CLAIMS

What is claimed is:

1. An image sensor pixel, comprising:

a substrate;

a photoelectric conversion unit supported by the substrate;

an protection film extending over and across the substrate; and,

a cascaded light guide wherein a first portion of said cascaded light guide is between the protection film and the substrate and a second portion extends above the protection film.

2. The pixel of claim 1, wherein each cascaded light guide includes a transparent portion and a color filter that is contiguous with said transparent portion and extends above said insulator.

3. The pixel of claim 1, wherein the second portion includes a color filter.

4. The pixel of claim 3, wherein the color filters from cascaded light guides of adjacent pixels are

separated by a first air gap that has a width no more than 0.45um.

5. The pixel of claim 4, wherein said first air gap has a depth at least 1.0 times a wavelength of light.

6. The pixel of claim 5, where said wavelength of light is 450nm.

7. The pixel of claim 3, wherein the color filter self-aligns within the cascaded light guide.

8. The pixel of claim 3, wherein the top surface of the color filter is an air interface.

9. (Intentionally left blank).

10. The pixel of claim 1, wherein all optical interfaces along the vertical axis of the cascaded light guide and above the protection film are flat and parallel.

11. (Intentionally left blank).

12. The pixel of claim 1, wherein at least two cascaded light guides from two different pixels have different cross-sectional profiles.

13. The pixel of claim 1, wherein the vertical centerlines of the first and second portions are mutually offset.

14. The pixel of claim 13, wherein the cascaded light guide is configured so that light exits and re-enters said cascaded light guide.

15. A method for fabricating an image sensor pixel, comprising:

forming a support film with an opening and over a substrate that supports a photoelectric conversion unit; and,

forming a color filter in the opening of the support film.

16. The method of claim 15, further comprising forming a protection film between the color filter and the substrate.

17. The method of claim 15, further comprising removing at least a portion of the support film between two adjacent color filters.

18. The method of claim 15, further comprising forming a transparent light guide in the opening of the support film.

19. The method of claim 18, further comprising removing a portion of the support film adjacent the transparent light guide.

20. The method of claim 18, further comprising forming a lower transparent light guide between the transparent light guide and the substrate.

21. The method of claim 20, where the vertical centerline of the lower transparent light guide is offset from the vertical centerline of the opening of the support film.

22. The method of claim 18, wherein the forming of the color filter creates a flat air interface on a top surface of the color filter.

23. A method for fabricating an image sensor pixel array, comprising:

forming an insulator over a substrate that supports a photoelectric conversion unit;

forming a plurality of walls adjacent to the insulator;

forming a plurality of light guides between the walls;

forming a plurality of color filters adjacent to the light guides; and,

removing at least a portion of the walls so that there is an air gap between adjacent color filters.

24. The method of claim 23, wherein the walls are formed by forming a support film and creating openings within the support film.

25. The method of claim 23, further comprising forming a protection film over the insulator.

26. The method of claim 23, wherein a portion of the support film is removed so that a portion of each light guide has an air interface.

27. An image sensor pixel, comprising:

a substrate;

a photoelectric conversion unit supported by said substrate;

a light guide coupled to said photoelectric conversion unit;

anti-reflection means for reducing reflection between said light guide and said photoelectric conversion unit.

28. The pixel of claim 27, wherein said anti-reflection means includes a first anti-reflection film and a second anti-reflection film, said first anti-reflection film having an index of refraction lower than an index of refraction of said second anti-reflection film and an index of refraction of said light guide, and said first anti-reflection film located between the second anti-reflection film and the light guide.

29. The pixel of claim 28, wherein said anti-reflection means includes a third anti-reflection film which has an index of refraction lower than an index of refraction of said second anti-reflection film and wherein said second anti-reflection film is between said

first anti-reflection film and said third anti-reflection film.

30. The pixel of claim 28, wherein a first pixel has a thinner anti-reflection film than a corresponding anti-reflection film of a second pixel having a color filter of a different color.

31. (Intentionally left blank).

32. (Intentionally left blank).

33. The pixel of claim 28, wherein said second anti-reflection film is a contact etch stop.

34. The pixel of claim 28, wherein said second anti-reflection film includes silicon nitride.

35. The pixel of claim 27, further comprising a light-guide etch-stop layer between said light guide and said anti-reflection means.

36. A method for fabricating an image sensor pixel, comprising:

forming an anti-reflection stack on a photoelectric conversion unit supported by a substrate; and,

forming a light guide adjacent to the photoelectric conversion unit.

37. (Intentionally left blank).

38. (Intentionally left blank).

39. A method for forming a portion of an image sensor pixel, comprising:

forming a first anti-reflection film over a substrate that supports a photoelectric conversion unit;

forming an insulator over said first anti-reflection film;

etching an opening in the insulator with an etchant that etches the insulator faster than the first anti-reflection film;

forming a second anti-reflection film within the opening; and

forming light guide material within the opening.

40. The method of claim 39, further comprising etching a vertical sidewall portion of the second anti-reflection film.

41. (Intentionally left blank).

42. A method for fabricating a color filter for an image sensor pixel, comprising:

forming at least one wall;

forming a color filter within the wall;

removing at least a portion of the wall.

CLAIMS

1. An image sensor that includes a plurality of pixels supported by a substrate, each one of the plurality of pixels comprising:

a photoelectric conversion unit in the substrate;

a light guide, the light guide having a light-guide refractive index; and,

an anti-reflection stack under the light guide and on the substrate, the anti-reflection stack arranged to transmit a light from the light guide to the photoelectric conversion unit, comprising:

a third film on the substrate, the third film having a third refractive index;

a second film on the third film, the second film having a second refractive index higher than the third refractive index; and

a top film on the second film, the top film having a first refractive index lower than the light-guide refractive index and the second refractive index,

wherein either:

the light guide is on the top film; or

each one of the plurality of pixels further comprises:

a light-guide etch-stop film sandwiched between the light guide and the top film.

2. The image sensor of claim 1, wherein a transmission coefficient of light from the light guide to the substrate across the top, second and third films peaks between 450nm and 490 nm of wavelength-of-light-in-air.

3. The image sensor of claim 1 or 2, wherein the light-guide etch-stop film is made of silicon nitride and has thickness between 100 and 300 Angstroms.

4. The image sensor of claim 1 or 2, wherein the top film is silicon oxide or silicon oxynitride and has a thickness between 750 Angstroms and 2000 Angstroms.

5. The image sensor of claim 1 or 2, wherein the second film includes silicon nitride.

6. The image sensor of claim 1 or 2, wherein the second film is made of silicon nitride and has a thickness between 300 Angstroms and 900 Angstroms.

7. The image sensor of claim 1 or 2, wherein the second film is also a contact etch-stop.

8. The image sensor of claim 1 or 2, wherein the third film is made of silicon oxide or silicon oxynitride (SiOxNy, 0<x<2, 0<y<4/3) and has a thickness between 25 Angstroms and 170 Angstroms.

9. The image sensor of claim 1 that includes the light guide etch-stop film, wherein, between a first pixel of the plurality of pixels and a second pixel of the plurality of pixels for a different colour than the first pixel, the top film is thinner for the first pixel than for the second pixel while the second and third films are as thick for the first pixel as for the second pixel.

10. The image sensor of claim 9, wherein, the first pixel is a green pixel whereas the second pixel is a blue pixel.

11. The image sensor of claim 1 that includes the light guide etch-stop film, wherein, between a first pixel of the plurality of pixels and a second pixel of the plurality of pixels for a different colour than the first pixel, the second film is thinner for the first pixel than for the second pixel while the top film is as thick for the first pixel as for the second pixel.

12. A method for forming an image sensor that comprises a plurality of pixels supported by a substrate, comprising, for each one of the plurality of pixels:

forming a photoelectric conversion unit in the substrate;

forming a third film on the substrate and over the photoelectric conversion unit, the third film having a third refractive index;

forming a second film on the third film, the second film having a second refractive index higher than the third refractive index;

forming a top film after the second film, the top film having a first refractive index lower than the second refractive index;

forming an insulating film above the second film;

forming an opening in the insulating film; and,

forming a light guide in the opening, the light guide comprising a light guide material having a light guide refractive index higher than the first refractive index,

wherein either:

the insulating film is formed on the second film before the top film, the opening exposes the second film, the top film is formed on the second film where it is exposed by the opening, and the light guide is formed on the top film in the opening; or

the method further comprises:

forming a light guide etch-stop film on the top film,

the top film is formed on the second film before the light guide etch-stop film, the insulating film is formed on the light guide etch-stop film, the opening exposes the light guide etch-stop film, and the light guide is formed on the light guide etch-stop film where it is exposed by the opening.

13. The method of claim 12, wherein a transmission coefficient of light from the light guide to the substrate across the top, second and third films peaks between 450nm and 490 nm of wavelength-of-light-in-air.

14. The method of claim 12 or 13, wherein the light-guide etch-stop film is made of silicon nitride and has thickness between 100 and 300 Angstroms.

15. The method of claim 12 or 13, wherein the top film is silicon oxide or silicon oxynitride and has a thickness between 750 Angstroms and 2000 Angstroms.

16. The method of claim 12 or 13, wherein the second film includes silicon nitride.

17. The method of claim 12 or 13, wherein the second film is made of silicon nitride and has a thickness between 300 Angstroms and 900 Angstroms.

18. The method of claim 12 or 13, wherein the second film is also a contact etch-stop film.

19. The method of claim 12 or 13, wherein the third film is silicon oxide or silicon oxynitride (SiO_xN_y, $0<x<2$, $0<y<4/3$) and has a thickness between 25 Angstroms and 170 Angstroms.

20. The method of claim 12 that includes forming the light guide edge-stop film, further comprising:

thinning the top film for a first pixel among the plurality of pixels but not for a second pixel among the plurality of pixels of a different colour than the first pixel before forming the light guide edge-stop film.

21. The method of claim 20, wherein the first pixel is a green pixel and the second pixel is a blue pixel.

22. The method of claim 12 that includes forming the light guide edge-stop film, further comprising:

thinning the second film for a first pixel among the plurality of pixels but not for a second pixel among the plurality of pixels of a different colour than the first pixel before forming the top film.