparticle size, a nanoparticle shape, a nanoparticle material, a nanoparticle porosity, a surface feature of a nanoparticle, a lattice constant of a plurality of nanoparticles, a concentration of nanoparticles in a medium, a void size of a nanoparticle, a property of a direct structure, a property of an inverse structure, a property of an ordered structure, a property of a disordered structure, a size of a microsphere of the array of nanoparticles, a shape of a microparticle composed of the array of nanoparticles, a

nanoparticle polydispersity, a shell thickness, a shell material, a concentration of microspheres in the bulk material, or a thickness of the bulk material.

4. The computer-implemented method of claim 2, wherein the output optical parameter of the one or more arrays of nanoparticles comprises one or more of a real index of refraction, a complex index of refraction, an absorption value, a dispersion value, a birefringence, a polarization, or a nonlinear coefficient.

5. The computer-implemented method of claim 1, wherein the output optical parameter comprises a wavelength, a range of wavelengths, a reflection curve, a transmission curve, an absorption curve, a speckle amount, a scattering parameter, an angle dependence, or an angle independence.

6. The computer-implemented method of claim 1, wherein the stochastic model comprises the Monte Carlo model.

7. The computer-implemented method of claim 1, wherein the stochastic model comprises the two-tiered stochastic model.

8. The computer-implemented method of claim 1, wherein the one or more input properties comprises one or more medium parameters.

9. The computer-implemented method of claim 8, wherein the one or more medium parameters comprises one or more of a material, a complex refractive index of the medium, a microsphere concentration, a microsphere mixture, an absorber amount, an absorber concentration, a thickness of the array of nanoparticles, or a degree of order of the array of nanoparticles.

10. The computer-implemented method of claim 1, further comprising sending, via the processor, a specification configured for a manufacturing device to produce the bulk material, wherein the bulk material includes at least one of a dye, a paint, or a coating comprising the one or more arrays of nanoparticles.

11. The computer-implemented method of claim 1, further comprising producing, with a manufacturing device, the bulk material, wherein the bulk material includes at least one of a dye, a paint, or a coating comprising the one or more arrays of nanoparticles.

12. A system for determining structural color, the system comprising a processor configured to execute machine readable instructions that cause the processor to:

receive one or more input properties, wherein each of the one or more input properties is indicative of a property of an array of nanoparticles, the array of nanoparticles being part of a bulk material, the bulk material including at least one microsphere containing the array of nanoparticles;

receive one or more input parameters for an optical simulation;

perform the optical simulation by applying a stochastic model of the array of nanoparticles according to the one or more input parameters, wherein the optical simulation accounts for properties of light as applied to the bulk material, wherein stochastic model comprises a Monte Carlo model or a two-tiered stochastic model, and wherein the one or more input properties affect the optical simulation by affecting a phenomena of light including a boundary condition for light scattering; and

determine from the optical simulation an output optical parameter indicative of structural color of the bulk material.

13. The system of claim 12, wherein the one or more input properties comprise one or more of (i) a structural property of the array of nanoparticles or (ii) an optical property of the array of nanoparticles.

14. The system of claim 13, wherein the structural property of the array of nanoparticles comprises one or more of a nanoparticle size, a nanoparticle shape, a nanoparticle material, a nanoparticle porosity, a surface feature of a nanoparticle, a lattice constant of an array of nanoparticles, a concentration of nanoparticles in a medium, a void size of a nanoparticle, a property of a direct structure, a property of an inverse structure, a property of an ordered structure, a property of a disordered structure, a nanoparticle polydispersity, a shell thickness, a shell material, a concentration of microspheres in the bulk material, and a thickness of the bulk material.

15. The system of claim 13, wherein the optical parameter of the array of nanoparticles comprises one or more of a real index of refraction, a complex index of refraction, an absorption value, a dispersion value, a birefringence, a polarization, and a nonlinear coefficient.

16. The system of claim 12, wherein the output optical parameter comprises a wavelength, a range of wavelengths, a reflection curve, a transmission curve, an absorption curve, a speckle amount, a scattering parameter, an angle dependence, or an angle independence.

17. The system of claim 12, wherein the stochastic model comprises the Monte Carlo model.

18. The system of claim 12, wherein the one or more input properties comprises one or more medium parameters.

19. The system of claim 18, wherein the one or more medium parameters comprises one or more of a material, a complex refractive index of a medium, a microsphere concentration, a microsphere mixture, an absorber amount, an absorber concentration, a thickness of the array of nanoparticles, or a degree of order of the array of nanoparticles.