

WHAT IS CLAIMED IS:

1. A device, comprising:
 - a plurality of capacitors, wherein a capacitor of the plurality of capacitors comprises:
 - a first electrode comprising an aluminum substrate comprising a top porous surface and a bottom porous surface,
 - a top dielectric layer conformal to the top porous surface and a bottom dielectric layer conformal to the bottom porous surface, and
 - a second electrode comprising (i) one or more other top layers disposed on the top dielectric layer and (ii) one or more other bottom layers disposed on the bottom dielectric layer,
 - wherein the first electrode, the second electrode, and the top dielectric layer or the bottom dielectric layer have substantially the same (i) areal footprint and (ii) areal geometry; and
 - a plurality of terminals comprising one or more first electrode terminals in electrical contact with one or more first electrodes of the plurality of capacitors and one or more second electrode terminals in electrical contact with one or more second electrodes of the plurality of capacitors.
2. The device of claim 1, wherein the aluminum substrate comprises a solid aluminum core disposed between the top porous surface and the bottom porous surface.
3. The device of claim 1, wherein the capacitor of the plurality of capacitors further comprises a through via in electrical contact with the one or more other top layers of the second electrode and the one or more other bottom layers of the second electrode.
4. The device of claim 1, wherein the capacitor of the plurality of capacitors further comprises a blind via in electrical contact with the one or more other top layers or the one or more other bottom layers of the second electrode, but not both.
5. The device of claim 1, wherein the capacitor of the plurality of capacitors further comprises a blind via in electrical contact with the first electrode.
6. The device of claim 1, wherein the capacitor of the plurality of capacitors further comprises a through via in electrical contact with the first electrode.

7. The device of claim 1, wherein the geometry is square, rectangular, or oblique.
8. The device of claim 1, wherein the one or more first electrode terminals comprise a top first electrode terminal and a bottom first electrode terminal, wherein the one or more second electrode terminals comprise at least a top second electrode terminal and a bottom second electrode terminal, and wherein the top first electrode terminal is co-planar with the top second electrode terminal and the bottom first electrode terminal is co-planar with the bottom second electrode terminal.
9. The device of claim 1, wherein the first electrode and the second electrode of the capacitor are electrically and physically isolated from an adjacent first electrode and an adjacent second electrode of an adjacent capacitor of the plurality of capacitors by an electrically insulating dielectric substantially filling a volume between the capacitor and the adjacent capacitor.
10. The device of claim 1, wherein the plurality of capacitors is arranged in a single layer within the device.
11. The device of claim 1, wherein the second electrode of the capacitor is less than about 10 millimeters from an adjacent second electrode of an adjacent capacitor of the plurality of capacitors.
12. The device of claim 1, wherein the first electrode is common to the plurality of capacitors.
13. The device of claim 1, wherein second electrode is common to the plurality of capacitors.
14. The device of claim 1, wherein the top dielectric layer or the bottom dielectric layer comprise aluminum oxide.
15. The device of claim 14, wherein the top dielectric layer or the bottom dielectric layer is doped with an additional oxide.
16. The device of claim 1, wherein the top dielectric layer or the bottom dielectric layer has a thickness of about 3 nanometers (nm) to about 100 nm.
17. The device of claim 1, wherein the first electrode comprises titanium.

18. The device of claim 1, wherein the first electrode has a thickness of about 5 micrometers (μm) to about 1000 μm .
19. The device of claim 1, wherein the one or more top layers comprise a top conductive material layer conformal to the top dielectric layer and the one or more bottom layers comprise a bottom conductive material layer conformal to the bottom dielectric layer.
20. The device of claim 19, wherein the one or more top layers and the one or more bottom layers further comprise one or more of a carbonaceous layer, a diffusion barrier layer, and a metallization layer.
21. The device of claim 19, wherein the conductive material layer and the bottom conductive material layer each have a thickness of about 5 nm to about 100 μm .
22. The device of claim 1, wherein the capacitor has a footprint of about 0.1 square millimeters (mm^2) to about 2500 mm^2 .
23. The device of claim 1, wherein the capacitor has a capacitance density of at least about 2 microfarads/ mm^2 at 10 kHz.
24. The device of claim 1, wherein the capacitor has a capacitance density of at least about 1.9 microfarads/ mm^2 at 100 kHz.
25. The device of claim 1, wherein the first electrode and the second electrode each have a lateral dimension of about 0.1 mm to about 50 mm.
26. A method comprising:
- (a) providing a capacitor, wherein the capacitor comprises:
 - a first electrode comprising a modified aluminum foil;
 - a dielectric layer conformal with the first electrode, the dielectric layer comprising aluminum oxide; and
 - a second electrode comprising a conductive material in conformal contact with the dielectric layer;
 - (b) subsequent to (a), patterning the capacitor to remove portions of the capacitor to form a plurality of individual capacitors arranged in a single device layer; and
 - (c) providing a plurality of capacitor terminals including one or more first electrode terminals and one or more second electrode terminals, wherein each first electrode terminal

of the one or more first electrode terminals is in electrical contact with one or more of the first electrodes, and wherein each second electrode terminal of the one or more second electrode terminals is in electrical contact with one or more of the second electrodes, thereby generating a multi-terminal capacitor device.

27. The method of claim 26, wherein providing the capacitor comprises:
 - providing the modified aluminum foil;
 - subjecting the modified aluminum foil to an anodizing process, wherein the anodizing process generates the dielectric layer conformal with the first electrode; and
 - arranging the conductive material adjacent to the dielectric layer.
28. The method of claim 27, wherein providing the capacitor further comprises one or more of:
 - depositing a conducting carbonaceous layer over the conductive material;
 - depositing a diffusion barrier layer over the conductive material; or
 - depositing a metallization layer over the conductive material.
29. The method of claim 27, wherein providing the capacitor further comprises:
 - patterning the modified aluminum foil prior to arranging the conductive material adjacent to the dielectric layer.
30. The method of claim 27, wherein the modified aluminum foil is patterned prior to arranging the conductive material adjacent to the dielectric layer.
31. The method of claim 27, wherein providing the capacitor further comprises:
 - patterning the modified aluminum foil prior to subjecting the modified aluminum foil to the anodizing process.
32. The method of claim 27, wherein the modified aluminum foil is patterned prior to subjecting the modified aluminum foil to the anodizing process.
33. The method of claim 27, wherein providing the capacitor comprises:
 - patterning the modified aluminum foil using a laser etching or laser ablation process.
34. The method of claim 26, wherein patterning the capacitor comprises one or more of:
 - patterning the first electrode to generate a plurality of individual first electrodes;

patterning the dielectric layer to generate a plurality of individual dielectric layers; or
patterning the second electrode to generate a plurality of individual second electrodes.

35. The method of claim 26, wherein patterning the capacitor comprises one or more of:
masking and etching the capacitor;
subjecting the capacitor to a laser etching or laser ablation process; or
mechanically dicing the capacitor.
36. The method of claim 26, wherein patterning the capacitor comprises:
depositing a polymer isolation bridge pattern; and
depositing a conductive material so that it is contained within the polymer isolation bridge pattern.
37. The method of claim 26, wherein patterning the capacitor comprises:
depositing a polymer isolation bridge pattern with polymer microdispensing or microprinting; and
depositing a conductive material with microdispensing or microprinting so that it is contained within the polymer isolation bridge pattern.
38. The method of claim 26, wherein masking and etching the capacitor comprises:
masking the second electrode with a photoresist; and
wet etching of unmasked second electrode portions or plasma etching of unmasked secondary electrode portions, thereby generating a plurality of individual second electrodes.
39. A device comprising a plurality of capacitors, the device comprising:
a first electrode comprising an aluminum substrate comprising a top porous surface, a bottom porous surface, wherein the first electrode is common to the plurality of capacitors;
a plurality of top dielectric regions conformal to the top porous surface, wherein each top dielectric region is isolated from other top dielectric regions;
a plurality of bottom dielectric regions conformal to the bottom porous surface, wherein each bottom dielectric region is isolated from other bottom dielectric regions;
a plurality of electrically isolated second electrodes, wherein a second electrode of the plurality of second electrodes is in contact with (i) a top dielectric region of the plurality of top dielectric regions and (ii) a bottom dielectric region of the plurality of bottom dielectric regions; and
a plurality of terminals comprising one or more first electrode terminals in electrical

contact with the first electrode and a plurality of second electrode terminals in electrical contact with the plurality of second electrodes,

wherein, for a capacitor of the plurality of capacitors, the first electrode, the second electrode, and the top dielectric region or the bottom dielectric region have substantially the same (i) areal footprint and (ii) areal geometry.

40. The device of claim 39, wherein the first electrode comprises a solid aluminum core that is continuous across the plurality of capacitors.

41. The device of claim 39, wherein the second electrode comprises one or more top layers in contact with the top dielectric region and one or more bottom layers in contact with the bottom dielectric region, and wherein the device comprises a through via in contact with the one or more top layers and the one or more bottom layers.

42. The device of claim 41, further comprising a blind via in electrical contact with the one or more top layers or the one or more bottom layers of the second electrode, but not both.

43. The device of claim 39, further comprising a blind via in electrical contact with the first electrode.

44. The device of claim 39, further comprising a through via in electrical contact with the first electrode.

45. A device comprising a plurality of capacitors, the device comprising:
a plurality of first electrodes, wherein each first electrode comprises a top porous surface and a bottom porous surface, and wherein each first electrode of the plurality of first electrodes is electrically isolated from other first electrodes of the plurality of first electrodes;

a plurality of top dielectric regions conformal to the top porous surfaces of the first plurality of electrodes and a plurality of bottom dielectric regions conformal to the bottom porous surfaces of the first plurality of electrodes; and

a second electrode that is common to the plurality of capacitors, wherein the second electrode is in contact with the plurality of top dielectric regions and the plurality of bottom dielectric regions; and

a plurality of terminals comprising a plurality of first electrode terminals in electrical contact with the plurality of first electrodes and one or more second electrode terminals in electrical contact with the second electrode,

wherein, for a capacitor of the plurality of capacitors, the first electrode, the second electrode, and the top dielectric region or the bottom dielectric region have substantially the same (i) areal footprint and (ii) areal geometry.

46. The device of claim 45, wherein the second electrode comprises one or more top layers in contact with the plurality of top dielectric regions and one or more bottom layers in contact with the plurality of bottom dielectric regions, and wherein the device comprises one or more through vias in contact with the one or more top layers and the one or more bottom layers.
47. The device of claim 46, further comprising a blind via in electrical contact with the one or more top layers or the one or more bottom layers of the second electrode, but not both.
48. The device of claim 46, further comprising a blind via in electrical contact with each first electrode.
49. The device of claim 46, further comprising a through via in electrical contact with each first electrode.
50. A multi-terminal capacitor device comprising:
a plurality of individual capacitors arranged in a single device layer, each individual capacitor comprising:
a first electrode comprising a modified aluminum foil;
a dielectric layer conformal with the first electrode, the dielectric layer comprising aluminum oxide; and
a second electrode comprising a conductive material in conformal contact with the dielectric layer,
wherein the first electrode, the second electrode, and the dielectric layer have substantially the same (i) areal footprint and (ii) areal geometry; and
a plurality of capacitor terminals including one or more first electrode terminals and one or more second electrode terminals, each first electrode terminal in electrical contact with one or more first electrodes and each second electrode terminal in electrical contact with one or more second electrodes.
51. The multi-terminal capacitor device of claim 50, wherein the plurality of individual capacitors comprises:
a continuous first electrode, wherein the continuous first electrode comprises the modified aluminum foil, and wherein the continuous first electrode corresponds to the first electrode of each of the plurality of individual capacitors;
a continuous dielectric layer conformal with the continuous first electrode, wherein

the continuous dielectric layer comprises the aluminum oxide, and wherein the continuous dielectric layer corresponds to the dielectric layer of each of the plurality of individual capacitors; and

a plurality of individual second electrodes each in conformal contact with the continuous dielectric layer, wherein each of the plurality of individual second electrodes comprises the conductive material, wherein each of the plurality of individual second electrodes is spatially separated from adjacent individual second electrodes by a spacing, and wherein each of the plurality of individual second electrodes corresponds to the second electrode of different individual capacitors of the plurality of individual capacitors.

52. The multi-terminal capacitor device of claim 51, wherein the continuous first electrode has lateral dimensions of from 1 mm to 100 mm.

53. The multi-terminal capacitor device of claim 51, wherein the plurality of individual second electrodes each independently have lateral dimensions of from 0.1 mm to 50 mm.

54. The multi-terminal capacitor device of claim 51, wherein the spacing is from 1 μm to 10 mm.

55. The multi-terminal capacitor device of claim 50, wherein the plurality of individual capacitors comprises:

a plurality of individual first electrodes, wherein each of the plurality of individual first electrodes comprises the modified aluminum foil, wherein each of the plurality of individual first electrodes is spatially separated from adjacent individual first electrodes by a spacing, and wherein each of the plurality of individual first electrodes corresponds to the first electrode of different individual capacitors of the plurality of individual capacitors;

a plurality of individual dielectric layers, wherein each of the plurality of individual dielectric layers is conformal with a corresponding individual first electrode, wherein each of the plurality of individual dielectric layers comprises the aluminum oxide, and wherein each of the plurality of individual dielectric layers corresponds to the dielectric layer of different individual capacitors of the plurality of individual capacitors; and

a continuous second electrode in conformal contact with each of the plurality of individual dielectric layers, wherein the continuous second electrode comprises the conductive material, and wherein the continuous second electrode corresponds to the second electrode of each of the plurality of individual capacitors.

56. The multi-terminal capacitor device of claim 55, wherein the continuous second electrode has lateral dimensions of from 1 mm to 100 mm.
57. The multi-terminal capacitor device of claim 55, wherein the plurality of individual first electrodes each independently have lateral dimensions of from 0.1 mm to 50 mm.
58. The multi-terminal capacitor device of claim 55, wherein the spacing is from 1 μm to 1 mm.
59. The multi-terminal capacitor device of claim 50, wherein each of the plurality of individual capacitors comprises:
- a plurality of individual first electrodes, wherein each of the plurality of individual first electrodes comprises the modified aluminum foil, wherein each of the plurality of individual first electrodes is spatially separated from adjacent individual first electrodes by a spacing, and wherein each of the plurality of individual first electrodes corresponds to the first electrode of different individual capacitors of the plurality of individual capacitors;
 - a plurality of individual dielectric layers, wherein each of the plurality of individual dielectric layers is conformal with a corresponding individual first electrode, wherein each of the plurality of individual dielectric layers comprises the aluminum oxide, and wherein each of the plurality of individual dielectric layers corresponds to the dielectric layer of different individual capacitors of the plurality of individual capacitors; and
 - a plurality of individual second electrodes, wherein each of the plurality of individual second electrodes is in conformal contact with a corresponding individual dielectric layer, wherein each of the plurality of individual second electrodes comprises the conductive material, wherein each of the plurality of individual second electrodes is spatially separated from adjacent individual second electrodes by the spacing, and wherein each of the plurality of individual second electrodes corresponds to the second electrode of different individual capacitors of the plurality of individual capacitors.
60. The multi-terminal capacitor device of claim 59, wherein the plurality of individual first electrodes and the plurality of individual second electrodes each independently have lateral dimensions of from 0.1 mm to 50 mm.
61. The multi-terminal capacitor device of claim 59, wherein the spacing is from 1 μm to 10 mm.

62. The multi-terminal capacitor device of claim 50, further comprising:
one or more additional device layers positioned adjacent to the single device layer in a stacked configuration, wherein each of the one or more additional device layers includes a plurality of additional individual capacitors, each additional individual capacitor comprising:
an additional first electrode comprising modified aluminum foil;
an additional dielectric layer conformal with the additional first electrode, the additional dielectric layer comprising aluminum oxide; and
an additional second electrode comprising conductive material in conformal contact with the additional dielectric layer; and
an additional plurality of capacitor terminals including one or more additional first electrode terminals and one or more additional second electrode terminals, each additional first electrode terminal in electrical contact with one or more additional first electrodes and each additional second electrode terminal in electrical contact with one or more additional second electrodes.
63. The multi-terminal capacitor device of claim 62, wherein a total capacitance of the multi-terminal capacitor device is a sum of a first capacitance provided by the single device layer and additional capacitances provided by the one or more additional device layers.
64. The multi-terminal capacitor device of claim 50, wherein the modified aluminum foil comprises a etched aluminum foil.
65. The multi-terminal capacitor device of claim 64, wherein the modified aluminum foil comprises an aluminum foil that is etched on a top surface of the aluminum foil, a bottom surface of the aluminum foil, or both top and bottom surfaces of the aluminum foil.
66. The multi-terminal capacitor device of claim 64, wherein the etched aluminum foil comprises a plurality of tunnels corresponding to recessed regions within the modified aluminum foil, and wherein the dielectric layer extends within the plurality of tunnels and conformally coats a surface therein.
67. The multi-terminal capacitor device of claim 50, wherein the first electrode comprises aluminum having a purity of greater than 80%.
68. The multi-terminal capacitor device of claim 50, wherein the first electrode has a thickness of from 5 μm to 500 μm .

69. The multi-terminal capacitor device of claim 50, wherein the first electrode exhibits a volumetric surface area of from $100 \text{ mm}^2/\text{mm}^3$ to $50,000 \text{ mm}^2/\text{mm}^3$.
70. The multi-terminal capacitor device of claim 50, wherein the modified aluminum foil comprises sintered aluminum powder supported by and in physical and electrical contact with an aluminum foil substrate or wherein the modified aluminum foil comprises any other high surface area material structures.
71. The multi-terminal capacitor device of claim 50, wherein the modified aluminum foil comprises vapor deposited aluminum, aluminum oxide, titanium, or titanium oxide supported by and in physical and electrical contact with an aluminum foil.
72. The multi-terminal capacitor device of claim 71, wherein the vapor deposited aluminum, aluminum oxide, titanium, or titanium oxide is deposited using a glancing angle deposition process.
73. The multi-terminal capacitor device of claim 50, wherein the first electrode comprises an aluminum alloy including one or more alloying elements or dopants selected from Ti, Zr, Si, Mg, Cu, Ta, Ba, or Ce.
74. The multi-terminal capacitor device of claim 50, wherein the dielectric layer comprises aluminum oxide doped with one or more of an oxide of Ti, Zr, Si, Mg, Cu, Ta, Ba, or Ce.
75. The multi-terminal capacitor device of claim 50, wherein the dielectric layer has a dielectric constant of from 5 to 1000.
76. The multi-terminal capacitor device of claim 50, wherein the dielectric layer has a thickness of from 3 nm to 100 nm.
77. The multi-terminal capacitor device of claim 50, wherein the dielectric layer is formed through a process including anodizing the modified aluminum foil.
78. The multi-terminal capacitor device of claim 50, wherein the conductive material is a conducting polymer, a metal, or a conductive ceramic.
79. The multi-terminal capacitor device of claim 78, wherein the conducting polymer is one or more of a polypyrrole, a polythiophene, a polyaniline, a polyacetylene, a

polyphenylene, a poly(p-phenylene-vinylene), PEDOT:PSS (poly(3,4-ethylenedioxythiophene) polystyrene sulfonate), or P3HT (poly(3-hexylthiophene-2,5-diyl)).

80. The multi-terminal capacitor device of claim 78, wherein the conductive ceramic is TiN.

81. The multi-terminal capacitor device of claim 50, wherein the conductive material conformally coats non-planar regions of the first electrode and is separated from the first electrode by the dielectric layer.

82. The multi-terminal capacitor device of claim 50, wherein the second electrode has a thickness of up to about 500 μm .

83. The multi-terminal capacitor device of claim 50, wherein the plurality of individual capacitors each exhibit a capacitance density of from 0.05 $\mu\text{F}/\text{mm}^2$ to 25 $\mu\text{F}/\text{mm}^2$.

84. The multi-terminal capacitor device of claim 50, wherein the plurality of individual capacitors each have independent lateral dimensions.

85. The multi-terminal capacitor device of claim 50, wherein the plurality of individual capacitors each independently have a footprint of 0.1 mm^2 to 2500 mm^2 .

86. The multi-terminal capacitor device of claim 50, wherein the single device layer has a thickness of from 50 μm to 500 μm .

87. The multi-terminal capacitor device of claim 50, further comprising a substrate or transfer tape supporting the plurality of individual capacitors.

88. The multi-terminal capacitor device of claim 50, wherein the second electrode further comprises:

a conducting carbonaceous layer in physical contact with the conductive material.

89. The multi-terminal capacitor device of claim 88, wherein the conducting carbonaceous layer comprises one or more of carbon black, graphite, a carbon-based ink, a polymeric binder, sputtered carbon, or carbon-polymer composites.

90. The multi-terminal capacitor device of claim 88, wherein the conducting carbonaceous layer has a thickness of from 100 nm to 100 μm .

91. The multi-terminal capacitor device of claim 50, wherein the second electrode further comprises:
a diffusion barrier layer in electrical contact with the conductive material.
92. The multi-terminal capacitor device of claim 91, wherein the diffusion barrier layer comprises Ti, W, Cr, Ti-W, TaN, or Co-W.
93. The multi-terminal capacitor device of claim 91, wherein the diffusion barrier layer has a thickness of from 10 nm to 2500 nm.
94. The multi-terminal capacitor device of claim 50, wherein the second electrode further comprises:
a metallization layer in electrical contact with the conductive material.
95. The multi-terminal capacitor device of claim 94, wherein the metallization layer comprises Ag, Au, Cu, Pt, Pd, and/or composites or alloys of these, polymers, epoxies, silicones, or fluoroelastomers.
96. The multi-terminal capacitor device of claim 94, wherein the metallization layer has a thickness of from 100 nm to 2500 nm.
97. The multi-terminal capacitor device of claim 50, wherein the second electrode further comprises:
a metal contact layer in electrical contact with the conductive material.
98. The multi-terminal capacitor device of claim 97, wherein the metal contact layer comprises Cu or Ag.
99. The multi-terminal capacitor device of claim 97, wherein the metal contact layer has a thickness of from 0.5 μm to 50 μm .
100. The multi-terminal capacitor device of claim 50, further comprising a dielectric planarization layer positioned adjacent to the plurality of individual capacitors.
101. The multi-terminal capacitor device of claim 100, further comprising a plurality of conductor filled vias, wherein each conductor filled via extends through the dielectric planarization layer, and wherein each conductor filled via provides electrical contact between

a corresponding capacitor terminal and a corresponding first electrode or corresponding second electrode.

102. The multi-terminal capacitor device of claim 100, wherein the dielectric planarization layer has a thickness of from 1 μm to 100 μm .

103. The multi-terminal capacitor device of claim 50, further comprising an insulating material in a spacing separating adjacent individual capacitors.

104. The multi-terminal capacitor device of claim 103, further comprising a plurality of conductor filled vias, wherein each conductor filled via is positioned within the spacing separating adjacent individual capacitors and extends through the insulating material, and wherein each conductor filled via provides electrical contact between a corresponding capacitor terminal and a corresponding first electrode or corresponding second electrode.

105. The multi-terminal capacitor device of claim 50, wherein a spacing separating adjacent individual capacitors is from 1 μm to 10 mm.

106. The multi-terminal capacitor device of claim 50, wherein the single device layer is in a planar configuration or a curved configuration exhibiting a radius of curvature greater than 5 cm.

107. The multi-terminal capacitor device of claim 50, further comprising a top encapsulation layer.

108. The multi-terminal capacitor device of claim 50, further comprising one or more surface-mounting structures.

109. A method comprising:
 providing a modified aluminum foil, wherein the modified aluminum foil comprises an aluminum core layer, a modified top surface, and a modified bottom surface;
 subjecting the modified aluminum foil to an anodizing process, wherein the anodizing process generates a dielectric layer on and conformal with the modified top surface and the modified bottom surface; and
 arranging a conductive material adjacent to the dielectric layer.

110. The method of claim 109, further comprising one or more of:
depositing a conducting carbonaceous layer over the conductive material;
depositing a diffusion barrier layer over the conductive material; or
depositing a metallization layer over the conductive material.
111. The method of claim 109, further comprising:
patterning the modified aluminum foil prior to arranging the conductive material adjacent to the dielectric layer.
112. The method of claim 109, further comprising:
patterning the modified aluminum foil prior to subjecting the modified aluminum foil to the anodizing process.
113. The method of claim 109, further comprising:
patterning the modified aluminum foil using a laser etching or laser ablation process.