CLAIMS

1. An electrically tunable lens, comprising:

a first alignment layer and a second alignment layer;

an active layer comprising liquid crystal confined between the first and second alignment layers in an optical path of the lens;

a first electrode disposed above the first alignment layer, the first electrode having a first patterned opening disposed over an aperture region of the active layer; and

a second electrode disposed below the second alignment layer, the second electrode having a second patterned opening arranged to induce in combination with the first electrode an electric field in the active layer;

wherein at least one of the first alignment layer and the second alignment layer comprises a flexible polymeric layer including liquid crystal moieties, and

a director of the liquid crystal moieties at a surface of the flexible polymeric layer adjacent liquid crystal in the active layer is parallel to a major surface of the active layer, and a director of the liquid crystal moieties in a central region of the flexible polymeric layer is orthogonal to the major surface of the active layer.

2. The electrically tunable lens of claim 1, wherein the first and second patterned openings have circular shapes.

3. The electrically tunable lens of claim 1, wherein the first and second patterned openings have circular shapes with a common radius.

4. The electrically tunable lens of claim 1, including a first resistive layer disposed above the first alignment layer and isolated by dielectric material from the first electrode and a second resistive layer disposed below the second alignment layer and isolated by dielectric material from the second electrode.

5. The electrically tunable lens of claim 1, including an array of elastic polymer posts in the active layer between the first alignment layer and the second alignment layer, posts in the array extending from the first alignment layer to the second alignment layer.

6. The electrically tunable lens of claim 1, wherein at least one of the first alignment layer and the second alignment layer comprises a polymeric layer including liquid crystal moieties.

7. The electrically tunable lens of claim 1, including a third alignment layer between the first alignment layer and the second alignment layer; and

a second active layer comprising liquid crystal confined between the third alignment layer and the second alignment layer.

8. The electrically tunable lens of claim 7, including a pad electrode disposed between the first and second active layers.

9. The electrically tunable lens of claim 1, wherein the active layer has an average thickness X prior to bending over a fold radius less than 10 mm, and an average thickness Y after recovering from the bending, wherein $Y=X\pm10\%X$.

10. The electrically tunable lens of claim 1, including a driver electrically connected to the first and second electrodes, configured to apply a drive signal across the first and second electrodes having an adjustable duty cycle.

11. The electrically tunable lens of claim 1, including a driver electrically connected to the first and second electrodes, configured to apply a drive signal across the first and second electrodes using pulse width modulation.

12. The electrically tunable lens of claim 1, including a driver electrically connected to the first and second electrodes, configured to apply a drive signal across the first and second electrodes having a DC offset.

13. The electrically tunable lens of claim 1, including a driver electrically connected to the first and second electrodes, configured to apply a drive signal across the first and second electrodes including an initial higher field power interval and a subsequent lower

field power interval, the lower field power being configured to establish a target lens power during the lower field power interval.

14. The electrically tunable lens of claim 1, wherein at least one of the first and second alignment layers has an anchoring strength greater than 10^{-4} J/m^2.

15. The electrically tunable lens of claim 1, wherein at least one of the first and second alignment layers comprises a polymeric layer including liquid crystal moieties, and having an anchoring strength greater than 10^{-4} J/m^2.

16. An electrically tunable lens, comprising:

a first alignment layer, a second alignment layer, a third alignment layer and a fourth alignment layer;

a first active layer comprising liquid crystal confined between the first and second alignment layers in an optical path of the lens;

a second active layer comprising liquid crystal confined between the third and fourth alignment layers in the optical path of the lens;

a first electrode disposed above the first alignment layer, the first electrode having a first patterned opening disposed in alignment with an aperture region of the first active layer; and

a second electrode disposed below the fourth alignment layer, the second electrode having a second patterned opening disposed in alignment with an aperture region of the second active layer; and

a pad electrode disposed between the first and second active layers; and

a driver electrically connected to the first and second electrodes, configured to apply a first drive signal to the first electrode and a second drive signal to the second electrode arranged to induce, in combination with the pad electrode, electric fields in the first and second active layers;

wherein at least two of the first through fourth alignment layers comprise respective flexible polymeric layers including liquid crystal moieties, and

directors of the liquid crystal moieties at surfaces of the respective flexible polymeric layers adjacent liquid crystal in one of the first and second active

layers is parallel to a major surface of the one of the first and second active layers, and directors of the liquid crystal moieties in central regions of the respective flexible polymeric layers are orthogonal to the major surface of the one of the first and second active layers.

17. The electrically tunable lens of claim 16, wherein the first and second patterned openings have circular shapes.

18. The electrically tunable lens of claim 16, wherein the first and second patterned openings have circular shapes with a common radius.

19. The electrically tunable lens of claim 16, including a first resistive layer disposed above the first alignment layer and isolated by dielectric material from the first electrode and a second resistive layer disposed below the fourth alignment layer and isolated by dielectric material from the second electrode.

20. An electrically tunable lens, comprising:

a first alignment layer, a second alignment layer, a third alignment layer and a fourth alignment layer;

a first active layer comprising liquid crystal confined between the first and second alignment layers in an optical path of the lens;

a second active layer comprising liquid crystal confined between the third and fourth alignment layers in the optical path of the lens;

a first electrode disposed above the first alignment layer, the first electrode having a first patterned opening disposed in alignment with an aperture region of the first active layer; and

a second electrode disposed below the fourth alignment layer, the second electrode having a second patterned opening disposed in alignment with an aperture region of the second active layer; and

a pad electrode disposed between the first and second active layers; and

a driver electrically connected to the first and second electrodes, configured to apply a first drive signal to the first electrode and a second drive signal to the second electrode

arranged to induce, in combination with the pad electrode, electric fields in the first and second active, including:

a first array of elastic polymer posts in the first active layer between the first alignment layer and the second alignment layer, posts in the array extending from the first alignment layer to the second alignment layer; and

a second array of elastic polymer posts in the second active layer between the third alignment layer and the fourth alignment layer, posts in the array extending from the third alignment layer to the fourth alignment layer.

21. The electrically tunable lens of claim 20, wherein at least one of the first alignment layer and the fourth alignment layer comprises a polymeric layer including liquid crystal moieties.

22. An electrically tunable lens, comprising:

a first alignment layer, a second alignment layer, a third alignment layer and a fourth alignment layer;

a first active layer comprising liquid crystal confined between the first and second alignment layers in an optical path of the lens;

a second active layer comprising liquid crystal confined between the third and fourth alignment layers in the optical path of the lens;

a first electrode disposed above the first alignment layer, the first electrode having a first patterned opening disposed in alignment with an aperture region of the first active layer; and

a second electrode disposed below the fourth alignment layer, the second electrode having a second patterned opening disposed in alignment with an aperture region of the second active layer; and

a pad electrode disposed between the first and second active layers; and

a driver electrically connected to the first and second electrodes, configured to apply a first drive signal to the first electrode and a second drive signal to the second electrode arranged to induce, in combination with the pad electrode, electric fields in the first and second active layers, wherein the first active layer has an average thickness X prior to

bending over a fold radius less than 10 mm, and an average thickness Y after recovering from the bending, wherein Y=X±10%X.

23. The electrically tunable lens of claim 16, wherein the first and second drive signals are different in at least one of DC offset, frequency, duty cycle and magnitude.

24. The electrically tunable lens of claim 16, wherein the driver is configured to provide the first and second drive signals using pulse width modulation.

25. The electrically tunable lens of claim 16, wherein at least one of the first drive signal and the second drive signal includes an initial higher field power interval and a subsequent lower field power interval, the lower field power being configured to establish a target lens power during the lower field power interval.

26. The electrically tunable lens of claim 16, wherein at least one of the first, second, third and fourth alignment layers has an anchoring strength greater than 10^{-4} J/m^2.

27. The electrically tunable lens of claim 16, wherein at least one of first, second, third and fourth alignment layers comprises a polymeric layer including liquid crystal moieties, and having an anchoring strength greater than 10^{-4} J/m^2.

28. The electrically tunable lens of claim 1, wherein the first alignment layer and the second alignment layer comprise respective flexible polymeric layers including liquid crystal moieties, and

directors of the liquid crystal moieties at respective surfaces of the first alignment layer and the second alignment layer adjacent liquid crystal in the active layer are parallel to the major surface of the active layer, and directors of the liquid crystal moieties in central regions of the first alignment layer and the second alignment layer are orthogonal to the major surface of the active layer.

29. The electrically tunable lens of claim 28, wherein directors of the liquid crystal moieties at respective opposing surfaces of both the first alignment layer and the second alignment layer are parallel to the major surface of the active layer.

30. The electrically tunable lens of claim 1, wherein the flexible polymeric layer has a second surface opposing said first mentioned surface, and a director of the liquid crystal moieties at the second surface of the flexible polymeric layer is parallel to the major surface of the active layer.

31. The electrically tunable lens of claim 16, wherein the first through fourth alignment layers comprise respective flexible polymeric layers including liquid crystal moieties, and

directors of the liquid crystal moieties at respective surfaces of the first through fourth alignment layers adjacent liquid crystal in active layers are parallel to the major surfaces of the active layers, and directors of the liquid crystal moieties in central regions of the first through fourth alignment layers are orthogonal to the major surfaces of the active layers.

32. The electrically tunable lens of claim 30, wherein directors of the liquid crystal moieties at respective opposing surfaces of both the first through fourth alignment layers are parallel to the major surfaces of the active layers.

33. The electrically tunable lens of claim 16, wherein the respective flexible polymeric layers have second surfaces opposing said first mentioned surfaces, and directors of the liquid crystal moieties at the second surfaces of the respective flexible polymeric layers are parallel to the major surfaces of the active layers.