SUMMARY

According to a first aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and an optical-transformation layer coupled to the light-emitting layer, the optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising a metasurface for adjusting one or more parameters of the light emitted from the light-emitting layer, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

In some embodiments, the light-emitting layer comprises one or more Light-Emitting Diodes (LEDs) for emitting light.

In some embodiments, the optical-transformation layer is printed onto the light-emitting layer.

In some embodiments, the light-emitting layer comprises one or more light-emitting units; the optical-transformation layer comprises a housing having one or more receptacles for receiving the one or more metasurfaces; and the one or more receptacles are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

In some embodiments, each of the one or more receptacles comprises an outwardly expanding inner surface having an inner opening for receiving light emitted from the light-emitting layer and an outer opening for passing through the received light, the outer opening having an area greater than that of the inner opening.

In some embodiments, the inner surface of each of the one or more receptacles is reflective.

In some embodiments, the cross-section of the inner surface of each of the one or more receptacles has a paraboloid shape.

According to a second aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and an optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising a metasurface, at least one metasurface being polarization-selective for selectively passing therethrough the light emitted from the light-emitting layer with a predefined polarization state, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

In some embodiments, each of the one or more metasurfaces comprises a plurality of nano-scale structures arranged in an asymmetric base geometry.

In some embodiments, the light-emitting apparatus further comprises a polarization-control layer sandwiched between the light-emitting layer and the optical-transformation layer for polarizing the light emitted from the light-emitting layer.

In some embodiments, the light-emitting apparatus is a grow light for facilitating the growth of one or more plants.

According to a third aspect of this disclosure, there is provided a light-emitting apparatus for facilitating the growth of one or more plants. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and at least one optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising a metasurface for adjusting one or more parameters of the light emitted from the light-emitting layer for optimizing illumination configurations of the one or more plants, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

According to a fourth aspect of this disclosure, there is provided a display apparatus. The display apparatus comprises: a light-emitting layer for emitting light; and at least one optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising a metasurface for adjusting one or more parameters of the light emitted from the light-emitting layer for displaying one or more images, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

According to a fifth aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; a polarization-control layer coupled to the light-emitting layer for polarizing the light emitted from the light-emitting layer; and at least one optical-transformation layer coupled to the polarization-control layer, the at least one optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising at least one metasurface, at least one metasurface being polarization-selective for selectively passing therethrough the polarized light from the polarization-control layer for switching between different illumination patterns or images, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

According to a sixth aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; a polarization-control layer coupled to the light-emitting layer for polarizing the light emitted from the light-emitting layer; and at least one optical-transformation layer coupled to the polarization-control layer, the at least one optical-transformation layer comprising one or more optical-transformation units, each optical-transformation unit comprising at least one metasurface, at least one metasurface being polarization-selective for selectively passing therethrough the polarized light from the polarization-control layer for creating multiple different illumination patterns or images at different locations, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more

light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

According to a seventh aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light towards a source field of view (FOV); and at least one metasurface layer in front of the light-emitting layer for directing the light emitted from the light-emitting layer towards a first FOV having an angular span smaller than that of the source FOV.

In some embodiments, the light-emitting apparatus further comprises a polarization-control layer sandwiched between the light-emitting layer and the at least one optical-transformation layer; the polarization-control layer is configured for, in response to a control signal, polarizing the light emitted from the light-emitting layer to a first polarization state or to a second polarization state; and wherein the at least one optical-transformation layer is configured for directing the light from the polarization-control layer in the first polarization state towards a first FOV having an angular span smaller than that of the source FOV, and directing the light from the polarization-control layer in the second polarization state towards a second FOV having an angular span greater than that of the first FOV.

According to an eighth aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and an optical-transformation layer in front of the light-emitting layer, the optical-transformation layer comprising a plurality of optical-transformation units, each optical-transformation unit comprising a metasurface for directing light emitted from the light-emitting layer towards a target area for forming a predefined light-distribution pattern, wherein the light-emitting layer comprises one or more light-emitting units; wherein the optical-transformation units are at locations corresponding to those of the one or more light-emitting units for aligning the one or more metasurfaces with the one or more light-emitting units.

In some embodiments, the predefined light-distribution pattern is a substantively uniform optical-energy distribution on the target area.

In some embodiments, the plurality of metasurfaces comprise a first set of metasurfaces for directing the light emitted from the light-emitting layer towards borders of the target area, and a second set of metasurfaces for directing the light emitted from the light-emitting layer towards a center of the target area, for generating the substantively uniform optical-energy distribution on the target area.

According to a ninth aspect of this disclosure, there is provided a solar-energy harvesting apparatus. The solar-energy harvesting apparatus comprises: a photovoltaic layer having a plurality of photovoltaic cells; and at least one metasurface layer in front of the photovoltaic layer for directing light to the photovoltaic layer substantively without causing reflection on the photovoltaic layer.

In some embodiments, the solar-energy harvesting apparatus comprises a plurality of metasurface layers for directing light at an incident angle within a predefined range to perpendicularly imping the photovoltaic layer.

According to a tenth aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and at least one metasurface layer in front of the light-emitting layer for directing the light emitted from the light-emitting layer in a first polarization state towards a first FOV and directing the light emitted from the light-emitting layer in a second polarization state towards a second FOV; the first and second FOVs are overlapped and laterally offset from each other for forming a three-dimensional (3D) perception to a user wearing a pair of glasses with lenses of different polarization states.

According to an eleventh aspect of this disclosure, there is provided a light-emitting apparatus. The light-emitting apparatus comprises: a light-emitting layer for emitting light; and at least one metasurface layer in front of the light-emitting layer for directing the light emitted from the light-emitting layer in a first polarization state towards a first FOV and directing the light emitted from the light-emitting layer in a second polarization state towards a second FOV; the first and second FOVs are laterally offset from each other such that the first FOV is only viewable to a first eye of a user at a predefined distance and the second FOV is only viewable to a second eye of the user at the predefined distance, for forming a 3D perception to the user.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic diagram showing a prior-art light source emitting a light beam towards a square image plane at a distance thereto;

FIG. 1B shows the light-intensity distribution on the image plane of the light emitted from the prior-art light source shown in FIG. 1A;

FIG. 2A is a schematic diagram showing a prior-art Light-Emitting Diode (LED) panel emitting a light beam towards a square image plane at a distance thereto;

FIG. 2B shows the illumination pattern on the image plane of the light emitted from the prior-art LED panel, obtained using ray-tracing;

FIG. 3 is a schematic diagram showing the structure of a lighting-emitting apparatus, according to some embodiments of this disclosure, the lighting-emitting apparatus comprising a LED light-emitting layer and an optical-transformation layer having one or more metasurfaces;

FIG. 4 is a schematic exploded view of the lighting-emitting apparatus shown in FIG. 3;

FIG. 5 shows an optical-transformation unit of an optical-transformation layer of the lighting-emitting apparatus shown in FIG. 3;

FIG. 6 shows an example of the structure of a metasurface for forming the optical-transformation unit shown in FIG. 5;

FIG. 7 is a schematic exploded view of a lighting-emitting apparatus, according to some embodiments of this disclosure, the lighting-emitting apparatus comprising a LED light-emitting layer, a polarization-control layer, and a metasurface optical-transformation layer;

FIG. 8A is a schematic diagram showing a pixel of the polarization-control layer of the light apparatus shown in FIG. 7, according to some embodiments of this disclosure;