What is claimed is:

1. A photolithographic method of forming a roughened surface for a light-emitting diode (LED) to improve LED light emission efficiency, comprising:

providing a semiconductor substrate having a surface covered with photoresist;

photolithographically imaging a phase-shift mask pattern onto the photoresist, the phase-shift mask pattern comprising a periodic array of first and second phase-shift regions that are separated by an opaque background section and ~~having a first~~ that have a sub-resolution dimension and a sub-resolution spatial frequency, said photolithographic imaging forming in the photoresist a periodic array of sub-resolution photoresist features having ~~a second spatial frequency substantially double the first~~ substantially the sub-resolution spatial frequency and substantially the sub-resolution dimension of the first and second phase-shift regions;

defining the roughened substrate surface by processing the photoresist and the photoresist features therein to form a corresponding periodic array of substrate posts in the substrate surface; and

forming a p-n junction multilayer structure atop the roughened substrate surface to form the LED, with the periodic substrate posts serving as scatter sites that improve the LED light emission efficiency as compared to the LED having no roughened substrate surface.

2. The ~~photolithographic~~ method of claim 1, ~~wherein~~ further comprising the substrate ~~is~~ being made of sapphire.

3. The ~~photolithographic~~ method of claim 1, wherein the photolithographic imaging is performed at an imaging wavelength, and wherein the first and second phase-shift regions are configured to provide respective phase shifts of 0° and 180° at the imaging wavelength.

4. The ~~photolithographic~~ method of claim 1, ~~wherein~~ further comprising the imaging wavelength ~~is~~ being 365 nm and the photolithographic imaging ~~is~~ being

performed at unit magnification.

5. The ~~photolithographic~~ method of claim 1, wherein the substrate posts have a diameter, a spacing and a height, the ~~photolithographic~~ method further comprising performing the photolithographic imaging at a numerical aperture that provides a maximum depth of focus for the diameter, the spacing and the height.

6. The ~~photolithographic~~ method of claim 1, wherein the first and second phase-shift regions have at least one of a circular shape, an oval shape and a polygonal shape.

7. The ~~photolithographic~~ method of claim 1, further comprising forming the substrate posts to have a width of 2 microns or less.

8. The ~~photolithographic~~ method of claim 7, further comprising forming the substrate posts to have an edge-to-edge spacing of between 0.5 microns and 3 microns.

9. The ~~photolithographic~~ method of claim 8, further comprising forming the substrate posts to have a height of up to 2 microns.

10. The ~~photolithographic~~ method of claim 1, ~~wherein~~ further comprising the periodic array of substrate posts have a substantially 1:1 pitch.

11. The ~~photolithographic~~ method of claim 1, wherein ~~the substrate posts have a dimension of one micron or less, and further comprising performing~~ the photolithographic imaging ~~at a numerical aperture of 0.5 or less~~ has a depth of focus of greater than 30 microns.

12. A method of forming a light-emitting diode (LED), comprising:

photolithographically exposing photoresist supported by a semiconductor substrate to form therein an array of photoresist posts having a second spatial

frequency, including passing illumination light through a phase-shift mask having a pattern comprising first and second phase-shift regions that are spaced apart by an opaque background section and that have a sub-resolution dimension and a sub-resolution spatial frequency, wherein the photolithographic exposure has a numerical aperture of 0.5 or less and an imaging wavelength defined by a mercury line;

processing the photoresist to form an array of substrate posts that ~~defined~~ defines a roughened substrate surface and that have substantially the sub-resolution dimension and substantially the sub-resolution spatial frequency of the first and second phase-shift regions; and

forming a p-n multilayer structure atop the roughened substrate surface to form the LED, wherein the roughened substrate surface acts to scatter light generated by the p-n multilayer structure to increase an amount of light emitted by the LED as compared to the LED having an unroughened substrate surface.

13. The method of claim 12, ~~wherein~~ further comprising:

the substrate posts have at least one dimension of 0.5 microns; and

the photolithographic exposure ~~has~~ having a numerical aperture of 0.5 or less and an imaging wavelength of about 365 nm.

14. The method of claim 12, ~~wherein~~ further comprising the substrate ~~is~~ being a sapphire substrate.

15. The method of claim 12, wherein the ~~phase-shift mask pattern has an~~ opaque background ~~region surrounding spaced apart the first and second phase-shift regions~~ section comprises a coating of either aluminum or chrome.

16. The method of claim 12, wherein the first and second phase-shift regions have at least one of a circular shape, an oval shape and a polygonal shape.

17. The method of claim 12, wherein the photolithographic exposure is performed at an imaging wavelength, and wherein ~~the~~ first and second phase-shift regions are configured to provide respective phase shifts of 0° and 180° at the

imaging wavelength.

18. The method of ~~any of claims~~ claim 12 ~~through 17~~, ~~wherein~~ further comprising the photolithographic exposure ~~is~~ being performed at unit magnification.

19. The method of claim 12, ~~wherein~~ further comprising the substrate posts have a dimension of one micron or less and further comprising performing said photolithographic exposure at a numerical aperture of 0.5 or less.

~~20. The method of claim 12, wherein the first and second phase-shift regions are not spaced apart.~~

~~21.~~20. A light-emitting diode (LED) product formed by the process comprising:

photolithographically exposing photoresist supported by a semiconductor substrate to form therein an array of photoresist posts, including passing illumination light through a phase-shift mask, the phase-shift mask having a periodic pattern of first and second phase-shift regions that are spaced apart by an opaque background section and that have a sub-resolution dimension and that define a sub-resolution spatial frequency;

processing the photoresist to form an array of substrate posts that ~~defined~~ define a substrate roughened surface and that have substantially the spatial frequency and substantially the sub-resolution dimension of the first and second phase-shift regions ; and

forming a p-n multilayer structure atop the roughened substrate surface to form the LED, wherein the roughened substrate surface acts to scatter light generated by the p-n multilayer structure to increase an amount of light emitted by the LED as compared to the LED having an unroughened substrate surface.