Claims

Claim 1. A method of forming an out-of-plane electrode comprising:

providing an oxide layer above an upper surface of a device layer;

providing a first cap layer portion above an upper surface of the oxide layer;

etching a first electrode perimeter defining trench extending through the first cap layer portion and stopping at the oxide layer;

depositing a first material portion within the first electrode perimeter defining trench;

depositing a second cap layer portion above the deposited first material portion;

vapor releasing a portion of the oxide layer;

depositing a third cap layer portion above the second cap layer portion;

etching a second electrode perimeter defining trench extending through the second cap layer portion and the third cap layer portion; and

depositing a second material portion within the second electrode perimeter defining trench, such that a spacer including the first material portion and the second material portion define a perimeter of an out-of-plane electrode.

Claim 2. The method of claim 1, further comprising:

etching an etch stop perimeter defining trench extending through the first cap layer portion and the oxide layer; and

depositing a third material portion within the etch stop perimeter defining trench, wherein vapor releasing a portion of the oxide layer comprises vapor releasing a portion of the oxide layer to a boundary defined by the third material portion.

Claim 3. The method of claim 2, further comprising:

depositing an etch stop layer portion on the deposited first material portion, wherein etching a second electrode perimeter defining trench comprises:

etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

Claim 4. The method of claim 1, wherein the first cap layer portion, the second cap layer portion, and the third cap layer portion are deposited by an epitaxial deposition process.

Claim 5. The method of claim 1, wherein the first material portion and the second material portion comprise silicon nitride.

Claim 6. The method of claim 1, further comprising:

depositing an etch stop layer portion on the deposited first material portion, wherein etching a second electrode perimeter defining trench comprises:

etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

Claim 7. The method of claim 1, further comprising;

etching vent holes through the first cap layer and the second cap layer, wherein vapor releasing a portion of the oxide layer comprises:

vapor releasing a portion of the oxide layer through the vent holes.

Embodiment 8. A device with an out-of-plane electrode comprising:

a device layer positioned above a handle layer;

a cap layer having a first cap layer portion spaced apart from an upper surface of the device layer; and

an out-of-plane electrode defined within the first cap layer portion by a spacer.

Claim 9. The device of claim 8, wherein the cap layer is an epitaxially deposited cap layer.

Claim 10. The device of claim 8, wherein the spacer comprises silicon nitride.

Claim 11. The device of claim 10, wherein the spacer comprises:

a first silicon nitride portion extending upwardly from a lower surface of the cap layer;

a second silicon nitride portion extending downwardly from an upper surface of the cap layer; and

an etch stop portion located between the first silicon nitride portion and the second silicon nitride portion.

Claim 12. The device of claim 8, further comprising:

an oxide layer portion located between a second cap layer portion and the upper surface of the device layer; and

an etch stop extending downwardly from within the cap layer and defining a boundary of the oxide layer portion.

Claim 13. The device of claim 12, wherein the spacer comprises:

a first silicon nitride portion extending upwardly from a lower surface of the cap layer;

a second silicon nitride portion extending downwardly from an upper surface of the cap layer; and

an etch stop portion located between the first silicon nitride portion and the second silicon nitride portion.

Claim 14. The device of claim 12, further comprising:

a buried oxide layer portion located between a lower surface of the device layer and an upper surface of a handle layer; and

an etch stop extending downwardly from the upper surface of the device layer and defining a boundary of the buried oxide layer portion.

Claim 15. A method of forming an out-of-plane electrode comprising:

providing an oxide layer above an upper surface of a device layer;

epitaxially depositing a first cap layer portion above an upper surface of the oxide layer;

etching a first electrode perimeter defining trench extending through the first cap layer portion and stopping at the oxide layer;

depositing a first insulating material portion within the first electrode perimeter defining trench;

epitaxially depositing a second cap layer portion above the deposited first material portion;

performing an HF vapor etch release on a portion of the oxide layer;

epitaxially depositing a third cap layer portion above the second cap layer portion;

etching a second electrode perimeter defining trench extending through the second cap layer portion and the third cap layer portion; and

depositing a second insulating material portion within the second electrode perimeter defining trench, such that a spacer including the first material portion and the second material portion define a perimeter of an out-of-plane electrode.

Claim 16. The method of claim 15, further comprising:

etching an etch stop perimeter defining trench extending through the first cap layer portion and the oxide layer; and

depositing a third material portion within the etch stop perimeter defining trench, wherein performing an HF vapor etch release on a portion of the oxide layer comprises performing an HF vapor etch release to a boundary defined by the third material portion.

Claim 17. The method of claim 16, further comprising:

depositing an etch stop layer portion on the deposited first insulating material portion, wherein etching a second electrode perimeter defining trench comprises:

etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

Claim 18. The method of claim 15, wherein the first insulating material portion and the second insulating material portion comprise silicon nitride.

Claim 19. The method of claim 15, further comprising:

depositing an etch stop layer portion on the deposited first material portion, wherein etching a second electrode perimeter defining trench comprises:

etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

Claim 20. The method of claim 15, further comprising;

etching vent holes through the first cap layer and the second cap layer, wherein performing an HF vapor etch release on a portion of the oxide layer comprises:

performing an HF vapor etch release on a portion of the oxide layer through the vent holes.

The invention claimed is:

1. A method of forming an out-of-plane electrode comprising: providing an oxide layer above an upper surface of a device layer; providing a first cap layer portion above an upper surface of the oxide layer; etching a first electrode perimeter defining trench extending through the first cap layer portion and stopping at the oxide layer; depositing a first material portion within the first electrode perimeter defining trench; depositing a second cap layer portion above the deposited first material portion; vapor releasing a portion of the oxide layer; depositing a third cap layer portion above the second cap layer portion after vapor releasing the portion of the oxide layer; etching a second electrode perimeter defining trench extending through the second cap layer portion and the third cap layer portion; depositing a second material portion within the second electrode perimeter defining trench, such that a spacer including the first material portion and the second material portion define a perimeter of an out-of-plane electrode, etching an etch stop perimeter defining trench extending through the first cap layer portion and the oxide layer; and depositing a third material portion within the etch stop perimeter defining trench, wherein vapor releasing a portion of the oxide layer comprises vapor releasing a portion of the oxide layer to a boundary defined by the third material portion.

2. The method of claim 1, wherein the first cap layer portion, the second cap layer portion, and the third cap layer portion are deposited by an epitaxial deposition process.

3. The method of claim 1, wherein the first material portion and the second material portion comprise silicon nitride.

4. The method of claim 1, further comprising: depositing an etch stop layer portion on the deposited first material portion, wherein etching a second electrode perimeter defining trench comprises: etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

5. The method of claim 1, further comprising; etching vent holes through the first cap layer and the second cap layer, wherein vapor releasing a portion of the oxide layer comprises: vapor releasing a portion of the oxide layer through the vent holes.

6. A method of forming an out-of-plane electrode comprising: providing an oxide layer above an upper surface of a device layer; epitaxially depositing a first cap layer portion above an upper surface of the oxide layer; etching a first electrode perimeter defining trench extending through the first cap layer portion and stopping at the oxide layer; depositing a first insulating material portion within the first electrode perimeter defining trench; epitaxially depositing a second cap layer portion above the deposited first material portion; performing an HF vapor etch release on a portion of the oxide layer; epitaxially depositing a third cap layer portion above the second cap layer portion after performing the HF vapor etch release; etching a second electrode perimeter defining trench extending through the second cap layer portion and the third cap layer portion; depositing a second insulating material portion within the second electrode perimeter defining trench, such that a spacer including the first material portion and the second material portion define a perimeter of an out-of-plane electrode; etching an etch stop perimeter defining trench extending through the first cap layer portion and the oxide layer; and depositing a third material portion within the etch stop perimeter defining trench, wherein performing an HF vapor etch release on a portion of the oxide layer comprises performing an HF vapor etch release to a boundary defined by the third material portion.

7. The method of claim 6, wherein the first insulating material portion and the second insulating material portion comprise silicon nitride.

8. The method of claim 6, further comprising: depositing an etch stop layer portion on the deposited first material portion, wherein etching a second electrode perimeter defining trench comprises: etching a second electrode perimeter defining trench extending through the second cap layer portion and to the etch stop layer.

9. The method of claim 6, further comprising; etching vent holes through the first cap layer and the second cap layer, wherein performing an HF vapor etch release on a portion of the oxide layer comprises: performing an HF vapor etch release on a portion of the oxide layer through the vent holes.