~~CLAIMS~~

~~What is claimed is:~~

CLAIMS

1. A light-emitting device comprising:

an array comprising a plurality of microLEDs and non-light-emitting areas separating adjacent microLEDs; and

a solid wavelength-converting ~~optical element~~layer disposed on the array and comprising:~~-~~

~~a solid material layer having opposite~~ a plurality of first ~~and second surfaces~~regions aligned with the plurality of microLEDs and comprising ~~a plurality of discrete pixel regions~~ phosphor particles of a first characteristic size dispersed in a first transparent binder material; and

a second region aligned with the non-light-emitting areas and ~~intervening border~~comprising phosphor particles of a second characteristic size dispersed in a second transparent binder material, the second region exhibiting optical scattering greater than optical scattering exhibited by the first regions.

2. The light-emitting device of claim 1, the first characteristic size differing from the characteristic second size.

3. The light-emitting device of claim 1, the second characteristic size being less than 50% of the first characteristic size.

4. The light-emitting device of claim 1, the first characteristic size being less than 10. μm, or the second characteristic size being less than 5. μm.

~~that at least partly surround each one of the pixel regions and at least partly separate each pixel region from~~5. The light-emitting device of claim 1, spacing of the microLEDs of the array being less than 0.10 mm, or width of the non-light-emitting areas separating adjacent ~~pixel regions;~~microLEDs of the array being less than 0.010 mm.

~~for each pixel region, a corresponding plurality~~6. The light-emitting device of ~~pixel~~claim 1, (i) the first regions comprising the phosphor particles ~~and~~of the first

characteristic size embedded in a first solid medium that is transparent ~~pixel binder, the pixel binder comprising either (i) a~~, and (ii) the second region comprising the phosphor particles of the second characteristic size embedded in a second solid medium that is transparent ~~pixel coating at least partly coating each pixel phosphor particle~~.

7. The light-emitting device of claim 6, the first regions differing from the second region with respect to differing compositions or refractive indices characterizing the solid first medium and ~~binding together~~ the solid second medium.

8. The light-emitting device of claim 6 further comprising scattering particles embedded in the second solid medium.

9. The light-emitting device of claim 6, the first solid medium including one or more polymers, or the second solid medium including one or more polymers.

10. The light-emitting device of claim 6, the first solid medium including one or more silicones, and the second solid medium including one or more silicones.

11. The light-emitting device of claim 6, the first and second solid media having the same material composition.

12. ~~pixel~~The light-emitting device of claim 1, (i) the first regions comprising the phosphor particles of the ~~corresponding pixel region while leaving voids among the bound pixel~~first characteristic size and a transparent first coating on the phosphor particles~~, or (ii) a transparent solid pixel medium substantially filling the corresponding pixel region in which the pixel~~ of the first regions that binds together the phosphor particles ~~are embedded; and~~

~~in~~of the ~~border~~first regions, ~~a plurality of border~~and (ii) the second region comprising the phosphor particles of the second characteristic size and a transparent ~~border binder, the border binder comprising either (i) a transparent border coating at least partly coating each border phosphor particle and binding~~second coating on the phosphor particles of the second region that binds together the ~~border~~ phosphor particles ~~while leaving voids among the bound border~~ of the second region.

13. The light-emitting device of claim 12, the first regions differing from the second region with respect to differing size, number density, or volume fraction characterizing voids among the phosphor particles~~, or (ii) a transparent solid border~~

medium substantially filling of the borderfirst regions in whichand voids among the border phosphor particles are embedded,of the second region.

14. The light-emitting device of claim 12, the pixelfirst regions differing from the border regionssecond region with respect to one or more of: (i) differing sizes, compositions, or refractive indices characterizing the pixel phosphor particles and the border phosphor particles, (ii) differing thicknesses, compositions, or refractive indices characterizing the pixelfirst coating and the bordersecond coating, (iii) differing size, number density, or volume fraction characterizing voids among the pixel phosphor particles and among the border phosphor particles, or (iv) differing compositions or refractive indices characterizing the solid pixel medium and the solid border medium.

152. The optical element of claim 1, the border regions exhibiting optical scattering of light emitted by the pixel or border phosphor particles that is greater than that optical scattering exhibited by the pixel regions.

3. The optical elementlight-emitting device of claim 112, the border phosphor particlesfirst coating having a characteristic size that is lessthickness greater than 50% of a characteristic size of the pixel phosphor particles.

4. The optical element of claim 1, the pixel phosphor particles having a non-zero characteristic size less than 10.0.20 μm, or the border phosphor particlessecond coating having a non-zero characteristic size less than 5. μm.

5. The optical element of claim 1: (i) the border coating having a characteristic thickness that is less than 50% of a characteristic thickness of the pixel coating, (ii) number density of voids among the pixel phosphor particles being less than 50% of number density of voids among the border phosphor particles, (iii) volume fraction of voids among the pixel phosphor particles being less than 50% of volume fraction of voids among the border phosphor particles, or (iv) a characteristic size of voids among the pixel phosphor particles being less than 50% of a characteristic size of voids among the border phosphor particles. less than 0.10 μm.

16. The 6. The optical element of claim 1, the pixellight-emitting device of claim 12, the first coating including one or more metal or semiconductor oxides, and the second coating including one or more metal or semiconductor oxides.

17. The light-emitting device of claim 12, the first and second coatings having the same material composition.

18. The light-emitting device of claim 12, the first coating or the ~~border~~second coating including one or more materials compatible with formation using an atomic layer deposition (ALD) process or using a conformal chemical vapor deposition (CVD) process.

~~7. The optical element~~ 19. The light-emitting device of claim ~~1:~~12, (i) the ~~pixel~~second coating having a characteristic thickness ~~greater~~that is less than ~~0.20 μm, or (ii) the border coating having~~50% of a ~~non-zero~~characteristic thickness ~~less than 0.10 μm.~~

~~8. The optical element of claim 1, the pixel~~ of the first coating, or (ii) number density or volume fraction of voids among the phosphor particles of the first regions being ~~embedded in the pixel medium and~~ less than 50% of number density or volume fraction of voids among the ~~border~~ phosphor particles ~~being embedded in the border medium, the border phosphor particles having a characteristic size that is less than 50% of a characteristic size of the pixel phosphor particles.~~of the second region.

20. ~~9. The optical element of claim 8, further comprising scattering particles embedded in the border medium.~~

~~10. The optical element of claim 8, the pixel medium including one or more polymers, or the border medium including one or more polymers.~~

~~11. The optical element of claim 1: (i) spacing of the pixel regions of the optical element being less than 0.10 mm, or (ii) width of the border regions separating adjacent pixel regions of the optical element less than 0.010 mm.~~

The ~~12. A light-emitting device incorporating the wavelength-converting optical element of any one of claims 1 through 11, the~~ light-emitting device ~~comprising:~~

~~the wavelength-converting optical element; and~~

~~an array of semiconductor light-emitting pixels that emit light at a first wavelength, spacing of the light-emitting pixels substantially matching spacing of the pixel regions of wavelength-converting optical element, the light-emitting pixel array being positioned so that light emitted by the light-emitting pixels enters the first surface of the material layer of the wavelength-converting optical element and~~

is at least partly absorbed by the pixel phosphor particles and the border phosphor particles, resulting in emission from those phosphor particles of down-converted light at one or more down-converted wavelengths longer than the first wavelength, the wavelength-converting optical element being positioned so that the pixel regions thereof are substantially aligned with the light-emitting pixels of the array.

13. The device of claim 121, the pixelfirst regions exhibiting a contrast ratio for down-converted light exiting the second surface of the optical elementwavelength-converting layer from adjacent pixelfirst regions thereof that is greater than 5:1, the down-converted light resulting from absorption of light emitted by the microLEDs and subsequent emission of the down-converted light at a wavelength longer than a wavelength of the light emitted by the microLEDs.

14. The device of claim 12: (i) spacing of light-emitting pixels of the array being equal to spacing of the pixel regions of the optical element, and (ii) the light-emitting pixels of the array being separated by non-light-emitting pixel borders, the border regions of the optical element being aligned with the pixel borders.

15. A method for making the optical element of any one of claims 1 through 11, comprising:

forming a mask on selected areas of a substrate, leaving remaining areas of the substrate unmasked;

depositing pluralities of first phosphor particles onto the unmasked areas of the substrate, and binding together the deposited first phosphor particles with a first binder;

removing the mask from the selected areas; and

depositing pluralities of second phosphor particles onto the substrate between the deposited, bound pluralities of first phosphor particles, and binding together the deposited second phosphor particles, and the pluralities of second phosphor particles to the bound pluralities of first phosphor particles, with a second binder,

with either (i) the first phosphor particles being the pixel phosphor particles, the first binder being the pixel binder, the second phosphor particles being the border phosphor particles, and the second binder being the border binder, or (ii) the first phosphor particles being the border phosphor particles, the first binder

being the border binder, the second phosphor particles being the pixel phosphor particles, and the second binder being the pixel binder.

16. The method of claim 15: (i) the first phosphor particles being bound together using one or more ALD processes or one or more CVD processes to form the first binder as a first coating on the first phosphor particles, or (ii) the second phosphor particles being bound together using one or more ALD processes or one or more CVD processes to form the second binder as a second coating on the second phosphor particles.

17. The method of claim 16, the second coating being formed on the bound first phosphor particles over the first coating.

18. The method of claim 15: (i) the first phosphor particles being bound together using deposition of one or more precursors and curing the one or more precursors to form the first binder as a first transparent solid medium embedding the first phosphor particles, or (ii) the second phosphor particles being bound together using deposition of one or more precursors and curing the one or more precursors to form the second binder as a second transparent solid medium embedding the second phosphor particles.

19. The method of claim 1, further comprising one or both of: (i) before removing the mask, removing from masked areas any first phosphor particles deposited on the mask material, or (ii) removing from the deposited, bound pluralities of the first phosphor particles any second phosphor particles thereon.

20. The method of claim 15, any second phosphor particles deposited and bound on the deposited, bound pluralities of the first phosphor particles being left in place, so that the bound pluralities of the first phosphor particles are covered by the bound second phosphor particles.