

CLAIMS:

1. A method of forming an LED array precursor comprising:
 - (a) forming a first LED stack on a substrate surface of a substrate, the first LED
5 stack comprising a plurality of first Group III-nitride layers defining a first semiconductor junction configured to output light having a first wavelength, wherein a n-type side of the semiconductor junction is orientated towards to the substrate surface;
 - (b) forming a p++ layer on the first LED stack, the p++ layer comprising a Group III-nitride;
 - 10 (c) forming a n++ layer over the substrate to cover the p++ layer, wherein a tunnel junction is formed at an interface between the n++ layer and the p++ layer, the n++ layer comprising a Group III-nitride;
 - (d) forming a second LED stack on the n++ layer; the second LED stack comprising a plurality of second Group III-nitride layers defining a second semiconductor junction
15 configured to output light having a second wavelength different to the first wavelength, wherein a n-type side of the semiconductor junction is provided closest to the n++ layer, wherein the method further comprises a step of:
selectively removing a portion of the first LED stack and a portion of the second LED stack on the substrate surface in order to define:
20 a first portion of the LED array in which the second LED stack is selectively removed comprising:
a first portion of the first LED stack;
a first portion of the p++ layer; and
a first portion of the n++ layer such that a tunnel junction is provided on the
25 first portion of the first LED stack; and
a second portion of the LED array comprising:
a second portion of the n++ layer; and
a first portion of the second LED stack provided on the second portion of the n++ layer.
- 30 2. A method according to claim 1, wherein
the plurality of first Group III-nitride layers of the first LED stack comprises:
a first n-type layer provided on the substrate surface;
a first active layer configured to generate light having the first wavelength provided
35 on the first n-type layer; and

- a first p-type layer provided on the first active layer, and/or
the plurality of Group III-nitride layer of the second LED stack comprises:
a second n-type layer provided on the n++ layer;
a second active layer configured to generate the light having a second wavelength
5 provided on the second n-type layer, wherein the second wavelength is different to the first wavelength; and
a second p-type layer provided on the second active layer.
3. A method according to any claim 2, wherein
10 the first active layer of the first LED stack comprises a first multiple quantum well laminate configured to output light of the first wavelength; and
the second active layer of the second LED stack comprises a second multiple quantum well laminate configured to output light of the second wavelength.
- 15 4. A method according to claim 3 wherein
the first multiple quantum well laminate comprises alternating layers of GaN and $\text{In}_x\text{Ga}_{1-x}\text{N}$, where $0 < X \leq 1$;
the second multiple quantum well laminate comprises alternating layers of GaN and $\text{In}_y\text{Ga}_{1-y}\text{N}$, where $0 < Y \leq 1$.
- 20 5. A method according to any of claims 2 to 4, wherein
the first LED stack comprises a first electron blocking layer between the first active layer and the first p-type layer; and/or
the second LED stack comprises a second electron blocking layer between the
25 second active layer and the second p-type layer.
6. A method according to any preceding claim, further comprising
(g) selectively removing a portion of the first and second LED stacks to expose
sidewall surfaces of the first and second LED stacks in order to defined a trench between
30 the first portion of the LED array and the second portion of the LED array; and
(h) depositing a passivation layer in the trench to cover the sidewall surfaces of the first and second LED stacks.
7. A method according to claim 6, wherein

a plurality of first portions of the LED array in which the second LED stack is selectively removed are formed on the substrate surface on respective first portions of the substrate; and

5 a plurality of trenches are formed between each first portion of the LED array and the second LED stack covering a plurality of second portions of the substrate surface.

8. A method according to any preceding claim, wherein
the first LED stack is formed by a process at a first temperature; and
the second LED stack is formed by a process at a second temperature lower than
10 the first temperature.

9. A method according to any preceding claim wherein the second wavelength is longer than the first wavelength.

15 10. A method according to any preceding claim wherein the steps of selectively removing portions of at least one of the first or second LED stacks comprises:
selectively depositing a mask layer on portions of the first or second LED stack covering a first or second portion of the substrate surface; and
etching an exposed portion of the first or second LED stack to expose the layer(s)
20 below.

11. A method according to any preceding claim, wherein
the first wavelength is at least 380 nm and no greater than 480 nm; and/or
the second wavelength is at least 500 nm and no greater than 580 nm.
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12. A method according to any preceding claim, wherein each portion of the LED array has surface dimensions on the substrate of less than 100 μm x 100 μm .

13. A method according to any preceding claim, wherein
30 the n++ layer has a charge carrier density of at least 10^{19} cm^{-3} ; and/or
the p++ layer has a charge carrier density of at least 10^{19} cm^{-3} .

14. A method according to any preceding claim, wherein forming the n++ layer over the substrate to cover the p++ layer comprises:

forming an etch stop sublayer within the n++ layer, the etch stop sublayer comprising a Group III-nitride including Al.

15. A method according to any preceding claim, further comprising:
- 5 (i) forming a first contact layer for the first portion of the LED array on the first portion of the n++ layer covering the first LED stack, and/or forming a second contact layer for the second portion of the LED array on the first portion of the second LED stack.
16. A method according to claim 15 wherein
- 10 the first contact layer comprises one or more of Ti, Al and Mo; and the second contact layer comprises one or more of Ni, Pt, Au, and Indium Tin Oxide (ITO).
17. A method according to any preceding claim:
- 15 wherein a second portion of the first LED stack is selectively removed to expose a second portion of the substrate surface before forming the n++ layer, and the n++ layer is formed over the substrate surface such that n++ layer covers the first portion of the first LED stack and a second portion of the substrate surface such that the second portion of the second LED stack is provided on the second portion of the
- 20 substrate surface.
18. A method according to claim 17 wherein
- a second portion of the p++ layer is selectively removed along with the second portion of the first LED stack to expose a second portion of the substrate surface.
- 25 19. A method according to claim 17, wherein
- the second portion of the first LED stack is selectively removed to expose a second portion of the substrate surface before forming the p++ layer.
- 30 20. A method according to any one of claims 1 to 16, wherein
- the second portion of the LED array further comprises:
- a second portion of the p++ layer on which the second portion of the n++ layer is provided; and
- a second portion of the first LED stack on which the second portion of the p++ layer
- 35 is provided.

21. A method according to claim 20, wherein
selectively removing a portion of the first LED stack and a portion of the second
LED stack comprises:
- 5 a first selective removal step comprising:
selectively masking the second portion of the second LED stack; and
selectively removing unmasked portions of the second LED stack, wherein the first
selective removal step is terminated on the n++ layer; and
a second selective removal step comprising:
- 10 selectively masking the first and second portions of the LED array; and
selectively removing unmasked portions of the LED array.
22. A Light Emitting Diode (LED) array precursor comprising:
a substrate having a substrate surface;
- 15 a first LED stack provided on a first portion of the substrate surface, the first LED
stack comprising a plurality of first Group III-nitride layers defining a first semiconductor
junction configured to output light having a first wavelength wherein a n-type side of the first
semiconductor junction is orientated towards the substrate surface;
- a p++ layer provided on the first LED stack, the p++ layer comprising a Group III-
- 20 nitride;
- a n++ layer having a first portion covering the p++ layer of the first LED stack and a
second portion covering a second portion of the substrate surface, wherein a tunnel
junction is formed at an interface between the n++ layer and the p++ layer, the n++ layer
comprising a Group III-nitride;
- 25 a second LED stack provided on the second portion of the n++ layer covering the
second portion of the substrate surface, the second LED stack comprising a plurality of
second Group III-nitride layers defining a second semiconductor junction configured to
output light having a second wavelength different to the first wavelength, wherein a n-type
side of the semiconductor junction is provided towards the n++ layer.
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23. A LED array according to claim 22 wherein
the plurality of first Group III-nitride layers of the first LED stack comprises:
- a first n-type layer provided on the substrate surface;
- a first active layer configured to generate light having a first
- 35 wavelength provided on the first n-type layer; and

- a first p-type layer provided on the first active layer;
a second n-type layer provided on the n++ layer;
the plurality of second Group III-nitride layers of the second LED stack comprises:
a second n-type layer provided on the n++ layer;
5 a second active layer configured to generate light having the second wavelength provided on the second n-type layer; and
a second p-type layer provided on the second active layer.
24. A LED array according to claim 22 or claim 23, wherein
10 a trench is provided between the first LED stack covering the first portion of the substrate surface and the second LED stack covering the second portion of the substrate, the trench defined by sidewall surfaces of the first and second LED stacks; and
a passivation layer is provided in the trench to cover the sidewall surfaces of the first and second LED stacks.
- 15 25. A LED array according to any of claims 22 to 24, further comprising:
a first contact layer provided on the first portion of the n++ layer covering the first LED stack, and/or a second contact layer provided on the second LED stack.
- 20 26. A method according to claim 25 wherein
the first contact layer comprises one or more of Ti, Al and Mo; and
the second contact layer comprises one or more of Ni, Pt, Au, and Indium Tin Oxide (ITO).
- 25 27. A LED array according to claim 25 or claim 26, wherein
a first adhesion layer is provided between the second n-type layer covering the first LED stack and the first contact layer, and/or a second adhesion layer is provided between the second contact layer provided and the second p-type layer of the second LED stack.
- 30 28. A LED array according to any of claims 22 to 27, wherein
a second portion of the n++ layer is provided on a second portion of the p++ layer;
and
a second portion of the p++ layer is provided on a second portion of the first LED stack, the first LED stack provided on the substrate surface.
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29. A LED array according to any of claims 22 to 28, wherein the n++ layer comprises an etch stop sublayer within the n++ layer, the etch stop sublayer comprising a Group III-nitride including Al.