

Claims

What is claimed is:

1. An integrated circuit (IC) package assembly comprising:
5 a first layer having a first side and a second side disposed opposite to the first side;
a second layer coupled with the first side of the first layer;
one or more antenna elements coupled with the second layer; and
a third layer coupled with the second side of the first layer, wherein the first
10 layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.
2. The IC package assembly of claim 1, wherein:
the second layer and the third layer have a same material composition; and
a surface roughness of the second layer and the third layer is less than a
15 surface roughness of the first layer.
3. The IC package assembly of claim 1, wherein:
the first layer comprises liquid crystal polymer (LCP) or prepreg material;
and
the second layer and the third layer comprise liquid crystal polymer (LCP)
20 or an epoxy-based material.
4. The IC package assembly of claim 3, wherein:
the first layer comprises LCP with glass; and
the second layer and the third layer comprise LCP without glass.
5. The IC package assembly of claim 1, wherein:
25 the one or more antenna elements comprise one or more plated metal features formed on the second layer.
6. The IC package assembly of claim 1, wherein a first side of the third layer is coupled with the second side of the first layer, the IC package assembly further comprising:
30 an electrical routing feature disposed on a second side of the third layer, the second side of the third layer being disposed opposite to the first side of the third layer; and

a via structure or plated-through hole structure coupled with the electrical routing feature and the one or more antenna elements, the via structure or plated-through hole structure extending through the first layer, the second layer and the third layer.

- 5 7. The IC package assembly of any of claims 1-6, wherein:
 the first layer defines a plane extending in a horizontal direction; and
 no plated metal features for routing electrical signals in the horizontal
 direction are directly disposed on the first layer.
- 10 8. The IC package assembly of any of claims 1-6, wherein the one or more
 antenna elements include a first capacitive element, the IC package assembly
 further comprising:
 a second capacitive element directly coupled with the third layer, wherein
 the first capacitive element and the second capacitive element are components of
 a multi-layer capacitively coupled antenna.
- 15 9. The IC package assembly of any of claims 1-6, further comprising:
 a fourth layer having a first side and a second side disposed opposite to the
 first side;
 a fifth layer coupled with the first side of the fourth layer; and
 a sixth layer coupled with the second side of the fourth layer, wherein the
20 fourth layer is a reinforcement layer having a tensile modulus that is greater than a
 tensile modulus of the fifth layer and the sixth layer, wherein the fifth layer is
 coupled with the third layer.
- 25 10. The IC package assembly of any of claims 1-6, further comprising:
 an antenna ground layer coupled with the third layer; and
 a radio frequency (RF) die coupled with the antenna ground layer.
- 30 11. A method of fabricating a multi-layer package assembly, the method
 comprising:
 providing a first layer having a first side and a second side disposed
 opposite to the first side;
 coupling a second layer with the first side of the first layer;
 coupling a third layer with the second side of the first layer; and

forming one or more antenna elements on the second layer, wherein the first layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.

12. The method of claim 11, wherein coupling the second layer with the first side of the first layer and coupling the third layer with the second side of the first layer is performed by lamination.

13. The method of any of claims 11-12, wherein forming the one or more antenna elements comprises plating the second layer with a metal.

14. The method of claim 13, further comprising:
forming an opening for a via or plated-through hole (PTH) through the first layer, the second layer and the third layer.

15. The method of claim 14, further comprising:
depositing a metal to fill the opening during a same metal deposition process that is used to form the one or more antenna elements.

16. The method of claim 14, further comprising:
forming a solder mask layer on the second layer.

17. A computing device comprising:
a circuit board; and
an integrated circuit (IC) package assembly coupled with the circuit board,
the IC package assembly including:

a first layer having a first side and a second side disposed opposite to the first side;

a second layer coupled with the first side of the first layer;

one or more antenna elements coupled with the second layer; and

a third layer coupled with the second side of the first layer, wherein the first layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.

18. The computing device of claim 17, wherein a first side of the third layer is coupled with the second side of the first layer, the IC package assembly further comprising:

an electrical routing feature disposed on a second side of the third layer, the second side of the third layer being disposed opposite to the first side of the third layer; and

a via structure or plated-through hole structure coupled with the electrical routing feature and the one or more antenna elements, the via structure or plated-through hole structure extending through the first layer, the second layer and the third layer.

5 19. The computing device of any of claims 17-18, wherein:

the first layer defines a plane extending in a horizontal direction; and
no plated metal features for routing electrical signals in the horizontal
direction are directly disposed on the first layer.

20. The computing device of any of claims 17-18, wherein:

10 the computing device is a mobile computing device including one or more
of a display, a touchscreen display, a touchscreen controller, a battery, an audio
codec, a video codec, a power amplifier, a global positioning system (GPS)
device, a compass, a Geiger counter, an accelerometer, a gyroscope, a speaker,
or a camera coupled with the circuit board.

Claims

What is claimed is:

1. An integrated circuit (IC) package assembly comprising:
a first layer having a first side and a second side disposed opposite to the first side;
a second layer coupled with the first side of the first layer;
one or more antenna elements coupled with the second layer; and
a third layer coupled with the second side of the first layer, wherein the first layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.
2. The IC package assembly of claim 1, wherein:
the second layer and the third layer have a same material composition; and
a surface roughness of the second layer and the third layer is less than a surface roughness of the first layer.
3. The IC package assembly of claim 1, wherein:
the first layer comprises liquid crystal polymer (LCP) or prepreg material; and
the second layer and the third layer comprise liquid crystal polymer (LCP) or an epoxy-based material.
4. The IC package assembly of claim 3, wherein:
the first layer comprises LCP with glass; and
the second layer and the third layer comprise LCP without glass.
5. The IC package assembly of claim 1, wherein:
the one or more antenna elements comprise one or more plated metal features formed on the second layer.

6. The IC package assembly of claim 1, wherein a first side of the third layer is coupled with the second side of the first layer, the IC package assembly further comprising:

an electrical routing feature disposed on a second side of the third layer, the second side of the third layer being disposed opposite to the first side of the third layer; and

a via structure or plated-through hole structure coupled with the electrical routing feature and the one or more antenna elements, the via structure or plated-through hole structure extending through the first layer, the second layer and the third layer.

7. The IC package assembly of claim 1, wherein:

the first layer defines a plane extending in a horizontal direction; and

no plated metal features for routing electrical signals in the horizontal direction are directly disposed on the first layer.

8. The IC package assembly of claim 1, wherein the one or more antenna elements include a first capacitive element, the IC package assembly further comprising:

a second capacitive element directly coupled with the third layer, wherein the first capacitive element and the second capacitive element are components of a multi-layer capacitively coupled antenna.

9. The IC package assembly of claim 1, further comprising:

a fourth layer having a first side and a second side disposed opposite to the first side;

a fifth layer coupled with the first side of the fourth layer; and

a sixth layer coupled with the second side of the fourth layer, wherein the fourth layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the fifth layer and the sixth layer, wherein the fifth layer is coupled with the third layer.

10. The IC package assembly of claim 1, further comprising:

an antenna ground layer coupled with the third layer; and
a radio frequency (RF) die coupled with the antenna ground layer.

11. A method of fabricating a multi-layer package assembly, the method comprising:
providing a first layer having a first side and a second side disposed opposite to the first side;
coupling a second layer with the first side of the first layer;
coupling a third layer with the second side of the first layer; and
forming one or more antenna elements on the second layer, wherein the first layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.
12. The method of claim 11, wherein coupling the second layer with the first side of the first layer and coupling the third layer with the second side of the first layer is performed by lamination.
13. The method of claim 11, wherein forming the one or more antenna elements comprises plating the second layer with a metal.
14. The method of claim 13, further comprising:
forming an opening for a via or plated-through hole (PTH) through the first layer, the second layer and the third layer.
15. The method of claim 14, further comprising:
depositing a metal to fill the opening during a same metal deposition process that is used to form the one or more antenna elements.
16. The method of claim 14, further comprising:
forming a solder mask layer on the second layer.
17. A computing device comprising:

a circuit board; and
an integrated circuit (IC) package assembly coupled with the circuit board, the IC package assembly including:
a first layer having a first side and a second side disposed opposite to the first side;
a second layer coupled with the first side of the first layer;
one or more antenna elements coupled with the second layer; and
a third layer coupled with the second side of the first layer, wherein the first layer is a reinforcement layer having a tensile modulus that is greater than a tensile modulus of the second layer and the third layer.

18. The computing device of claim 17, wherein a first side of the third layer is coupled with the second side of the first layer, the IC package assembly further comprising:

an electrical routing feature disposed on a second side of the third layer, the second side of the third layer being disposed opposite to the first side of the third layer; and

a via structure or plated-through hole structure coupled with the electrical routing feature and the one or more antenna elements, the via structure or plated-through hole structure extending through the first layer, the second layer and the third layer.

19. The computing device of claim 17, wherein:

the first layer defines a plane extending in a horizontal direction; and
no plated metal features for routing electrical signals in the horizontal direction are directly disposed on the first layer.

20. The computing device of claim 17, wherein:

the computing device is a mobile computing device including one or more of a display, a touchscreen display, a touchscreen controller, a battery, an audio codec, a video codec, a power amplifier, a global positioning system (GPS) device, a compass, a

Geiger counter, an accelerometer, a gyroscope, a speaker, or a camera coupled with the circuit board.