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Toyama et al.

(54) THROUGH-MEMORY-LEVEL VIA STRUCTURES FOR A THREE-DIMENSIONAL MEMORY DEVICE

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(21) Appl. No.: **15/269,017**

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Publication Classification

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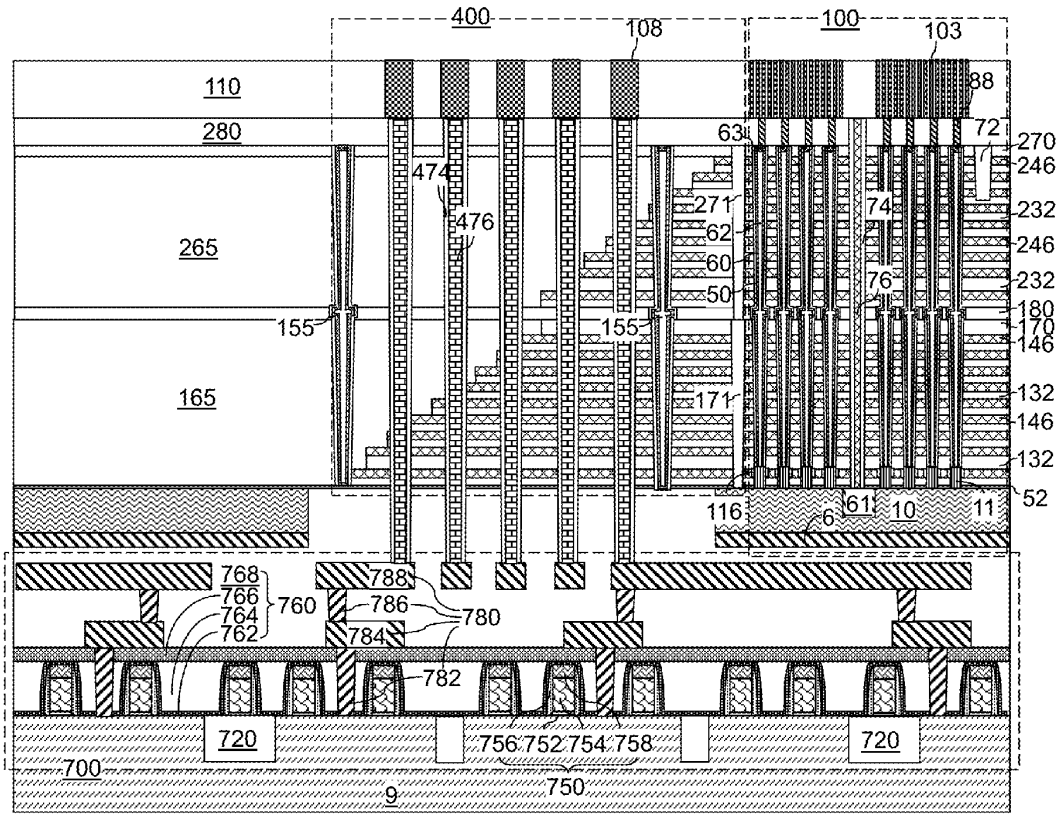
H01L 23/522 (2006.01)
H01L 21/768 (2006.01)
H01L 27/115 (2006.01)

(52) **U.S. Cl.**

CPC *H01L 23/5283* (2013.01); *H01L 27/11524* (2013.01); *H01L 27/11556* (2013.01); *H01L 27/11529* (2013.01); *H01L 27/1157* (2013.01); *H01L 27/11582* (2013.01); *H01L 27/11573* (2013.01); *H01L 23/5226* (2013.01); *H01L 21/76816* (2013.01); *H01L 21/76831* (2013.01); *H01L 21/76877* (2013.01)

(57) **ABSTRACT**

A three dimensional NAND memory device includes word line driver devices located on or over a substrate, an alternating stack of word lines and insulating layers located over the word line driver devices, a plurality of memory stack structures extending through the alternating stack, each memory stack structure including a memory film and a vertical semiconductor channel, and through-memory-level via structures which electrically couple the word lines in a first memory block to the word line driver devices. The through-memory-level via structures extend through a through-memory-level via region located between a staircase region of the first memory block and a staircase region of another memory block.



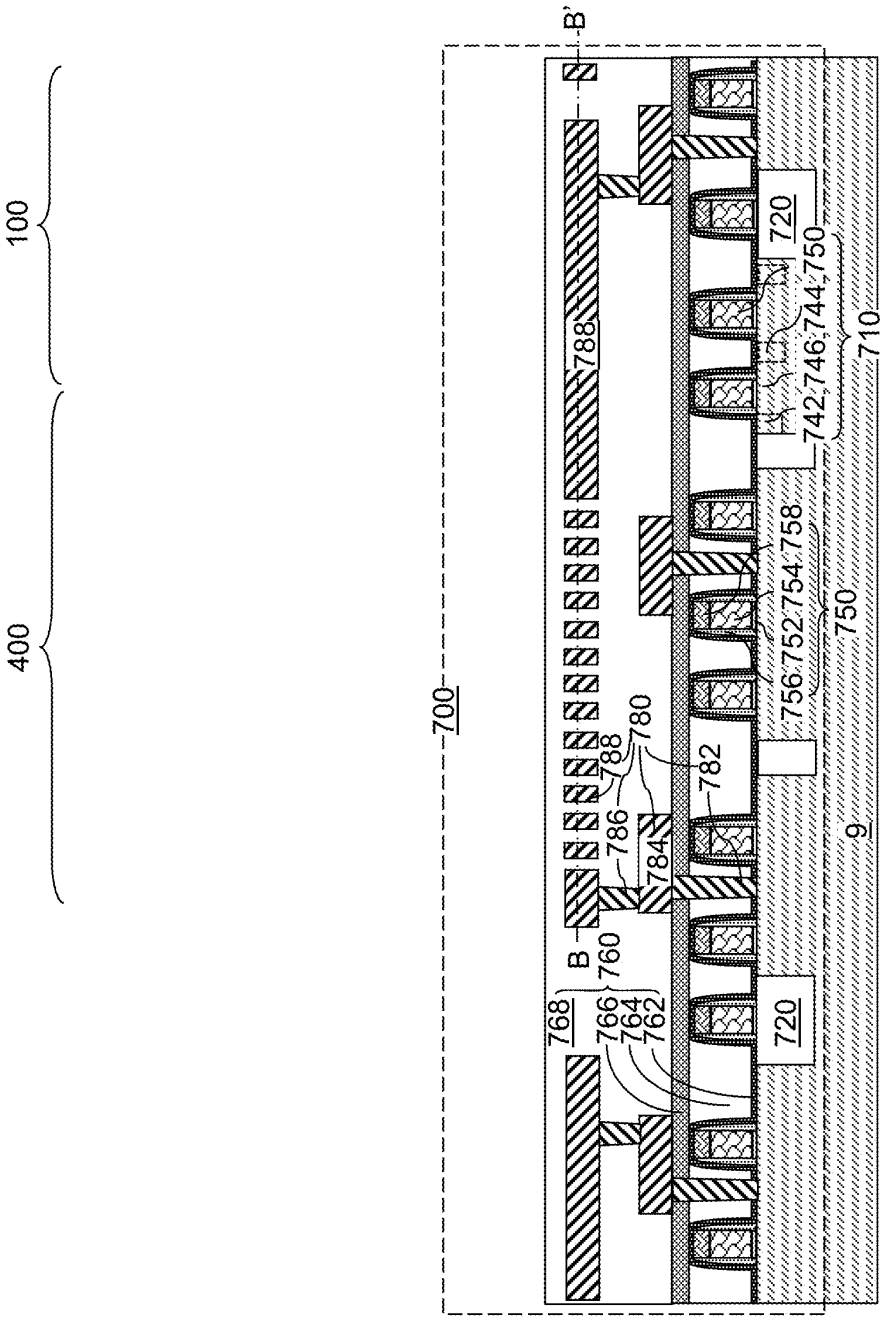

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FIG. 1A

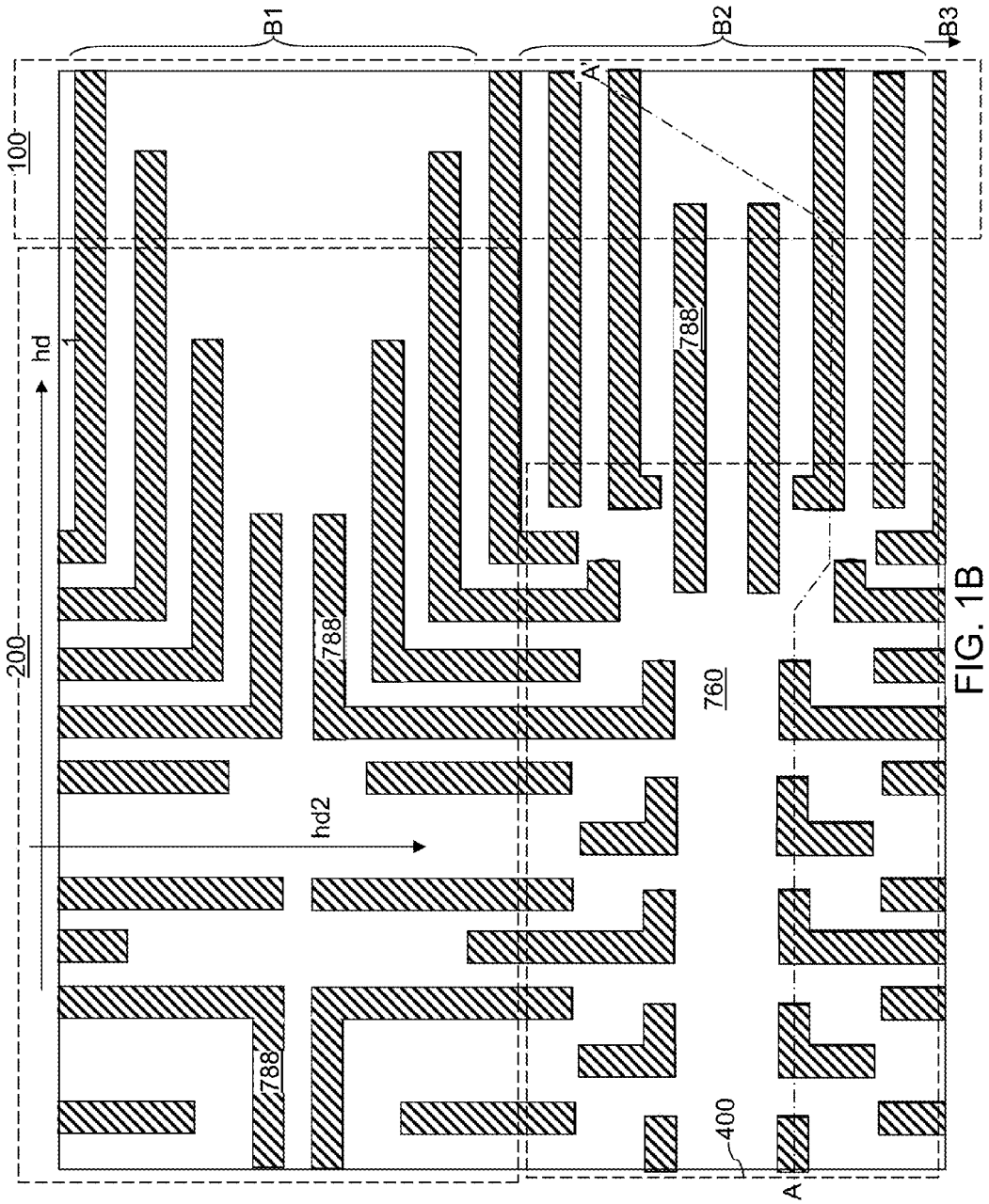

FIG. 1B

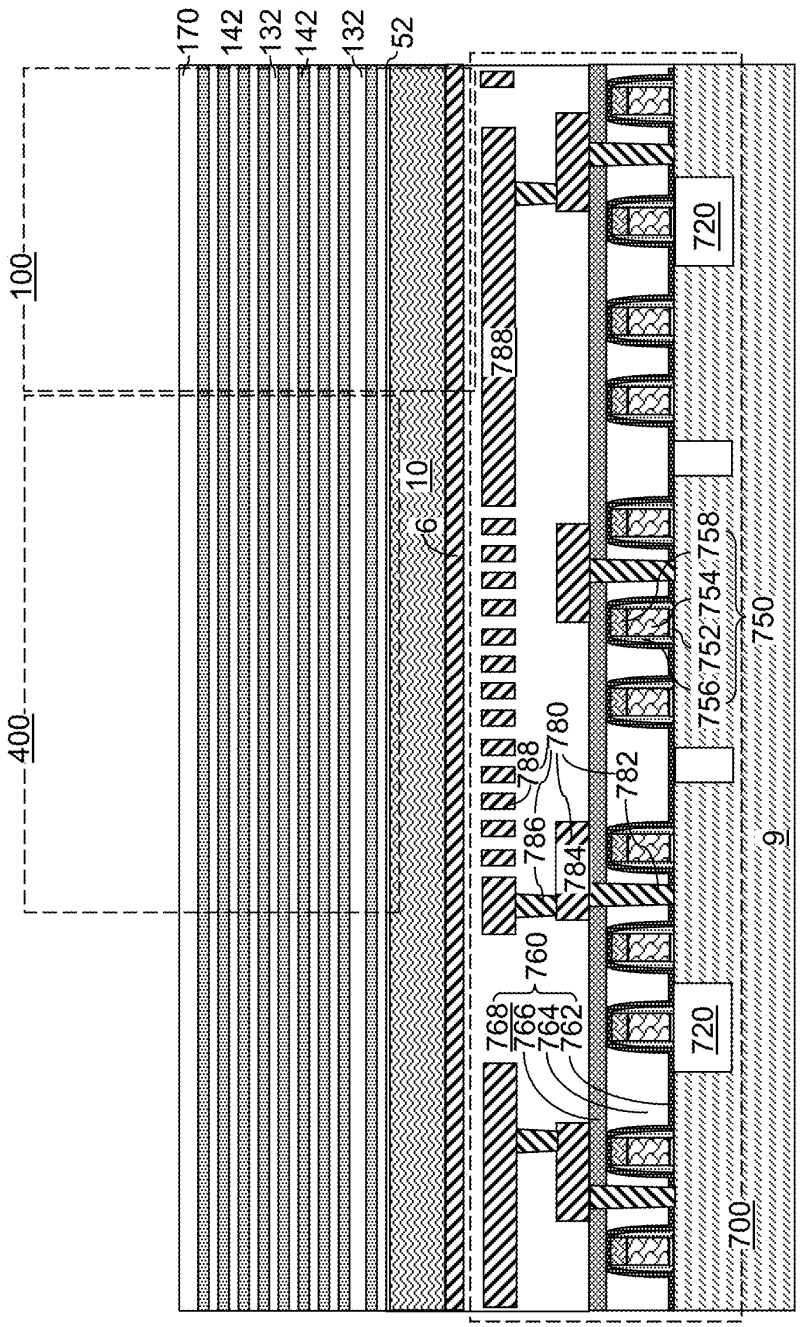
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FIG. 2

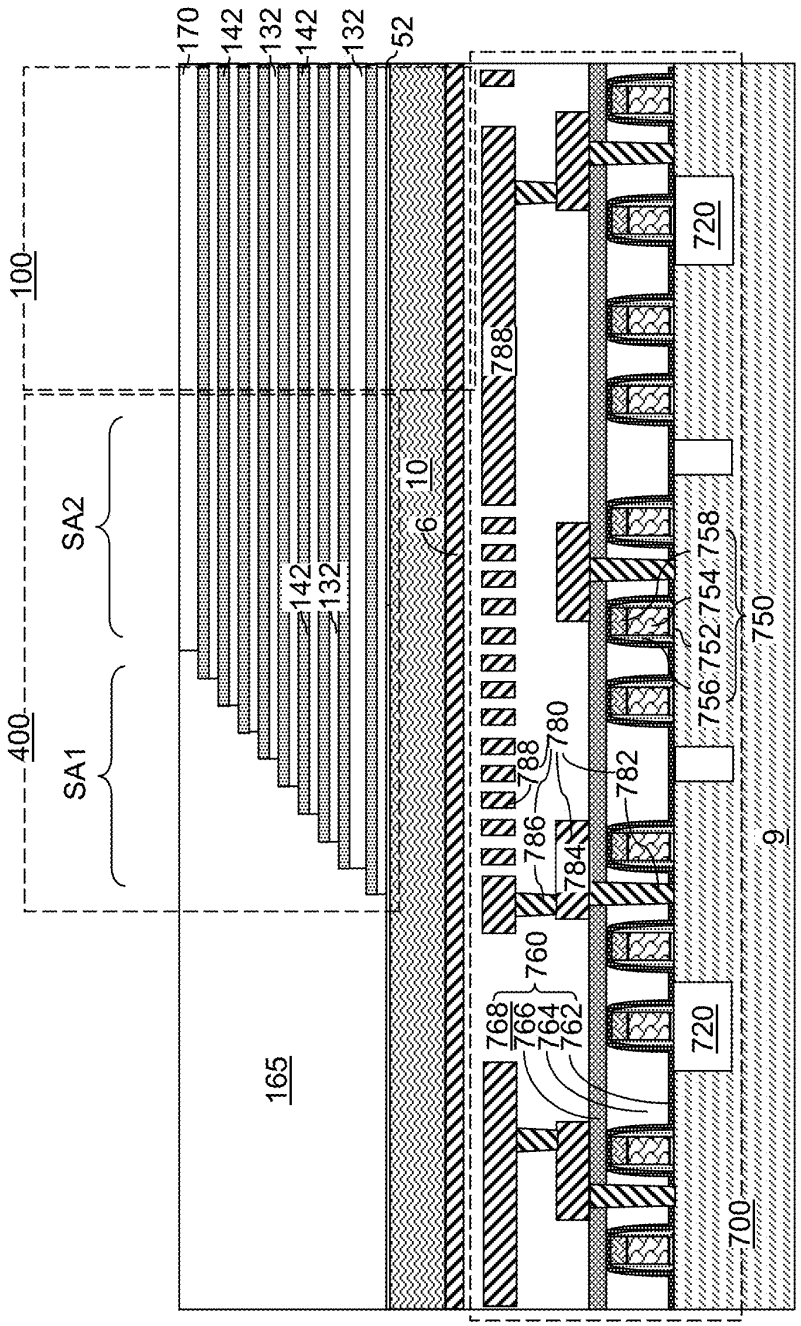
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FIG. 3

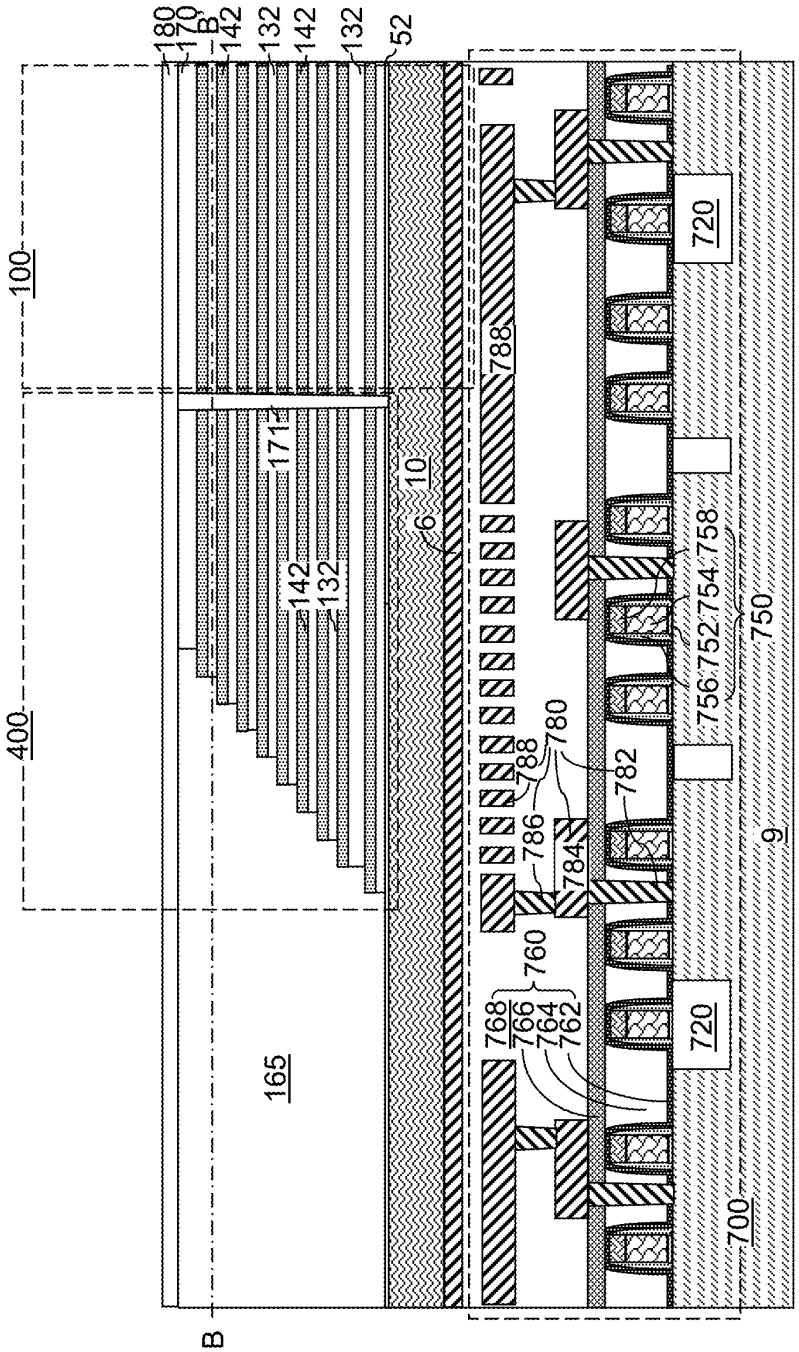
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FIG. 4A

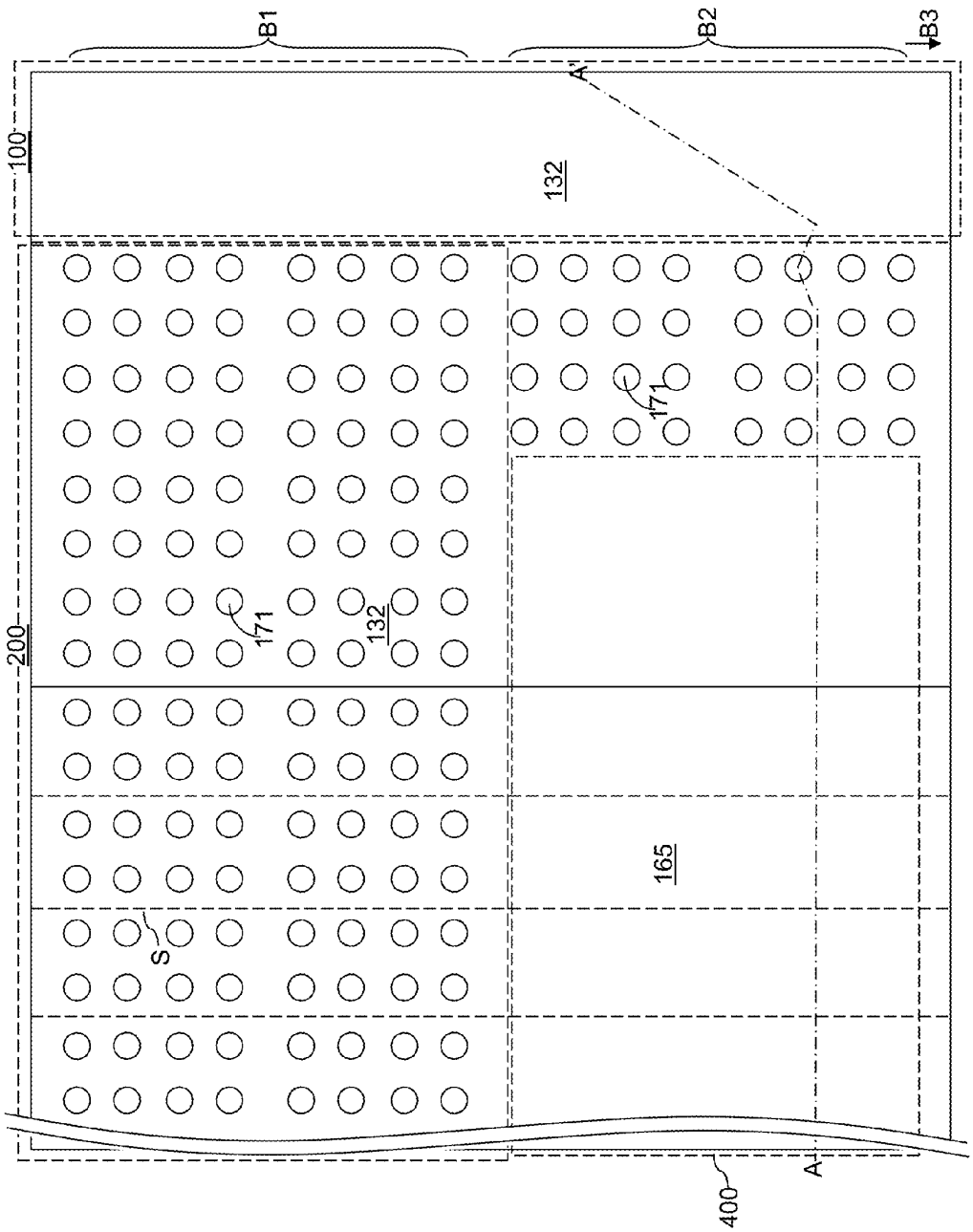

FIG. 4B

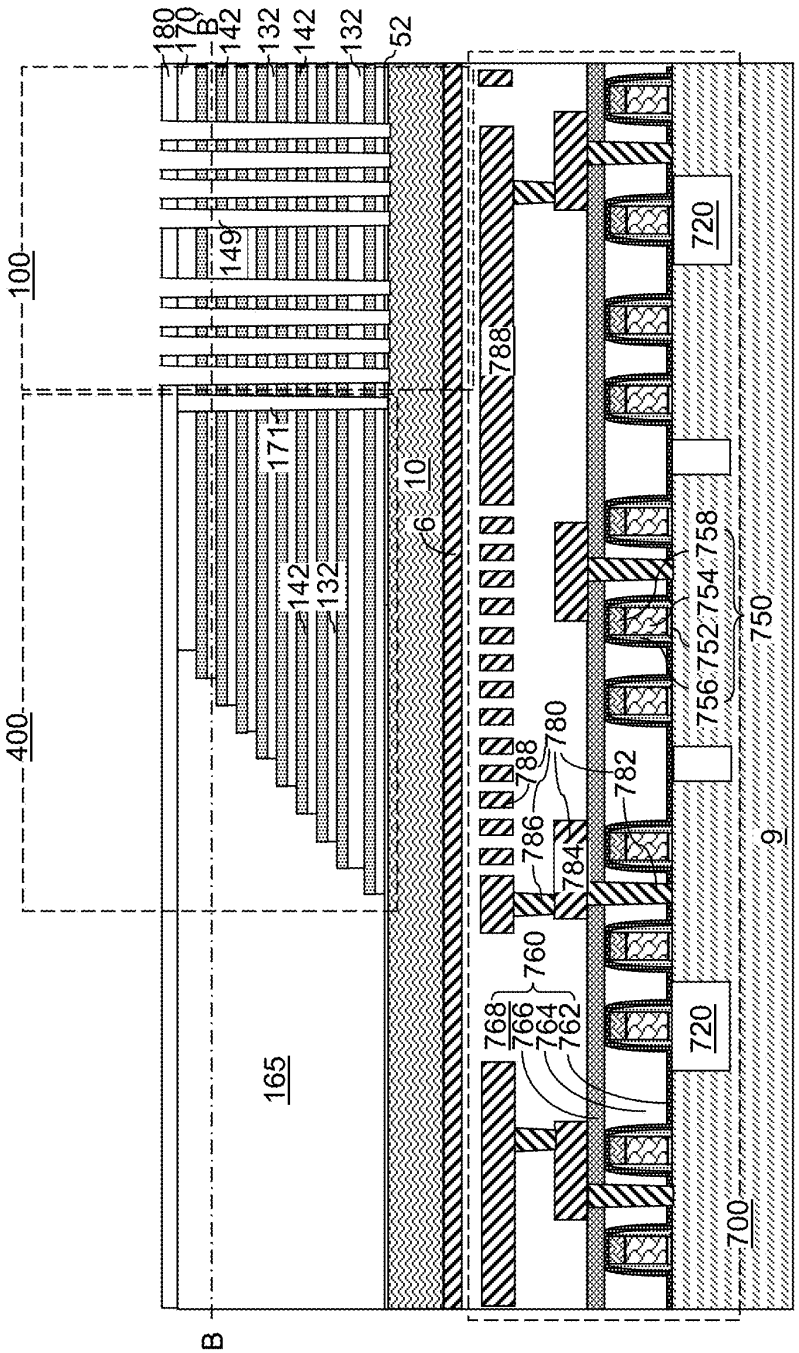
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FIG. 5A

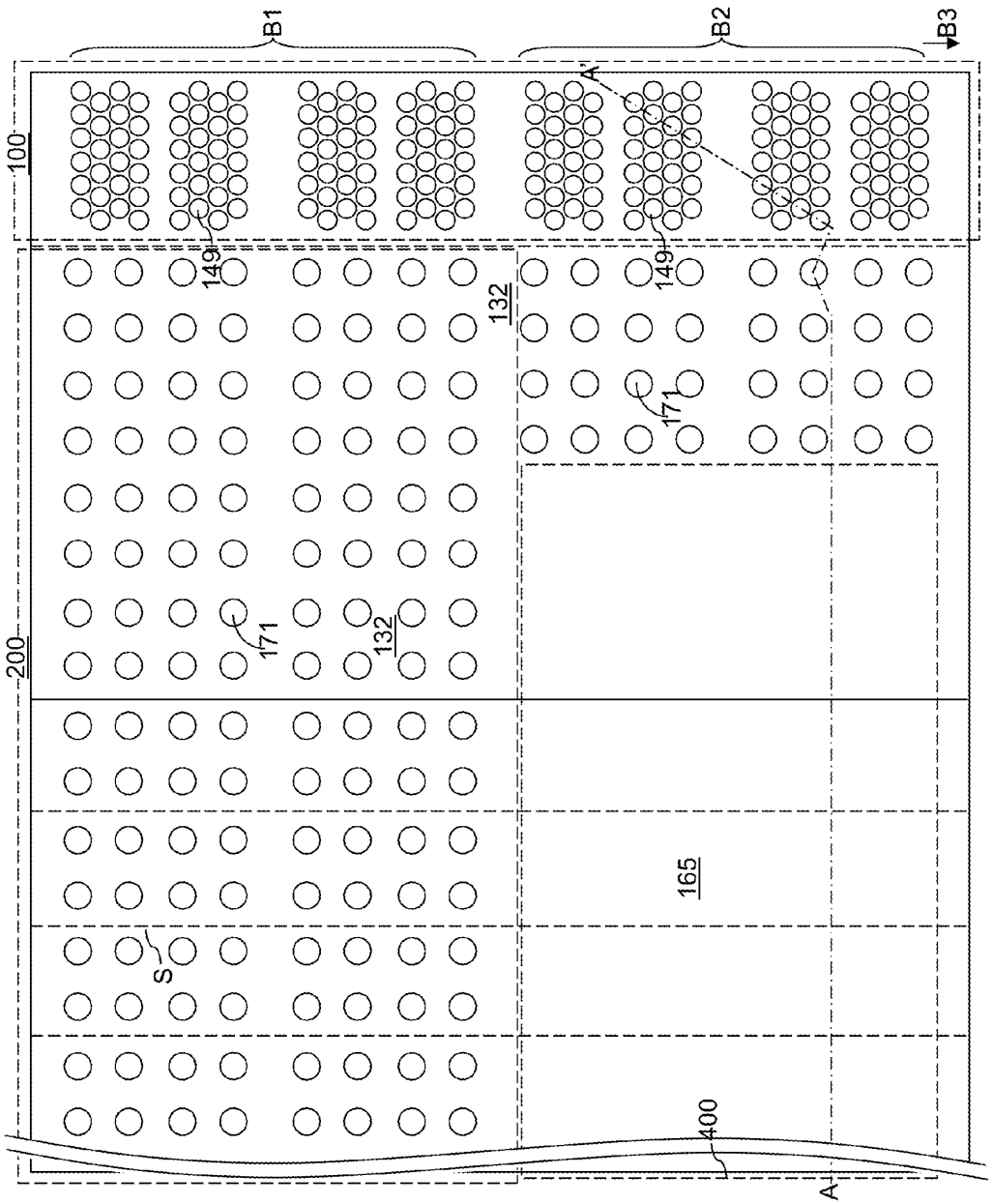

FIG. 5B

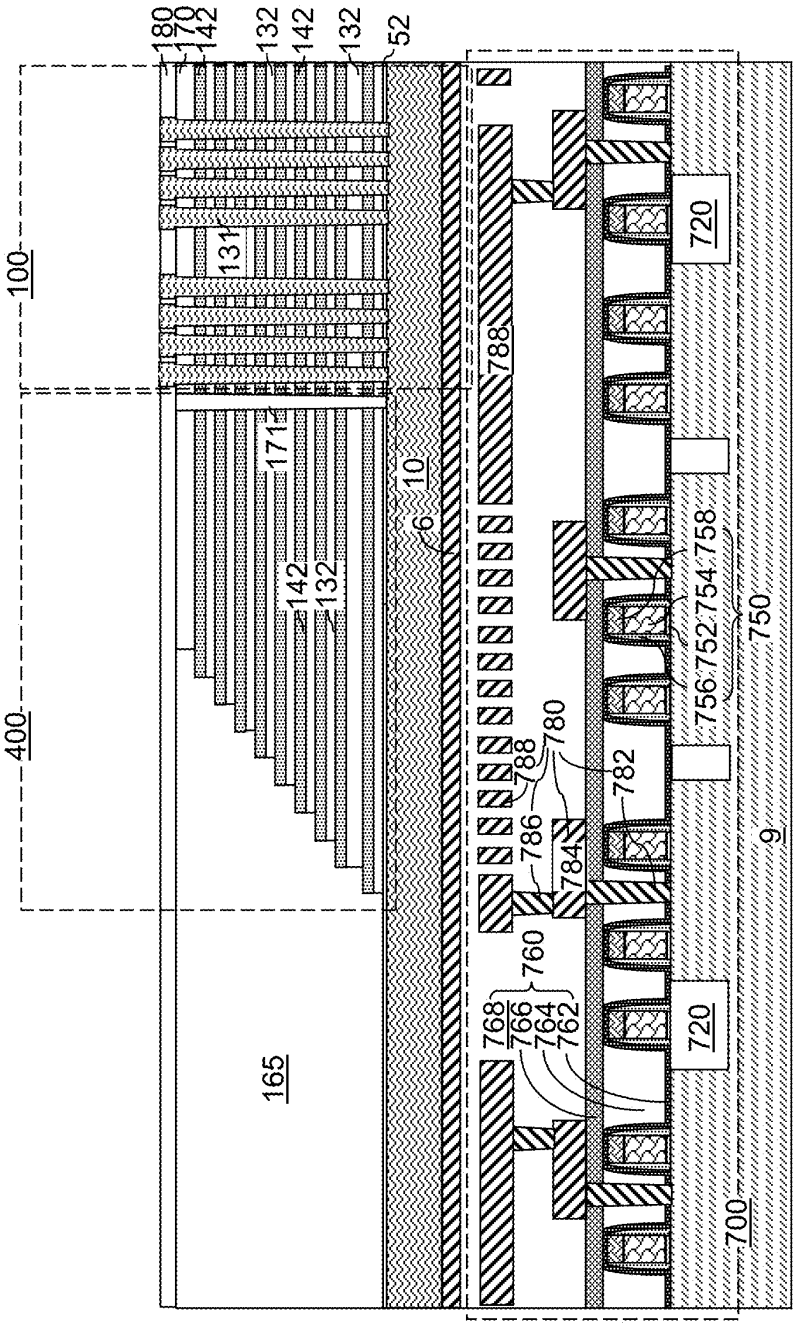
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FIG. 6

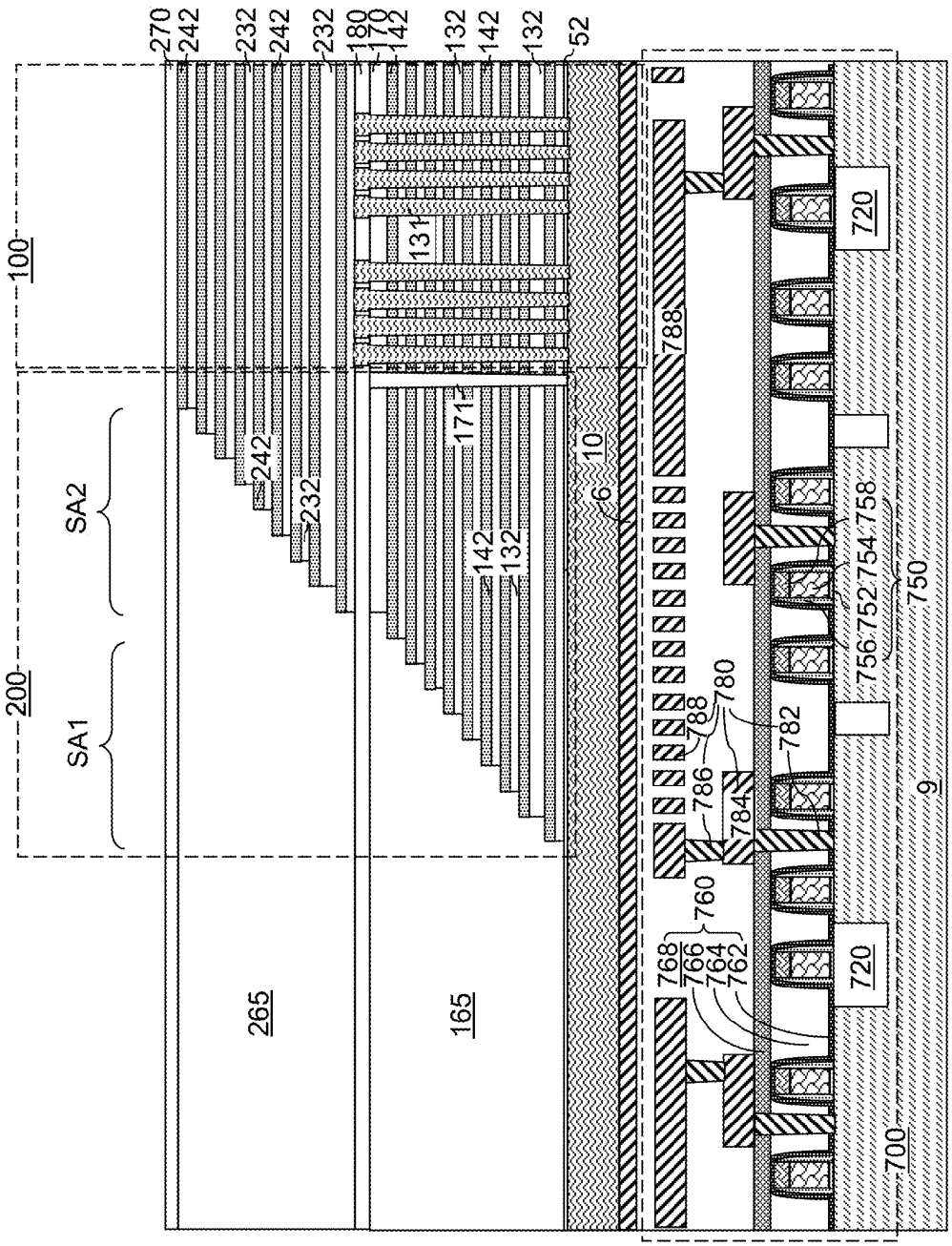
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FIG. 7

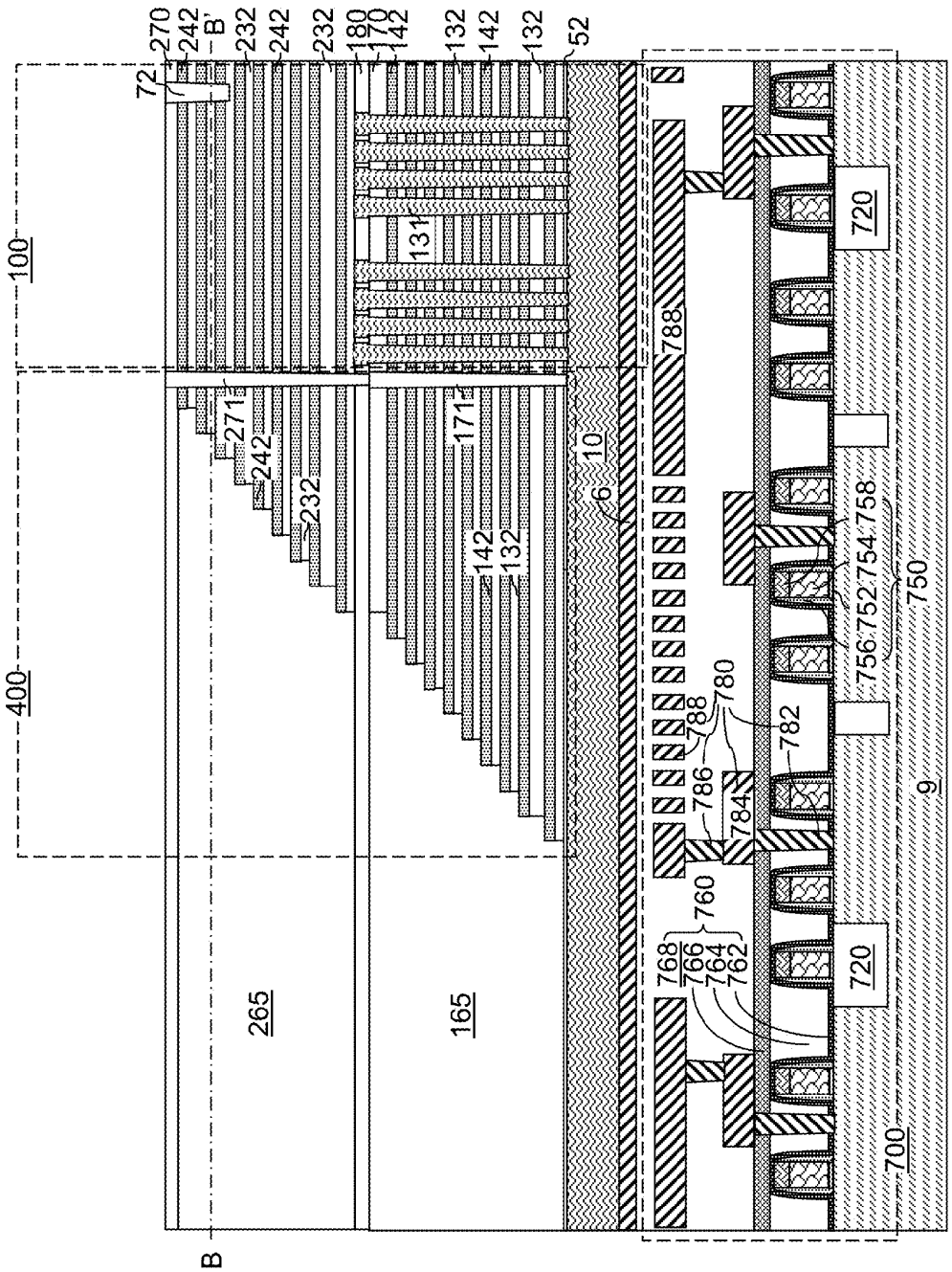
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FIG. 8A

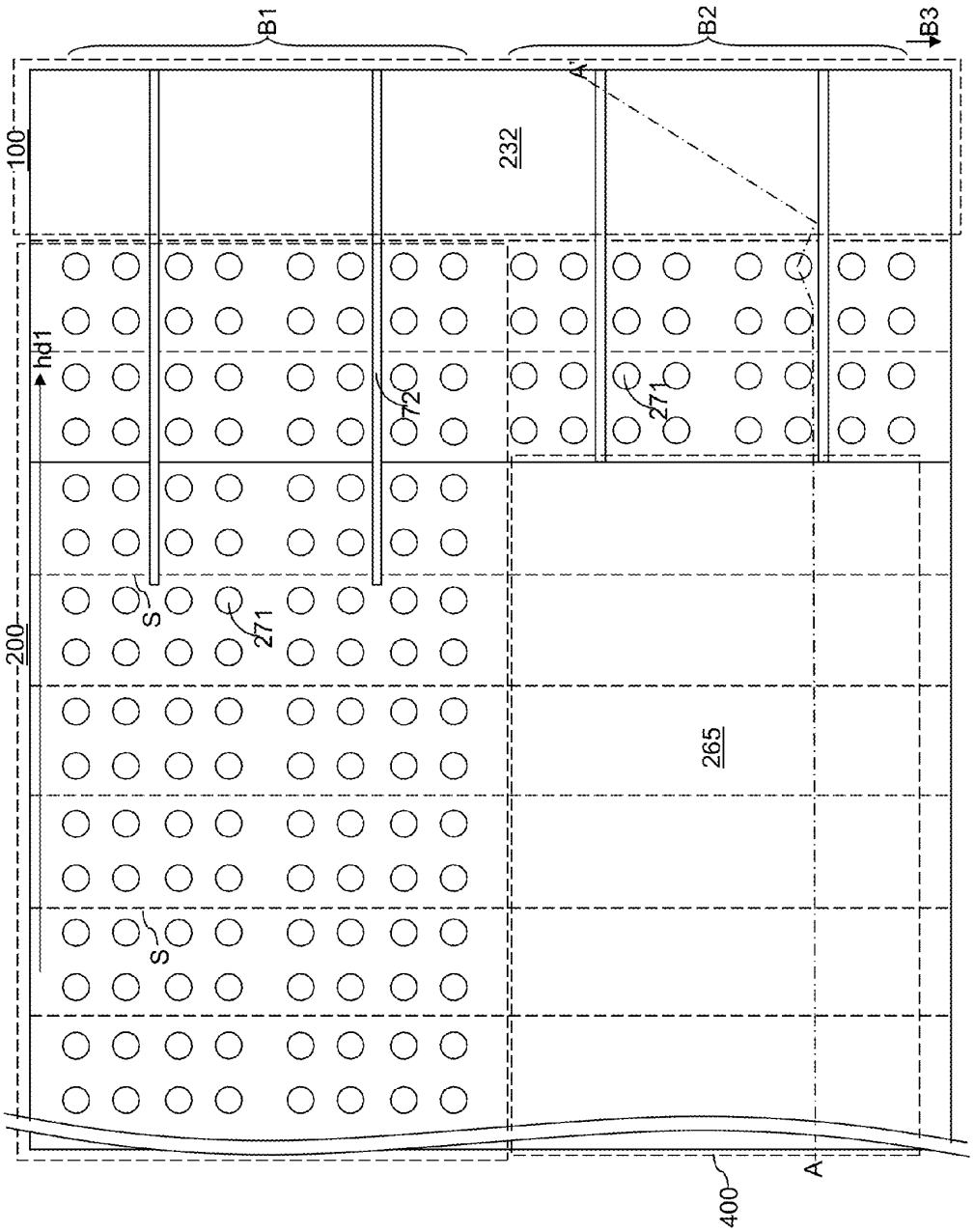

FIG. 8B

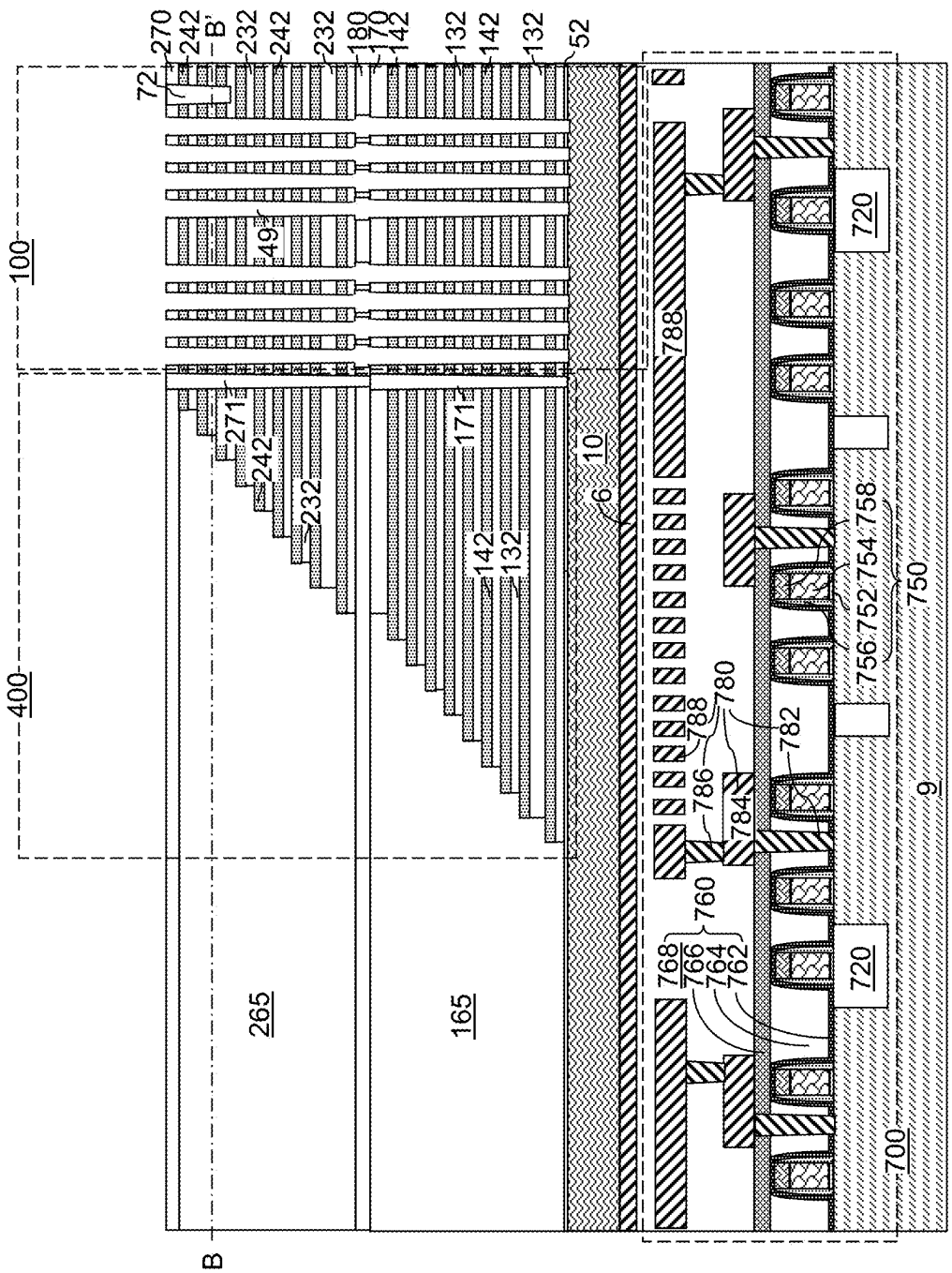
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FIG. 9A

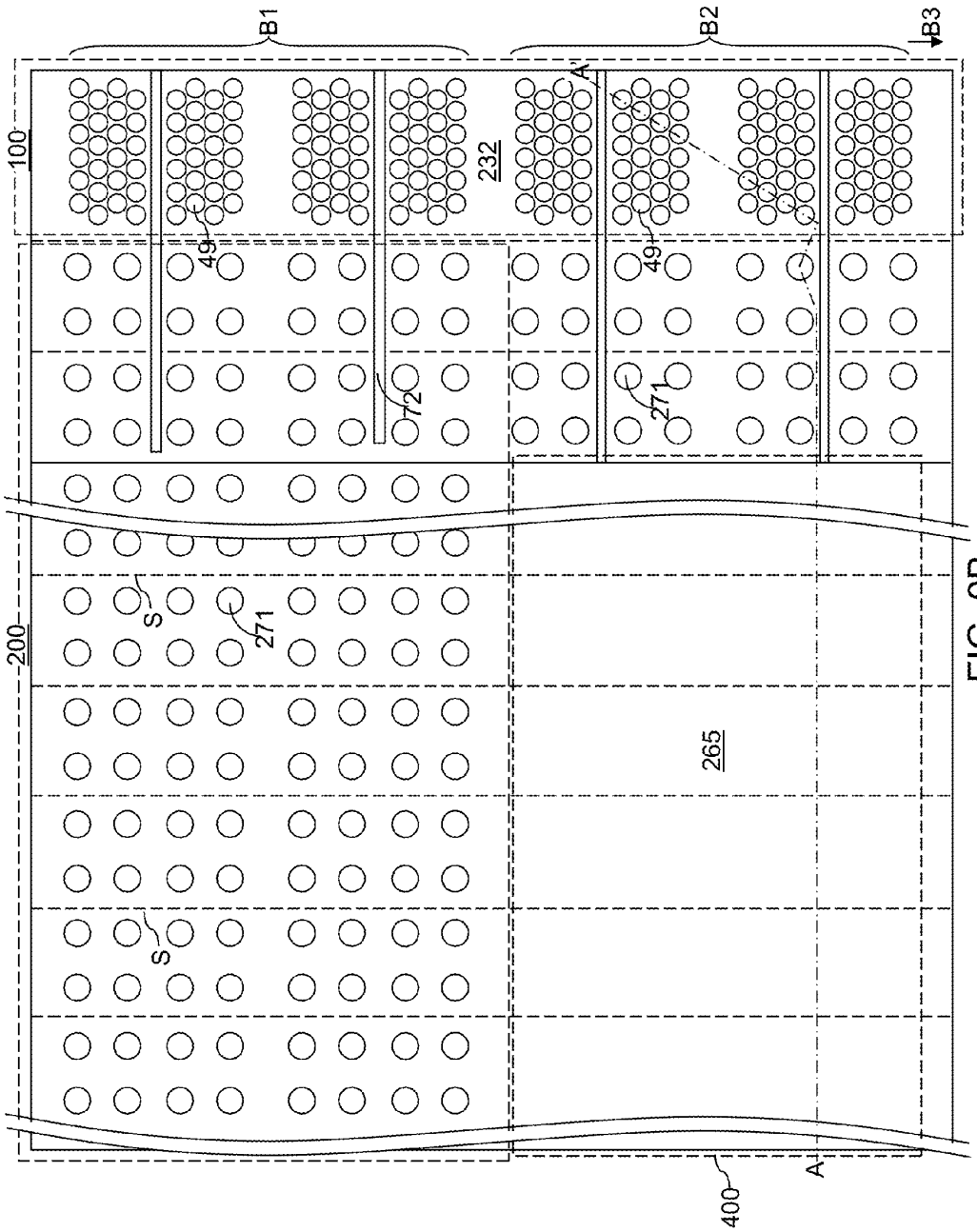

FIG. 9B

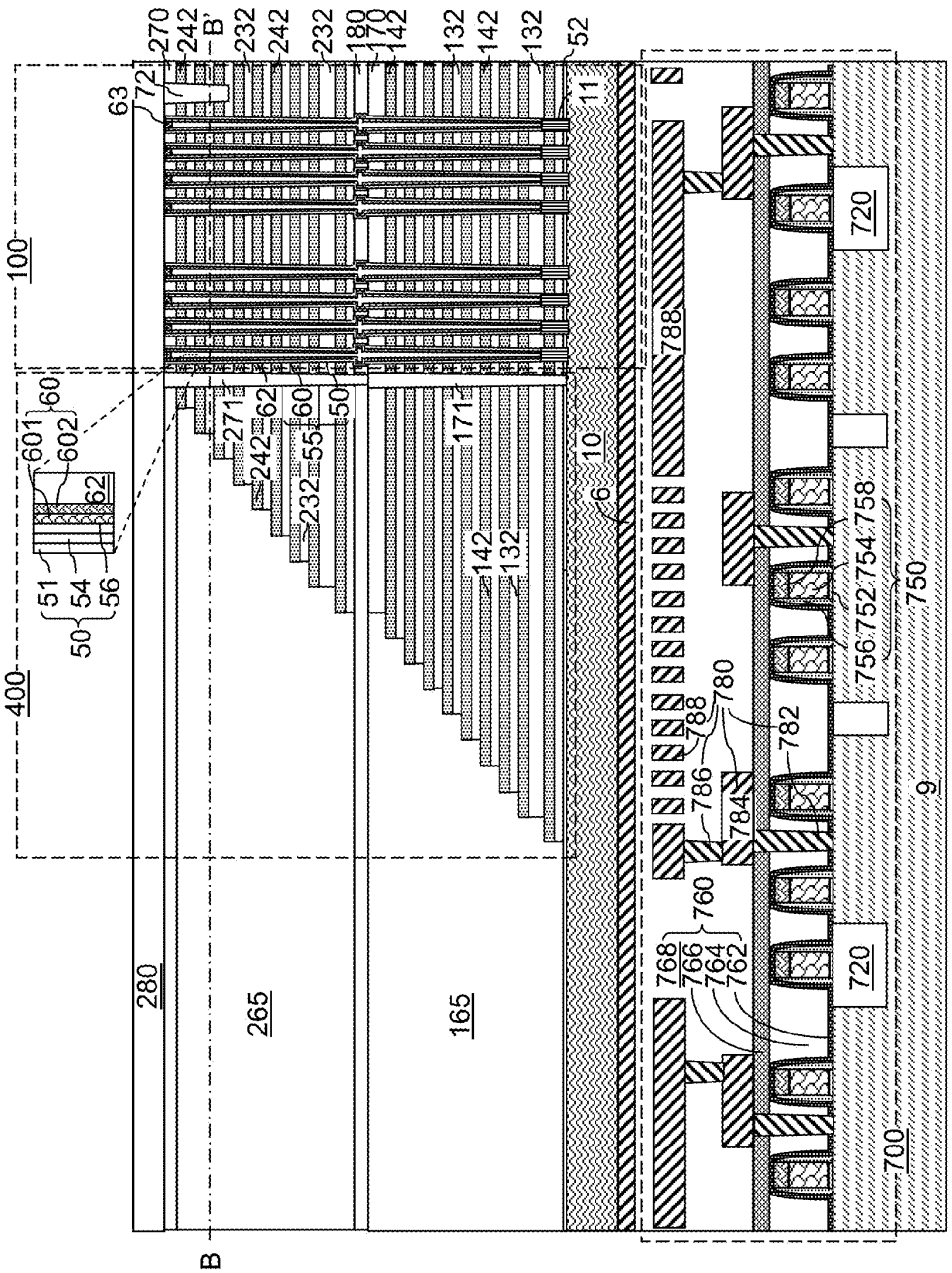
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FIG. 10A

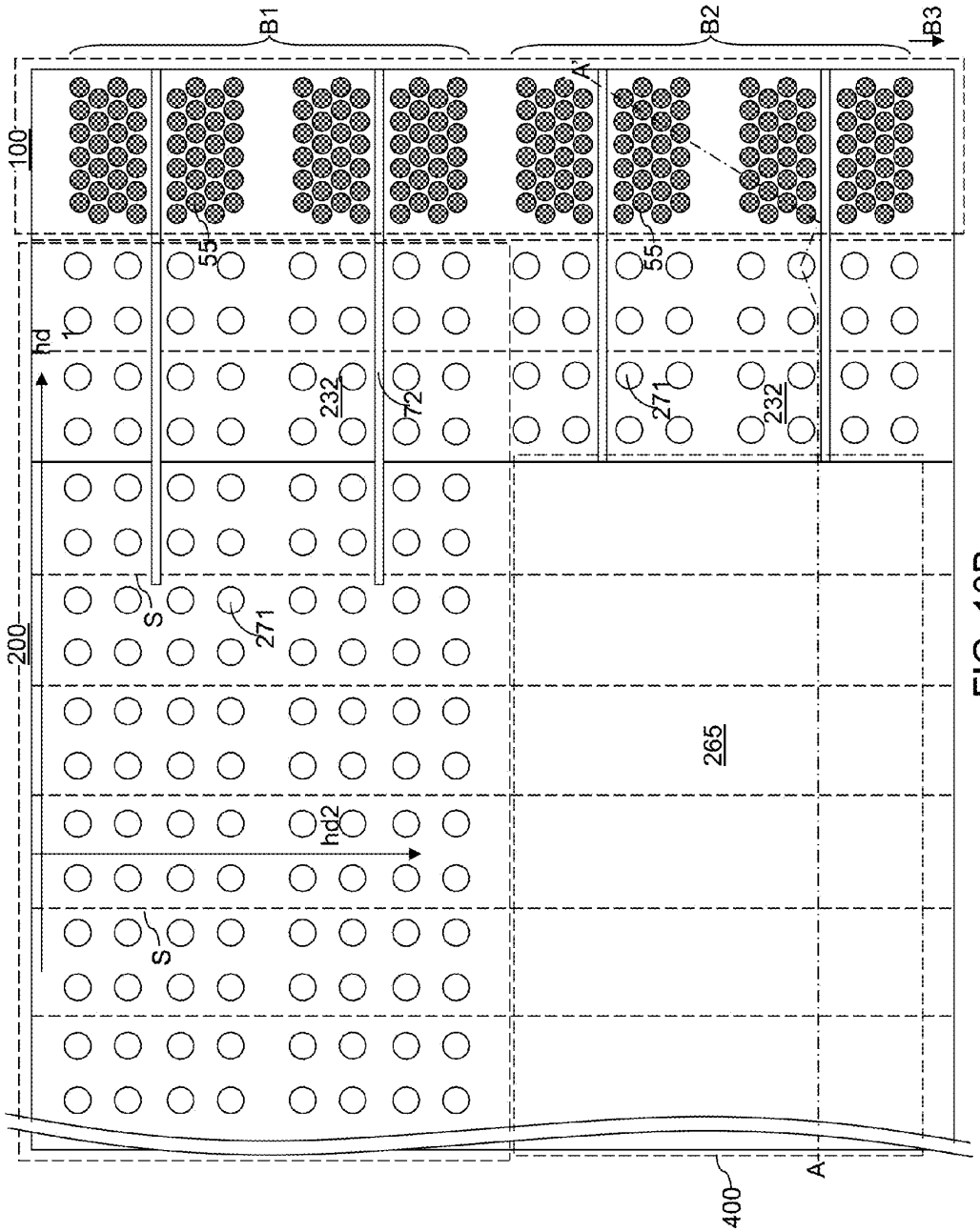

FIG. 10B

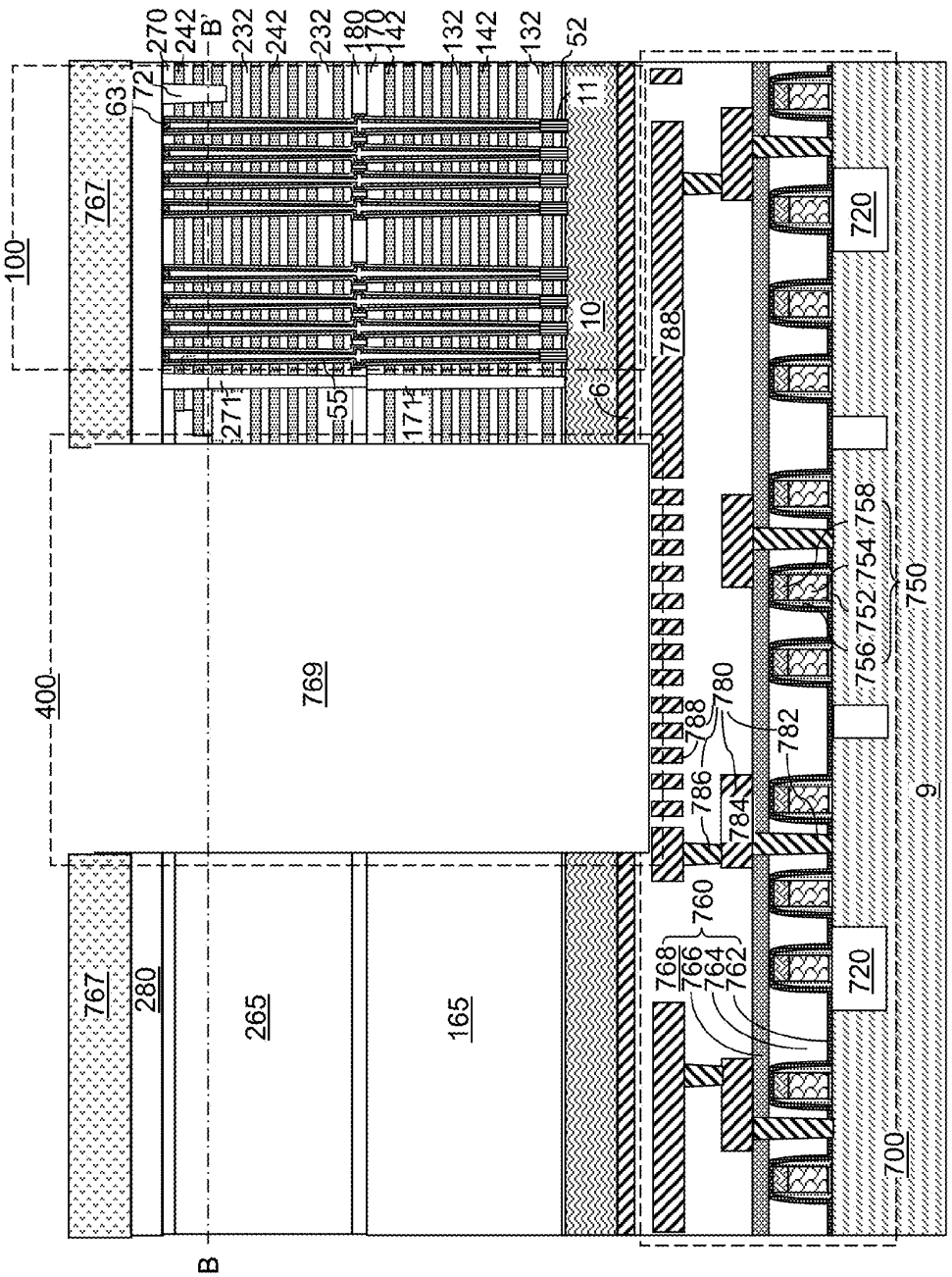
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FIG. 11A

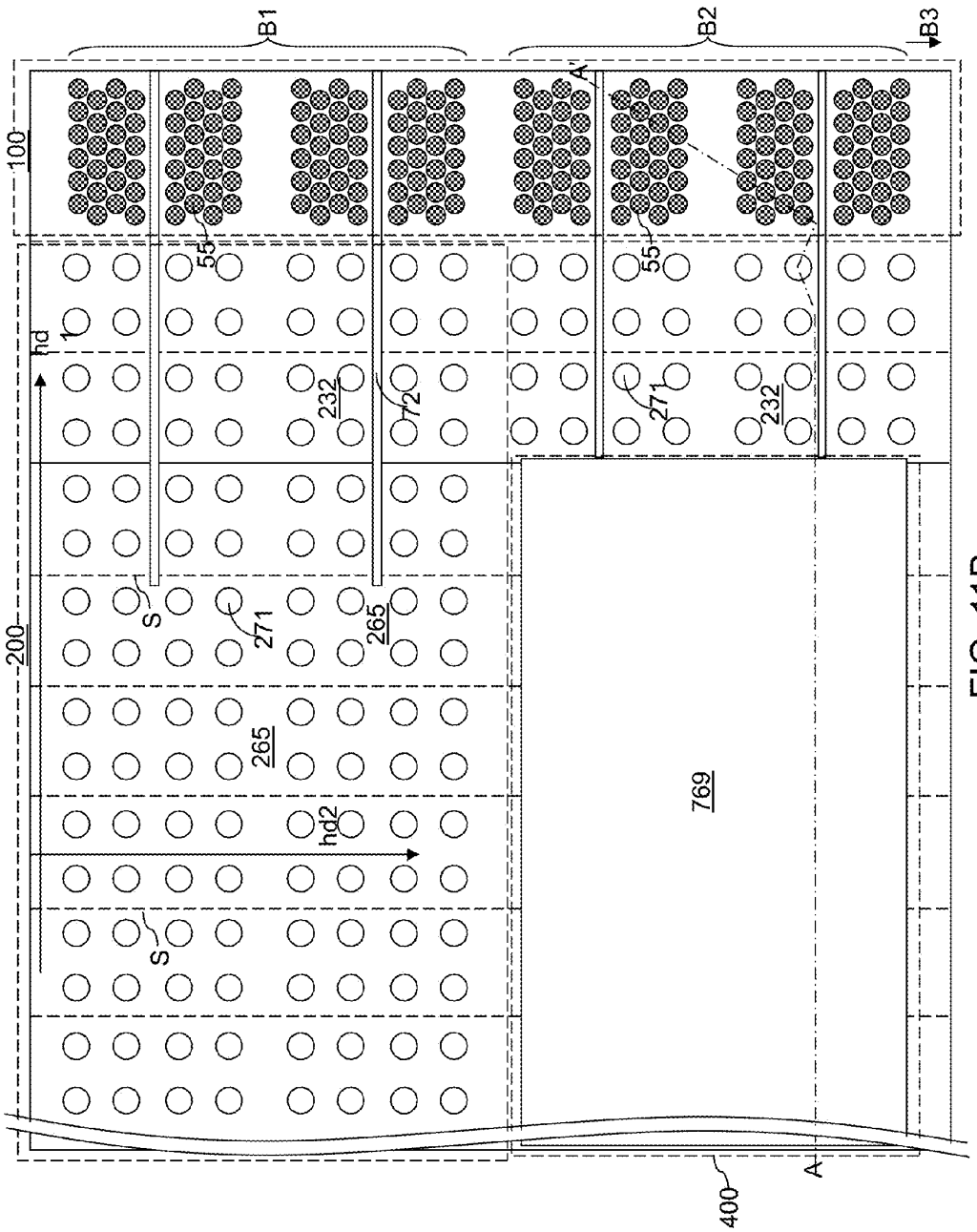
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FIG. 11B

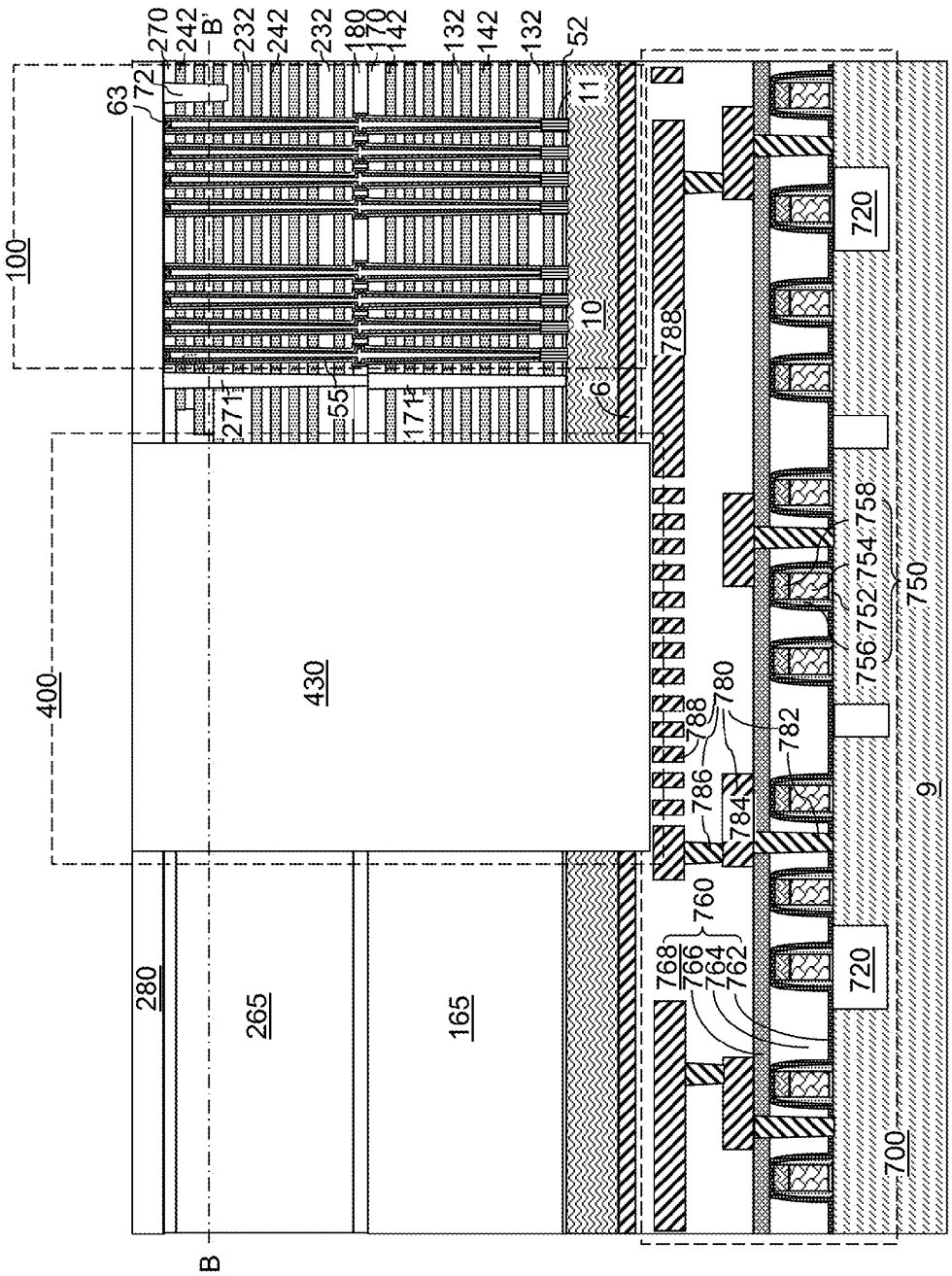
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FIG. 12A

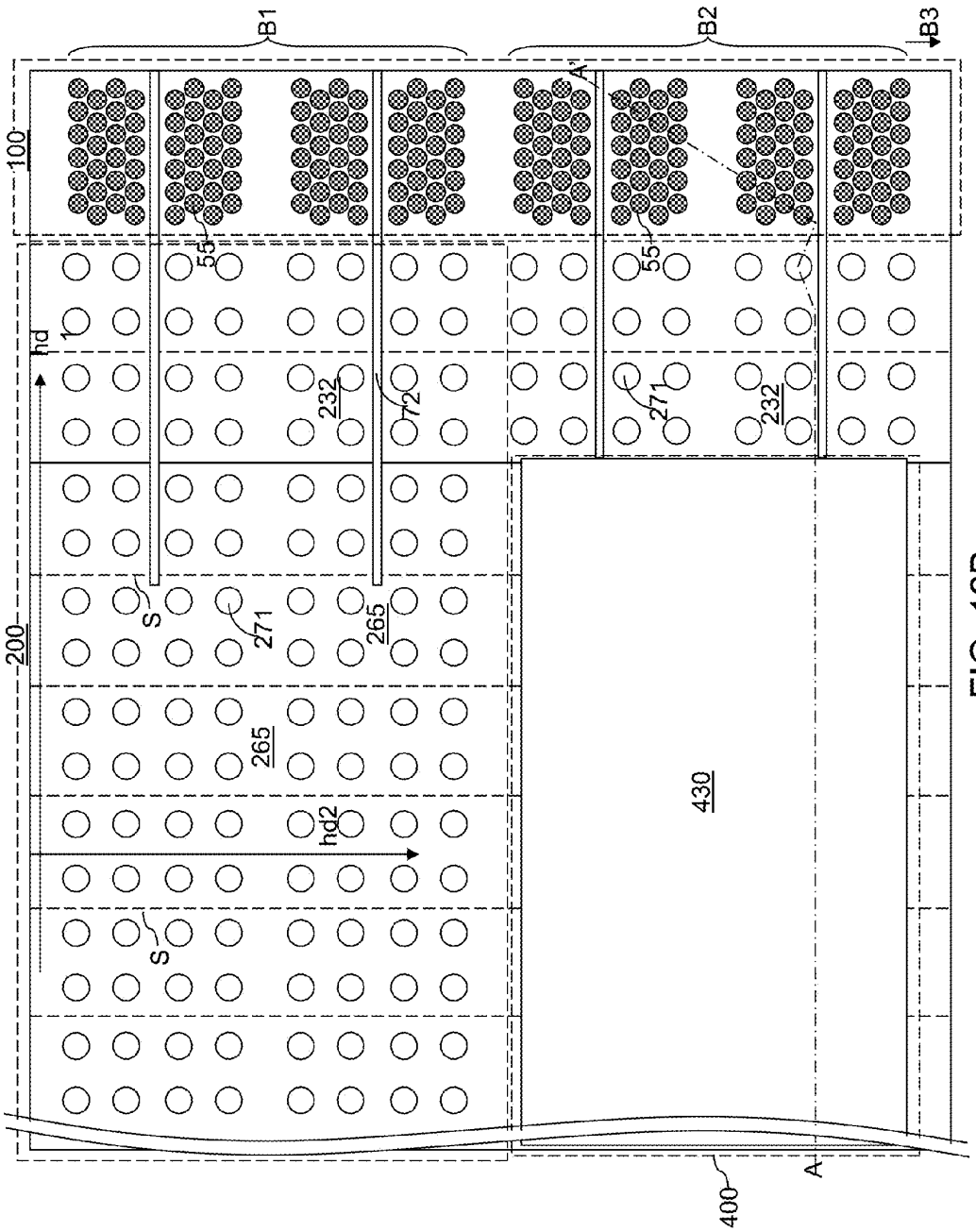
B1
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FIG. 12B

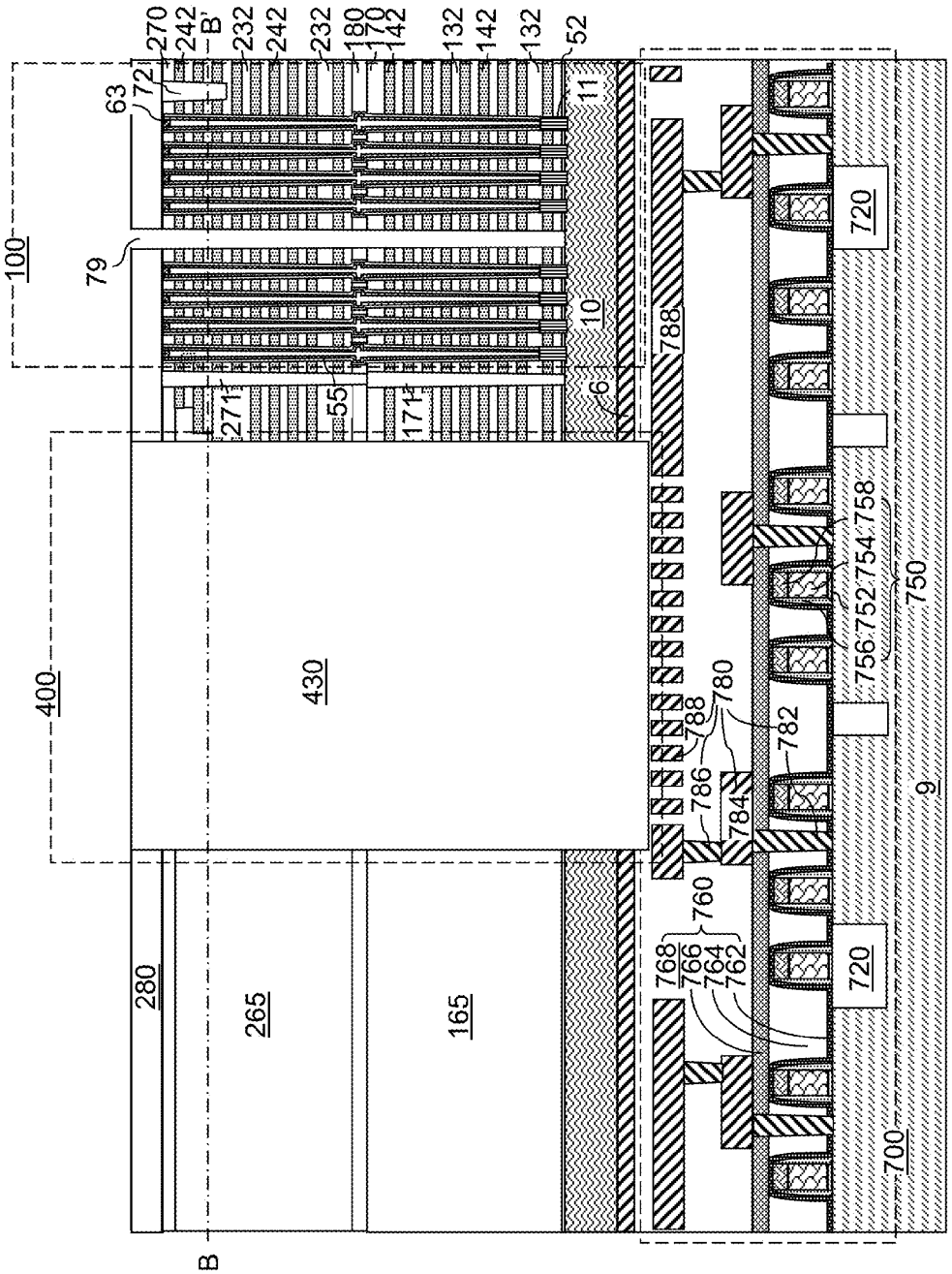
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FIG. 13A

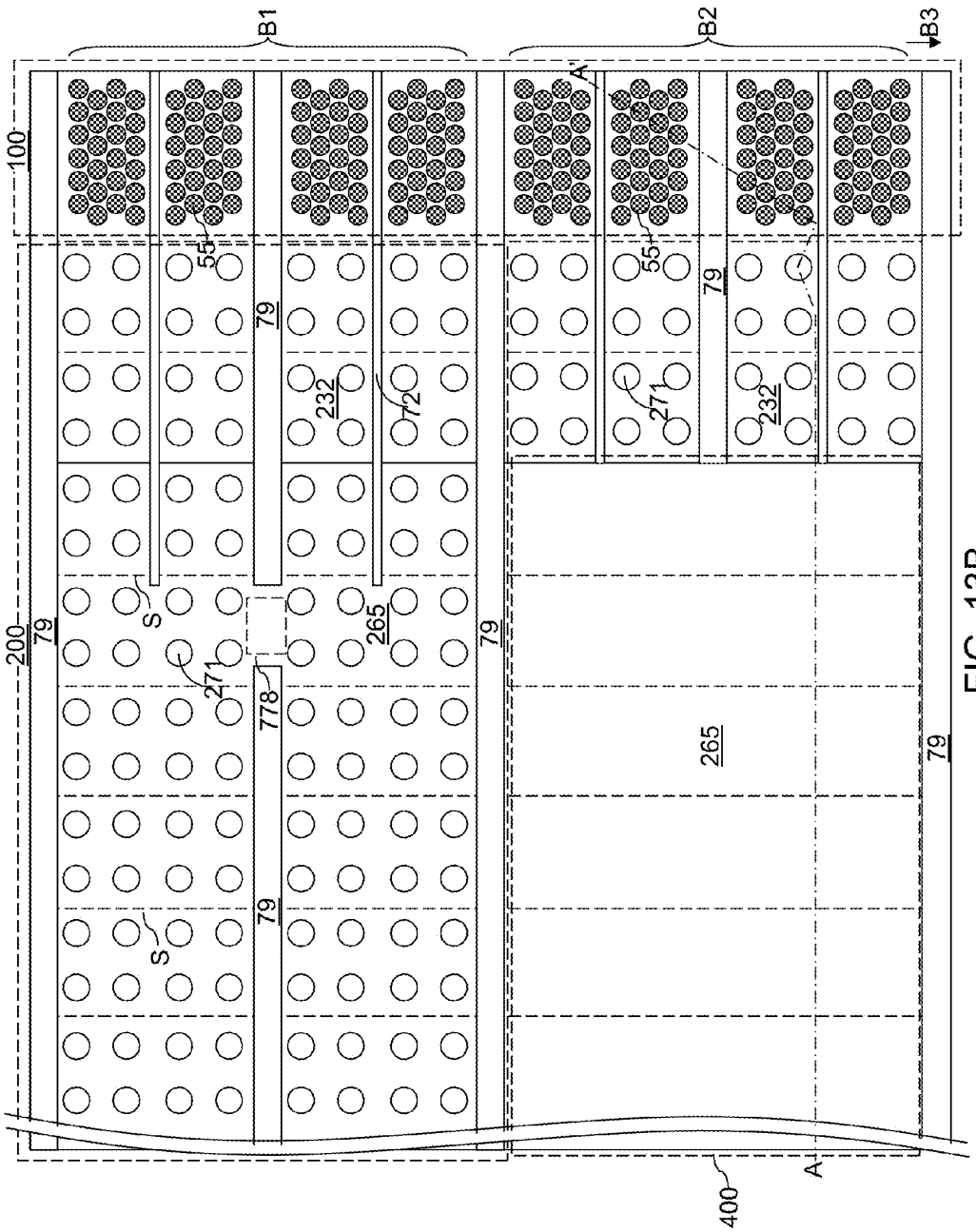

FIG. 13B

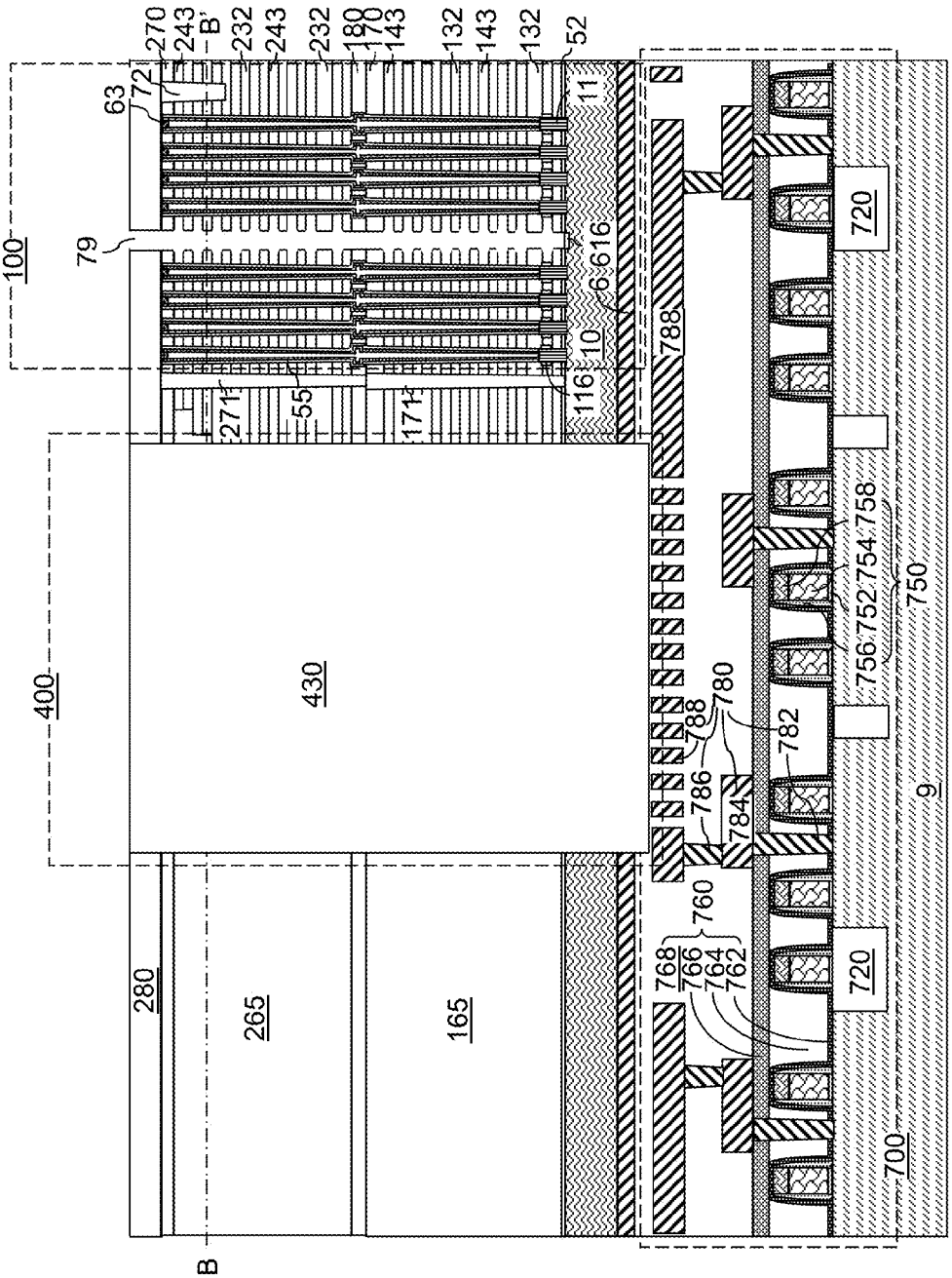
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FIG. 14A

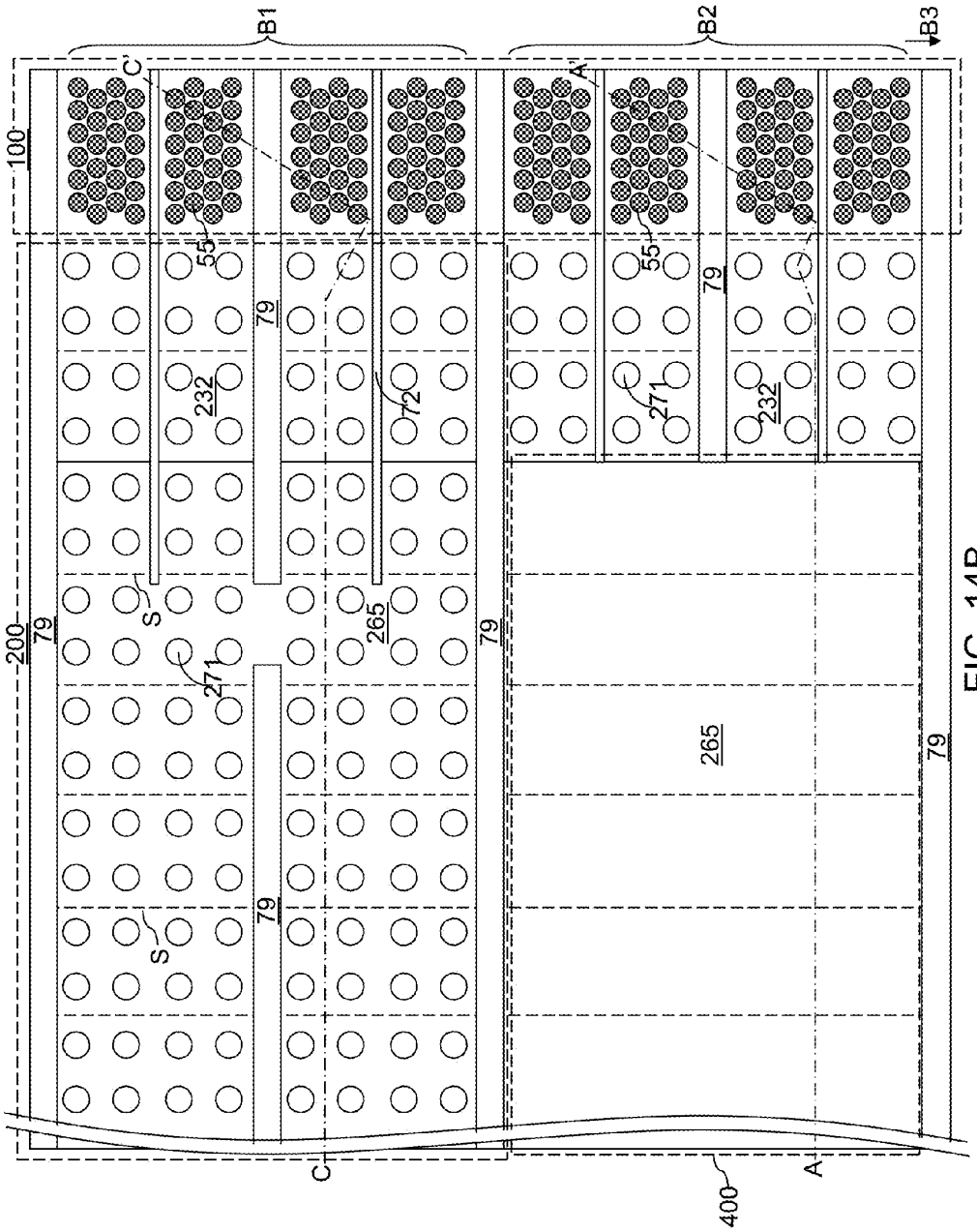

FIG. 14B

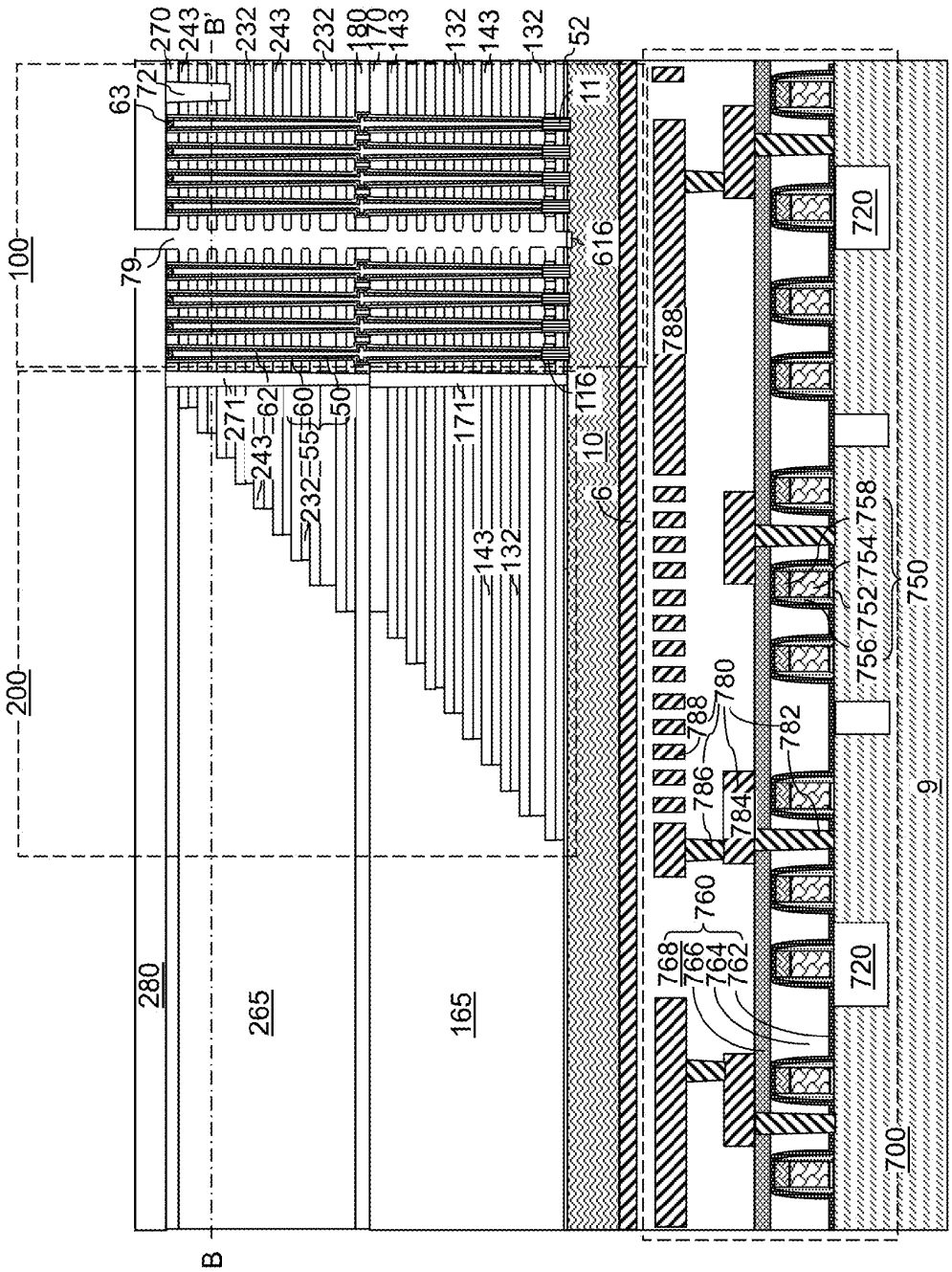
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FIG. 14C

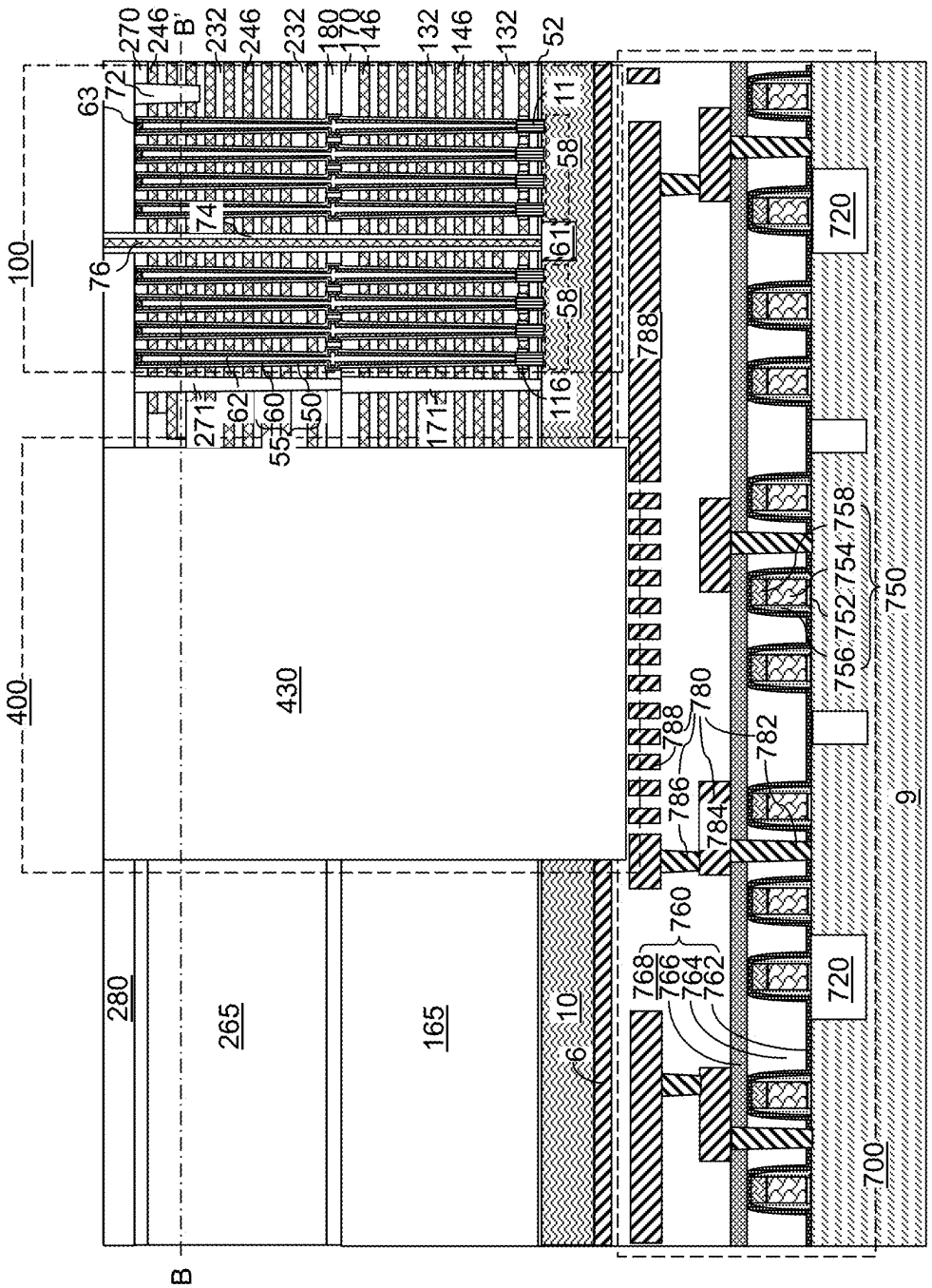
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FIG. 15A

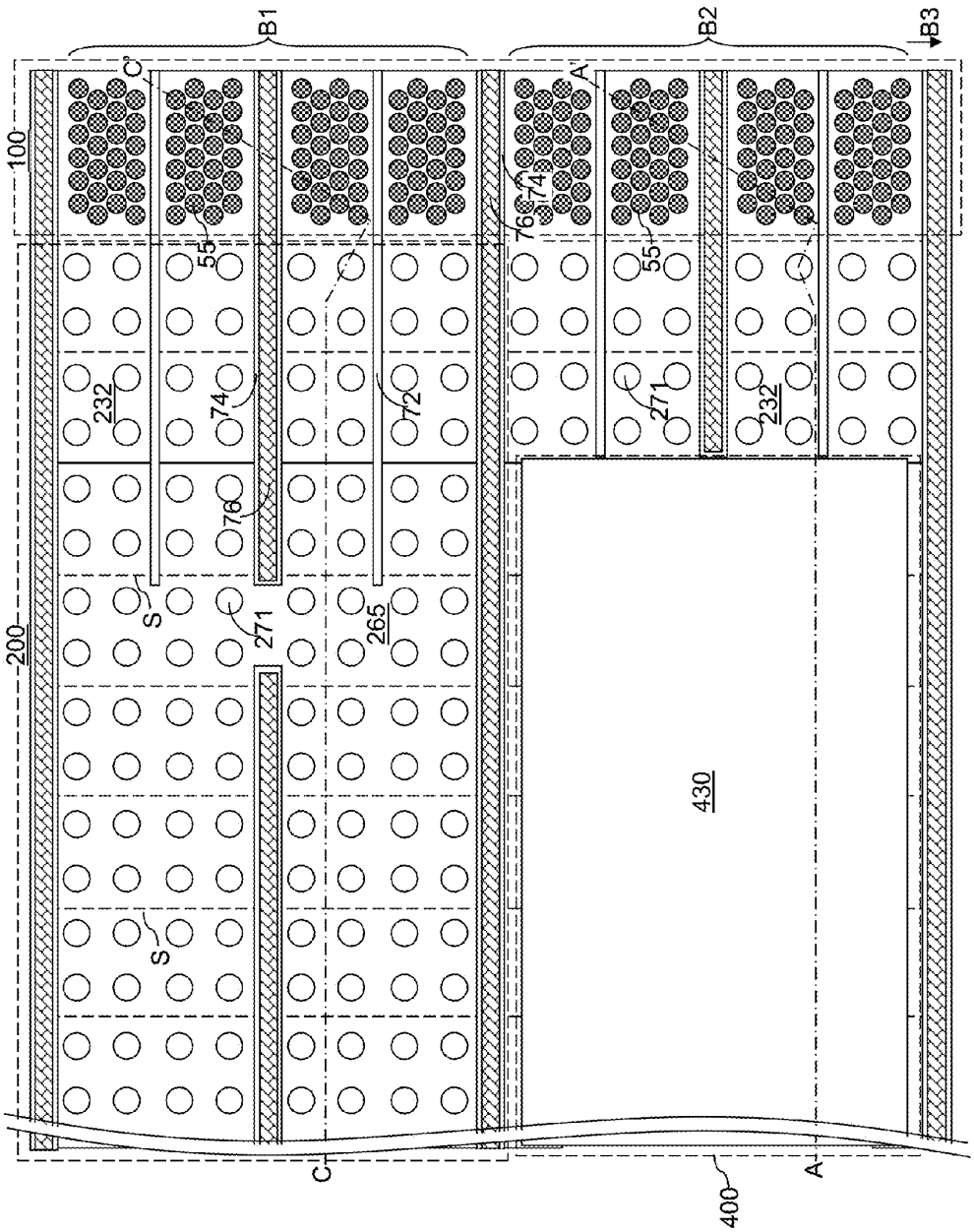

FIG. 15B

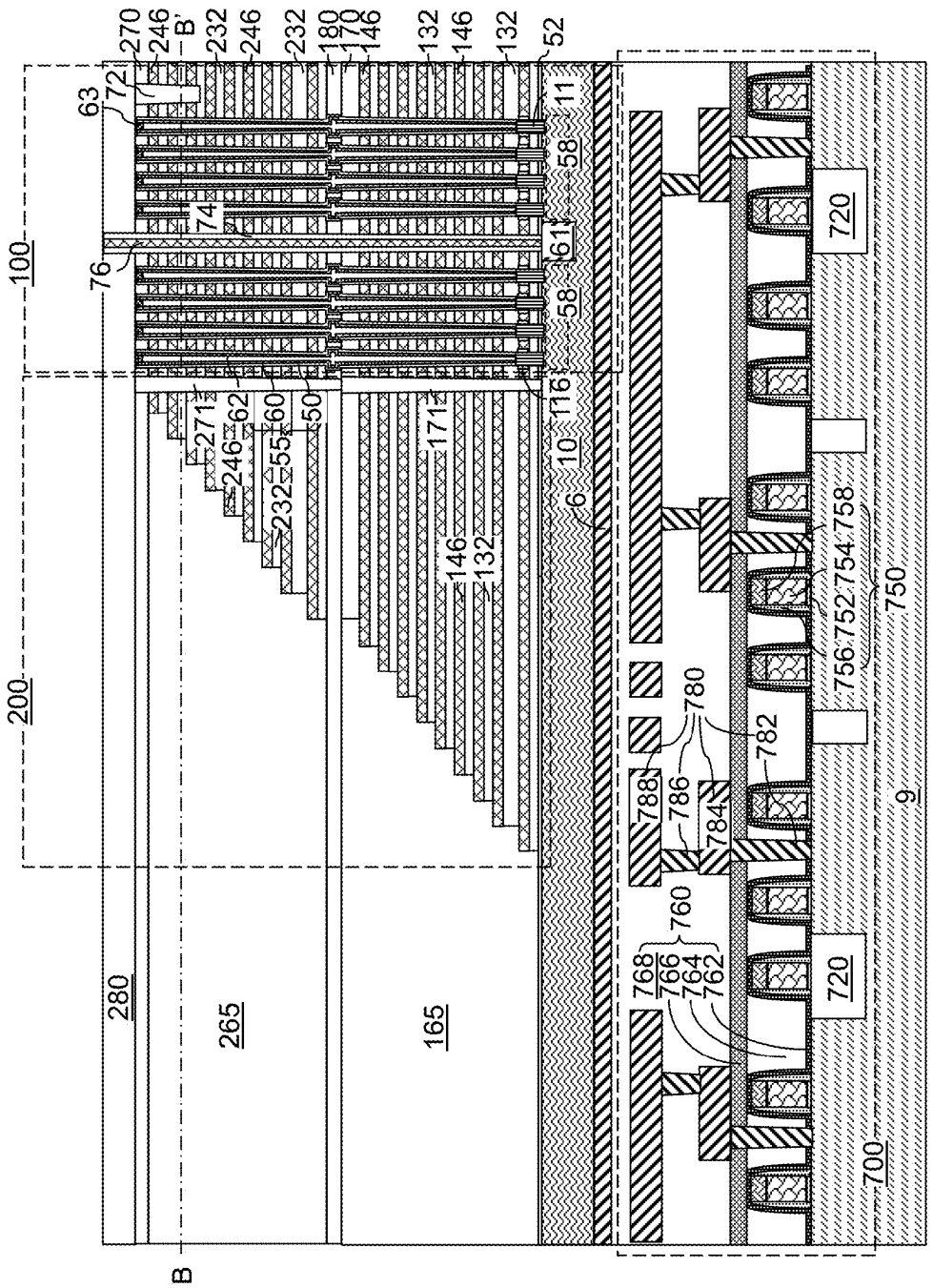
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FIG. 15C

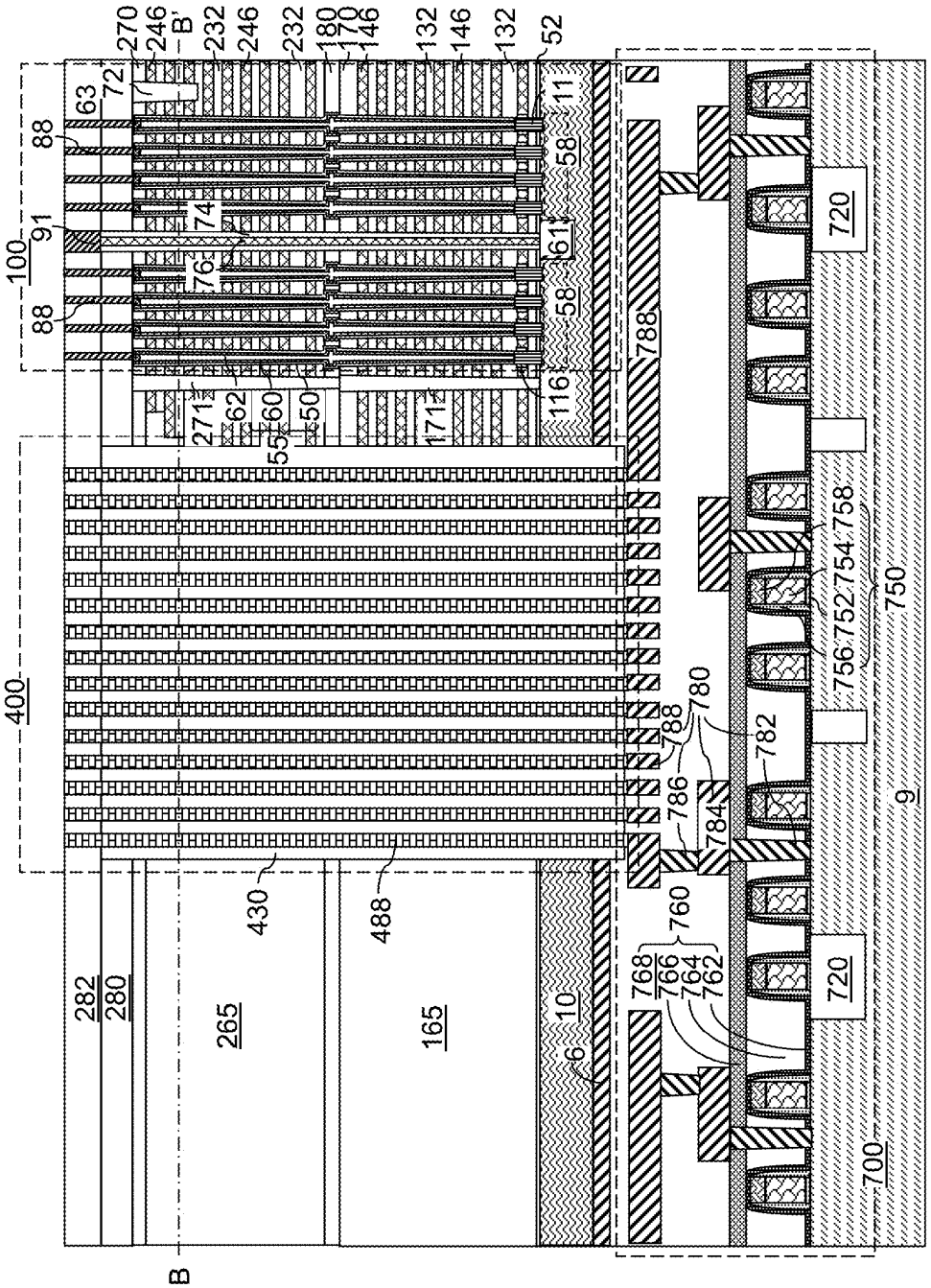
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FIG. 16A

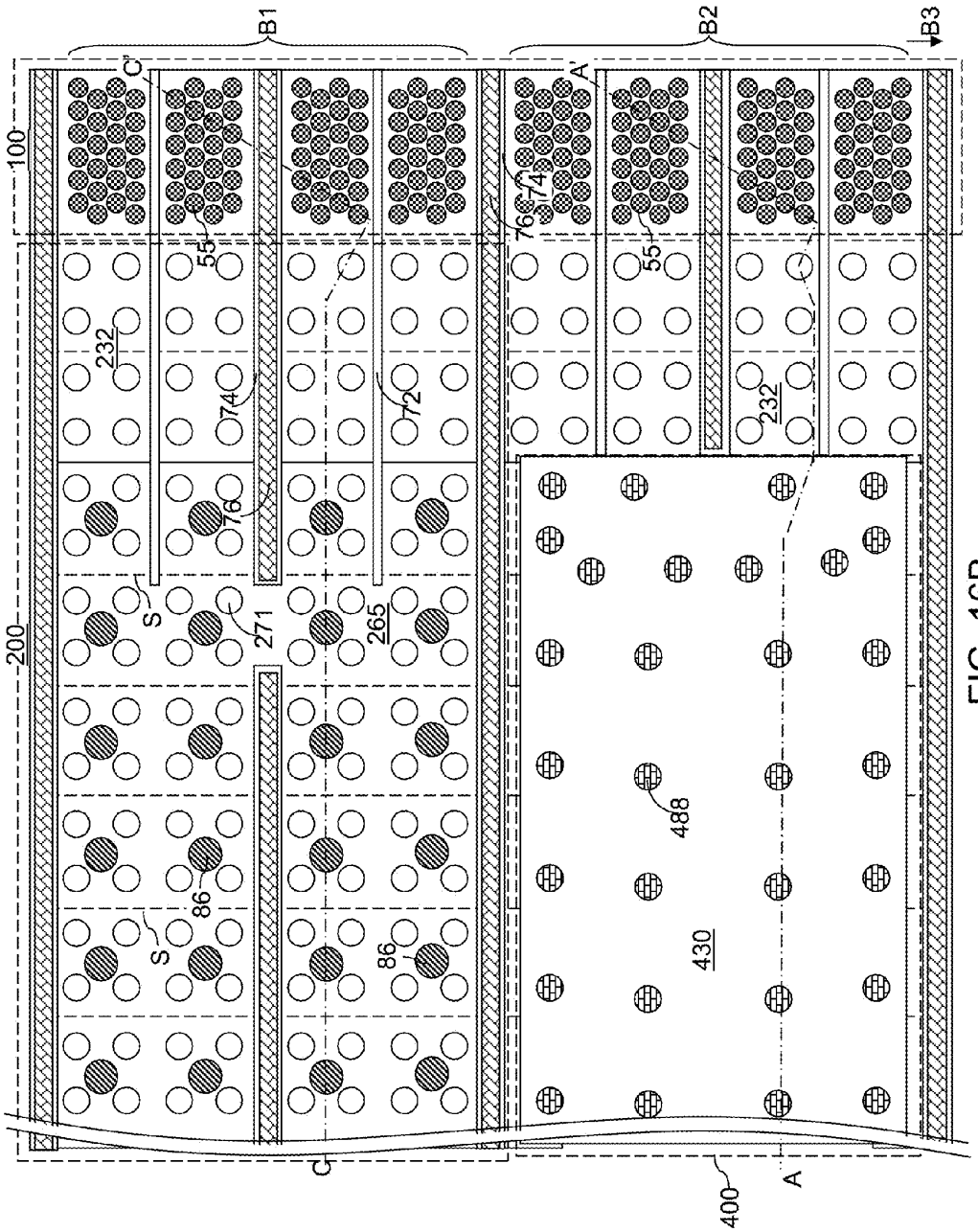
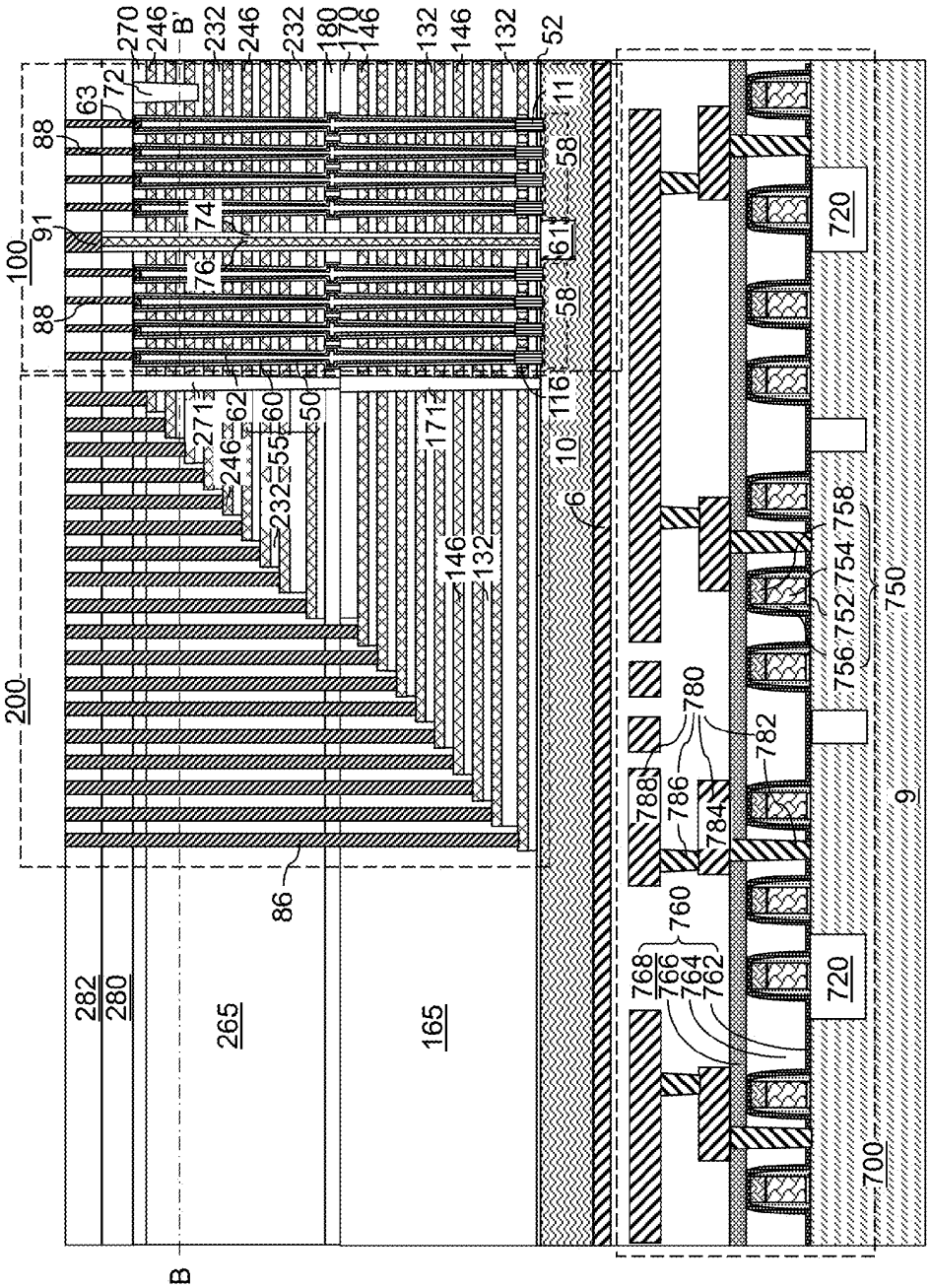


FIG. 16B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100
88
74
76
11
58
61
58
116
10
6
271
62
60
50
246
55
232
171
146
132
200
86
282
280
265
165
B
720
720
758
754
752
756
750
780
782
788
786
784
760
768
766
764
762
9
700

FIG. 16C

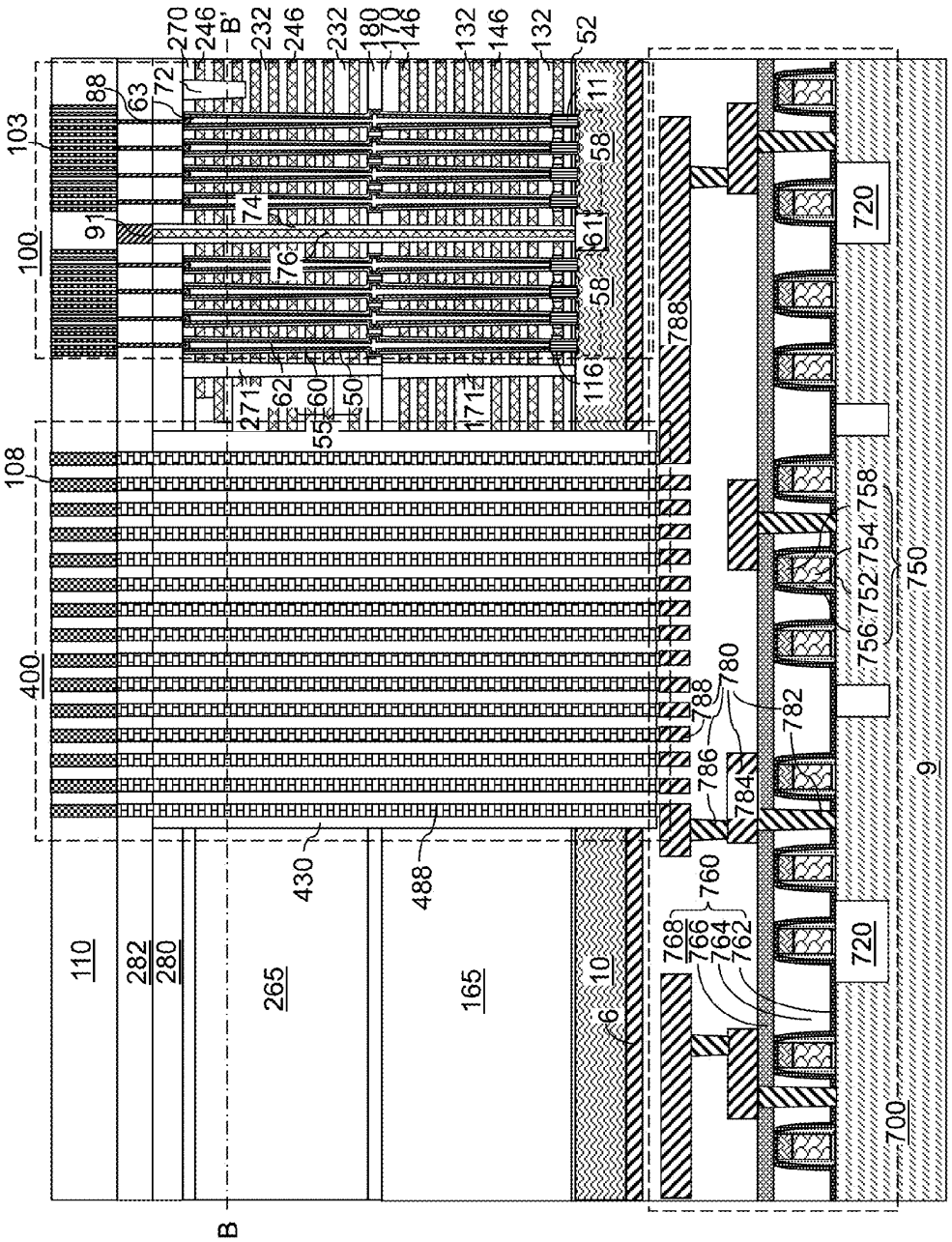

103
100
108
400
110
282
280
265
165
430
488
B
B'
270
246
232
180
170
146
132
52
11
58
61
88
63
72
91
74
76
271
62
60
50
55
171
116
788
720
756
752
754
758
750
9
780
782
786
784
760
768
766
764
762
10
6
700

FIG. 17A

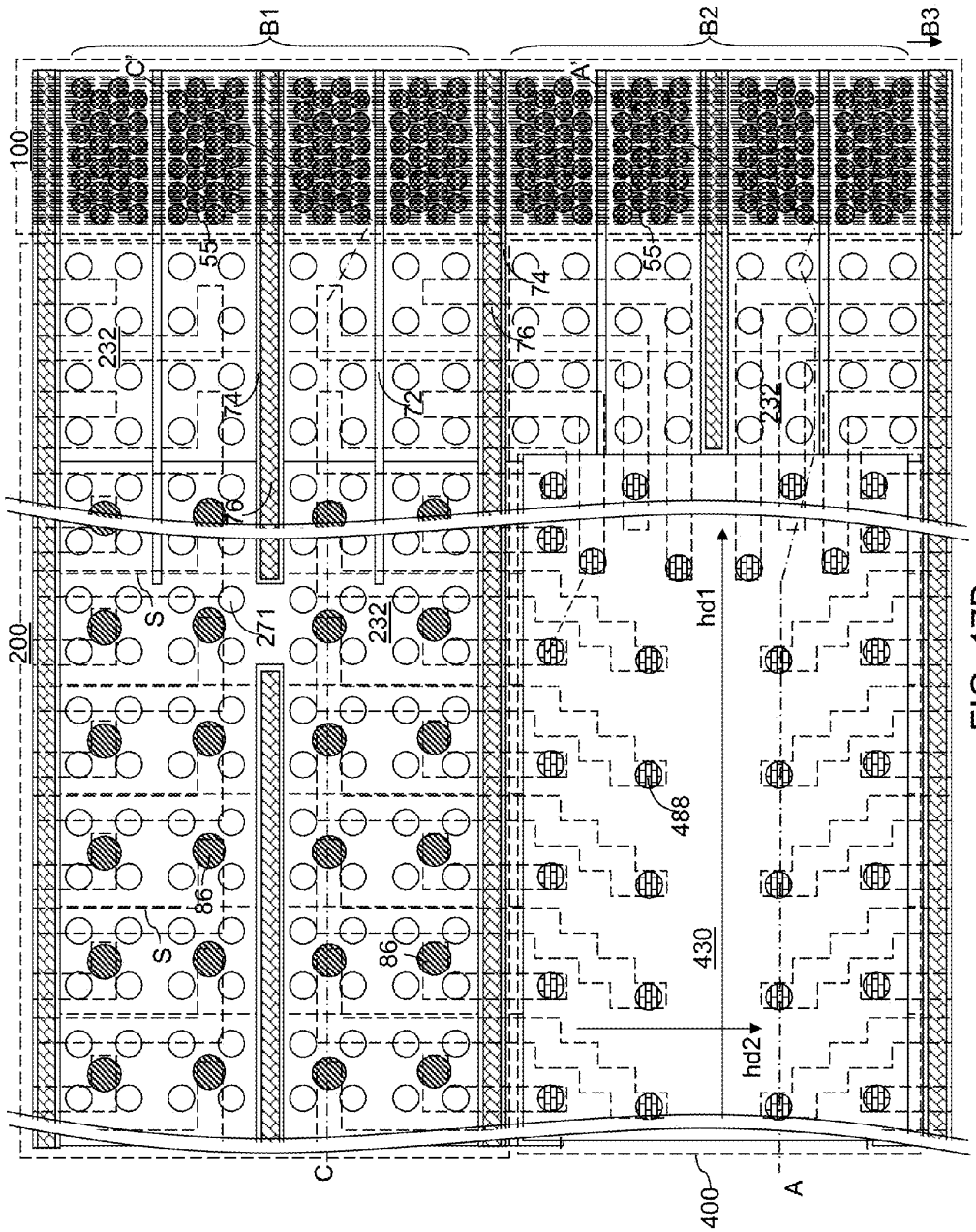


FIG. 17B

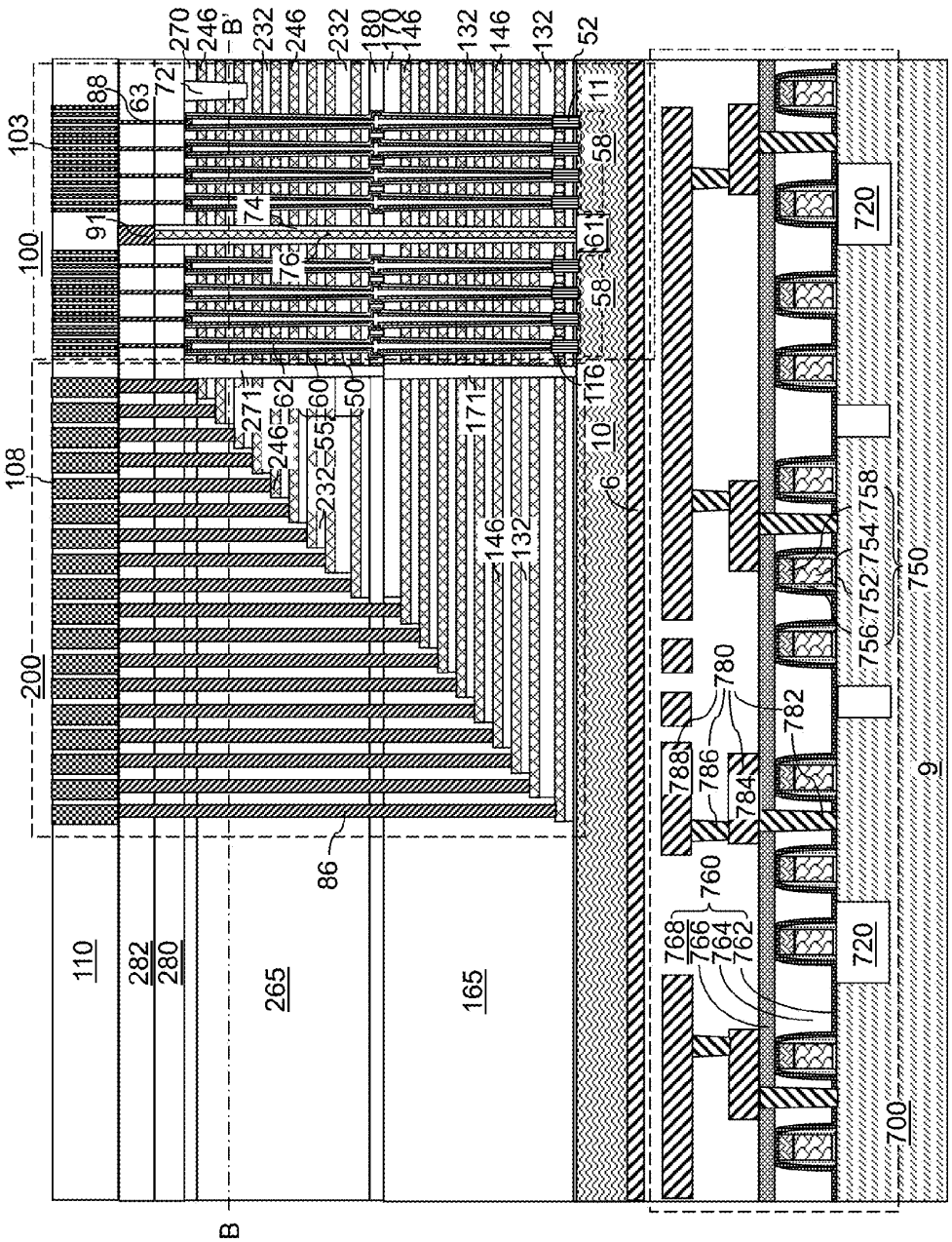

270
246
B'
232
246
232
180
170
146
132
146
132
52
88
63
72
11
103
58
74
91
100
76
61
58
116
271
62
60
50
171
10
108
246
55
232
6
146
132
200
86
110
282
280
265
165
B
720
758
754
752
756
750
780
782
788
786
784
760
768
766
764
762
720
9
700

FIG. 17C

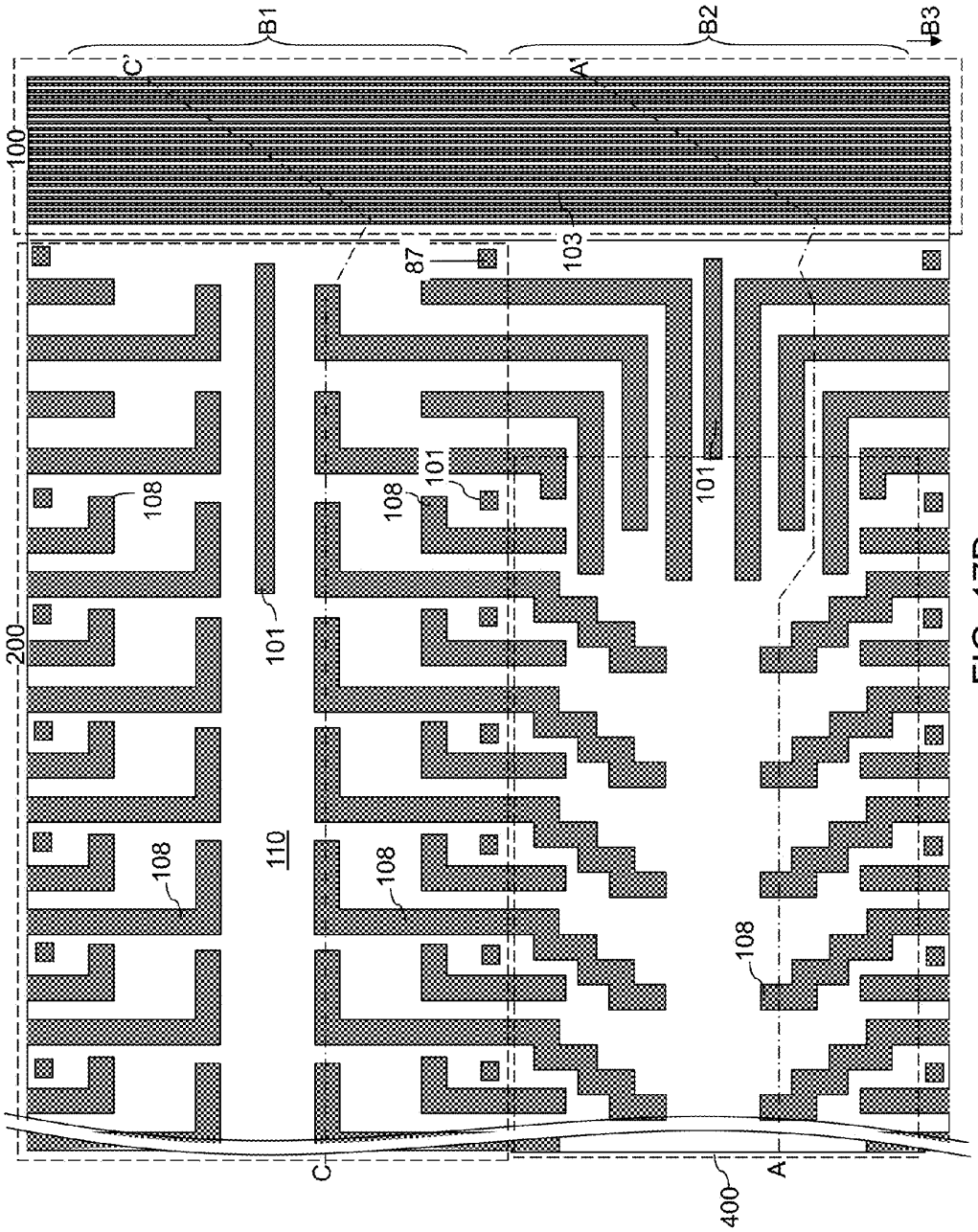


FIG. 17D

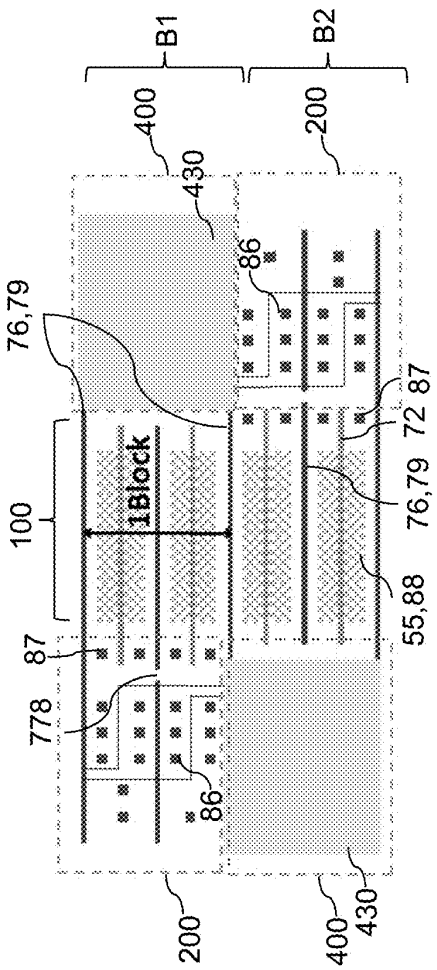

B1
B2
400
200
430
86
76,79
87
72
76,79
55,88
100
1Block
87
778
86
200
400
430

FIG. 17E

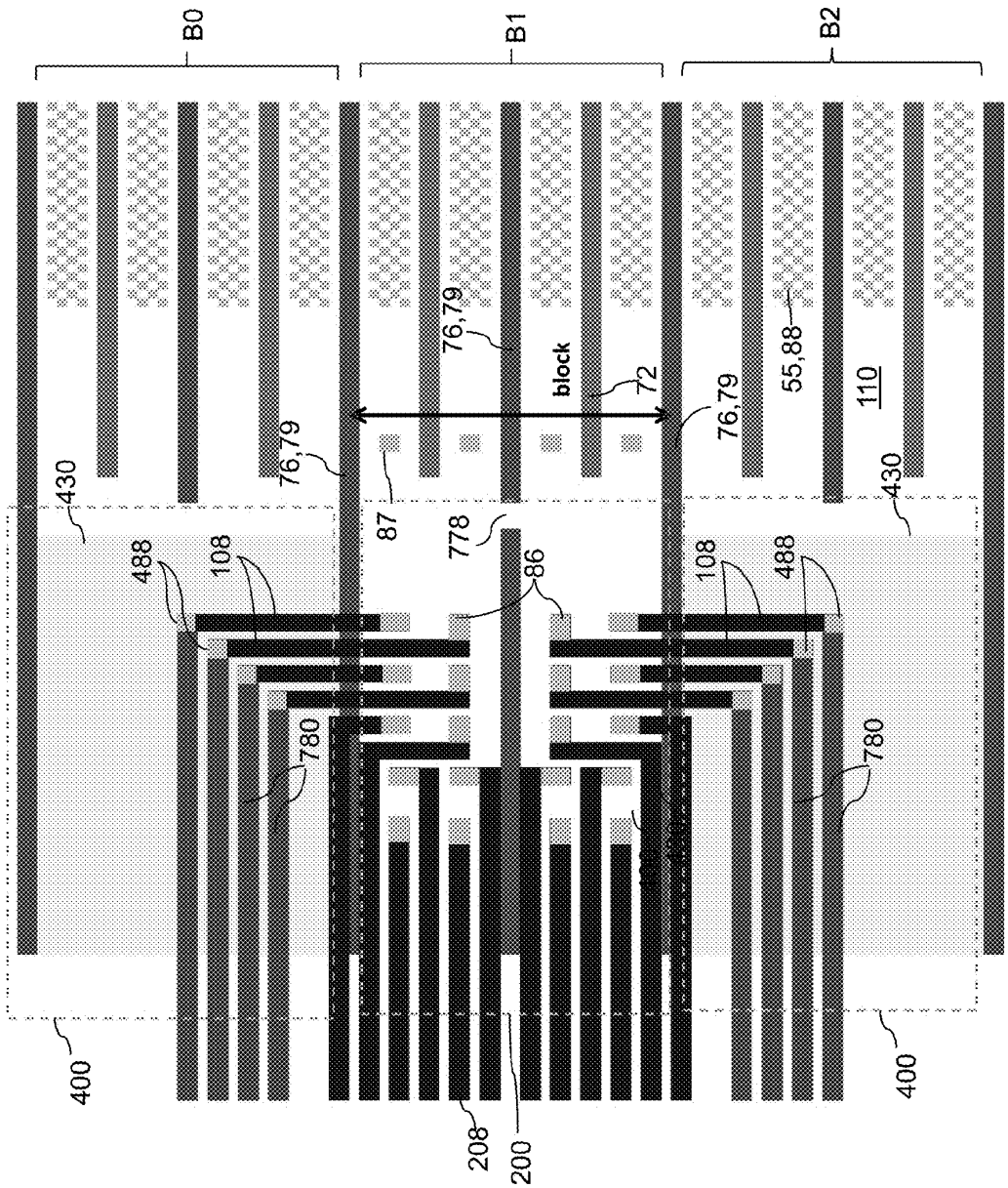

B0
B1
B2
block
76,79
72
55,88
110
430
87
778
86
488
108
780
400
208
200

FIG. 17F

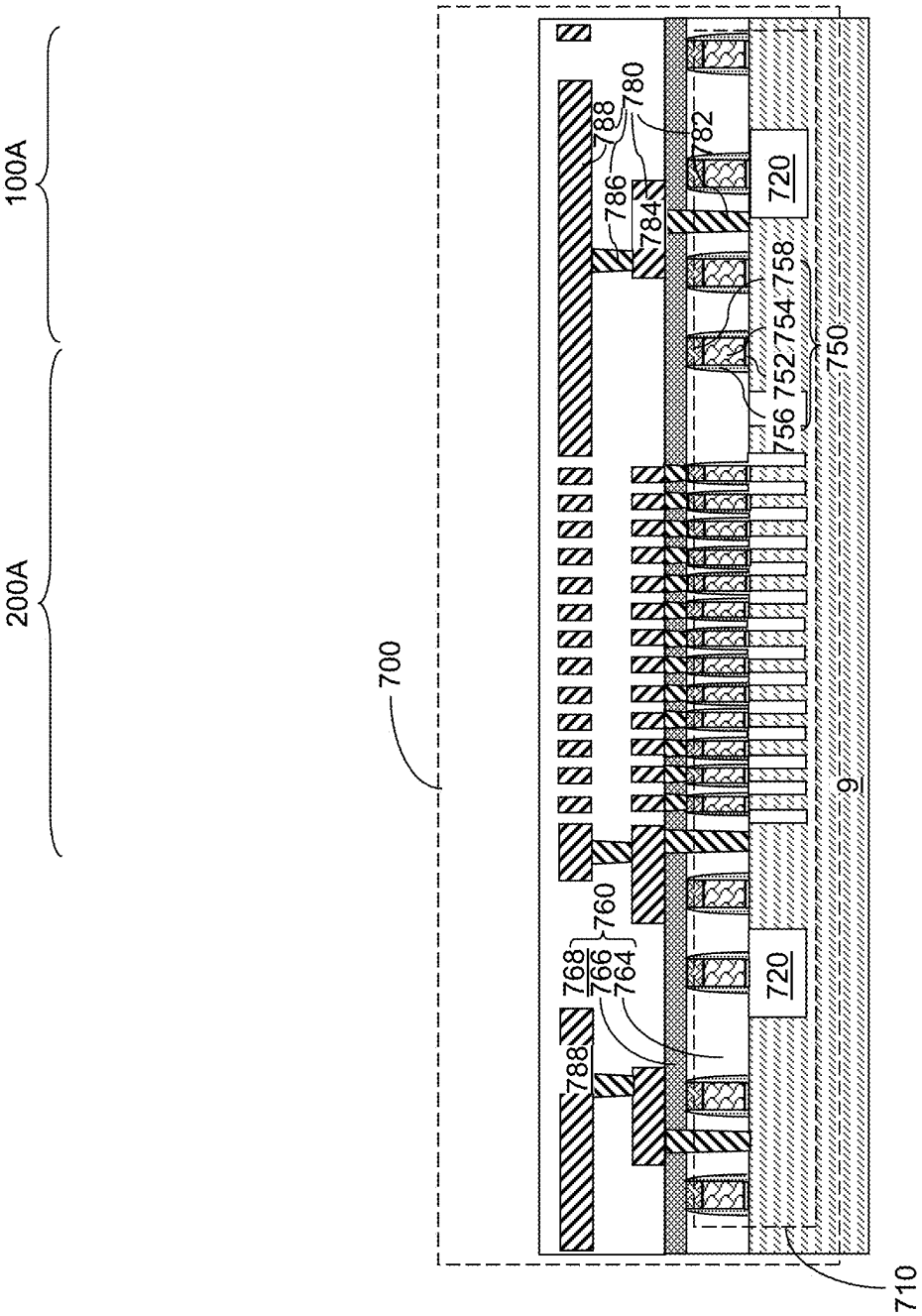

100A
200A
700
788
780
782
786
784
720
758
754
752
756
750
9
760
768
766
764
720
788
710

FIG. 18

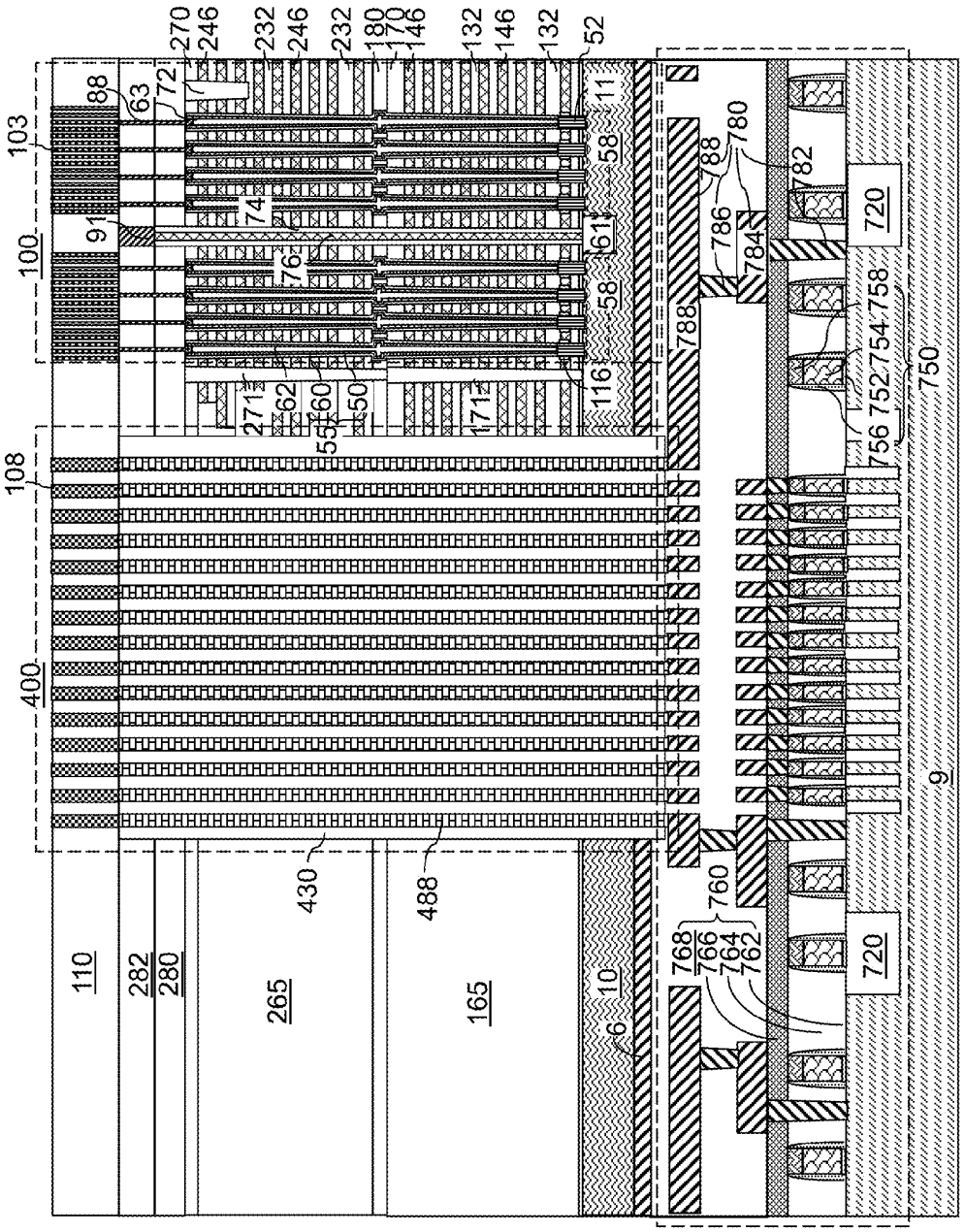

270
246
232
246
232
180
170
146
132
146
132
52
88
63
72
11
103
58
74
91
100
61
76
58
116
271
62
60
50
55
171
108
400
430
488
110
282
280
265
165
10
6
788
780
782
786
784
720
758
754
752
756
750
9
760
768
766
764
762
720

FIG. 19A

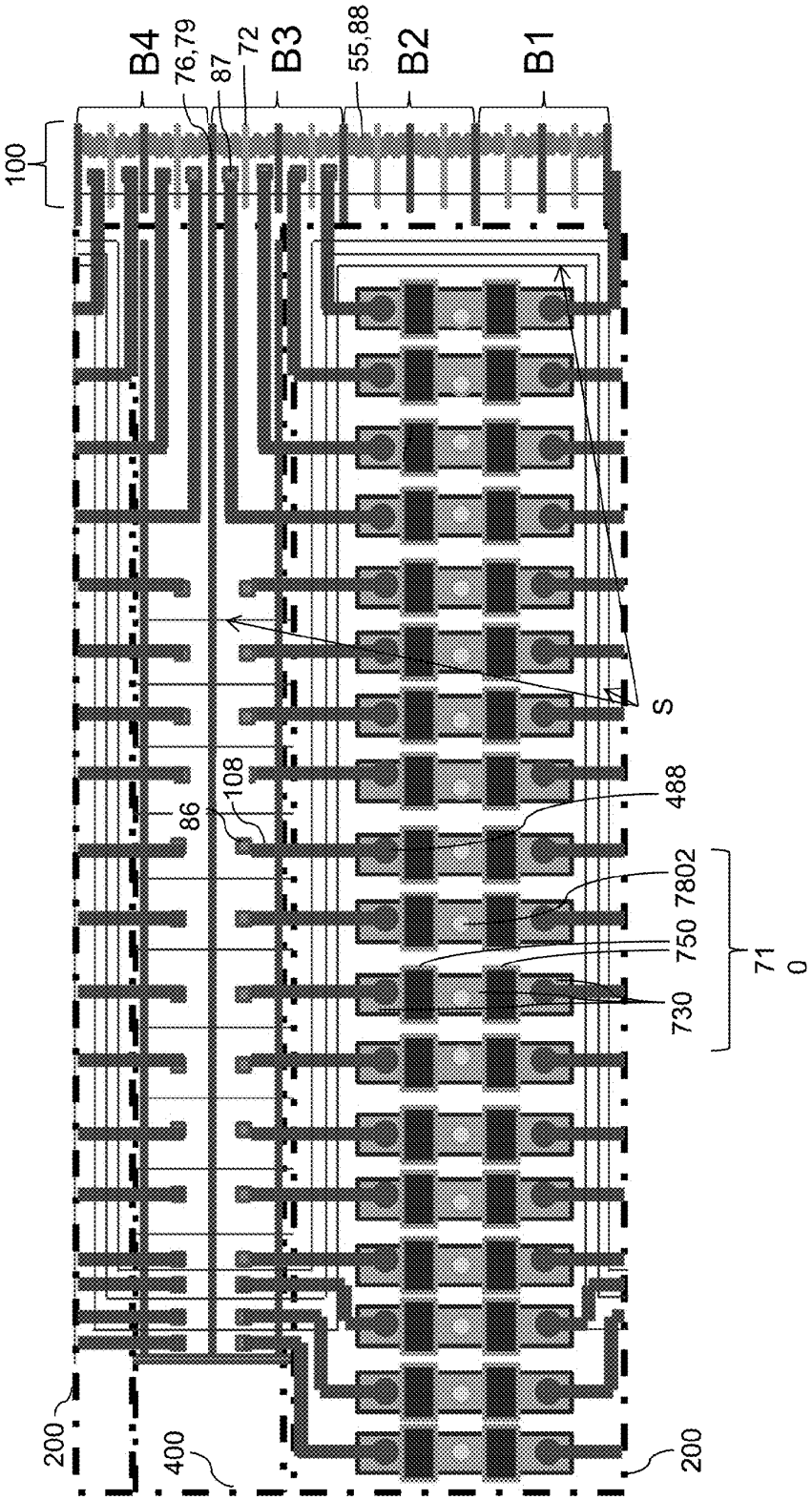

B4
76,79
87
72
B3
55,88
B2
B1
100
S
108
86
488
7802
750
730
710
200
400
200

FIG. 19B

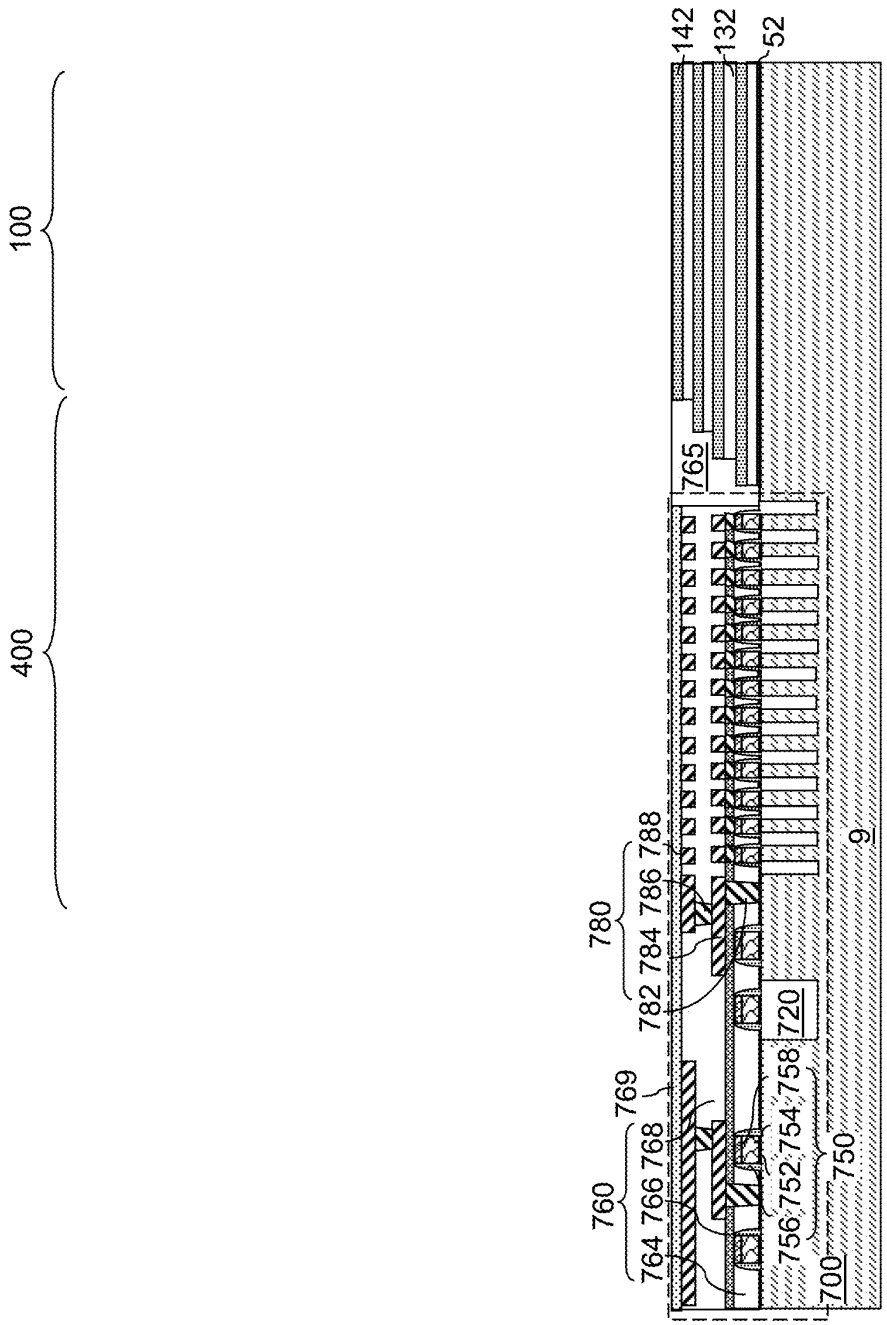

100
400
142
132
52
765
780
782 784 786 788
720
769
760
764 766 768
756 752 754 758
750
700
9

FIG. 20

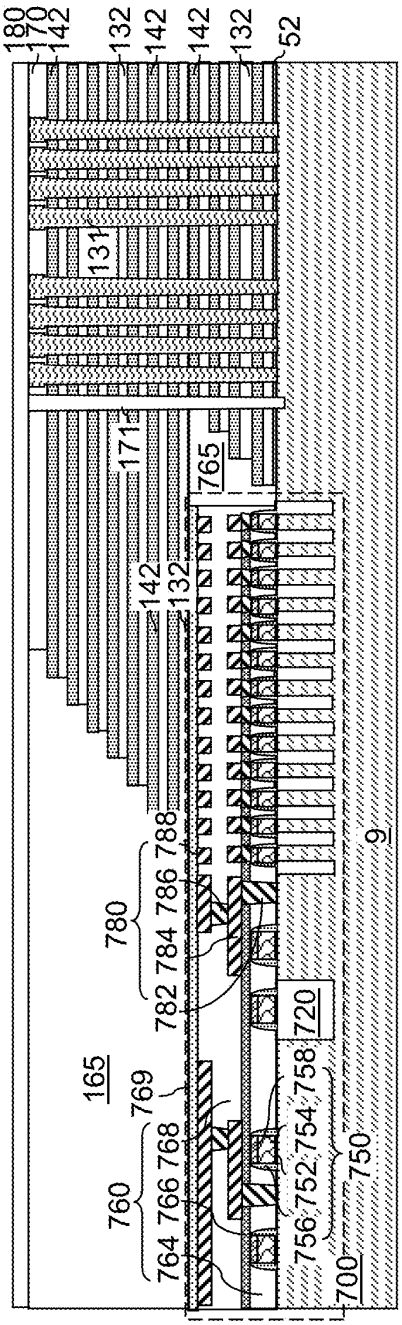

180
170
142
132
142
142
132
52
131
171
765
142
132
788
786
780
784
782
9
720
165
769
758
754
752
750
768
766
760
764
756
700

FIG. 21

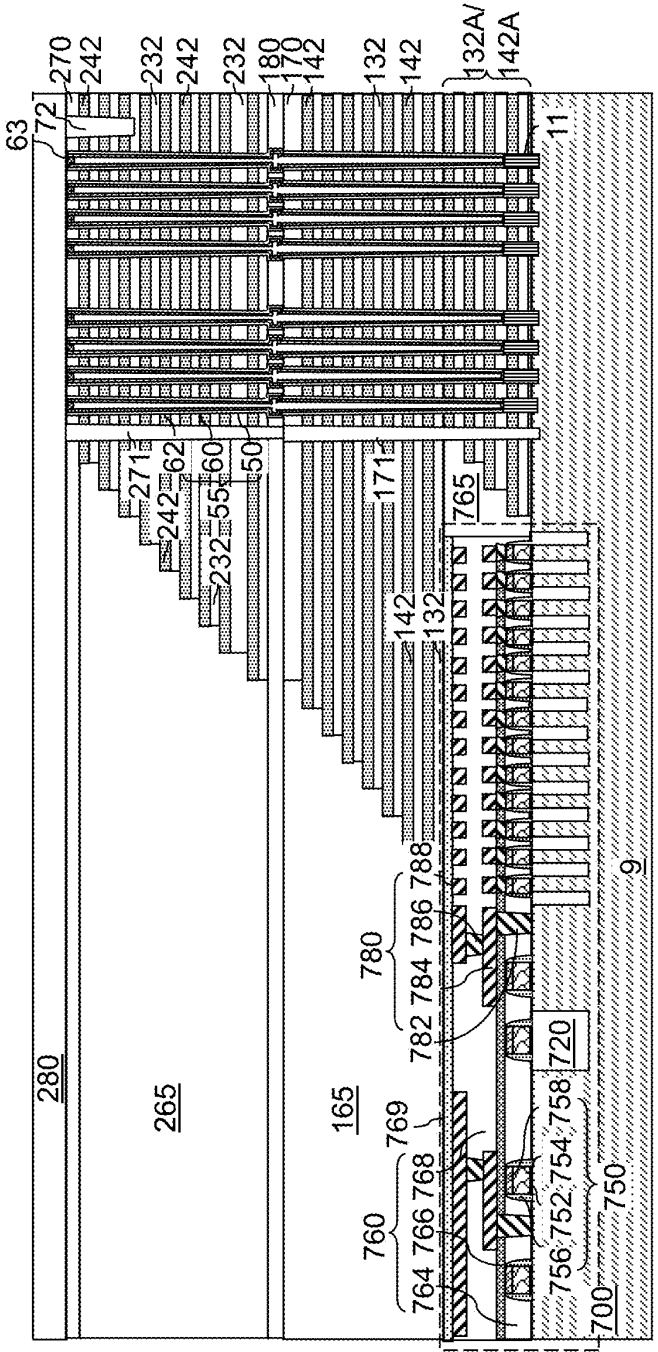

63
72
270
242
232
242
232
180
170
142
132
142
132A/
142A
11
271
62
60
50
242
55
232
171
765
142
132
788
786
780
784
782
720
9
280
265
165
769
768
760
766
764
758
754
752
756
750
700

FIG. 22

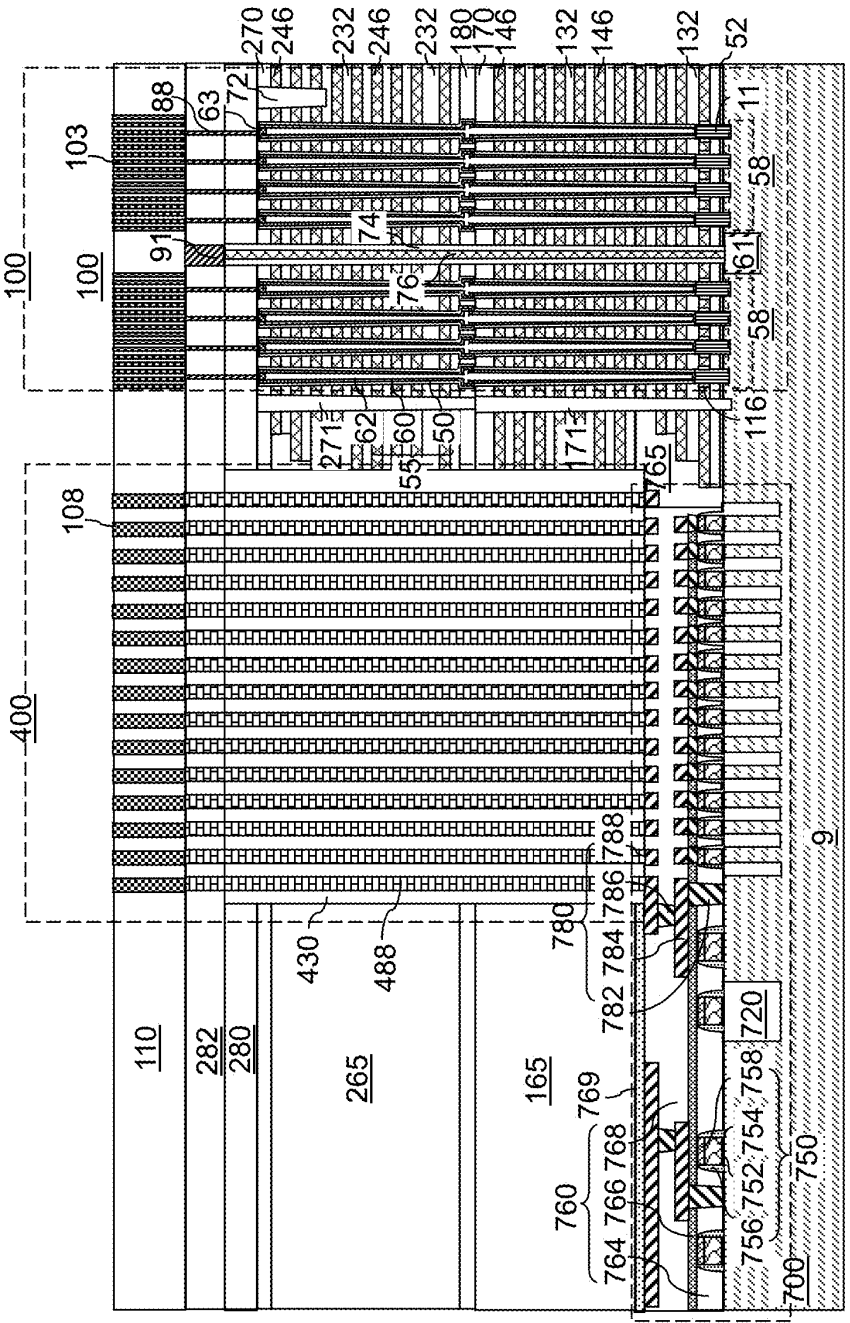

270
246
232
246
232
180
170
146
132
146
132
52
88
63
72
11
103
58
74
91
61
100
100
76
58
116
271
62
60
50
171
55
765
108
400
788
786
780
784
782
430
488
9
720
110
282
280
265
165
769
758
754
752
750
768
766
760
764
756
700

FIG. 23

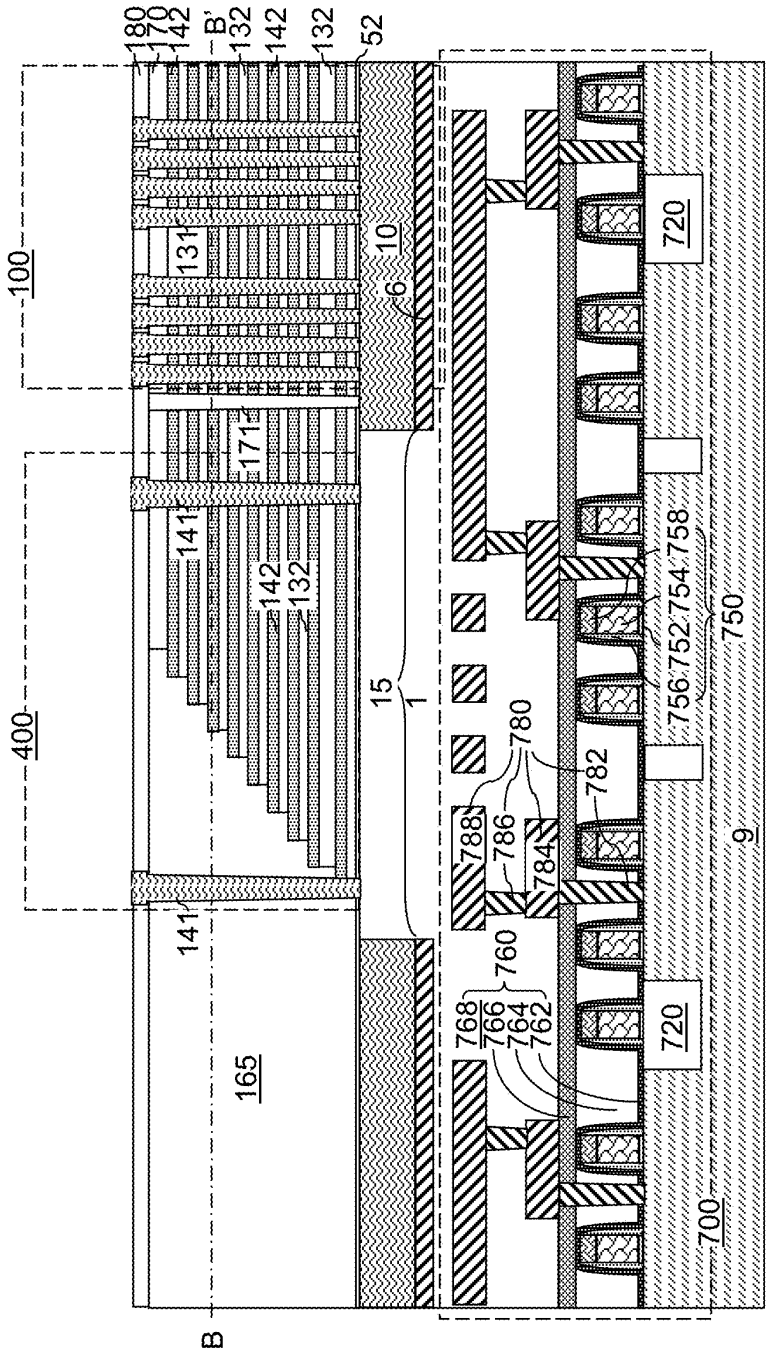

180
170
142
B'
132
142
132
52
100
131
10
6
171
141
142
132
400
15
1
141
165
B
780
782
788
786
784
760
768
766
764
762
720
720
756
752
754
758
750
9
700

FIG. 24A

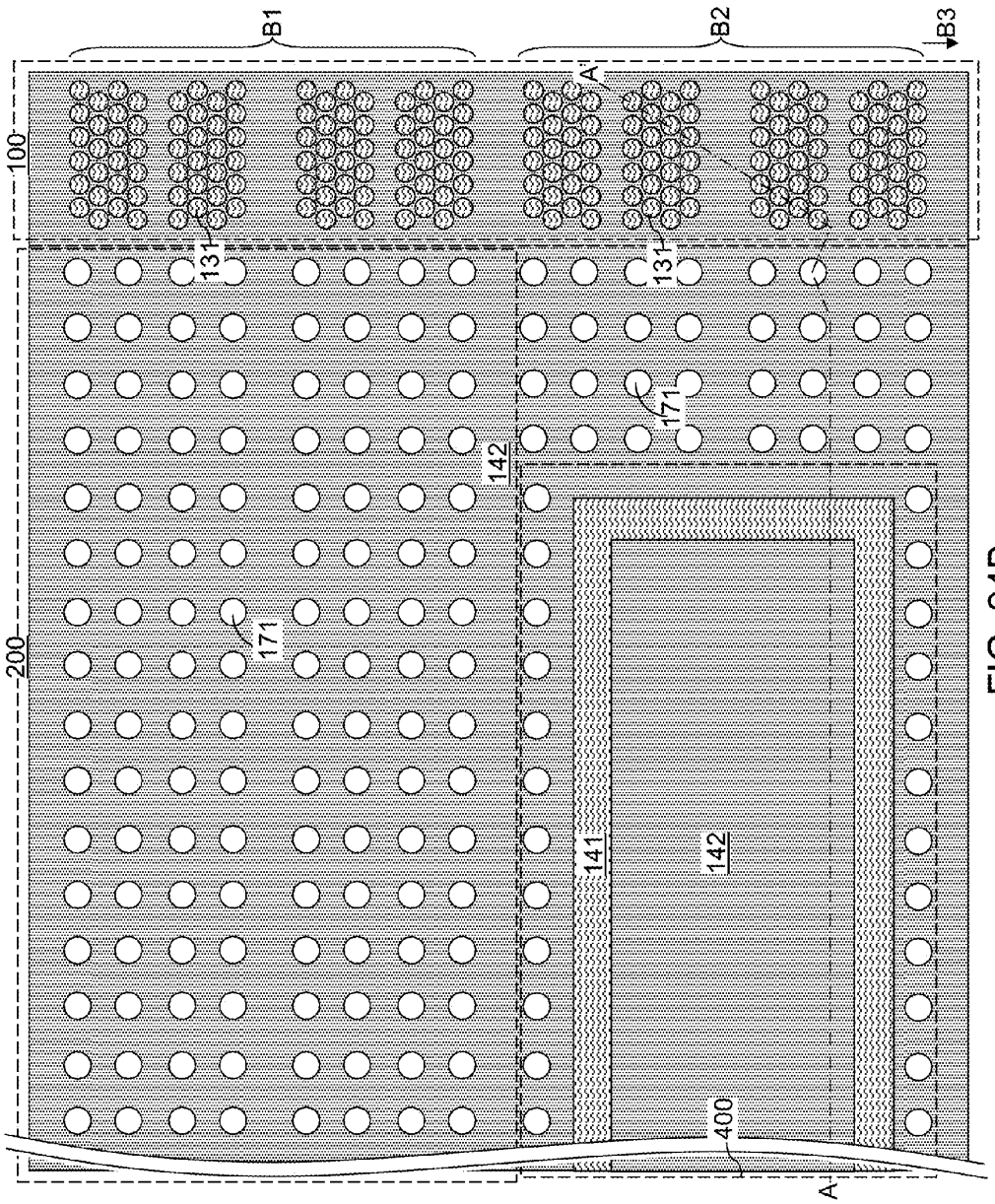
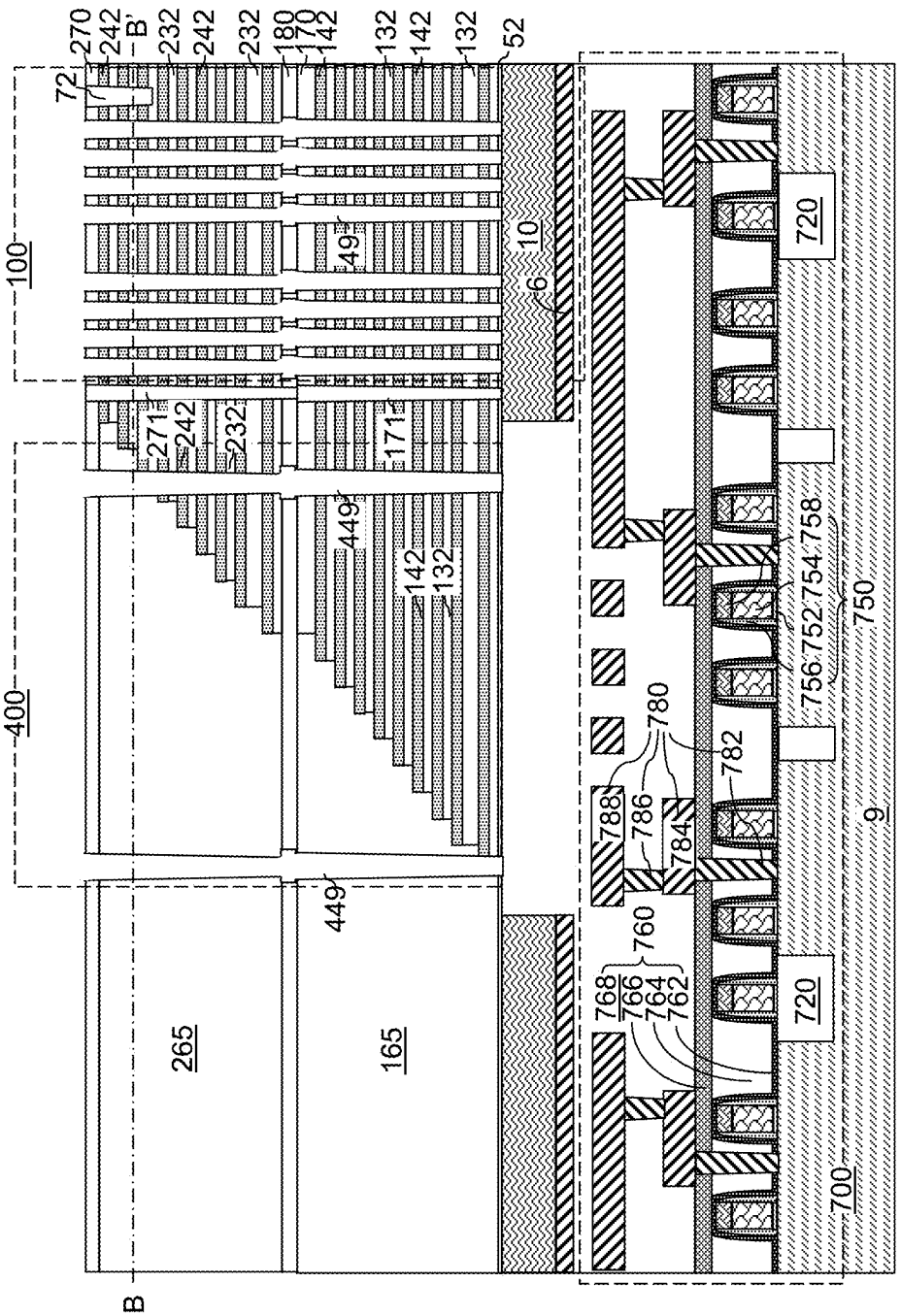


FIG. 24B


270
242
B'
232
242
232
180
170
142
132
142
132
52
72
100
10
6
49
271
242
232
171
449
142
132
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449
265
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754
758
750
780
782
788
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784
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766
764
762
9
700

FIG. 25A

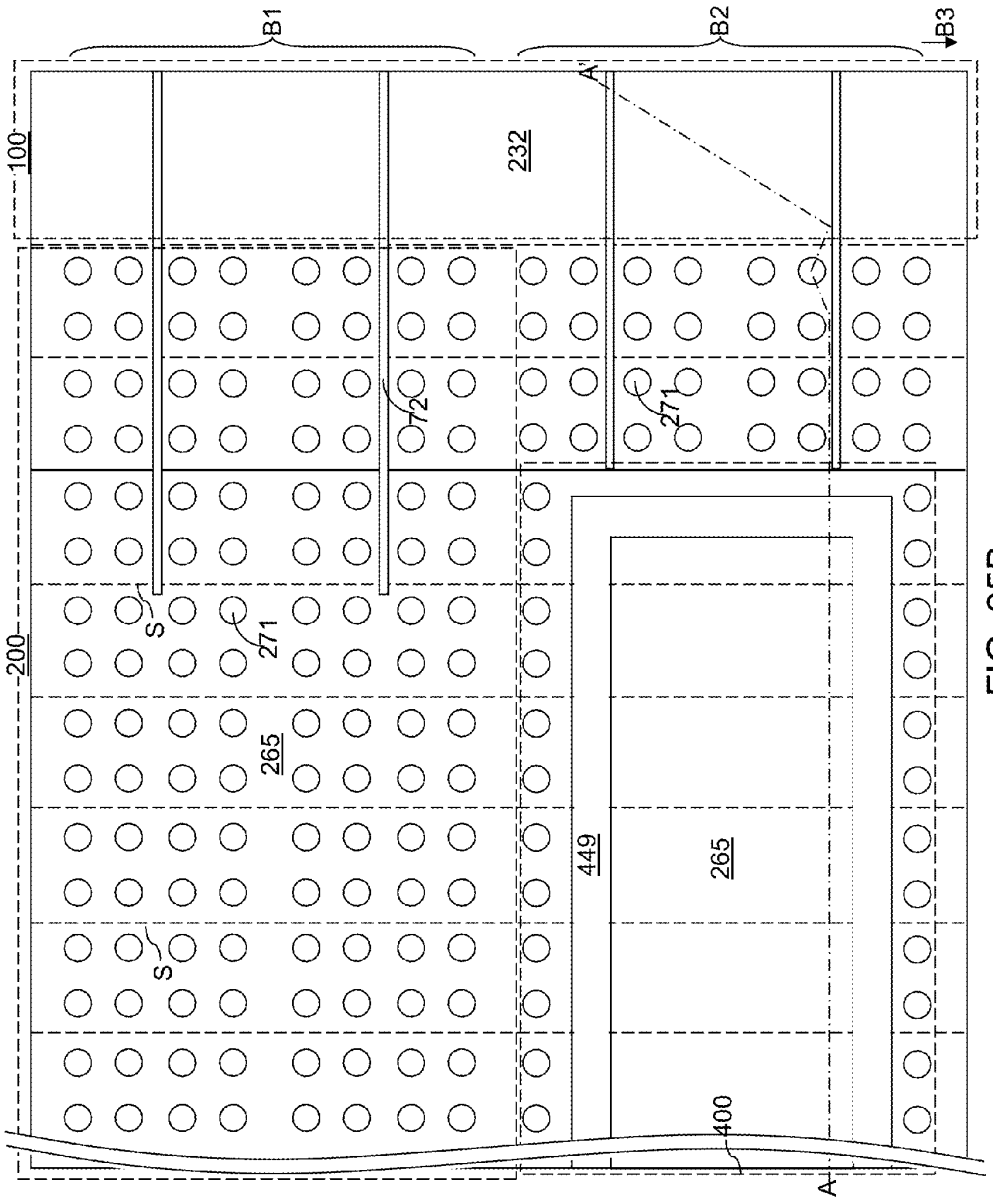
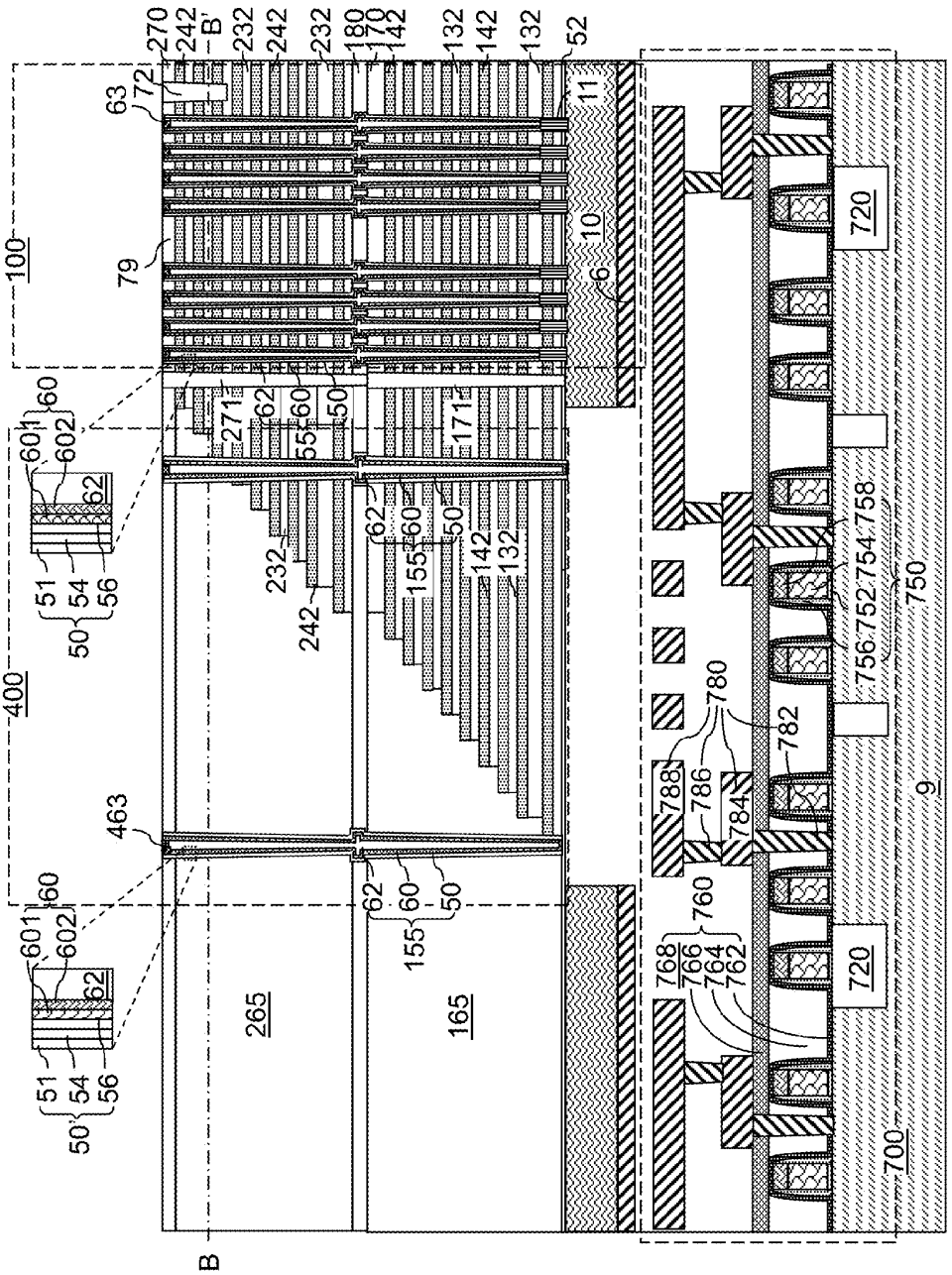


FIG. 25B


270
242
B'
232
242
232
180
170
142
132
142
132
52
63
72
11
100
79
10
6
720
60
601
602
62
271
62
60
50
55
171
51
54
56
50
232
242
62
60
50
155
142
132
758
754
752
756
750
400
780
782
788
786
784
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463
60
601
602
62
62
60
50
155
760
768
766
764
762
720
265
165
51
54
56
50
700
B

FIG. 26A

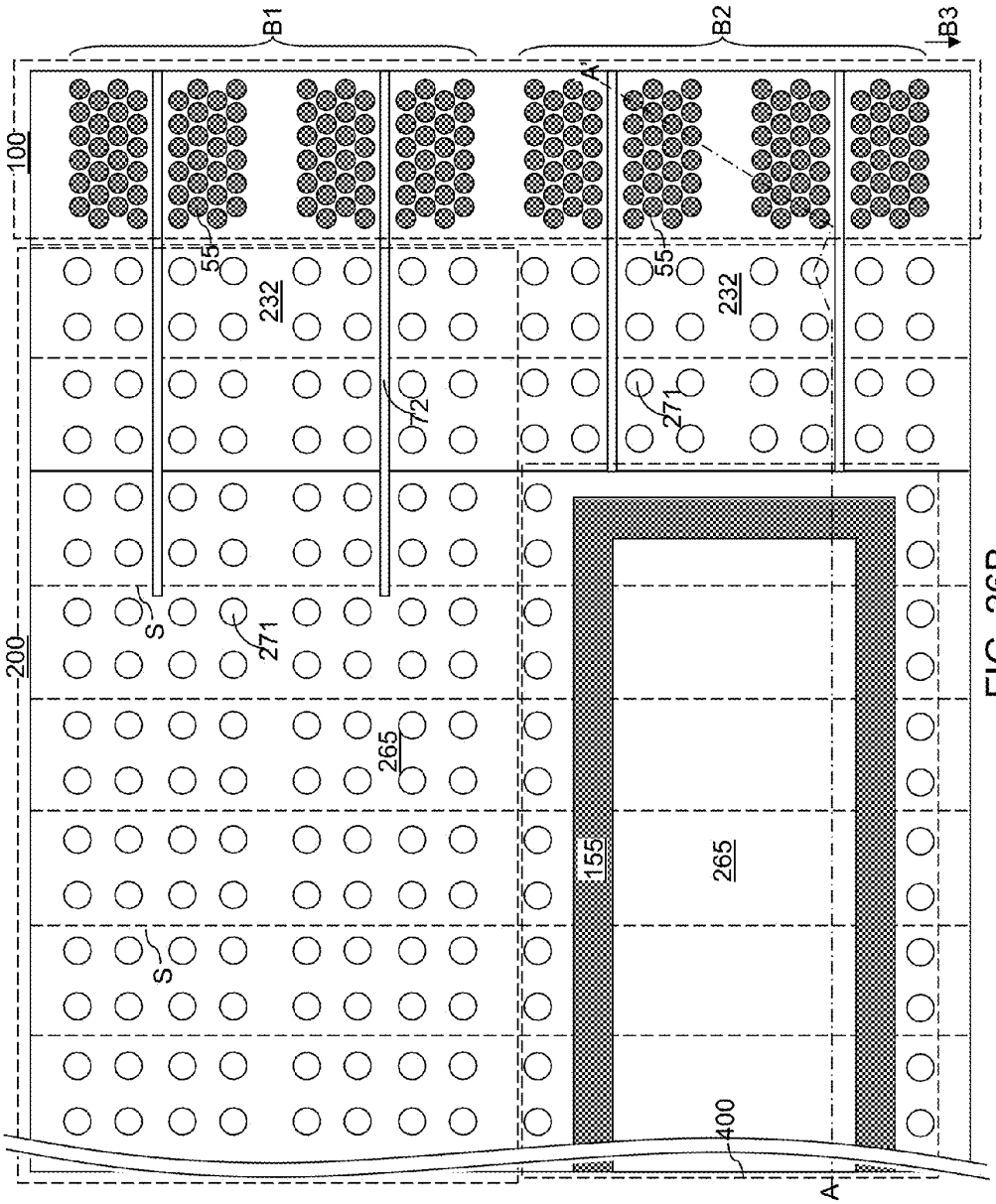


FIG. 26B

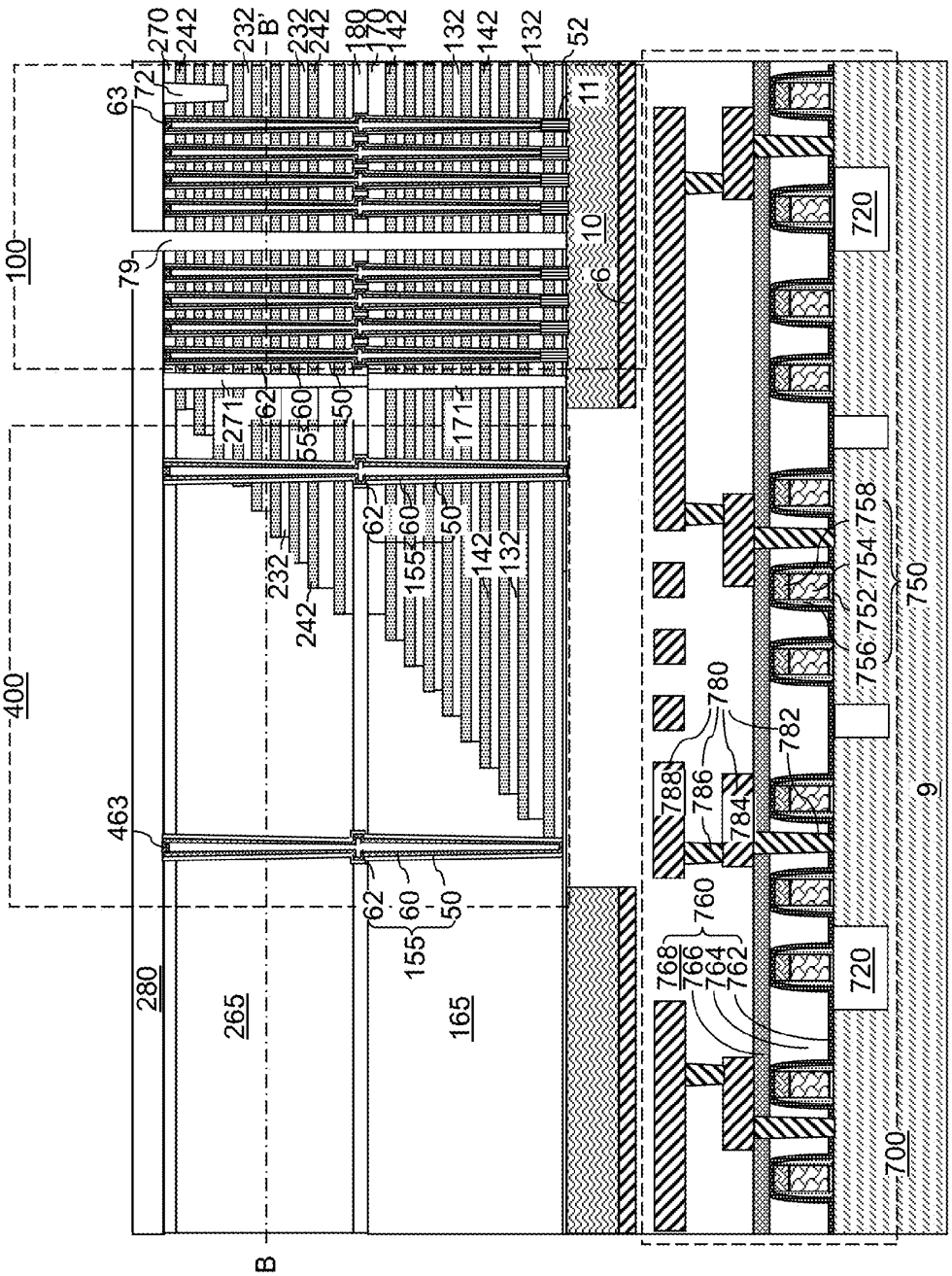

100
400
63
72
270
242
232
B'
232
242
180
170
142
132
142
132
52
11
10
6
79
271
62
60
55
50
171
232
242
62
60
155
50
142
132
463
62
60
155
50
280
265
165
B
720
720
756
752
754
758
750
780
782
788
786
784
760
768
766
764
762
9
700

FIG. 27A

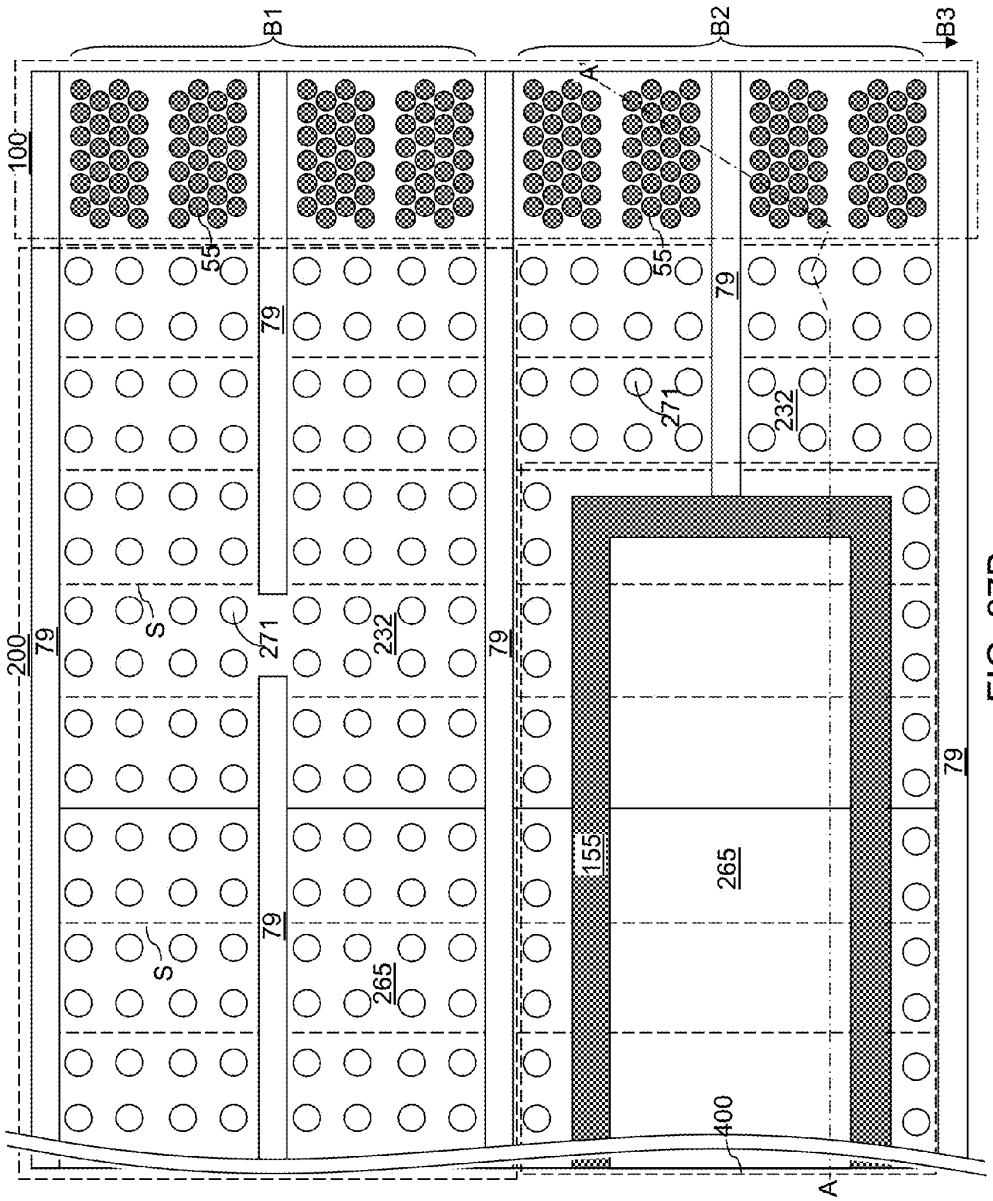


FIG. 27B

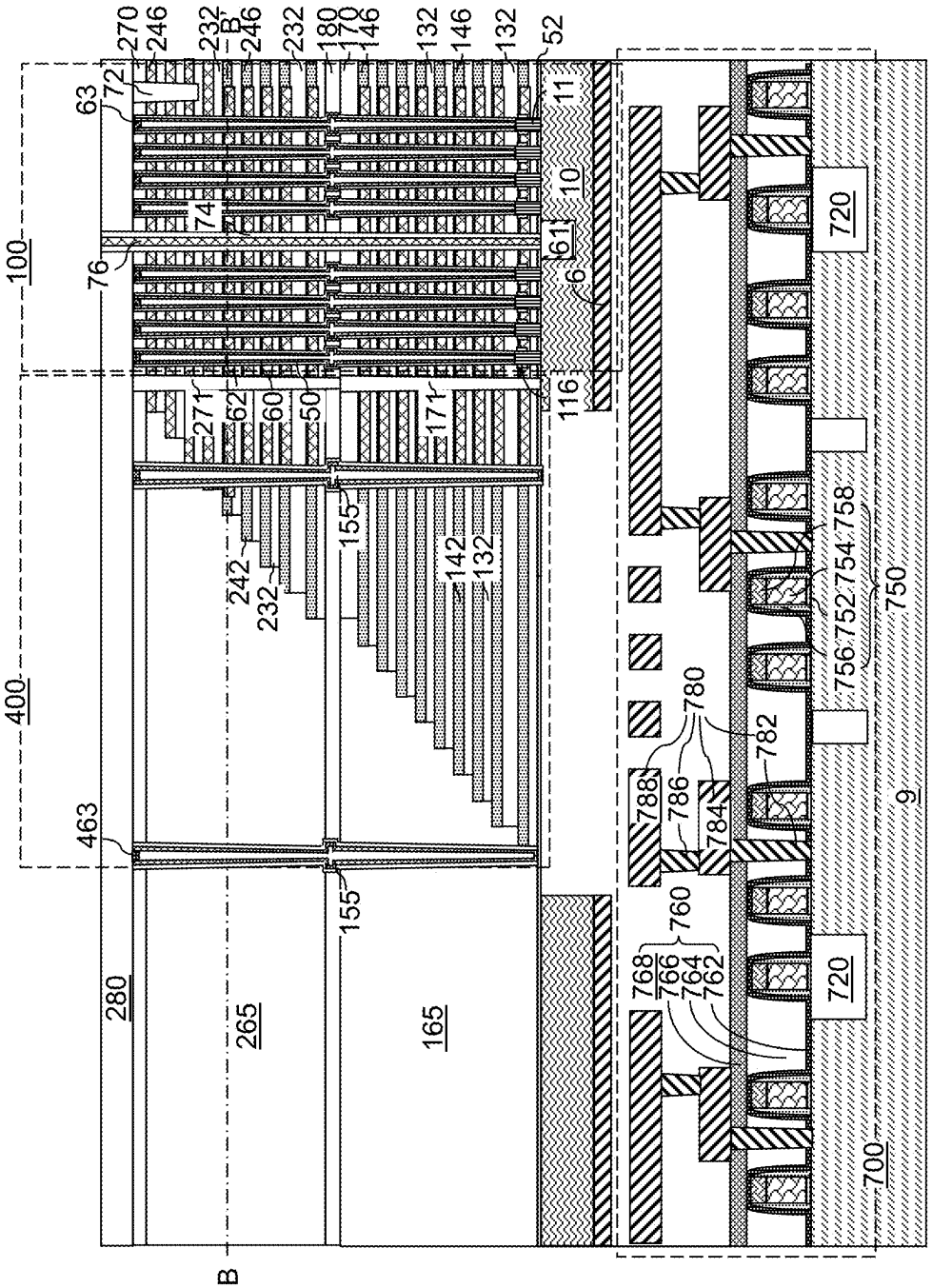

270
246
232
B'
246
232
180
170
146
132
146
132
52
63
72
11
10
74
61
100
76
6
271
62
60
50
171
116
155
242
232
142
132
400
463
155
280
265
165
B
768
766
764
762
760
788
786
784
780
782
720
720
756
752
754
758
750
9
700

FIG. 28A

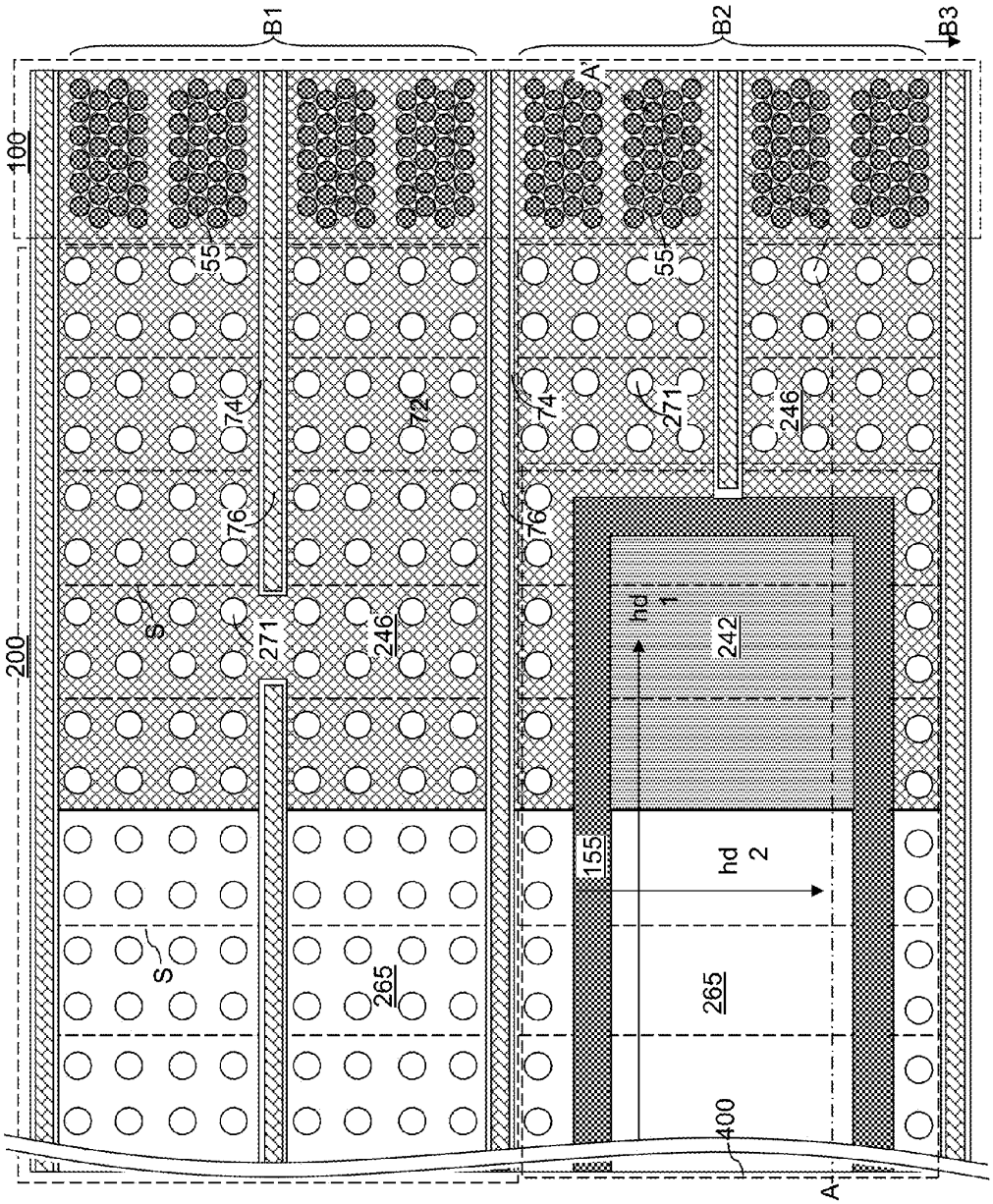


FIG. 28B

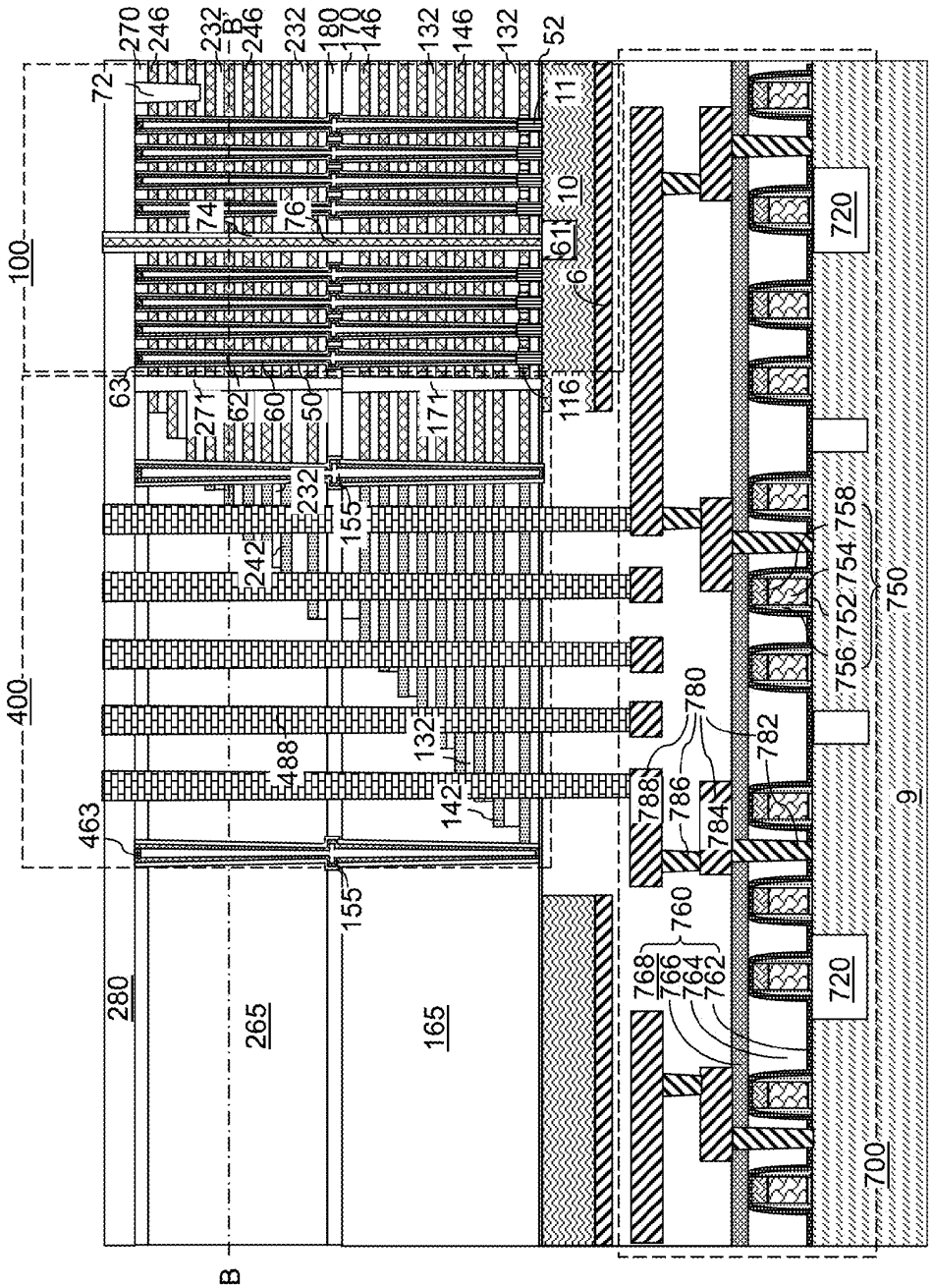

270
246
232
B'
246
232
180
170
146
132
146
132
52
72
11
10
74
76
61
6
100
63
271
62
60
50
171
116
232
155
242
400
488
132
142
463
155
280
265
165
B
720
758
754
752
756
750
780
782
788
786
784
760
768
766
764
762
720
9
700

FIG. 29A

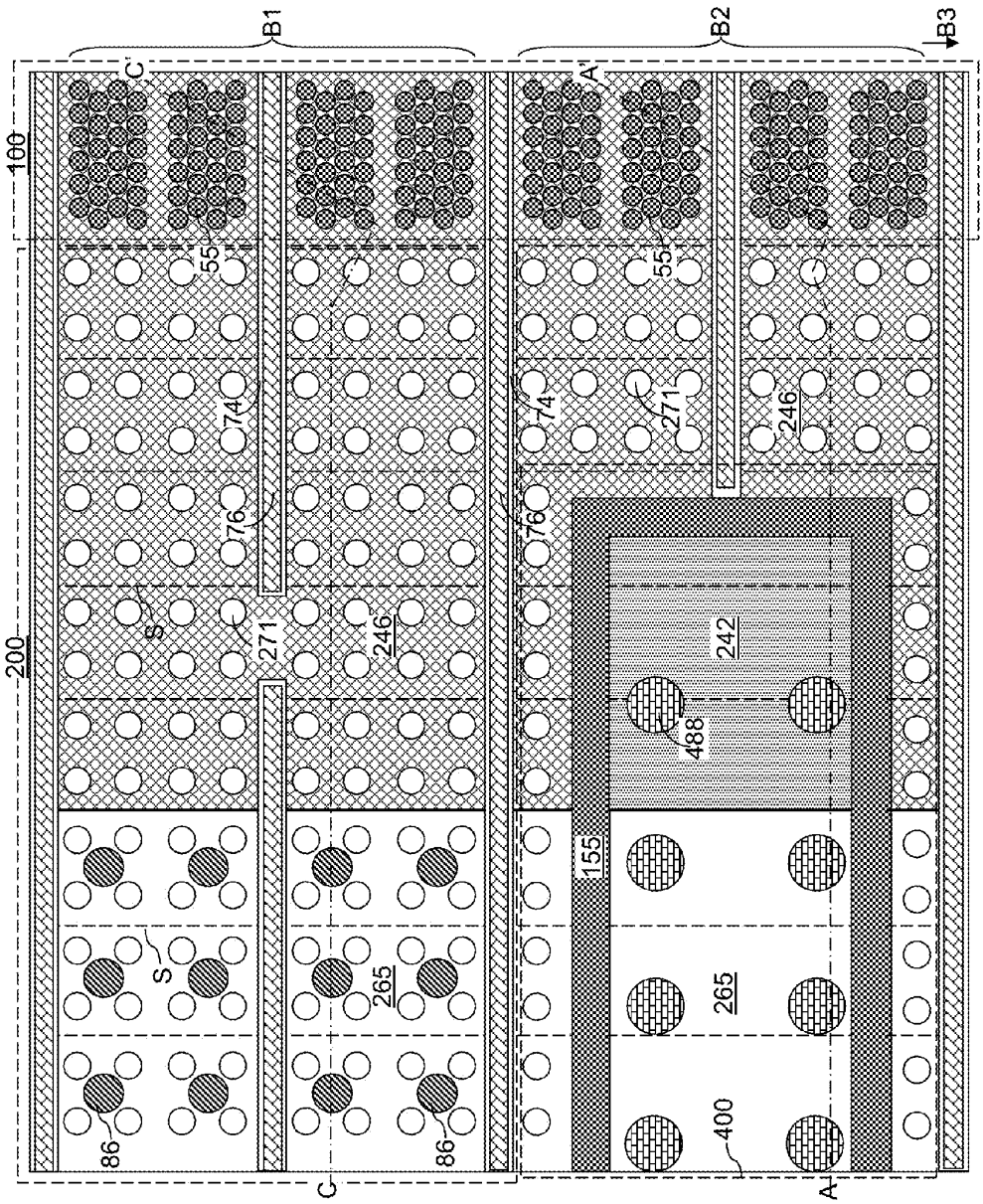
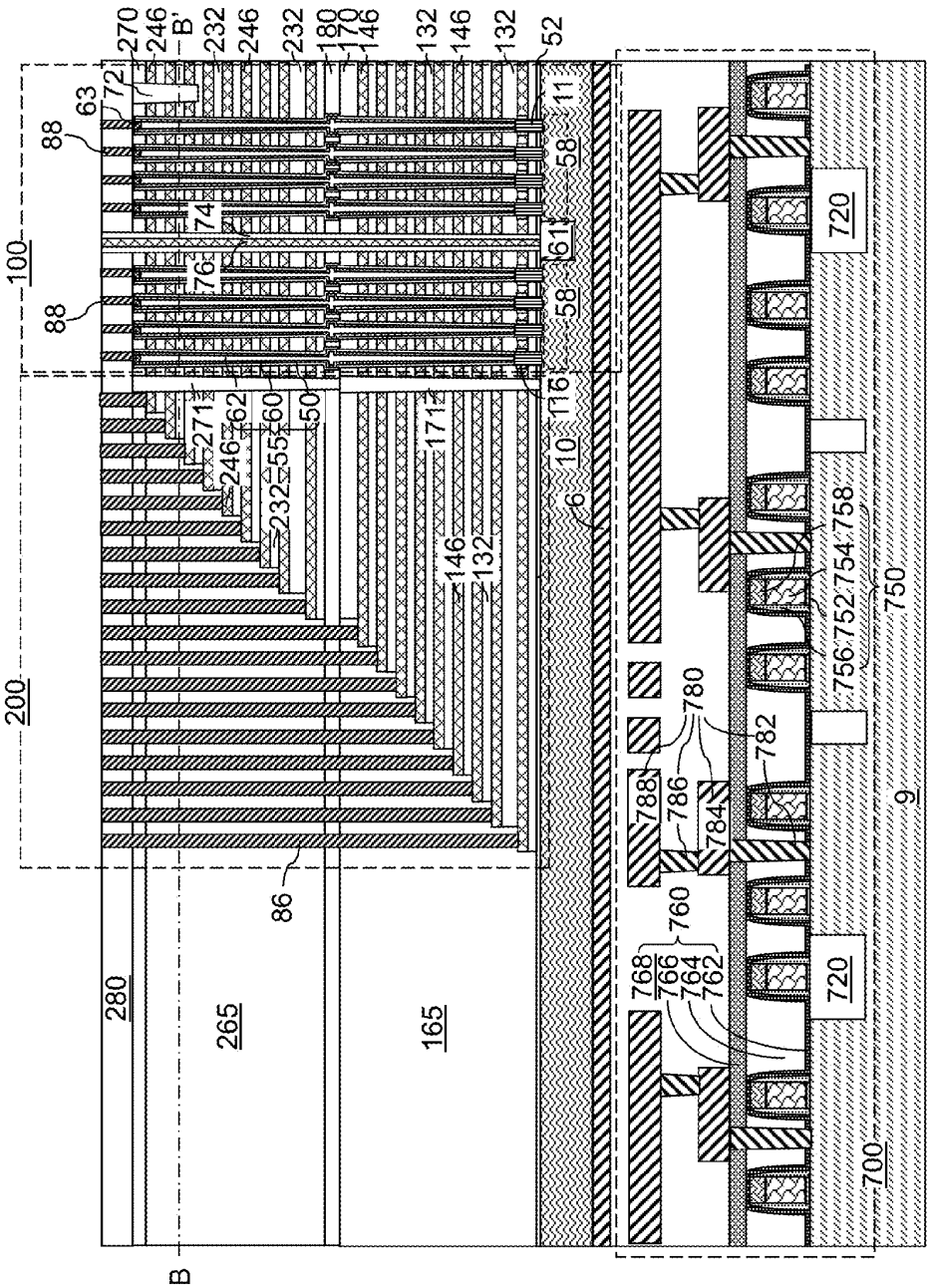


FIG. 29B


270
246
B'
232
246
232
180
170
146
132
146
132
52
72
63
88
11
58
74
61
76
58
88
100
116
271
62
60
50
171
246
55
10
232
6
146
132
200
86
280
265
165
B
720
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754
752
756
750
780
782
788
786
784
760
768
766
764
762
720
9
700

FIG. 29C

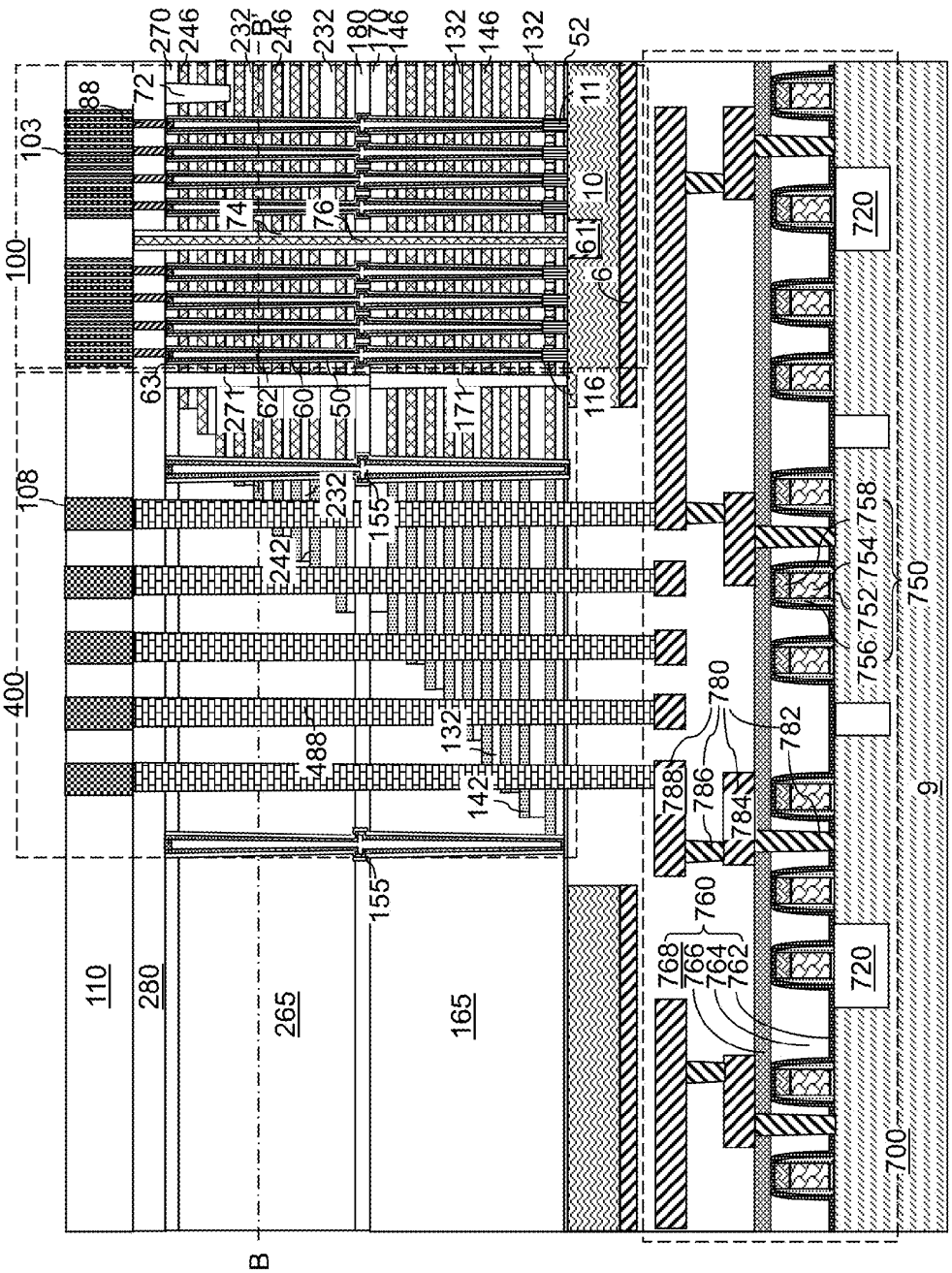
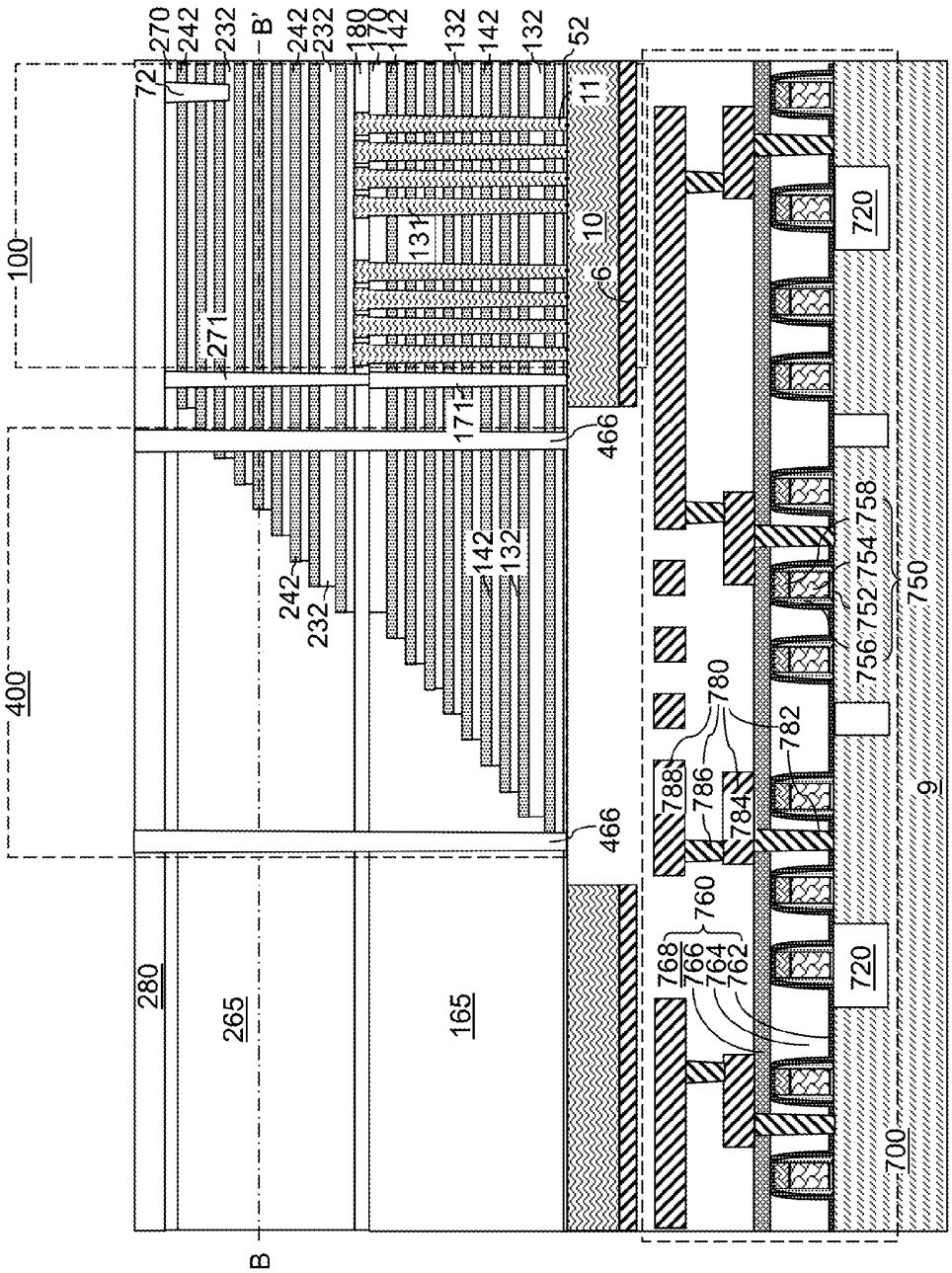

270
246
232
B'
246
232
180
170
146
132
146
132
52
88
72
103
11
10
74
76
61
6
100
63
271
62
60
50
171
116
108
232
155
242
758
754
752
756
750
400
488
132
142
780
782
788
786
784
9
155
760
768
766
764
762
720
720
110
280
265
165
700
B

FIG. 30


100
400
270
242
232
B'
242
232
180
170
142
132
142
132
52
72
11
10
131
6
271
171
466
242
232
142
132
466
280
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165
B
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752
756
750
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768
766
764
762
9
700

FIG. 31A

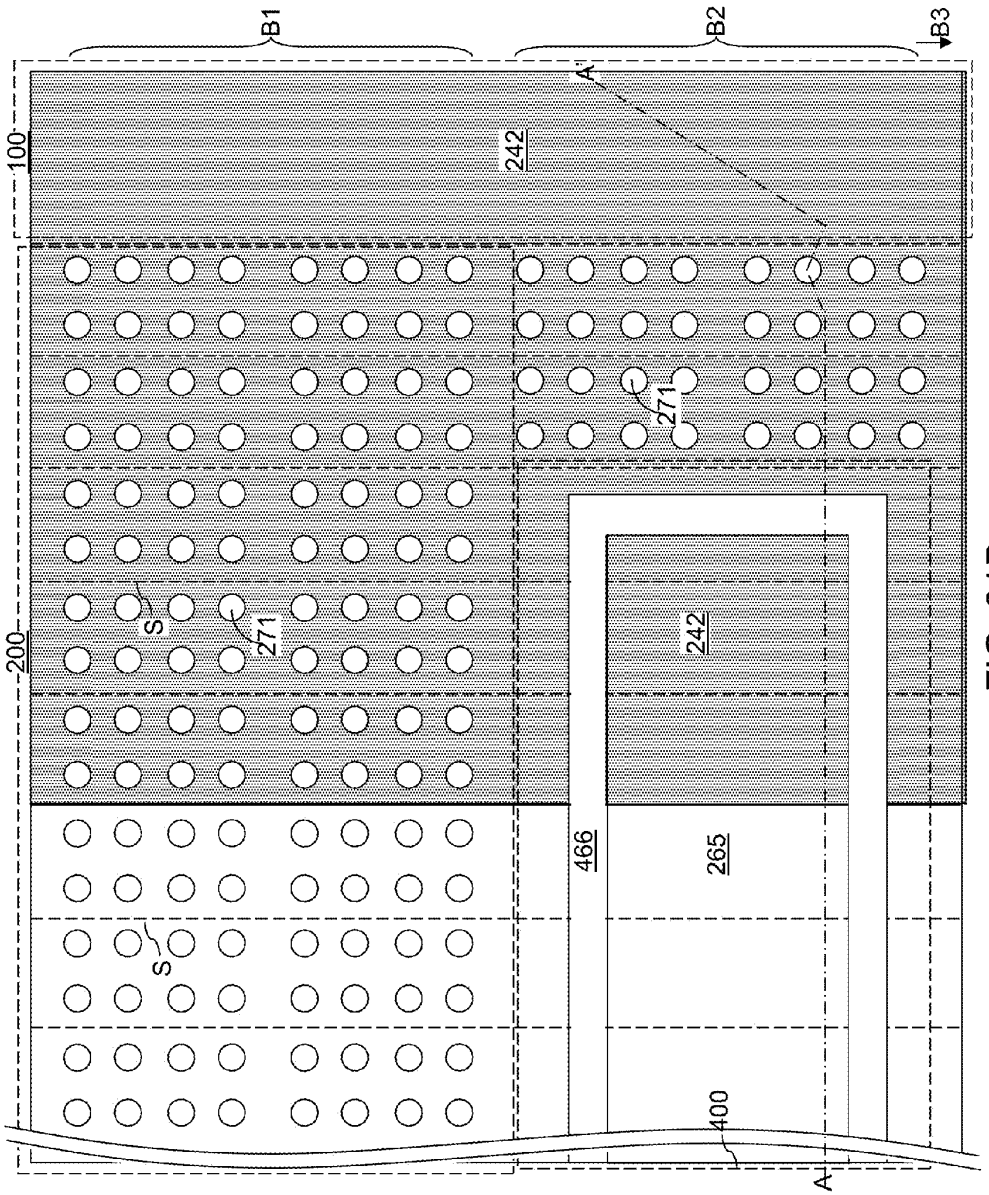

FIG. 31B

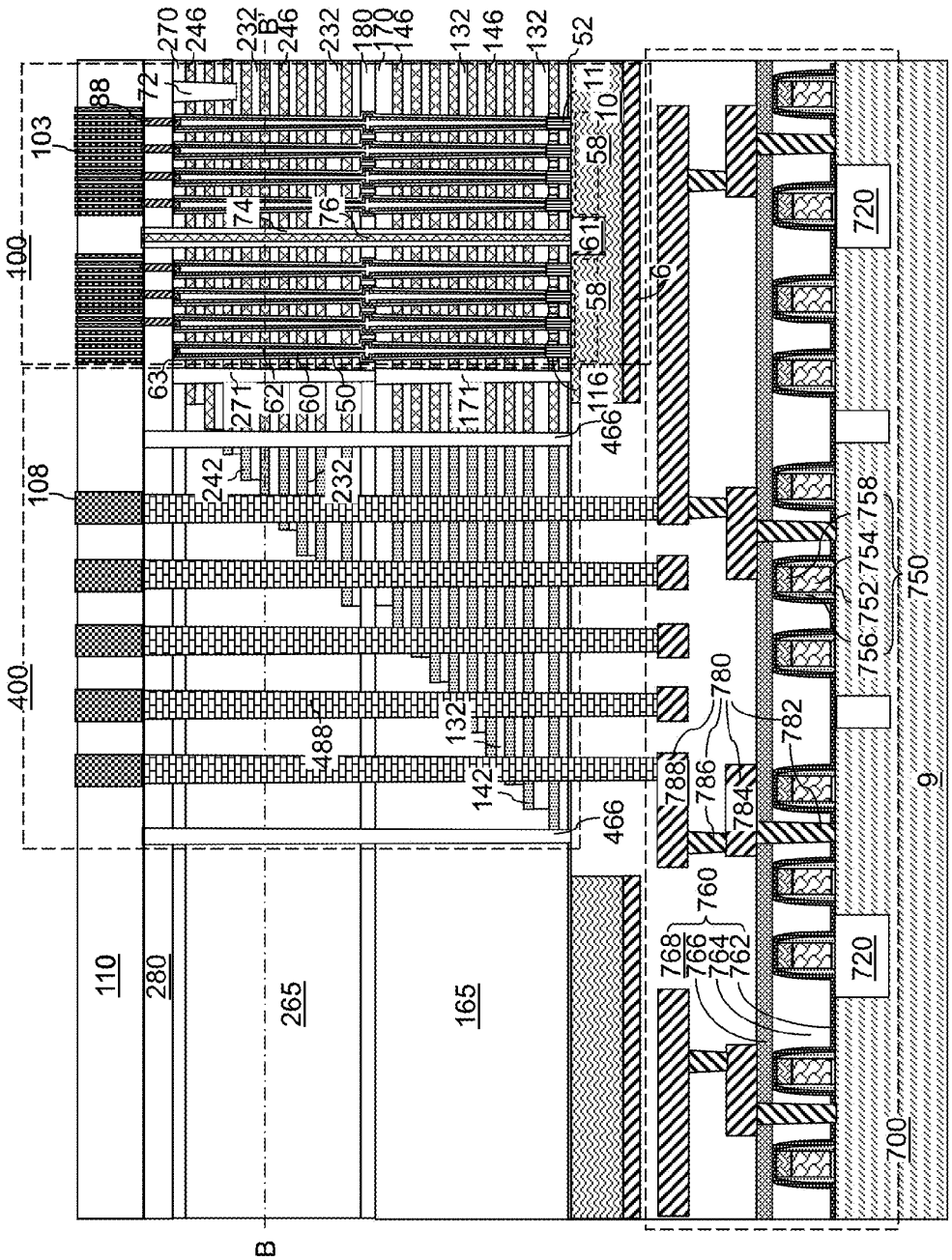
270
246
232
B'
246
232
180
170
146
132
146
132
52
88
72
11
10
103
58
74
76
61
100
58
6
63
271
62
60
50
171
116
466
242
232
108
758
754
752
756
750
400
780
782
488
132
788
786
784
142
466
760
768
766
764
762
720
720
9
110
280
265
165
700
B

FIG. 32A

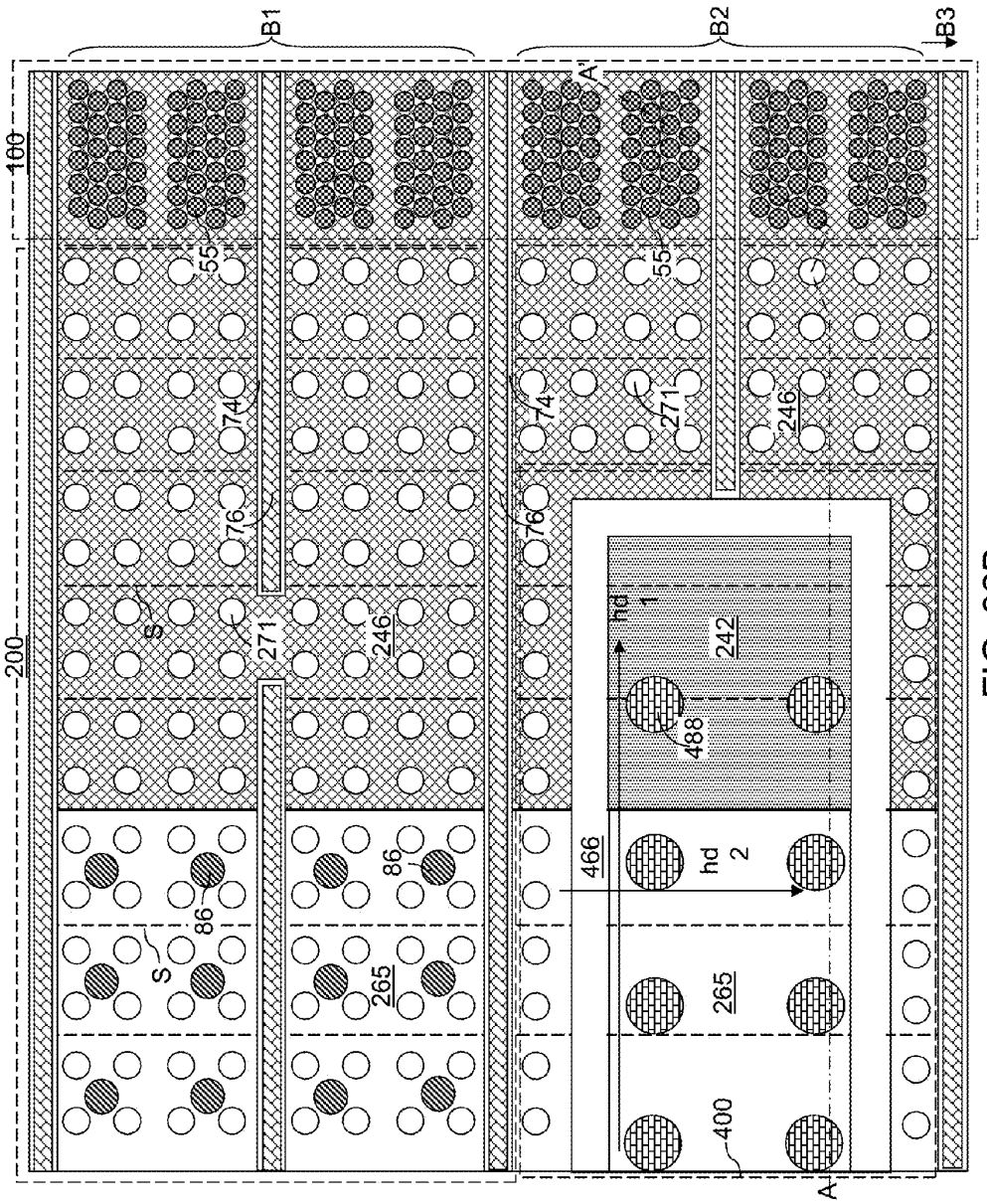

FIG. 32B

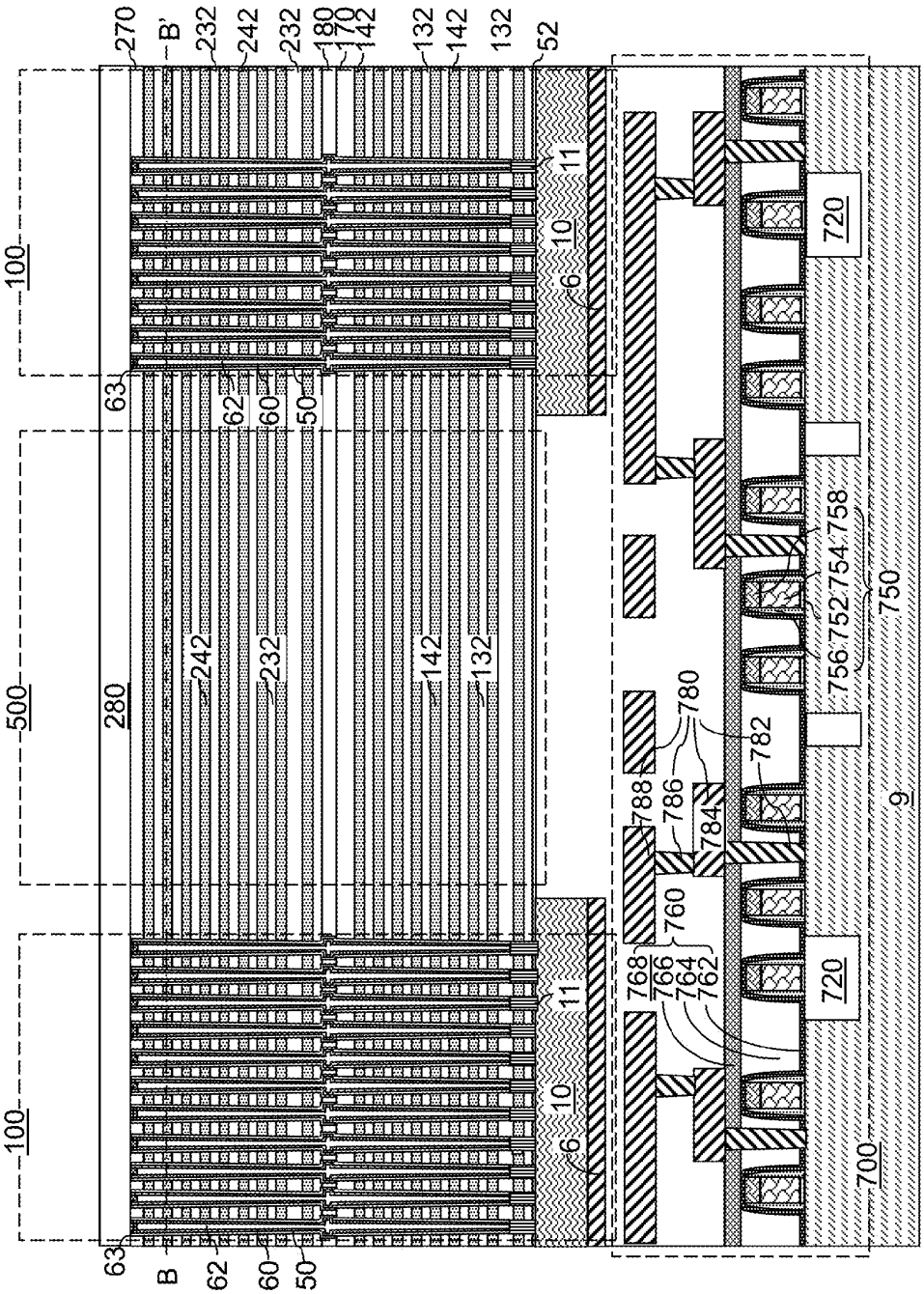
270
B'
232
242
232
180
170
142
132
142
132
52
100
63
62
60
50
11
10
6
500
280
242
232
142
132
780
782
788
786
784
760
768
766
764
762
720
756
752
754
758
750
9
700
B

FIG. 33A

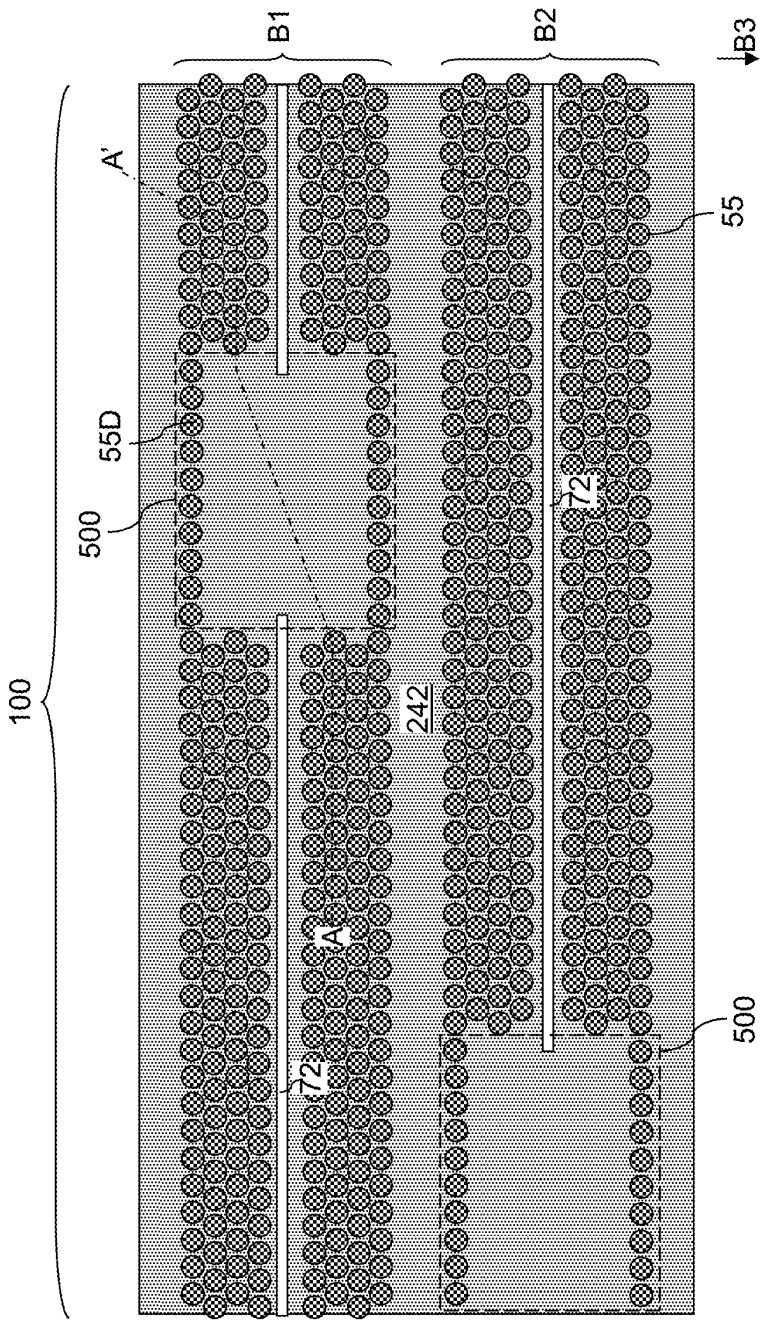

FIG. 33B

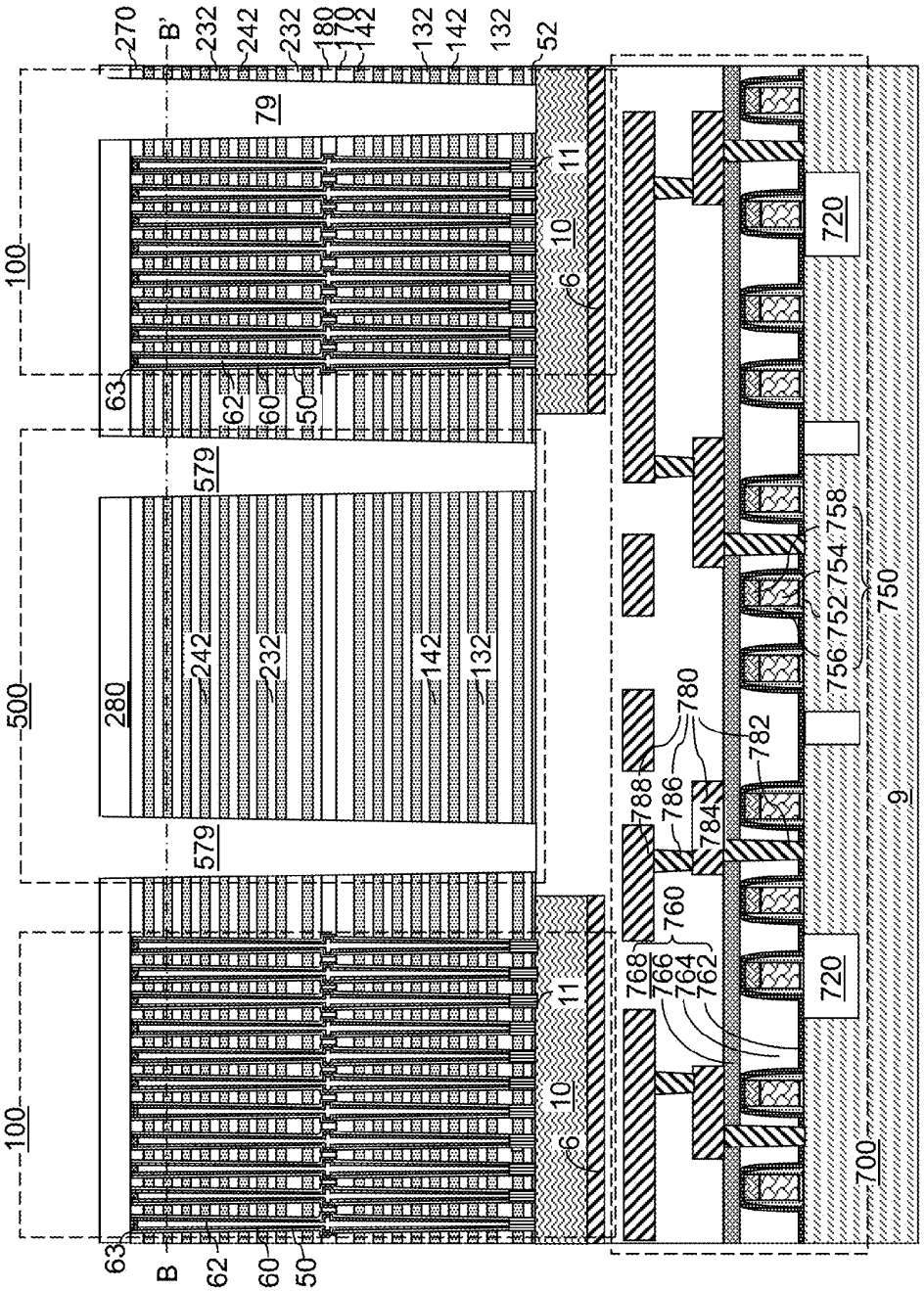
270
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FIG. 34A

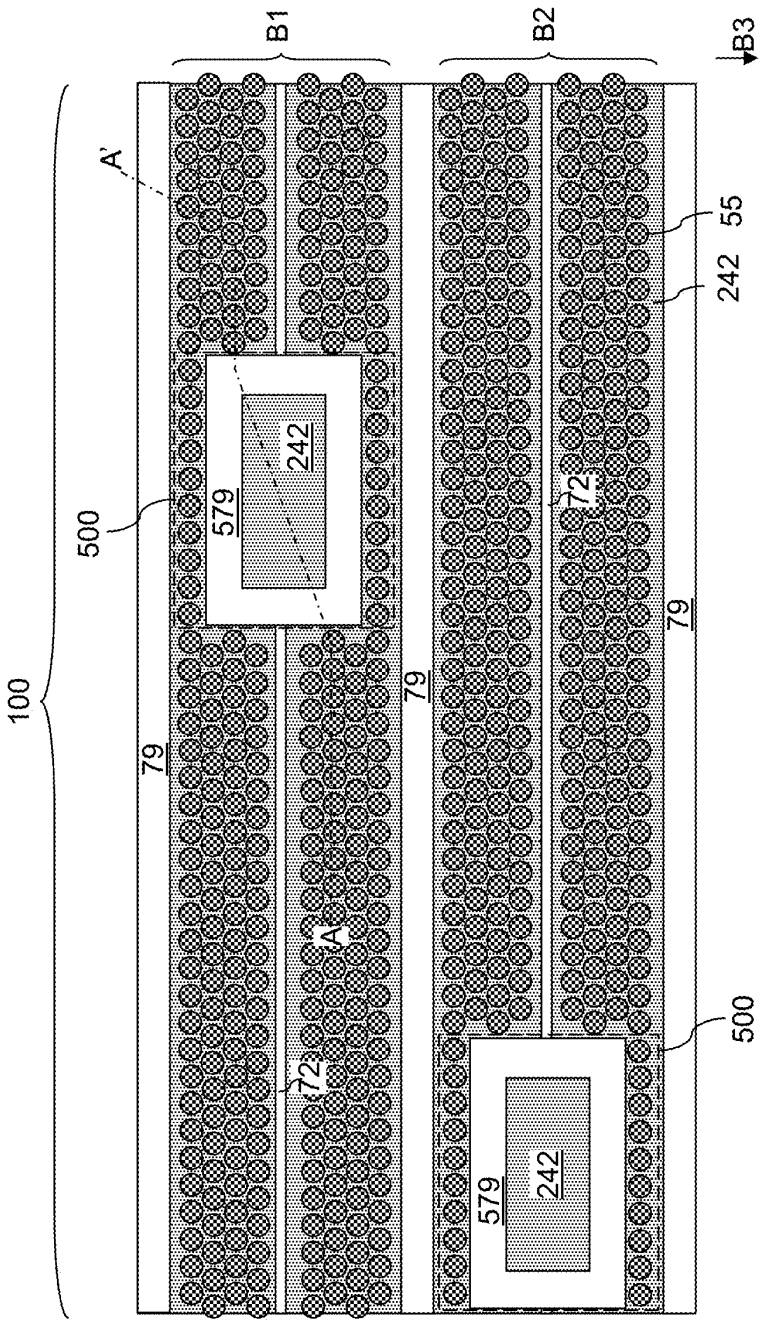

FIG. 34B

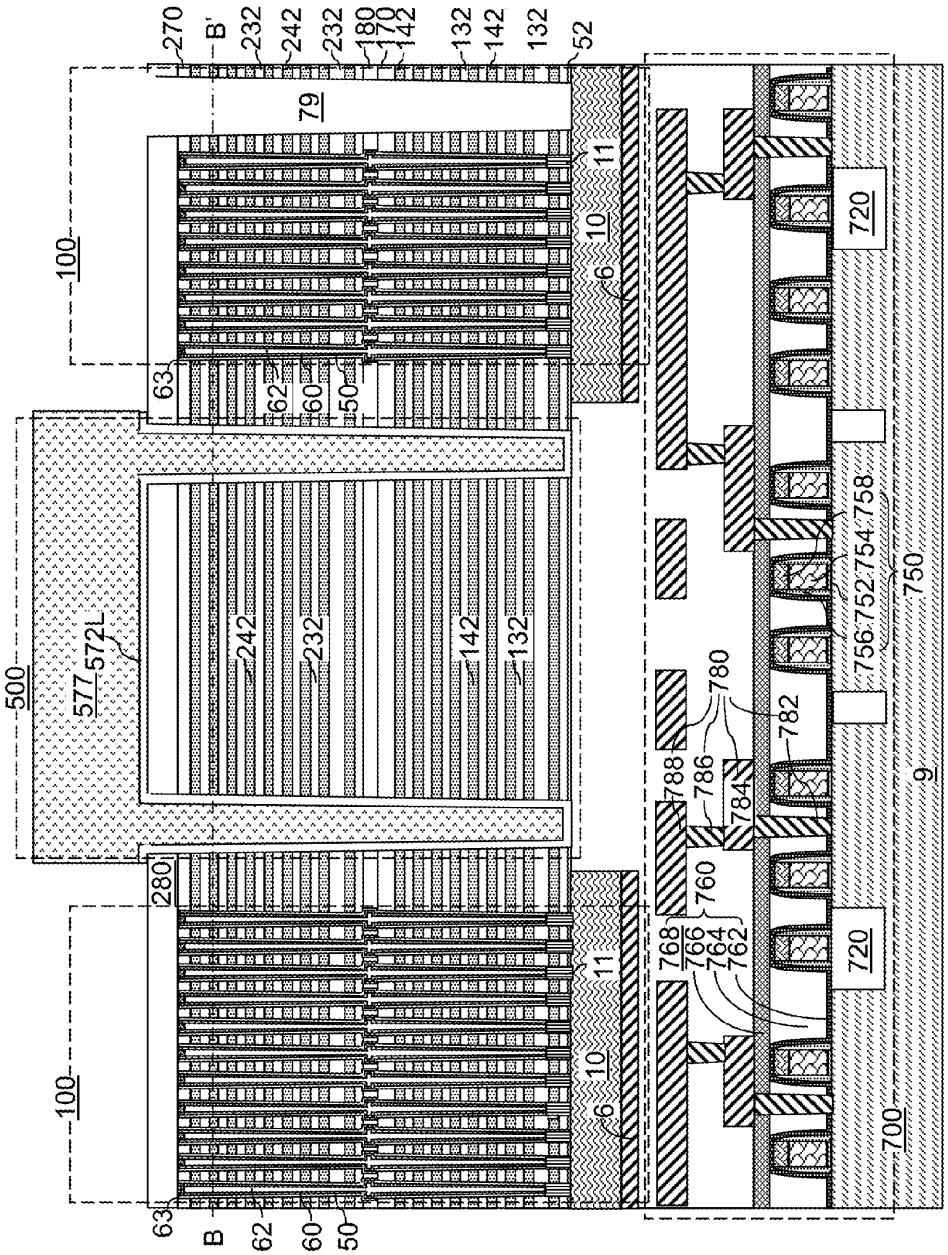
270
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FIG. 35A

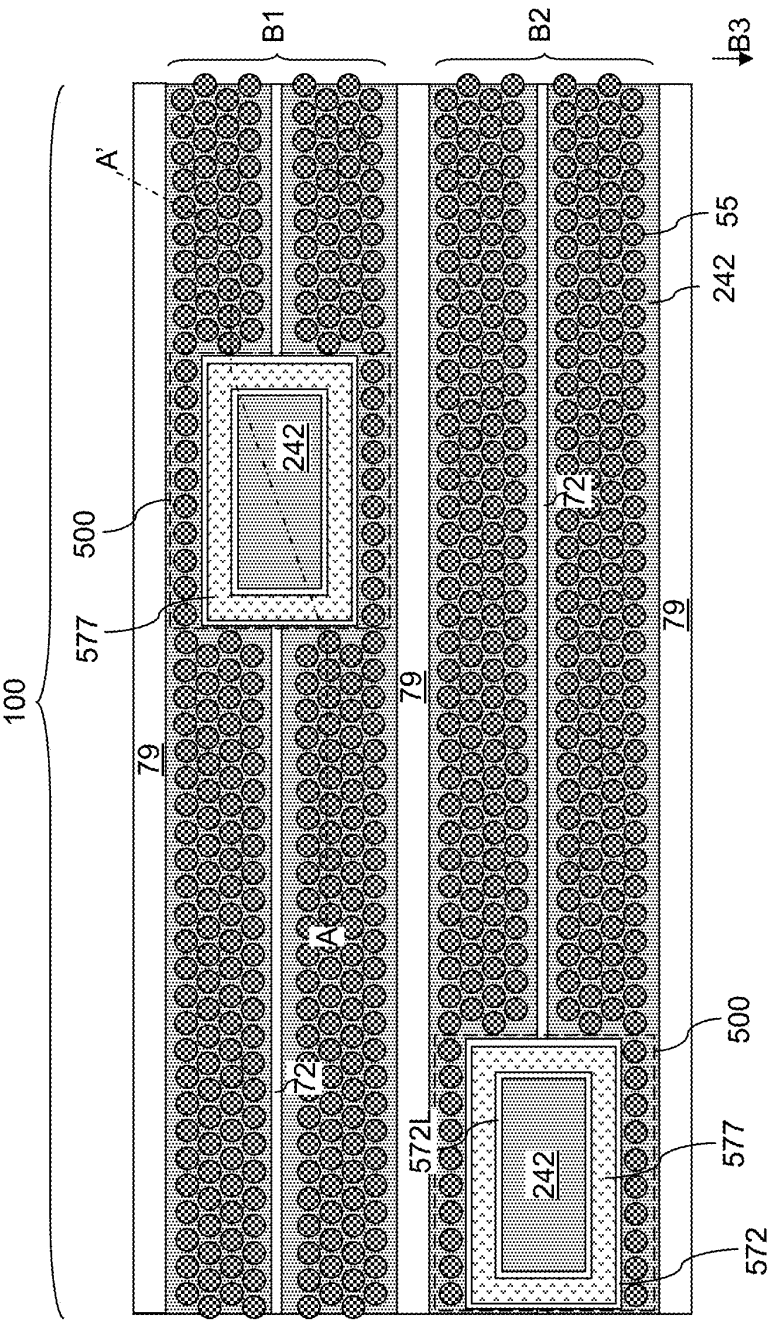

FIG. 35B

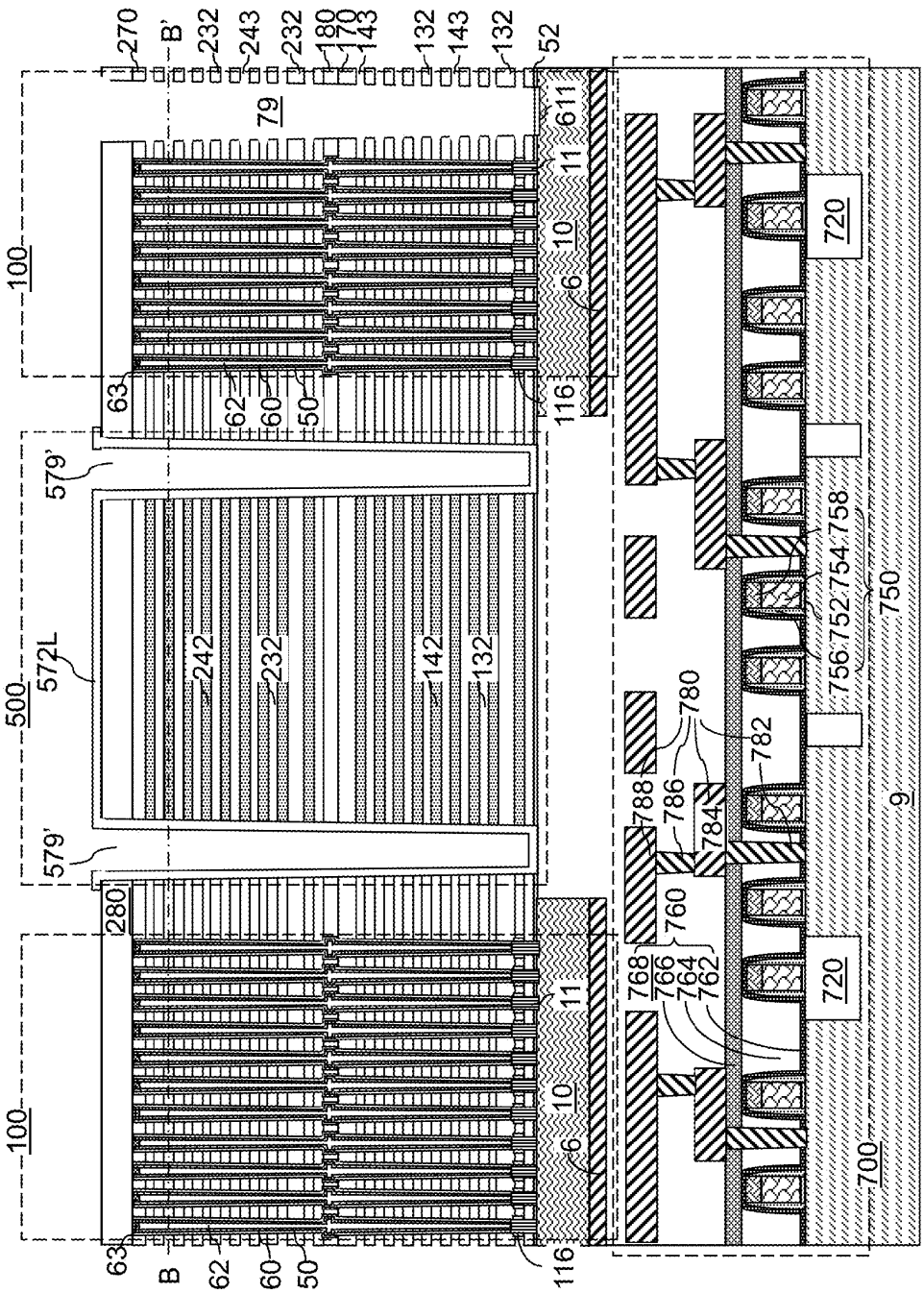
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FIG. 36A

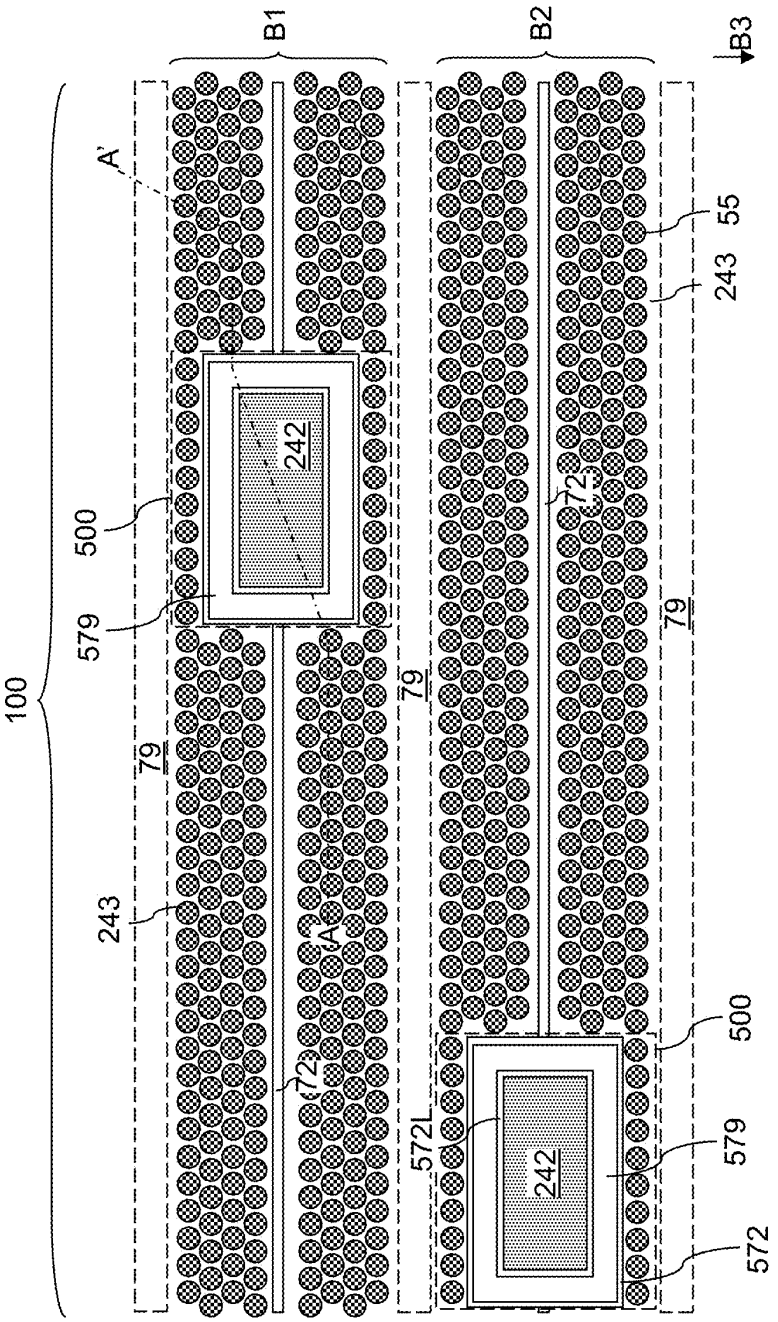

FIG. 36B

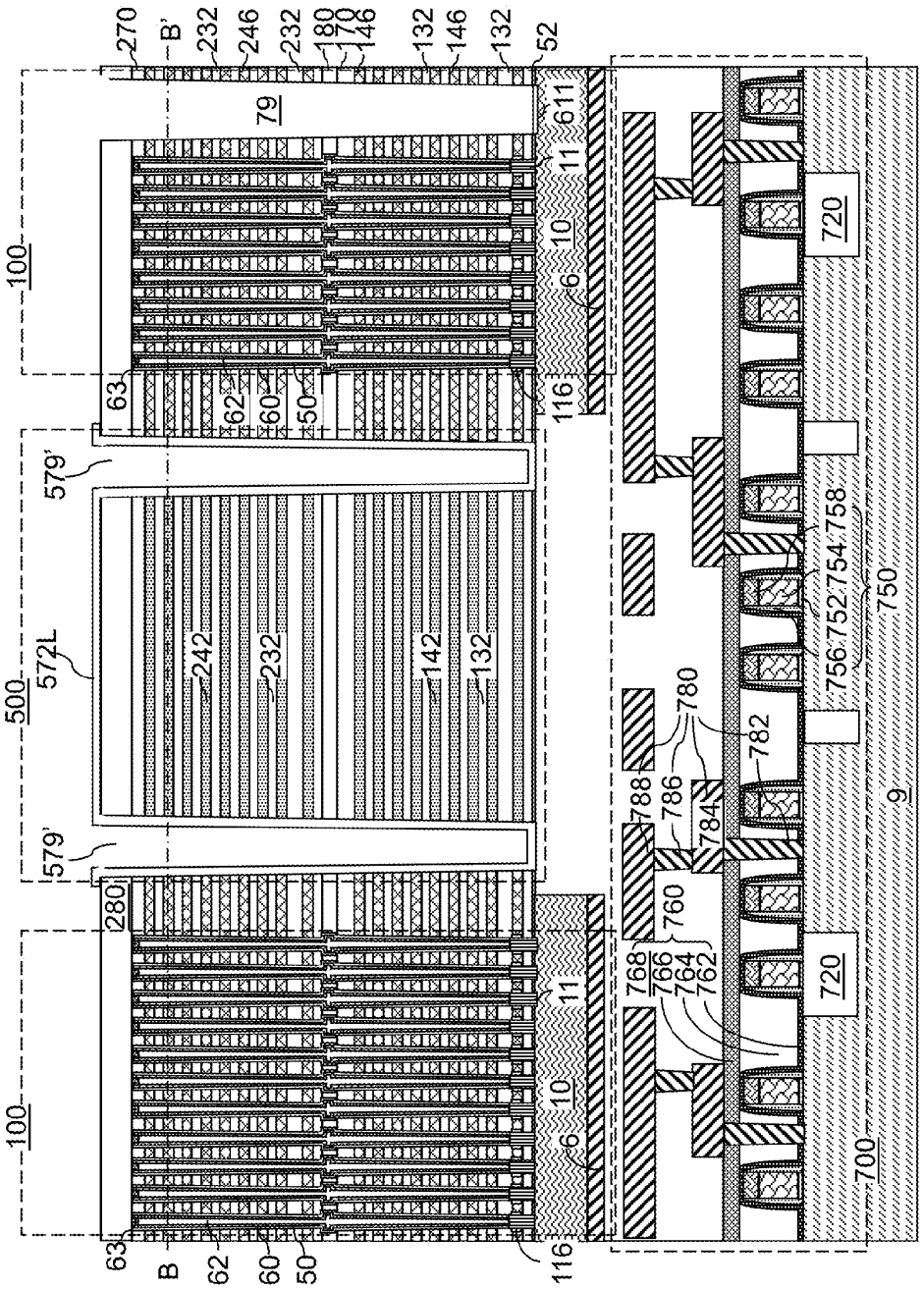
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FIG. 37A

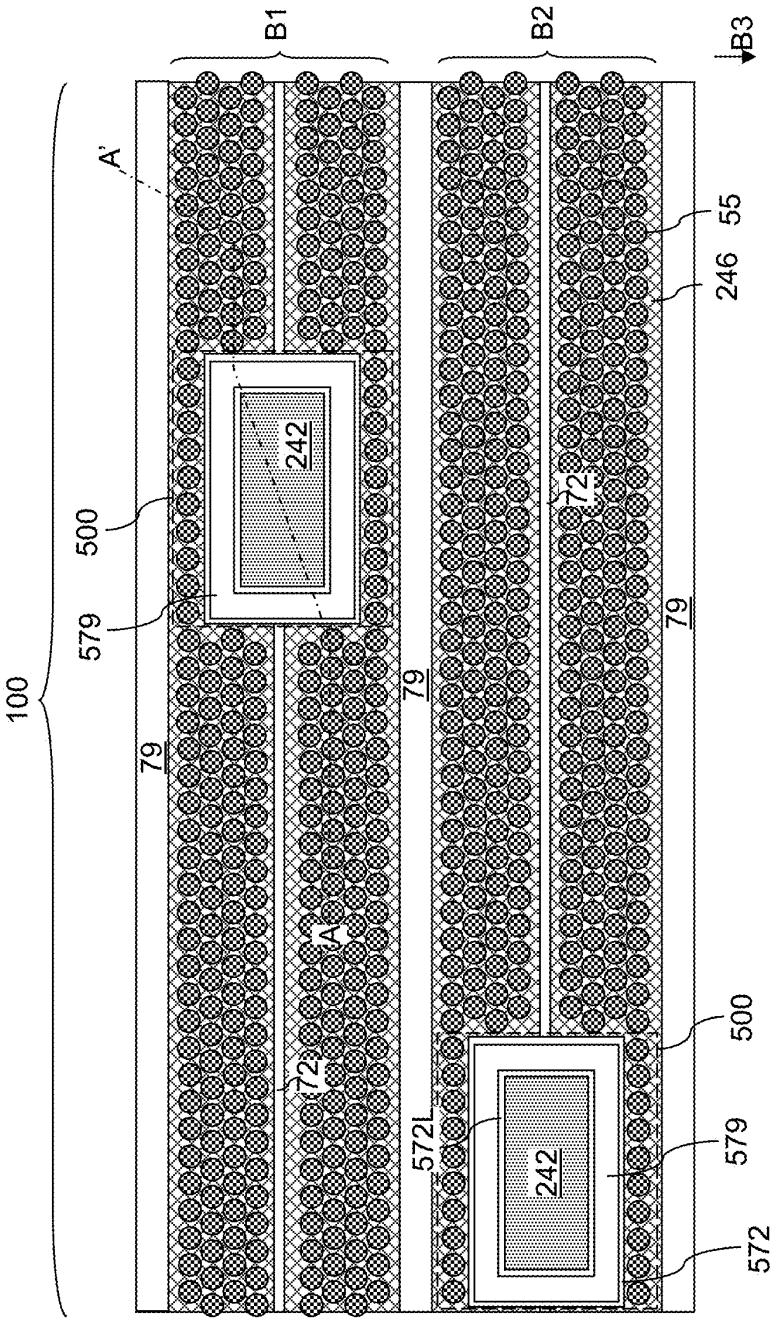

FIG. 37B

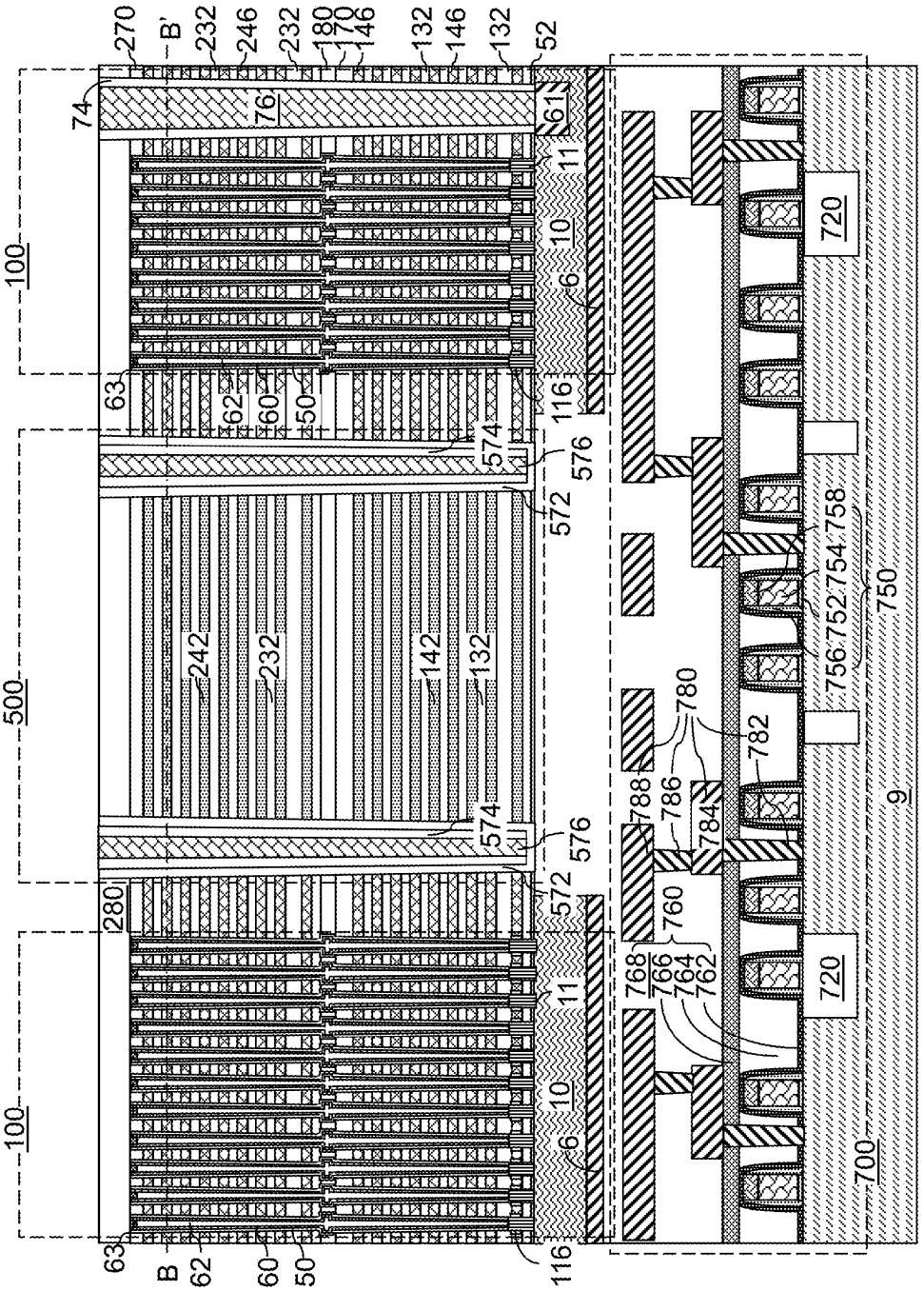
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FIG. 38A

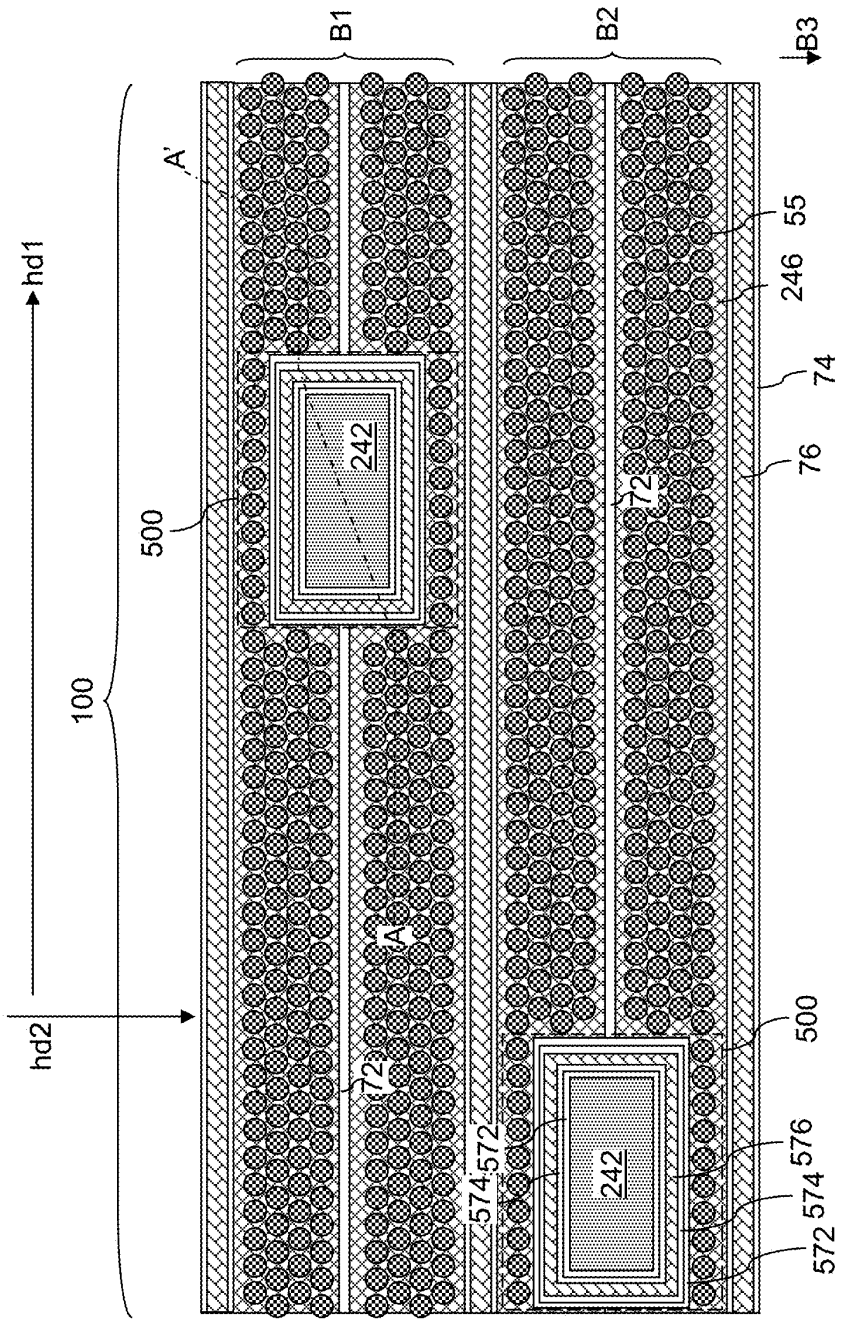

FIG. 38B

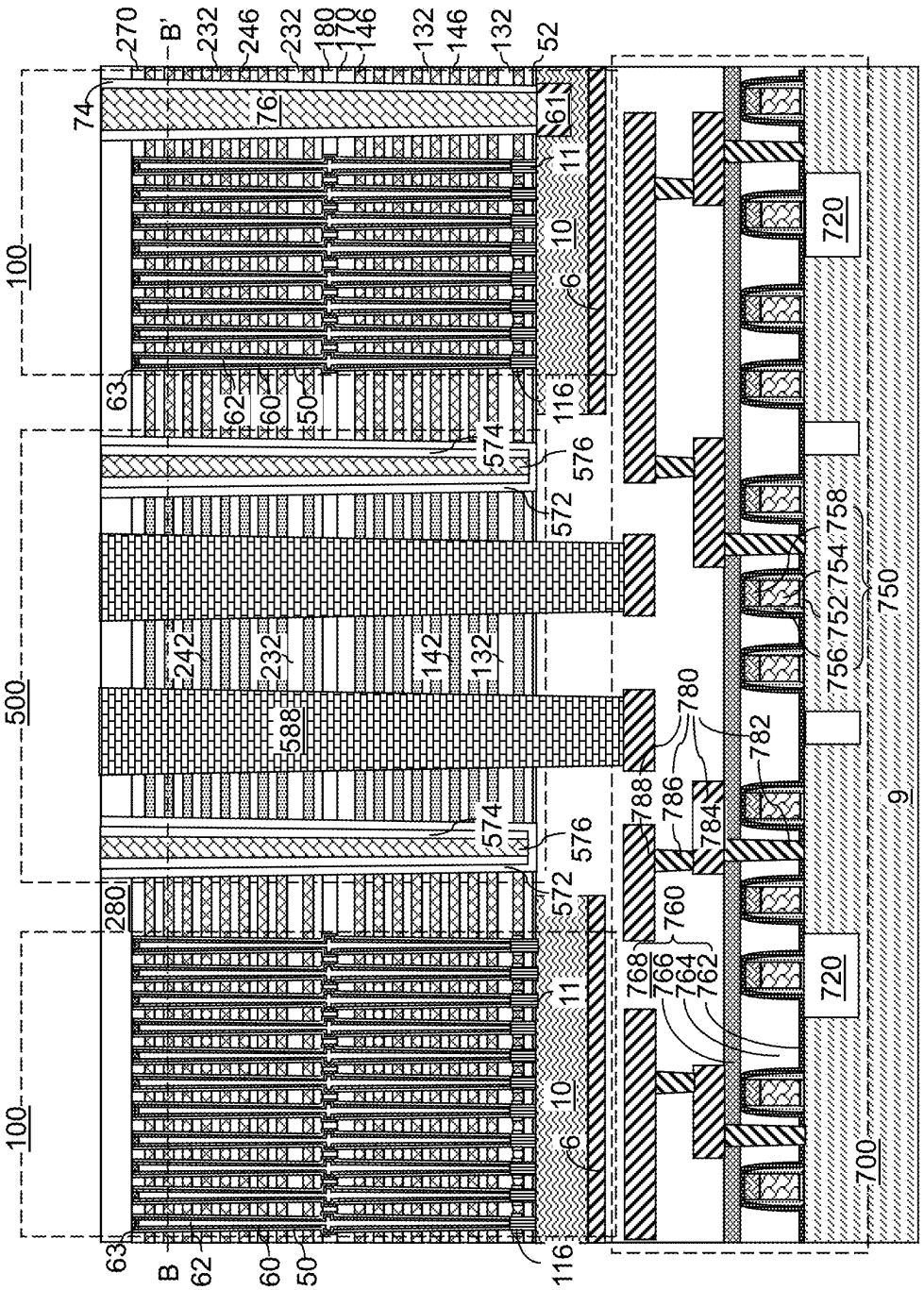
270
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FIG. 39A

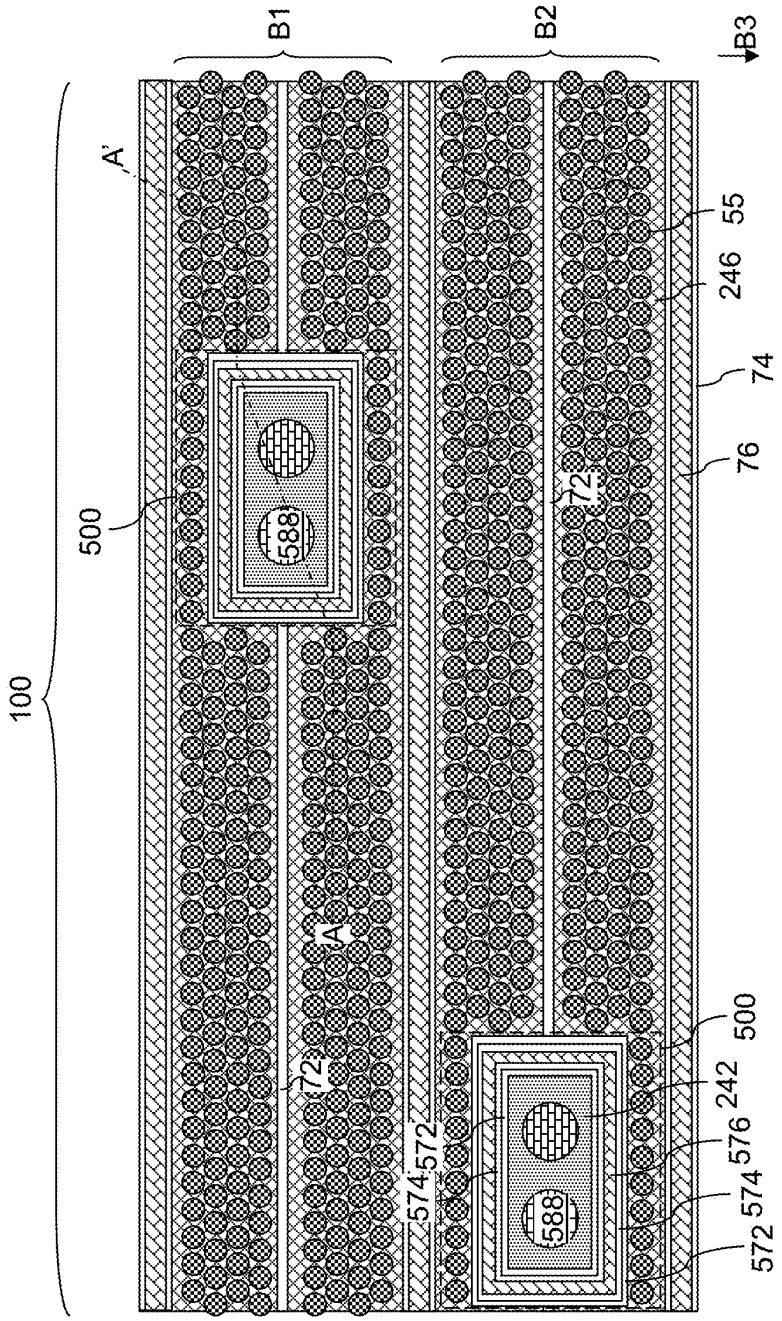

FIG. 39B

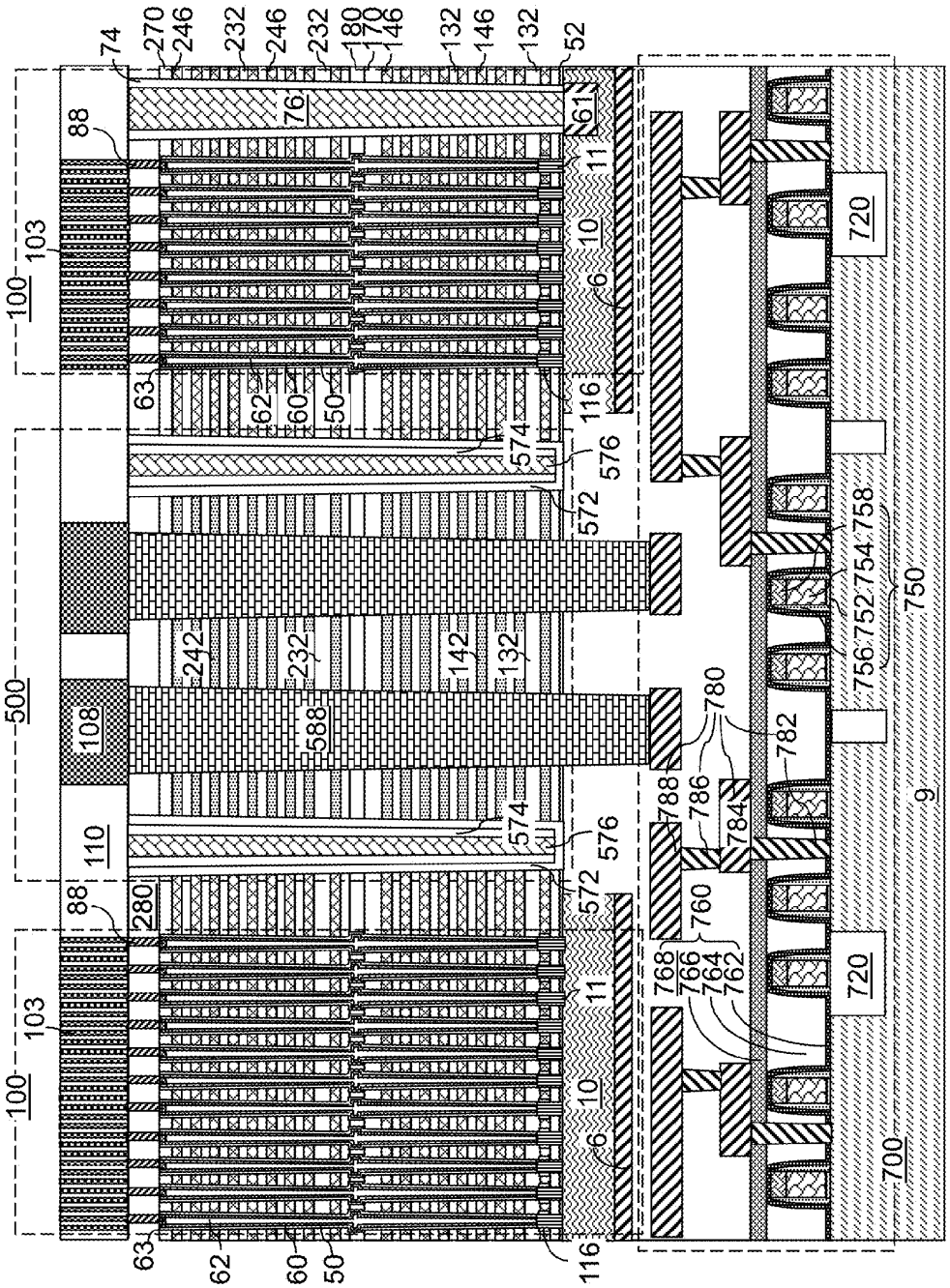
74
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FIG. 40

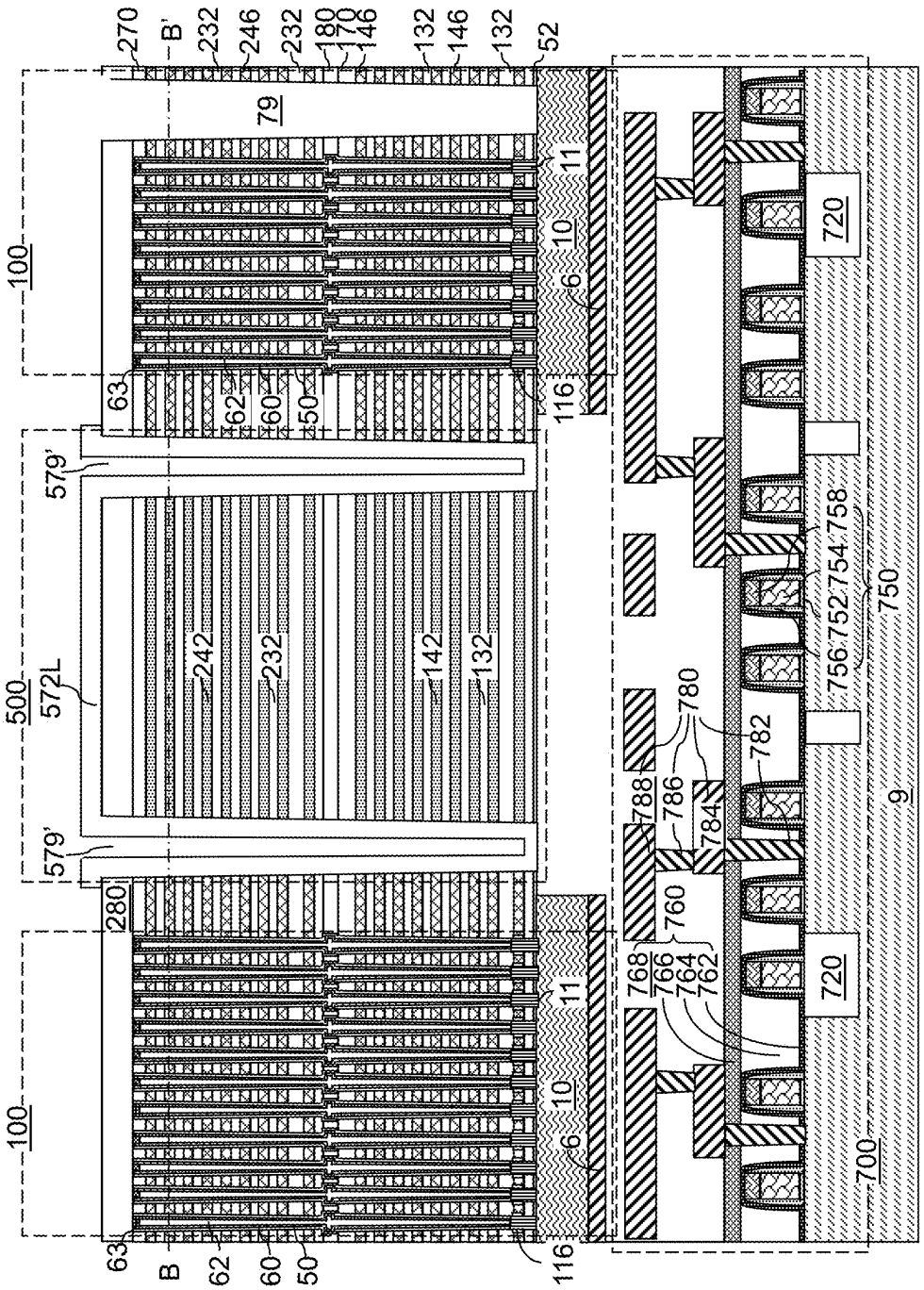
270
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FIG. 41

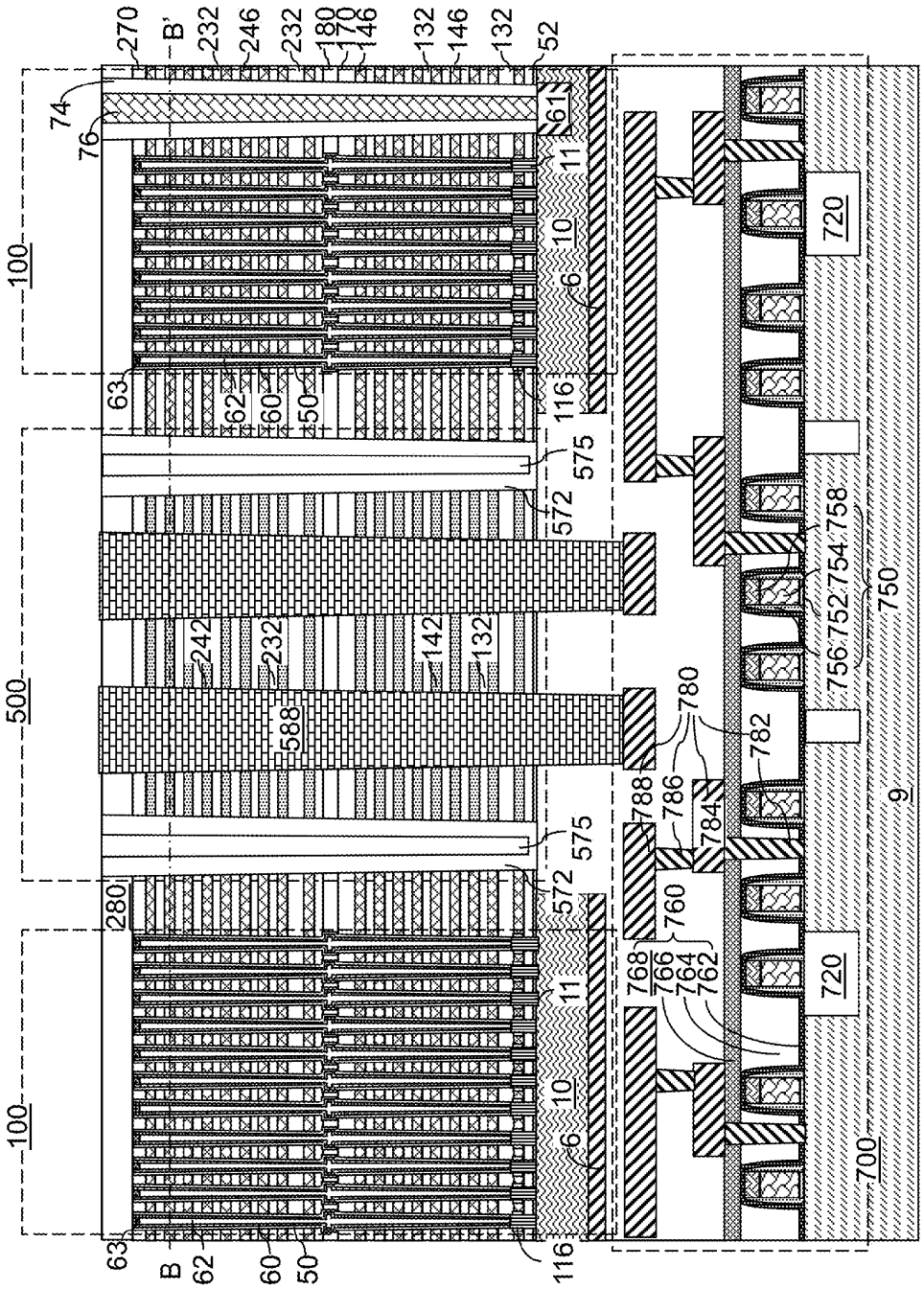
270
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FIG. 42

Micron Ex. 1011, p. 81
Micron v. YMTC
IPR2025-00191

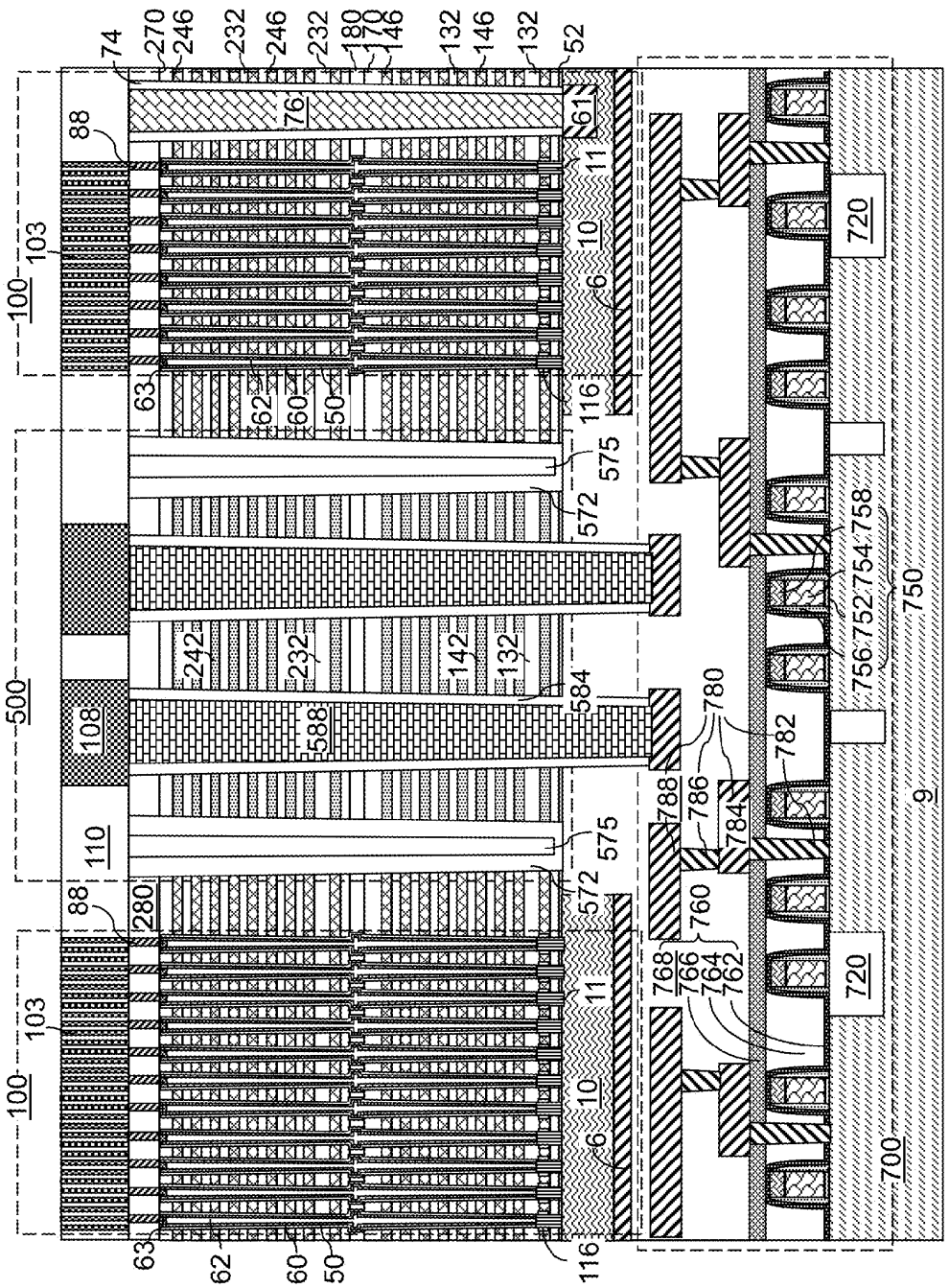
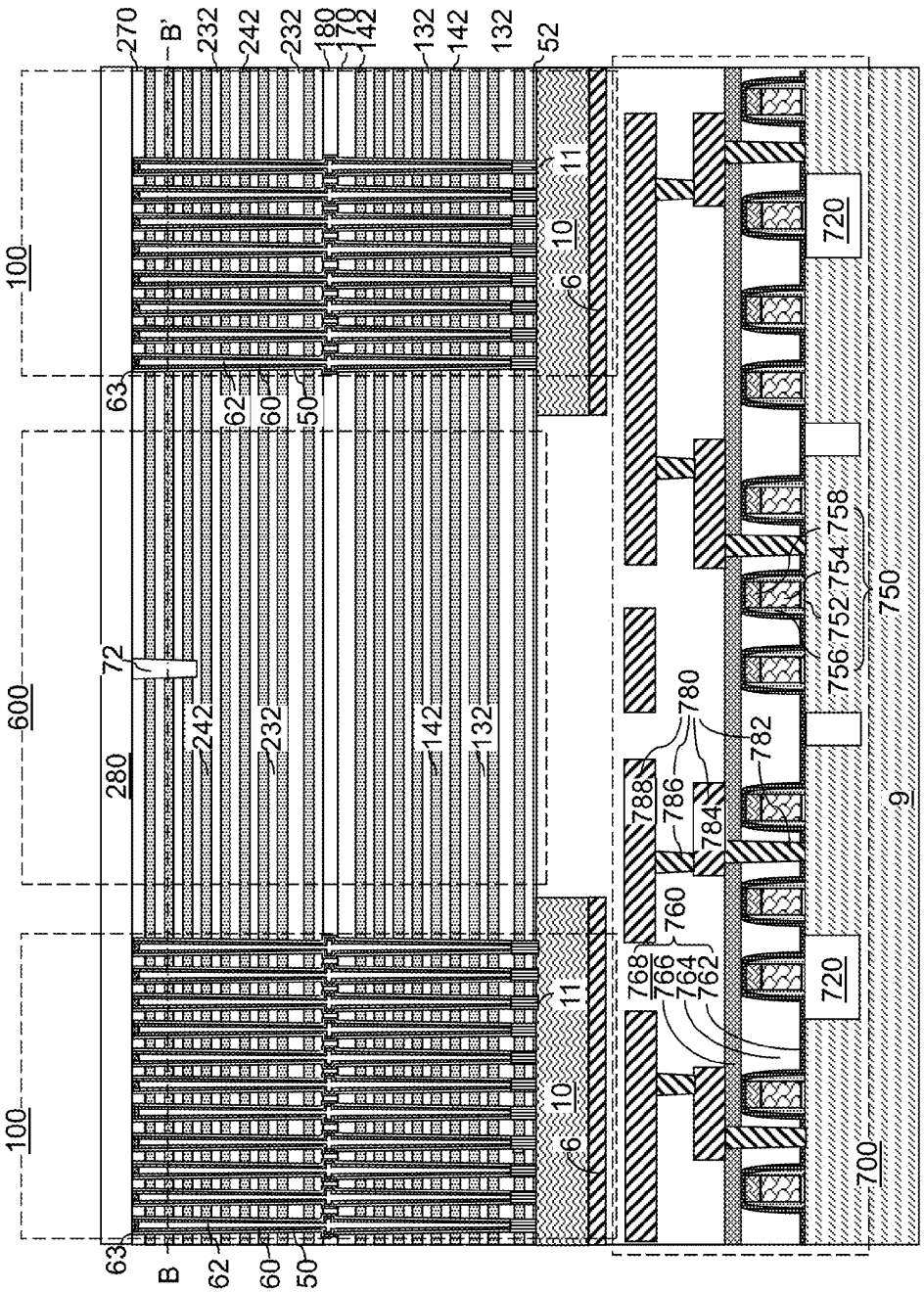


FIG. 43


100
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62
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72
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FIG. 44A

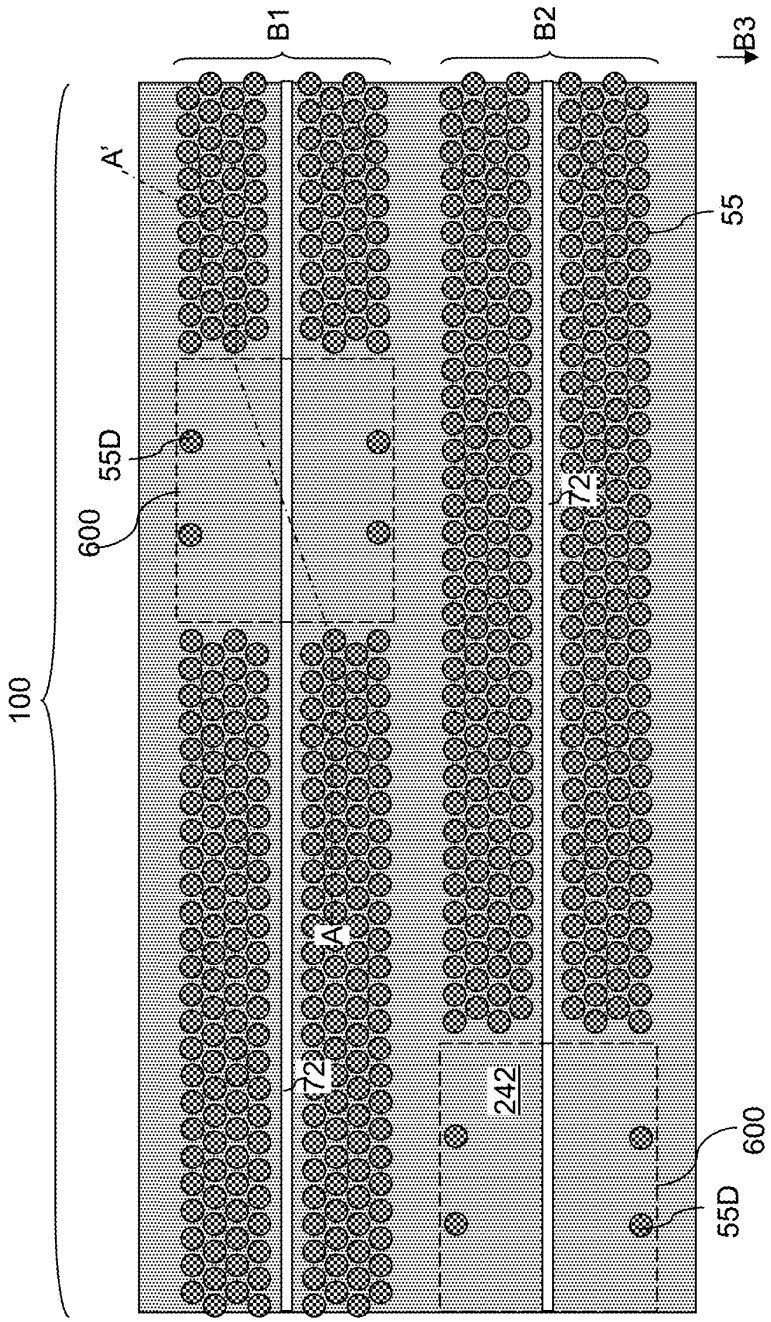

FIG. 44B

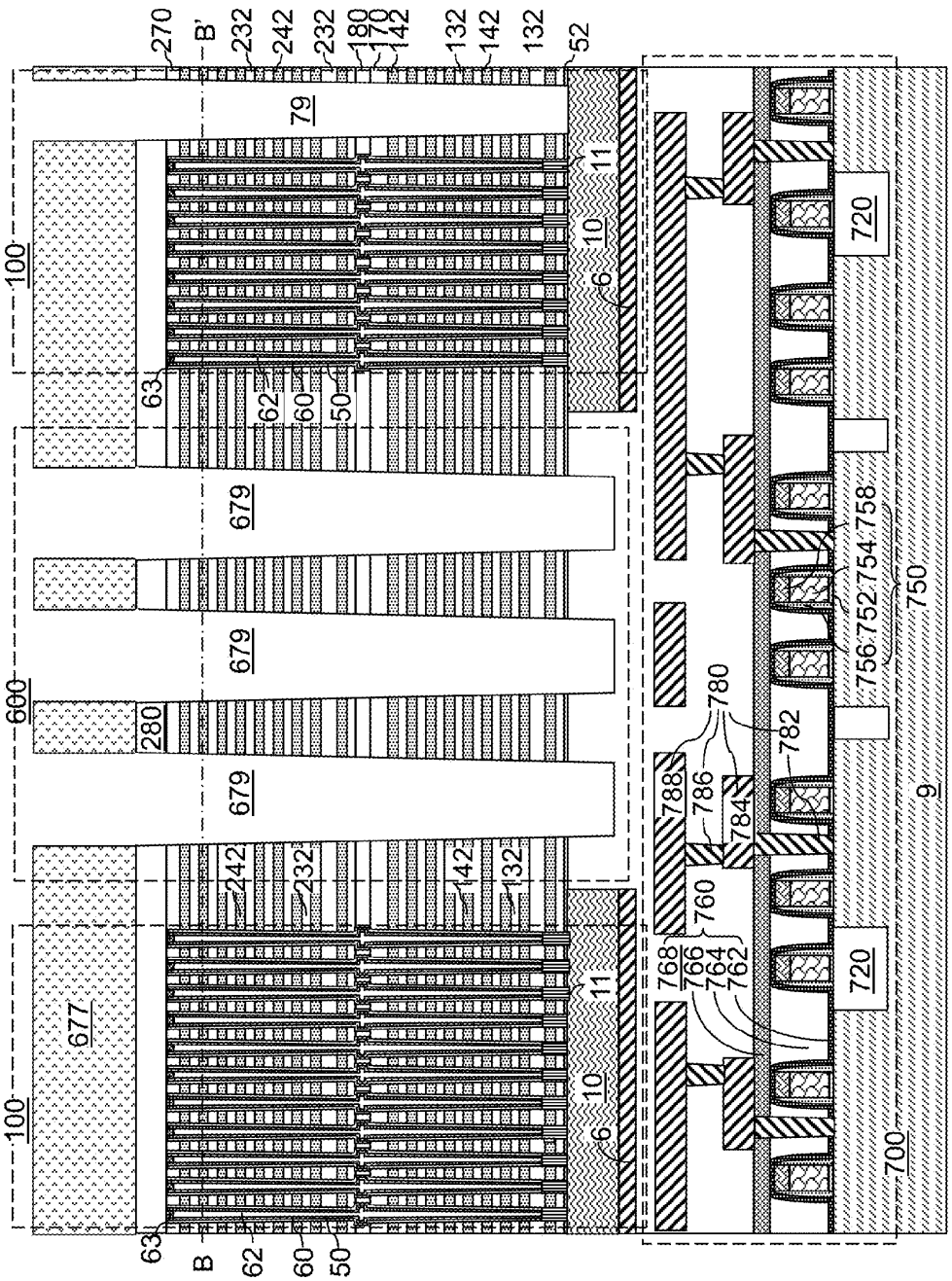
270
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FIG. 45A

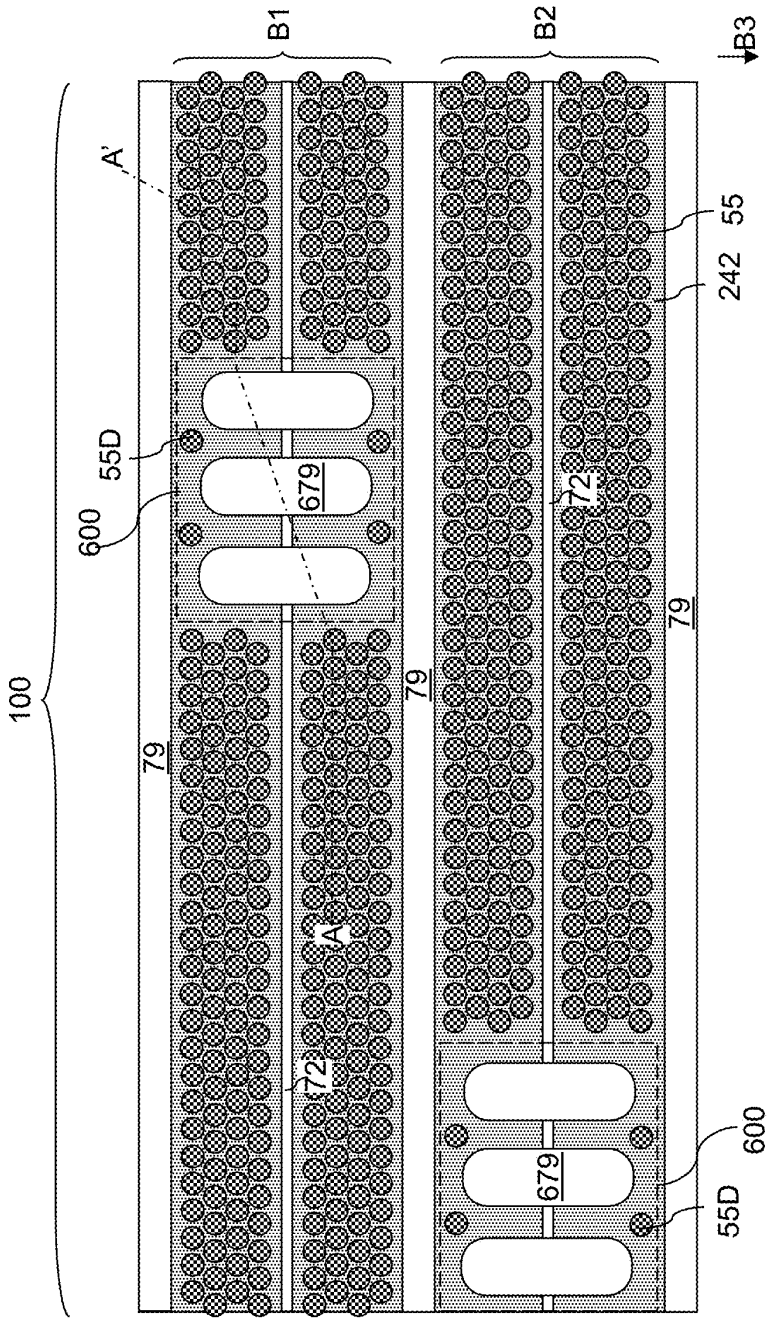

FIG. 45B

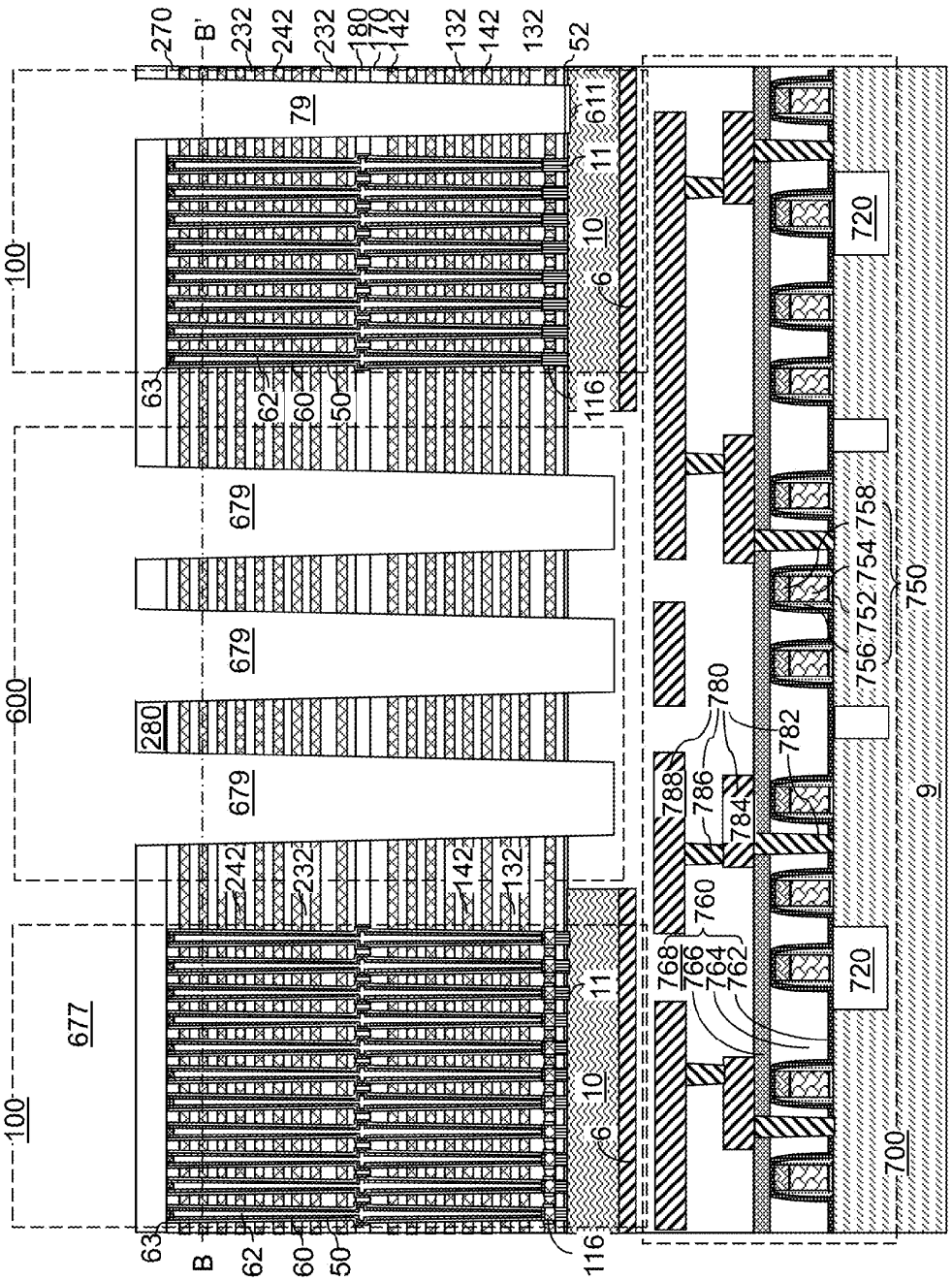
270
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FIG. 46A

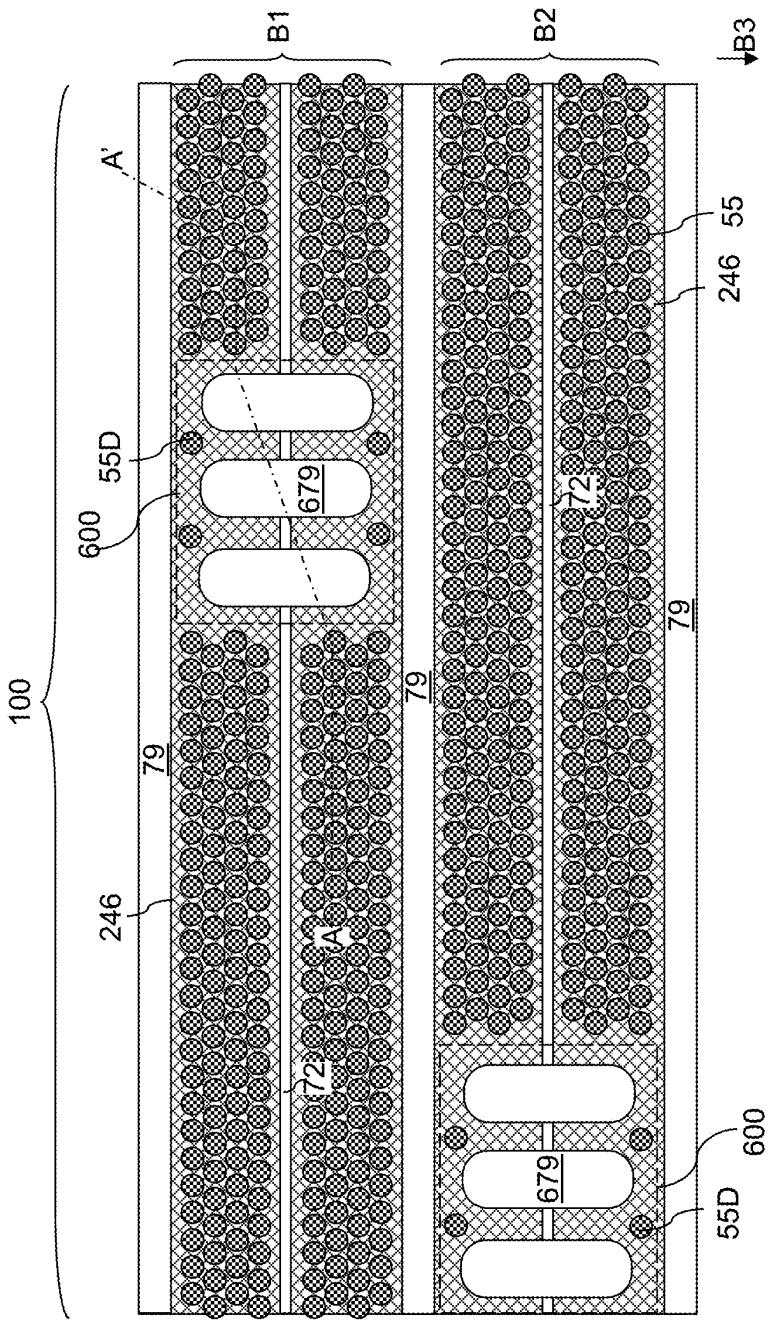
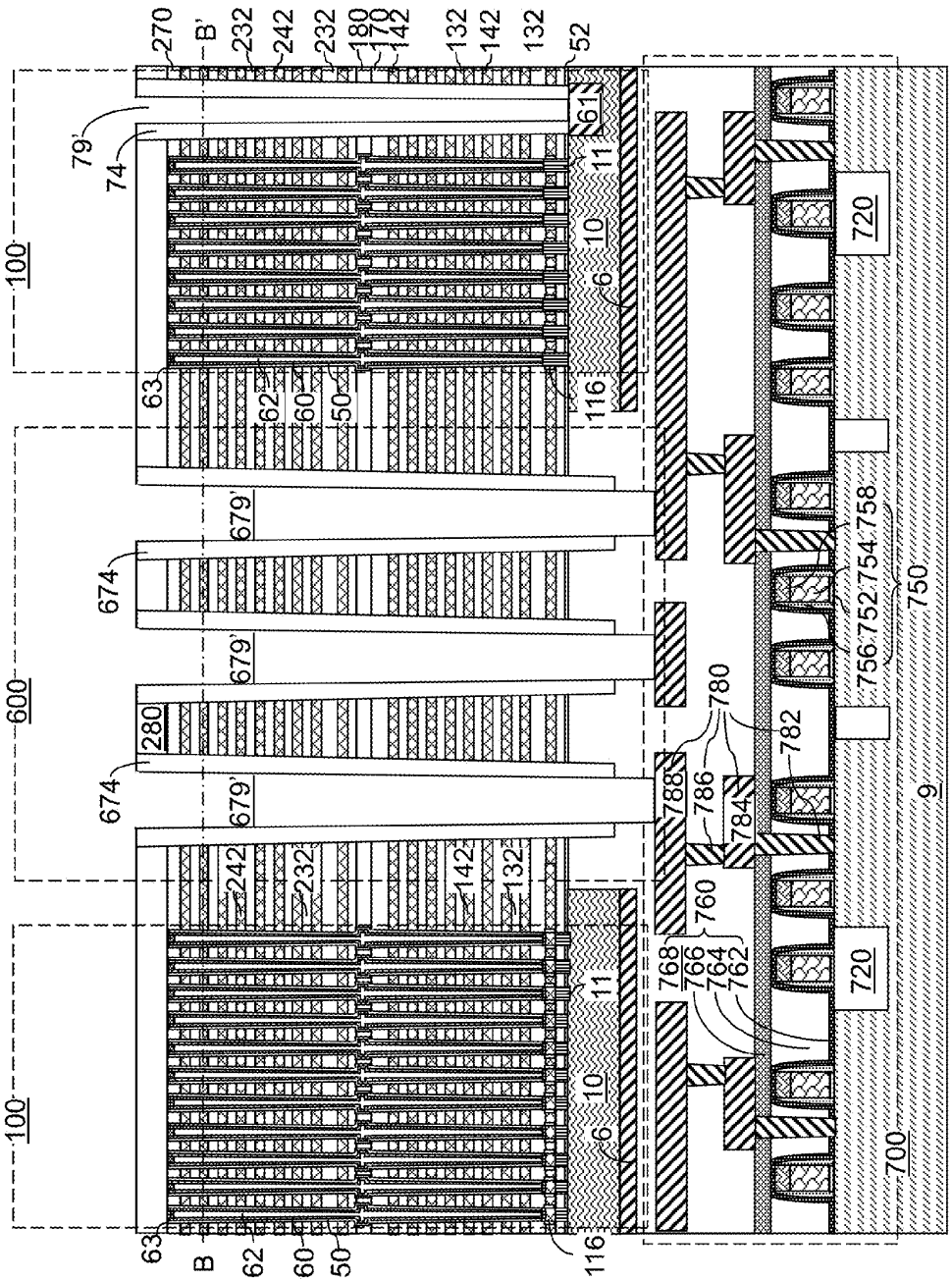


FIG. 46B


270
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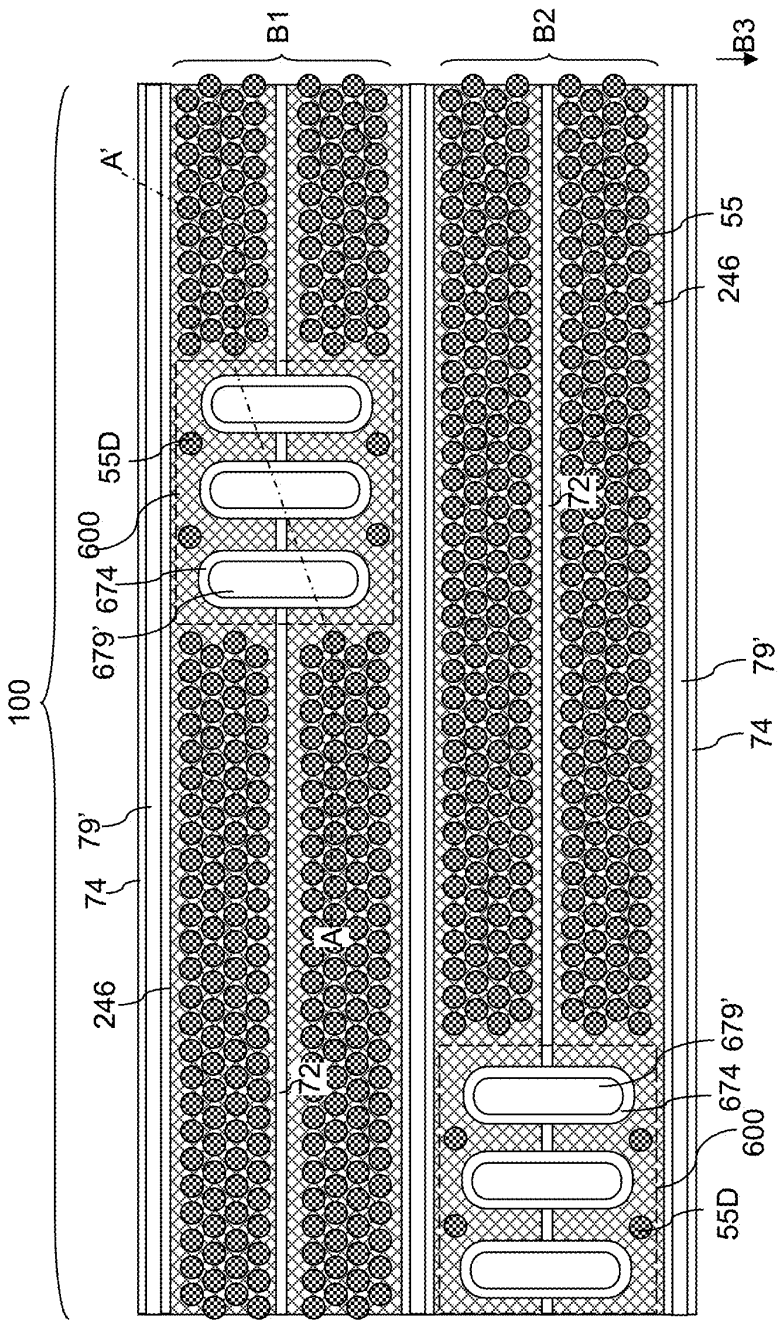
B

FIG. 47A


100
A'
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79'
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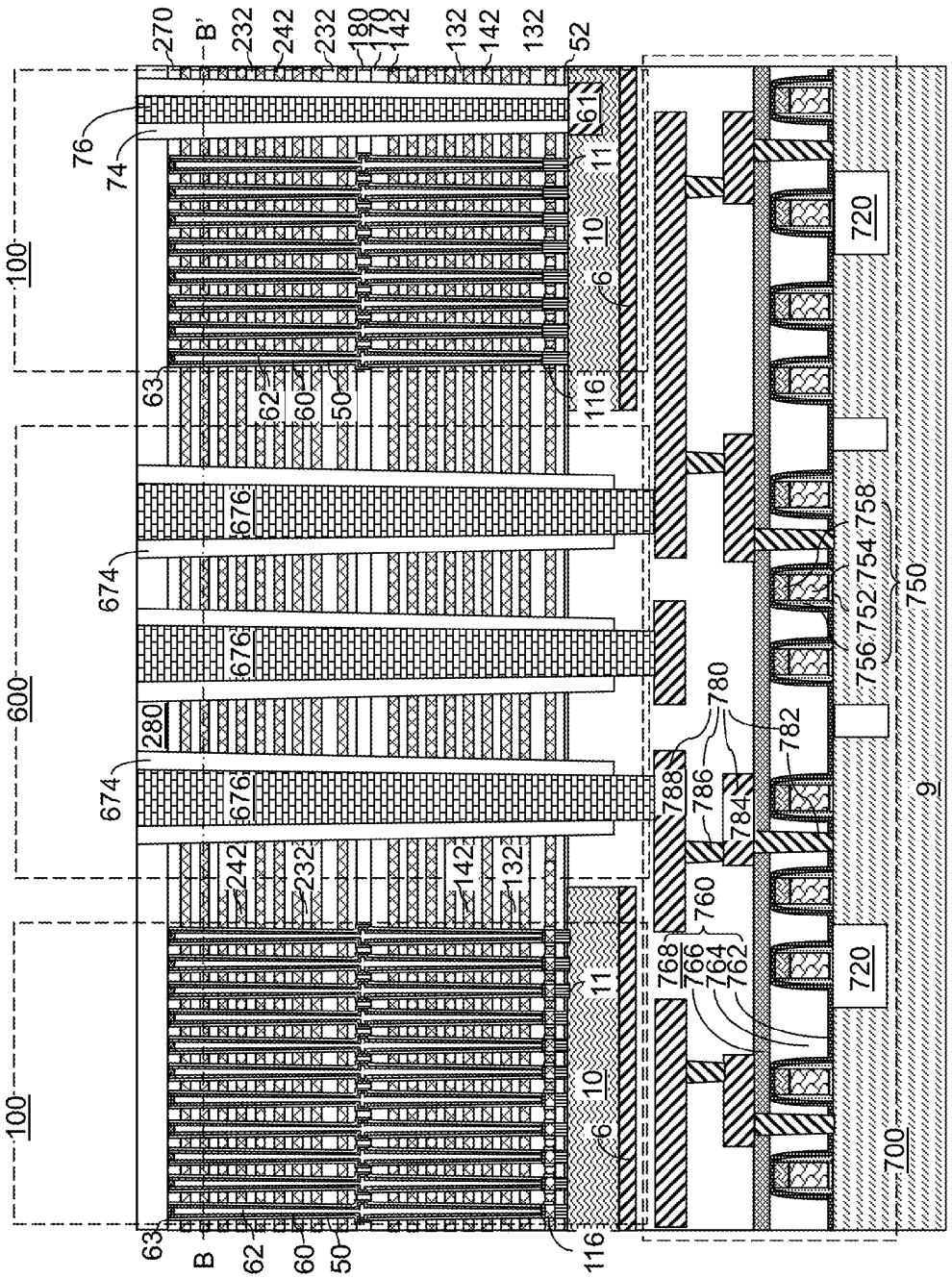
A
55
246
72
79'
74
679'
674
600
55D

FIG. 47B


270
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676
674
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674
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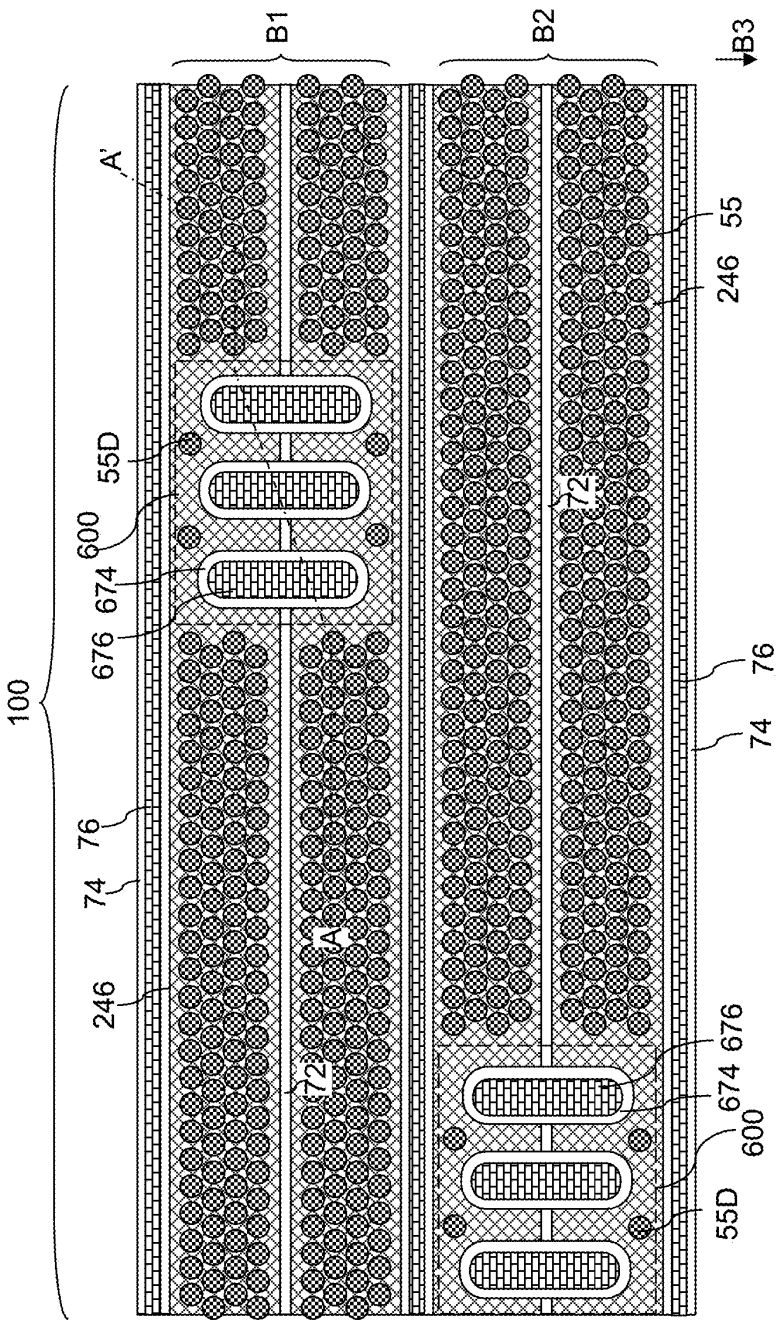
FIG. 48A


100
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B2
B3
55D
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74
246
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246
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676
674
600
55D

FIG. 48B

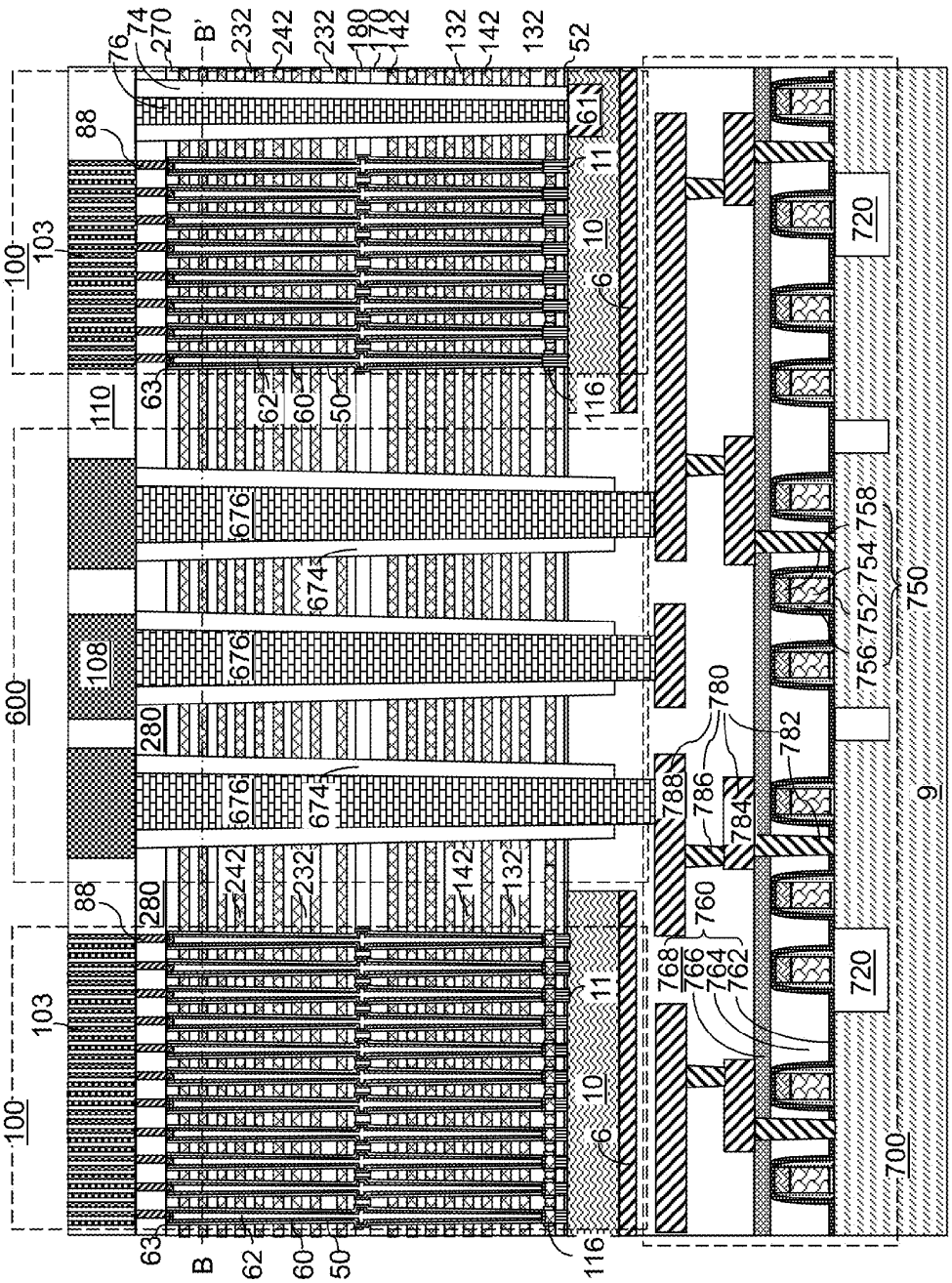
76
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FIG. 49

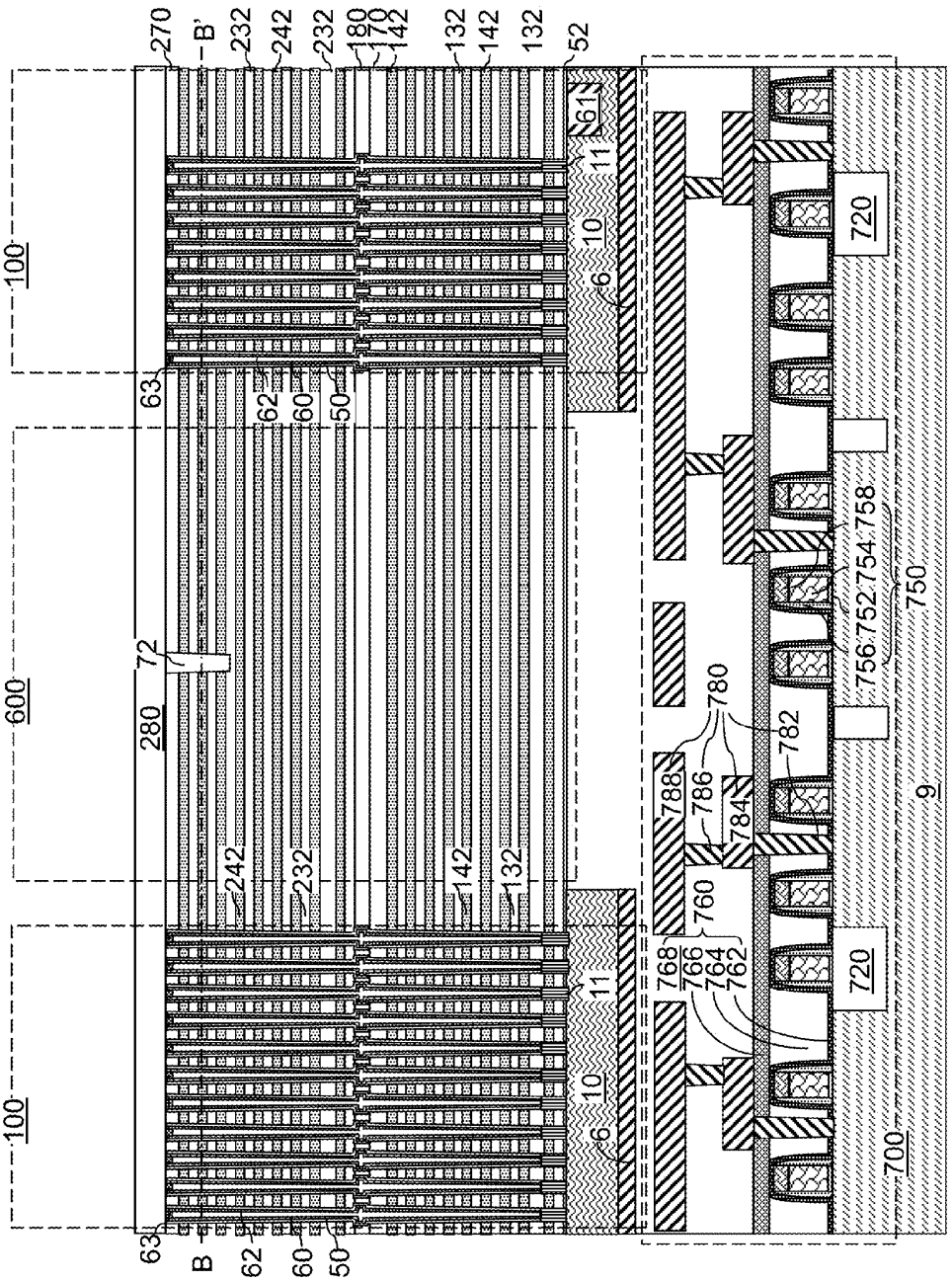
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FIG. 50A

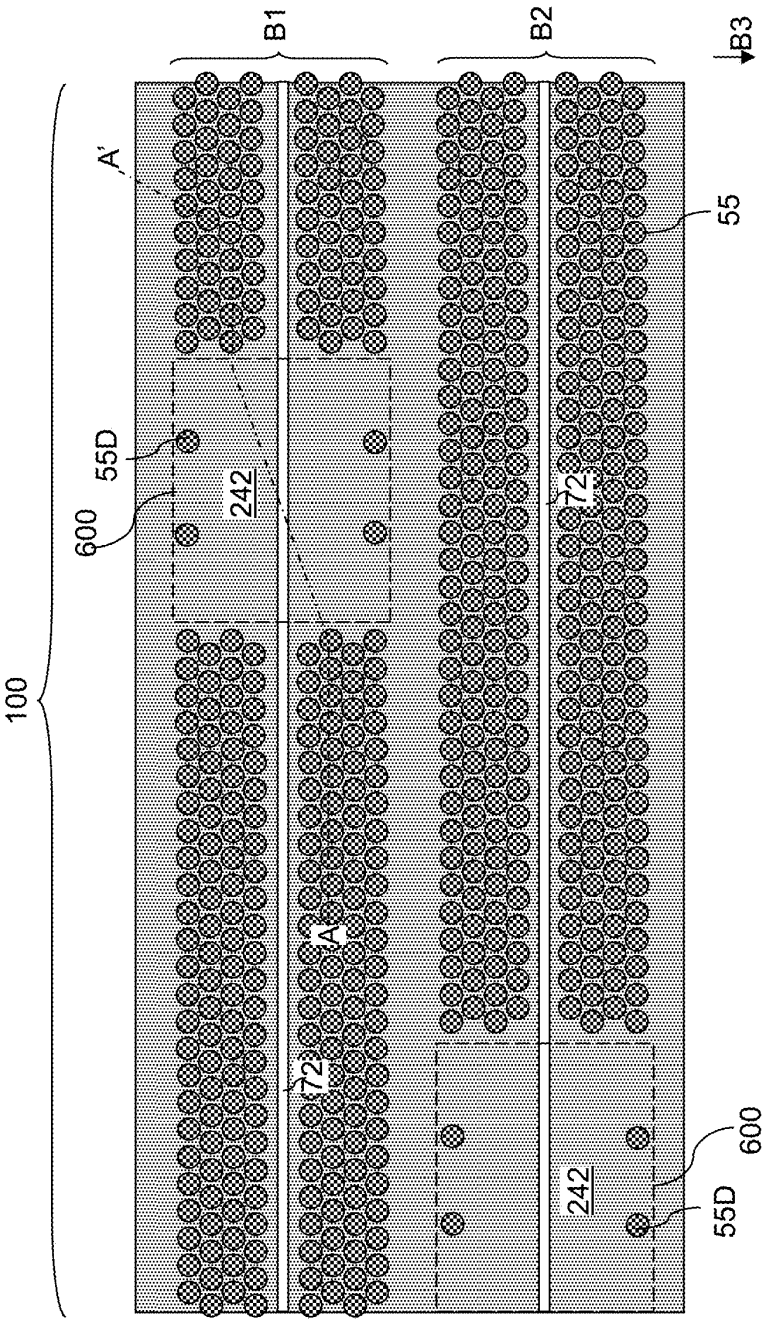

FIG. 50B

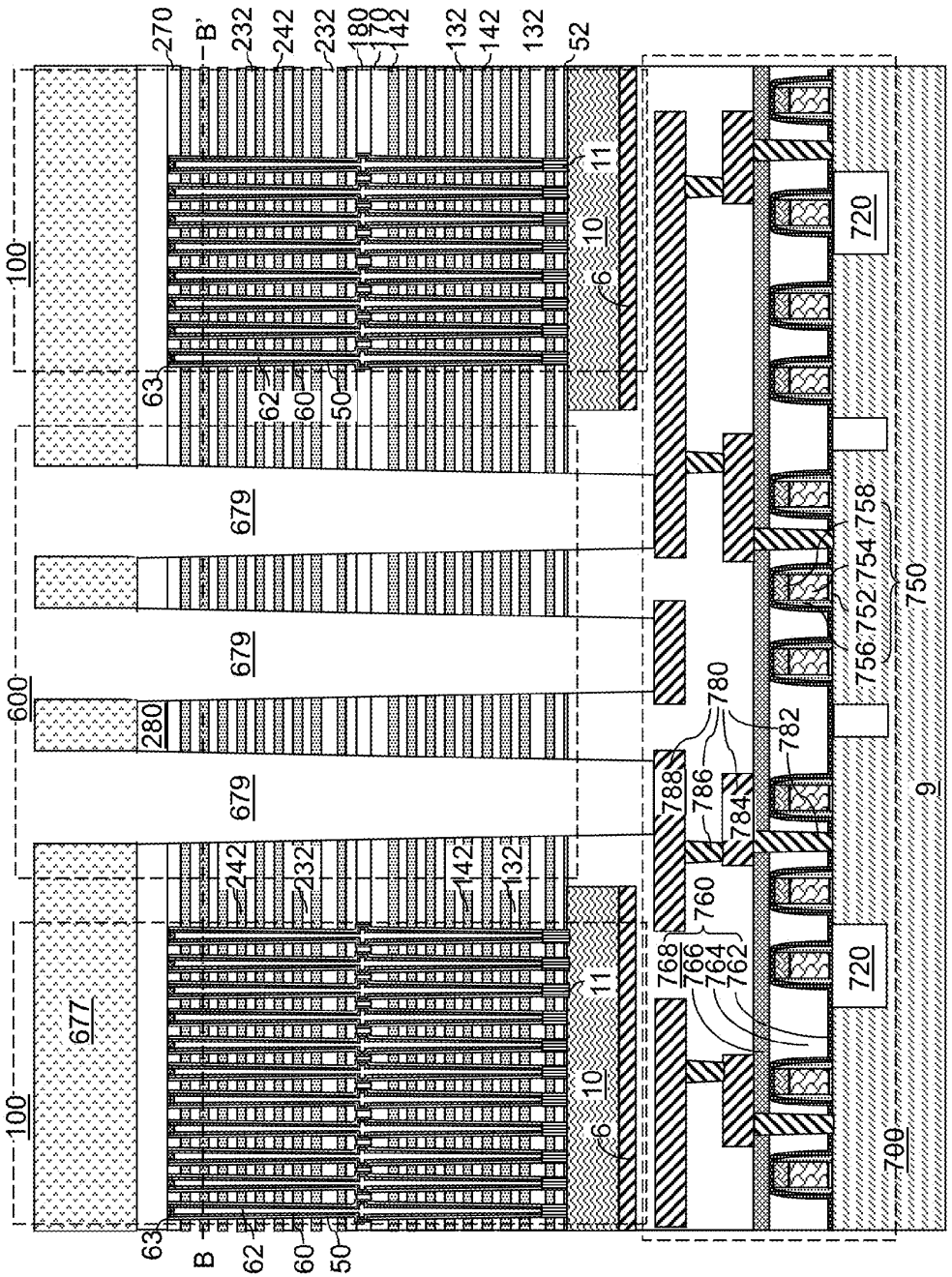
270
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FIG. 51A

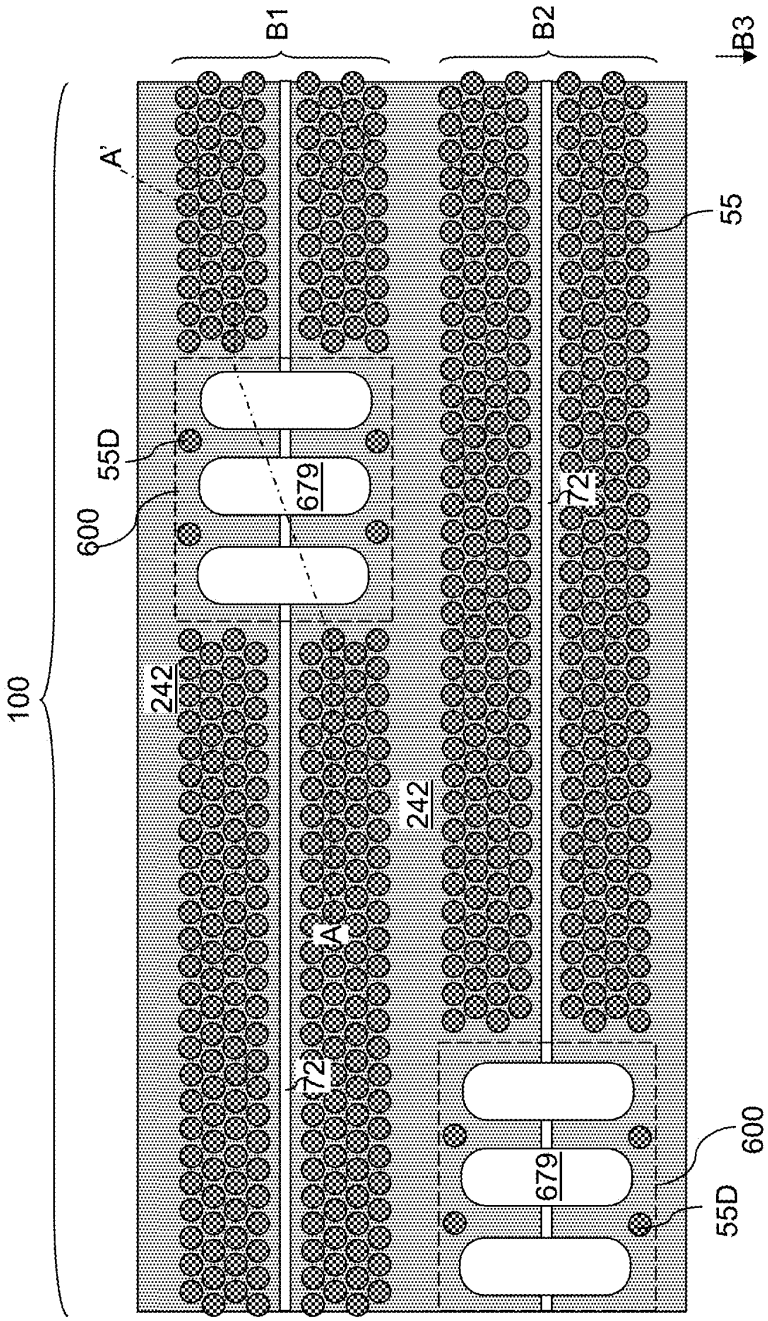

FIG. 51B

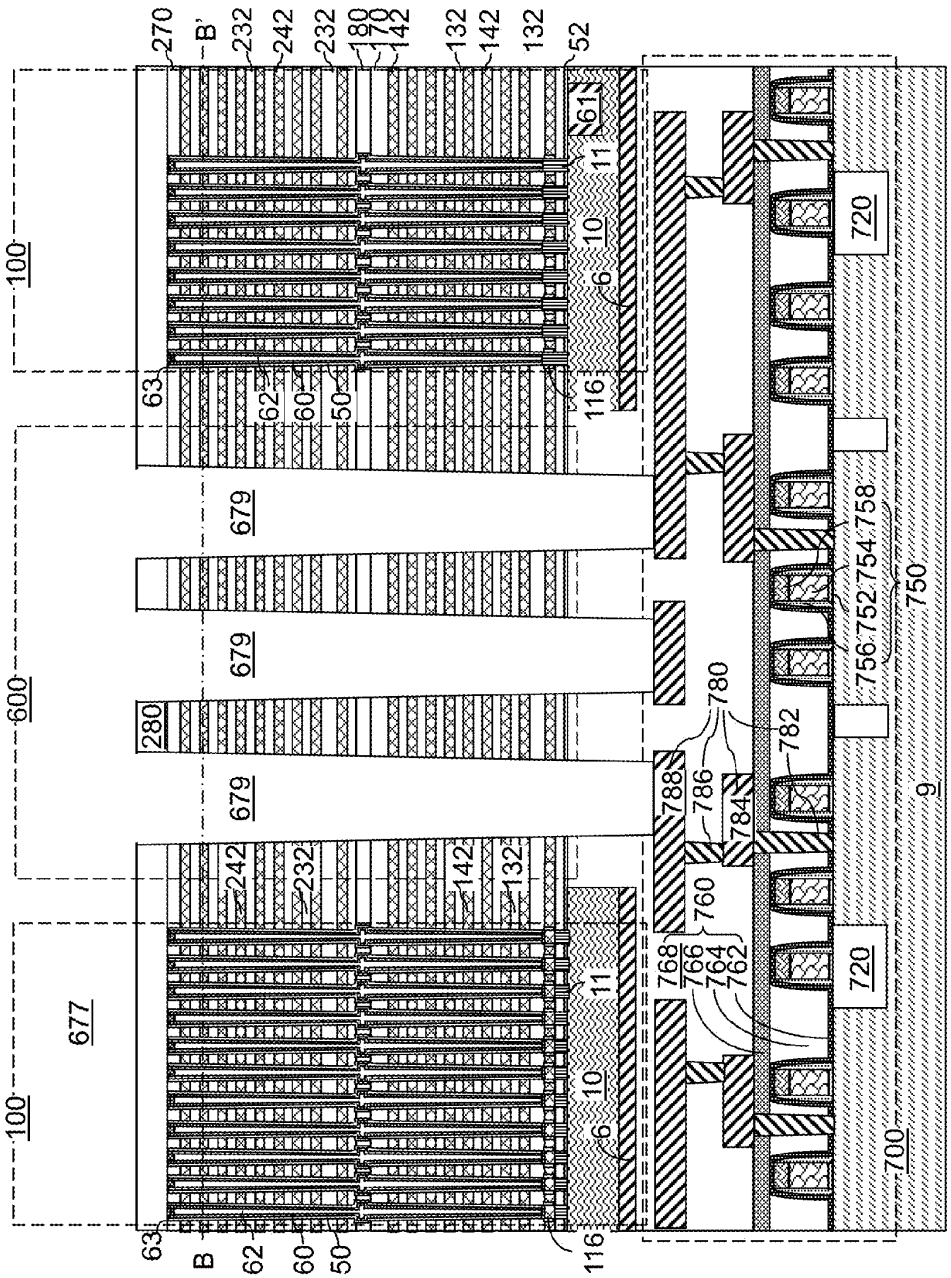
100
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FIG. 52A

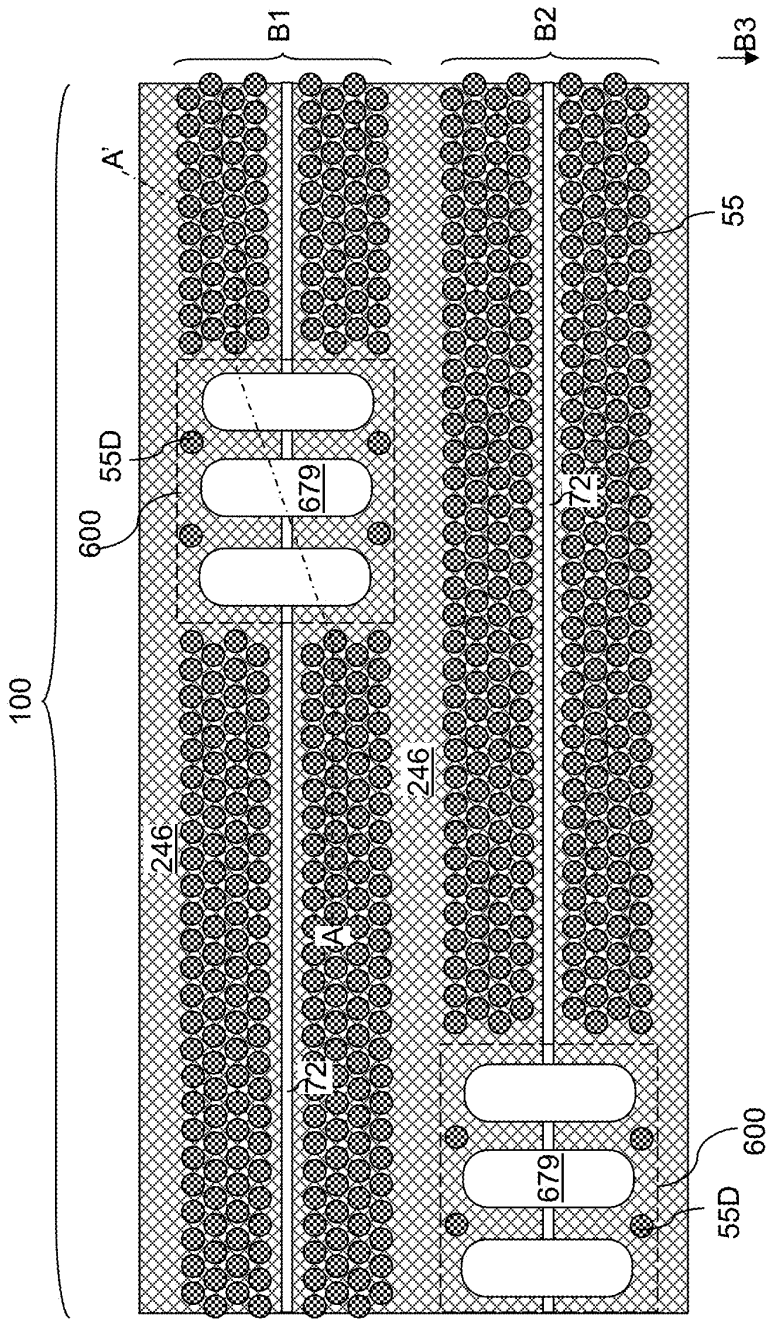
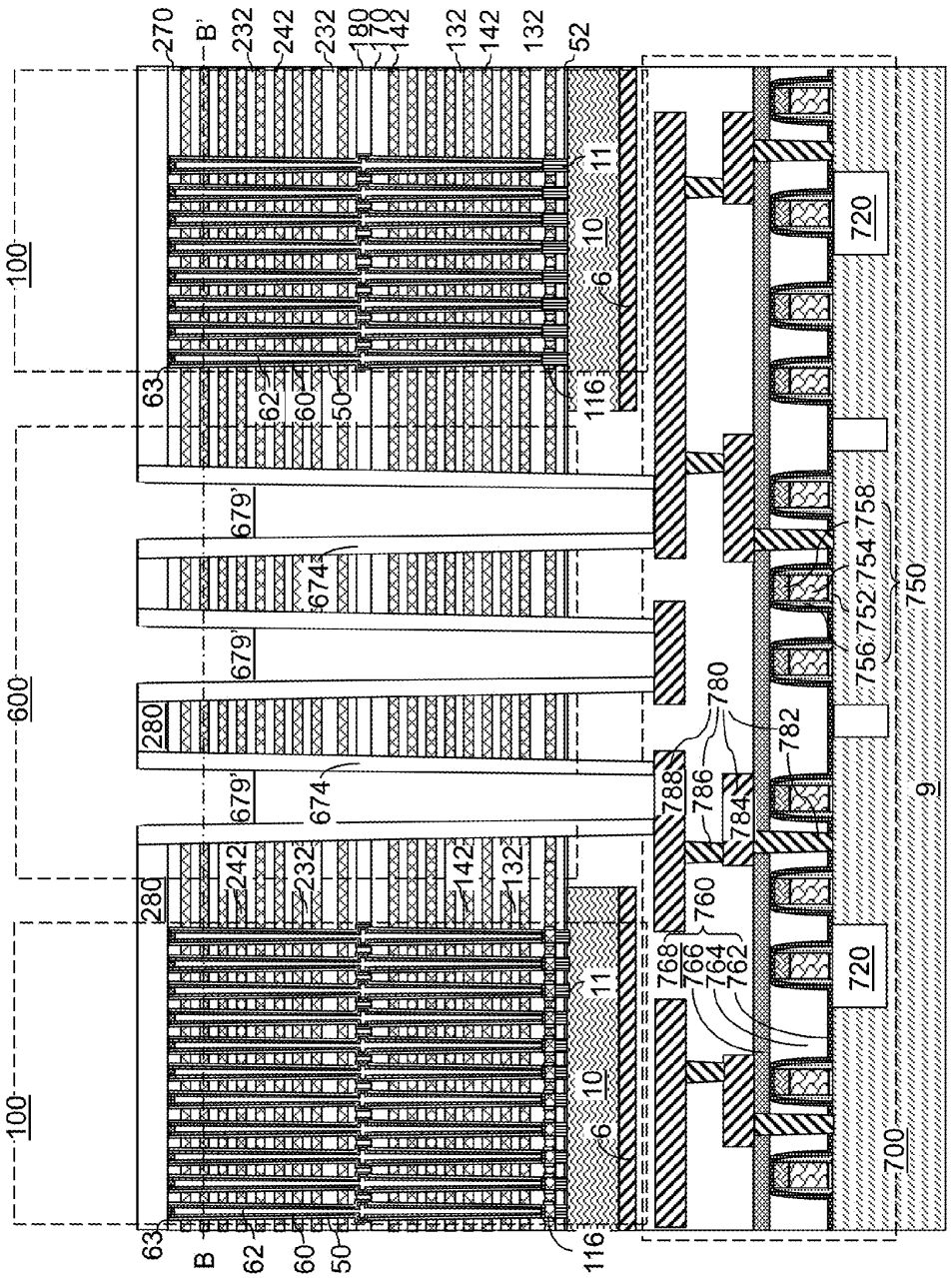


FIG. 52B


270
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142
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679'
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679'
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FIG. 53A

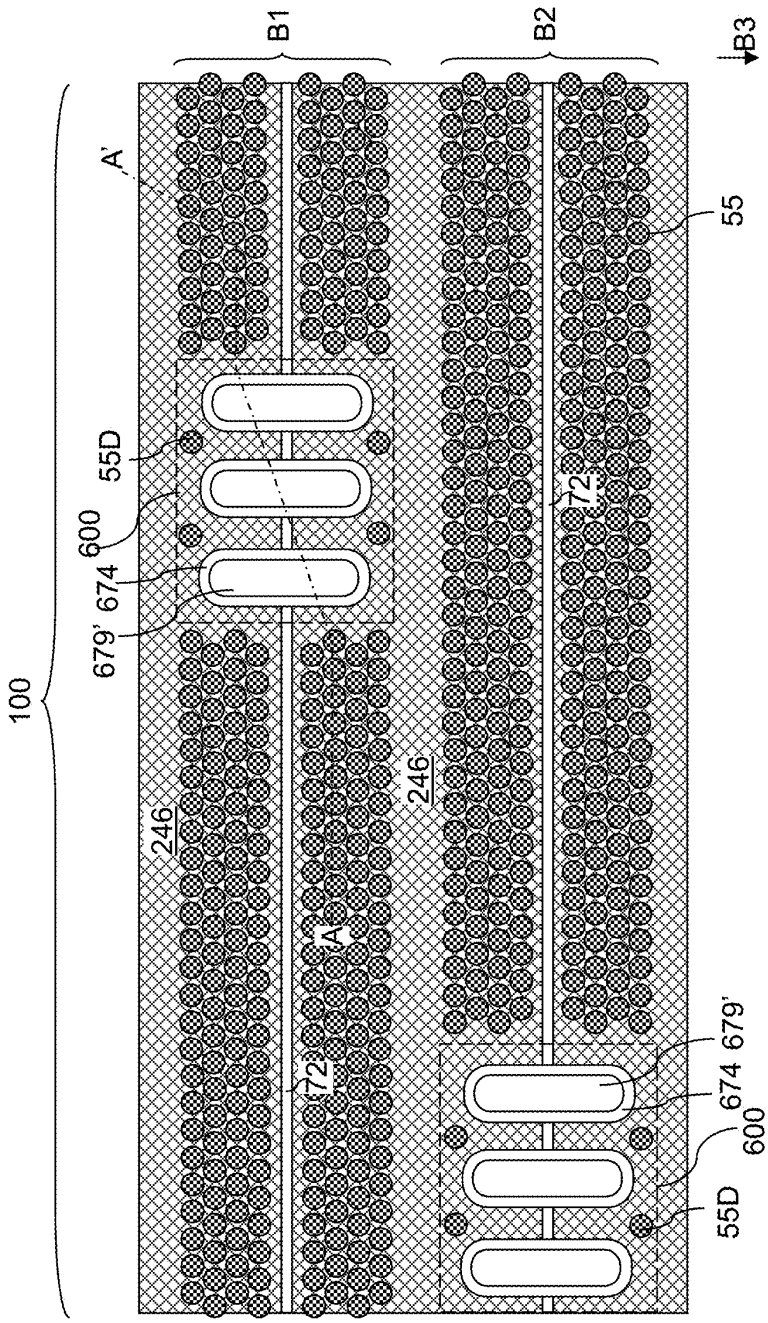

FIG. 53B

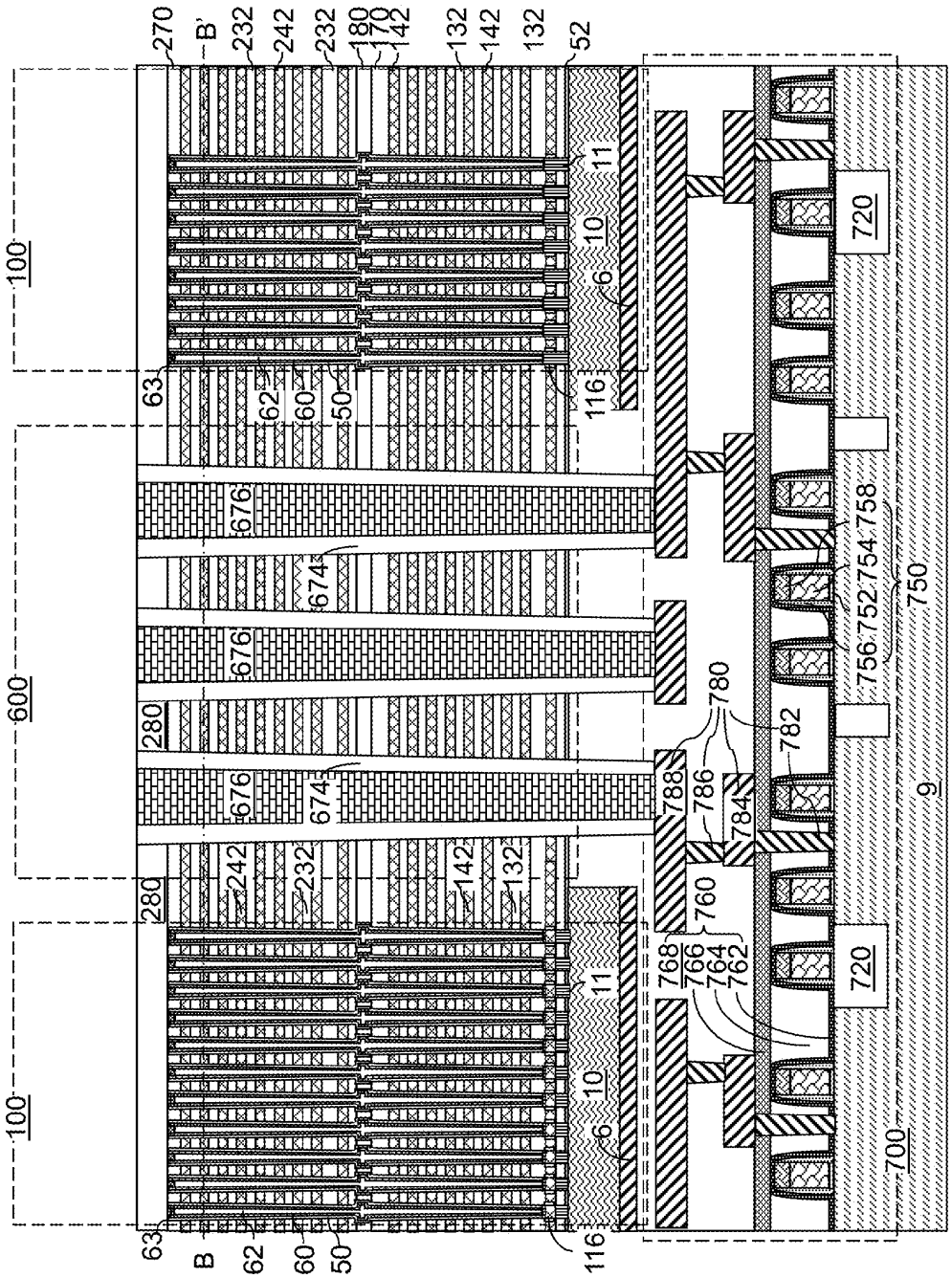
100
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FIG. 54A

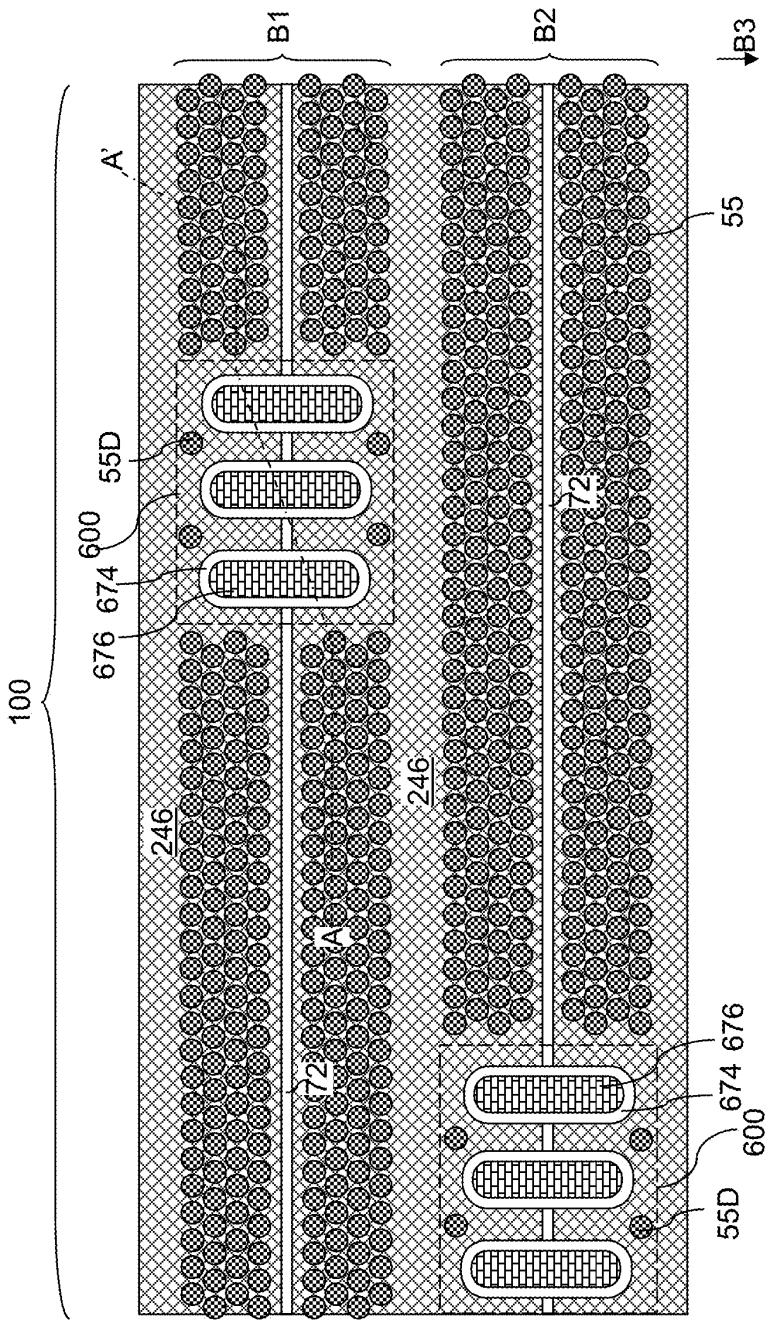

FIG. 54B

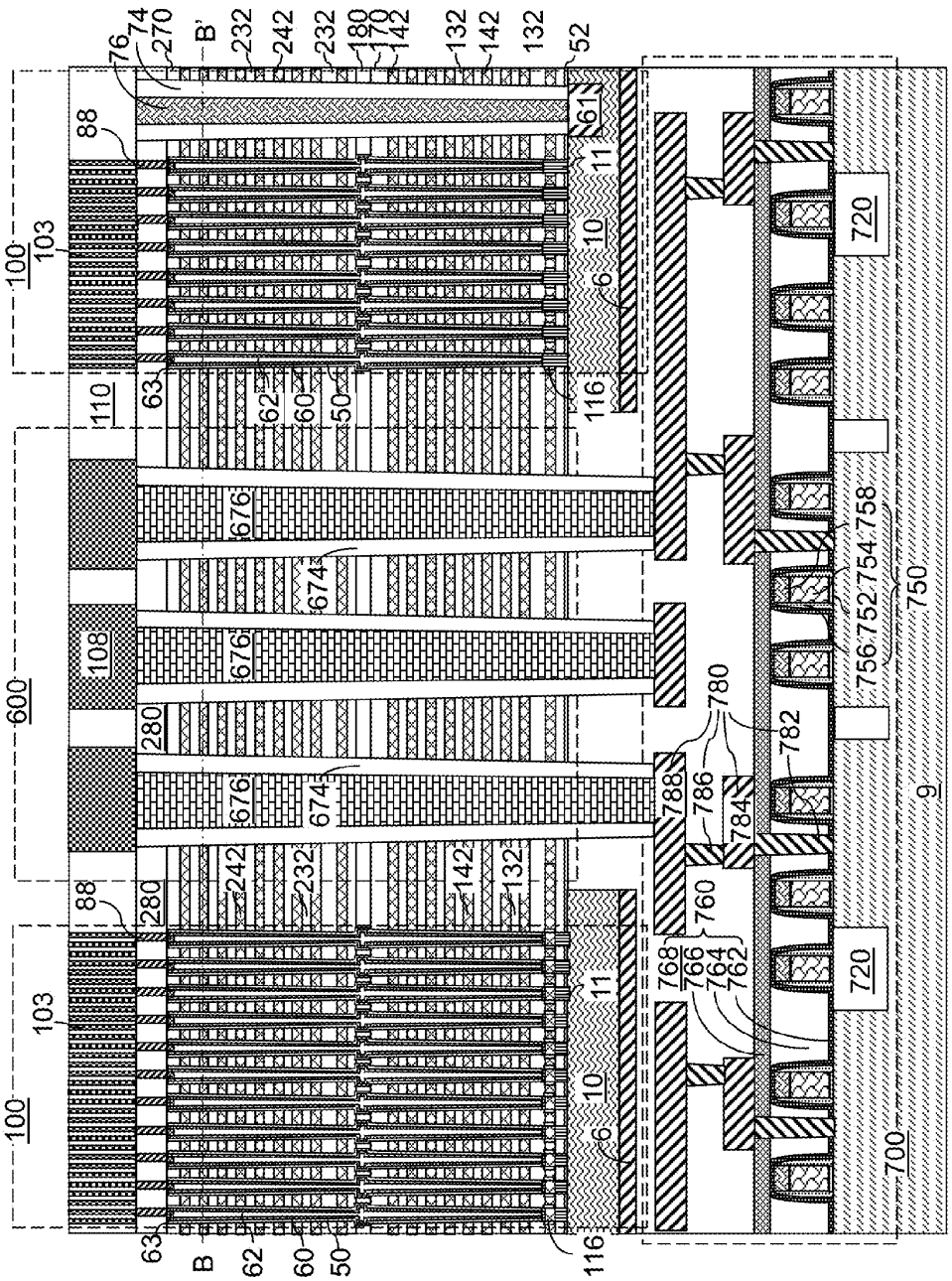
100
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FIG. 55A

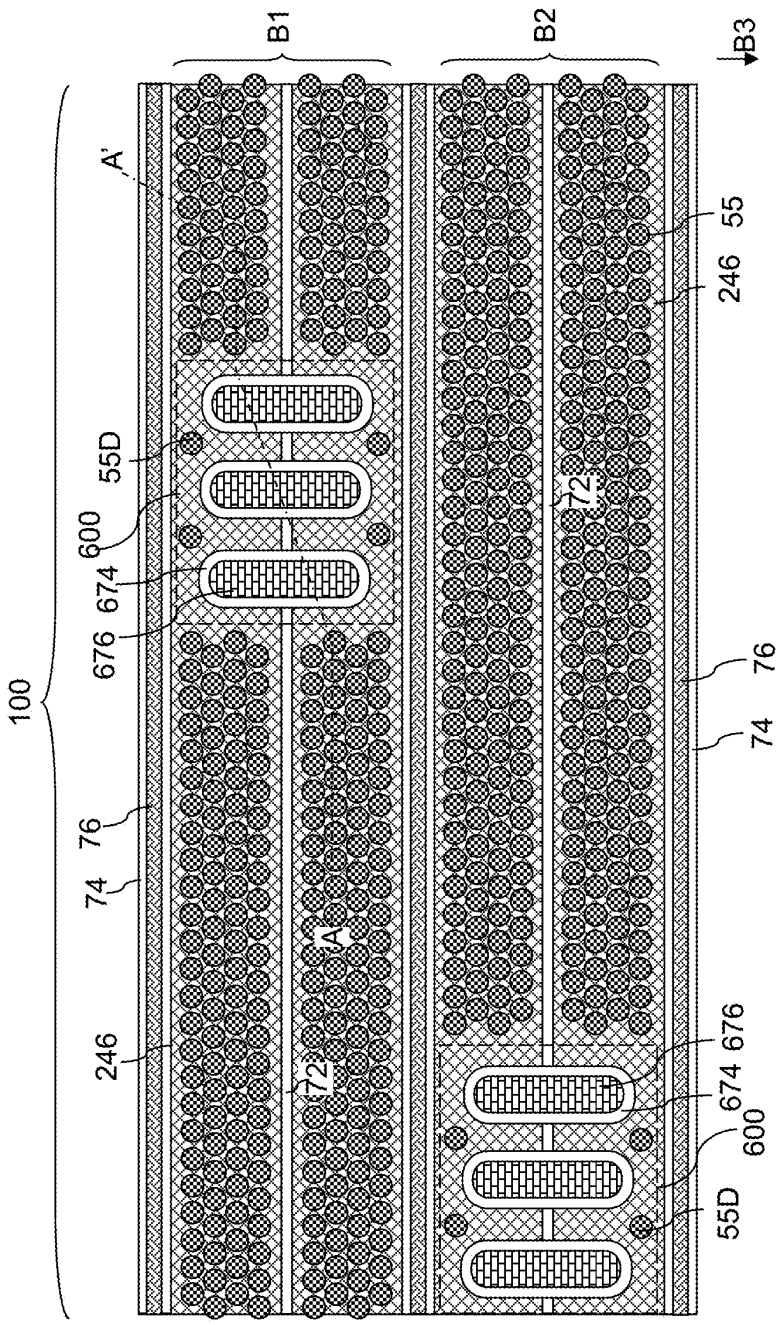

FIG. 55B

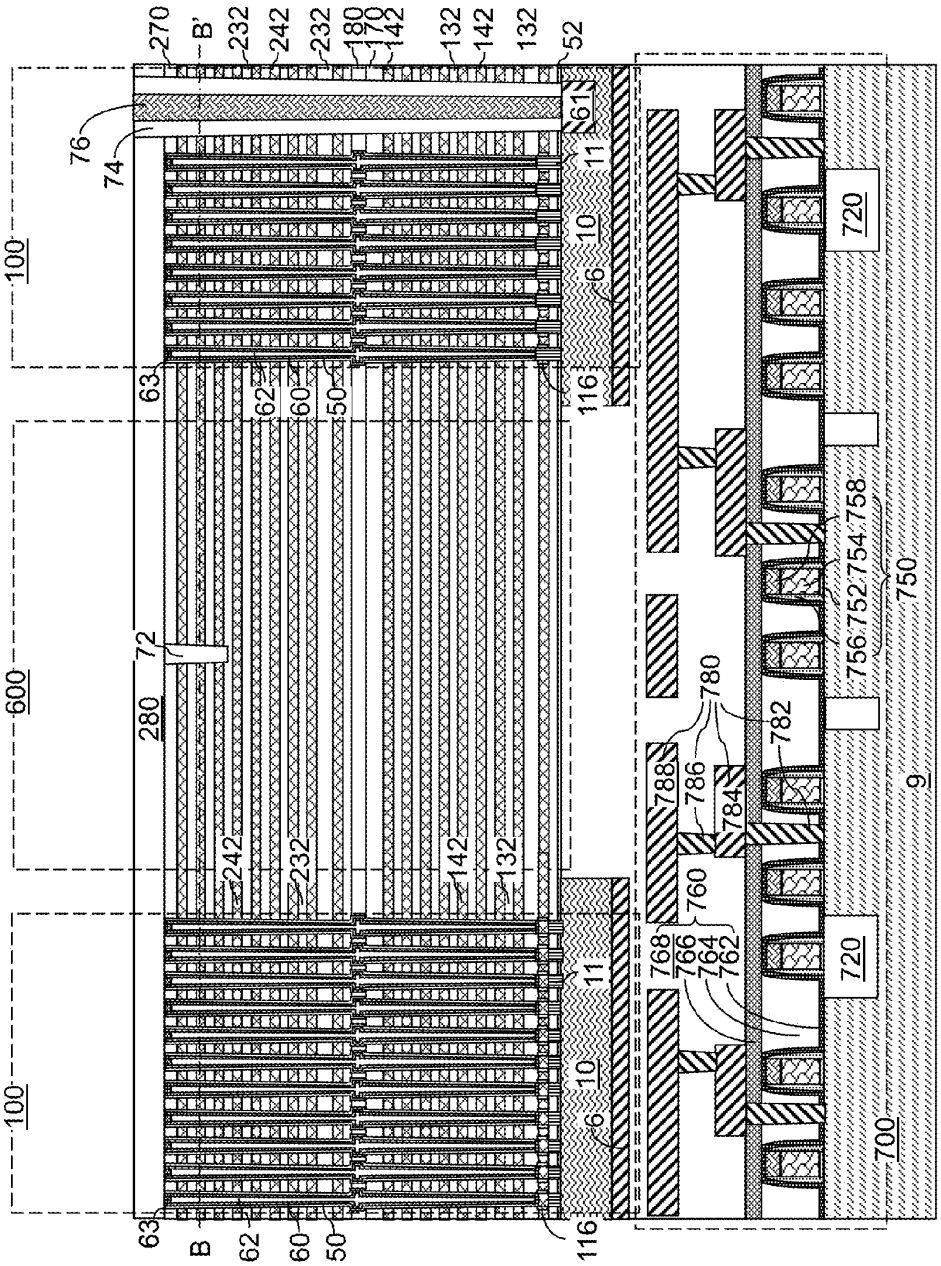
270
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FIG. 56A

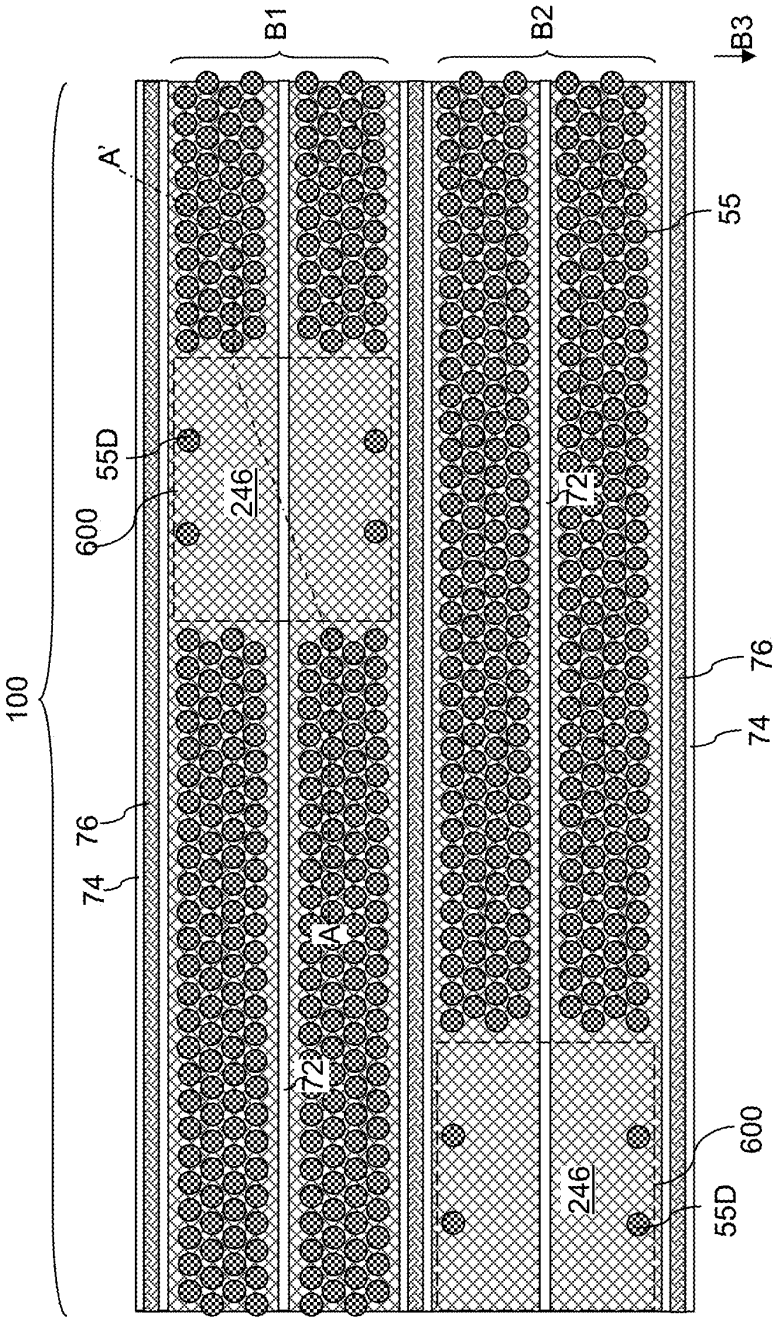

FIG. 56B

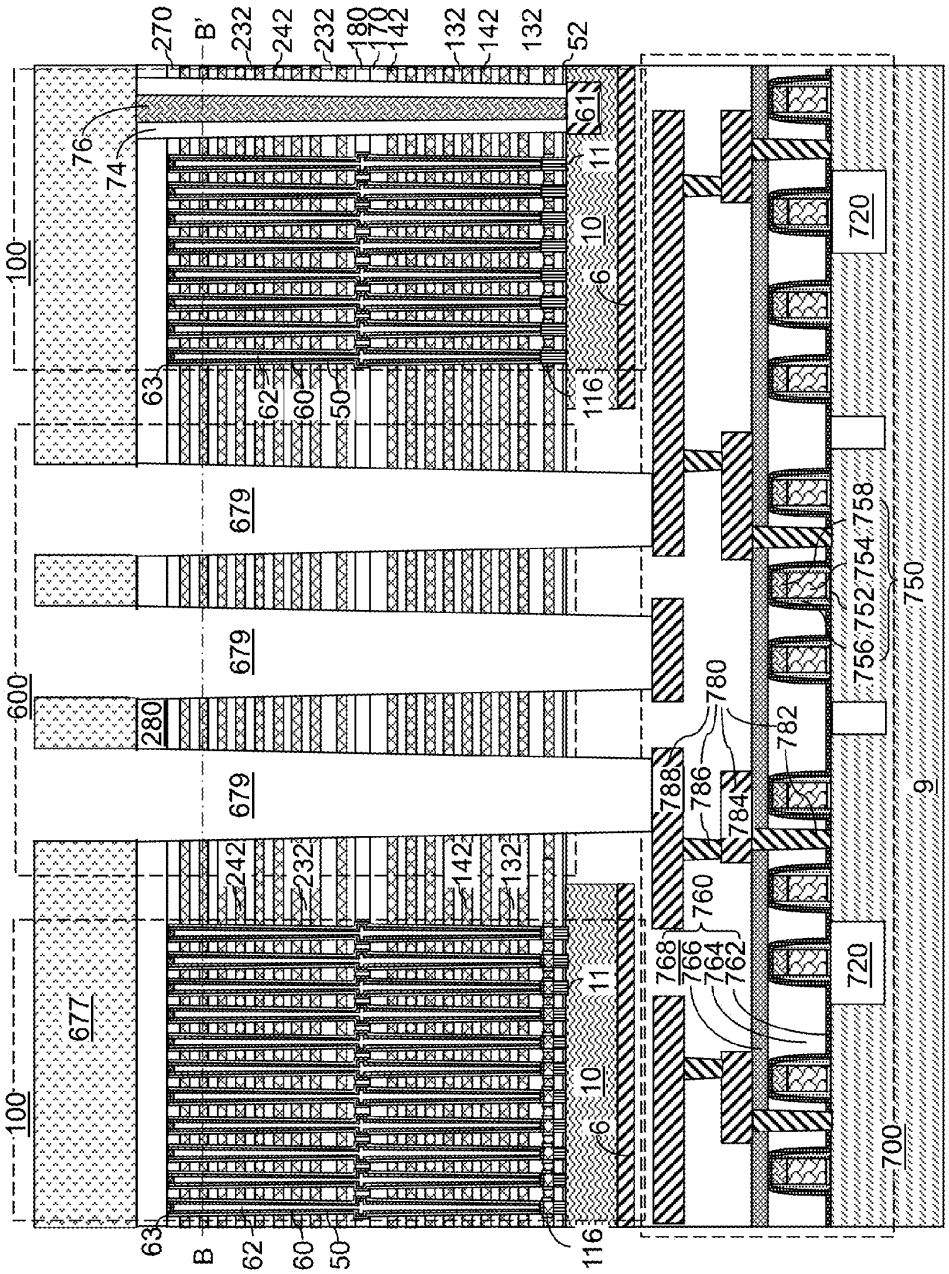
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FIG. 57A

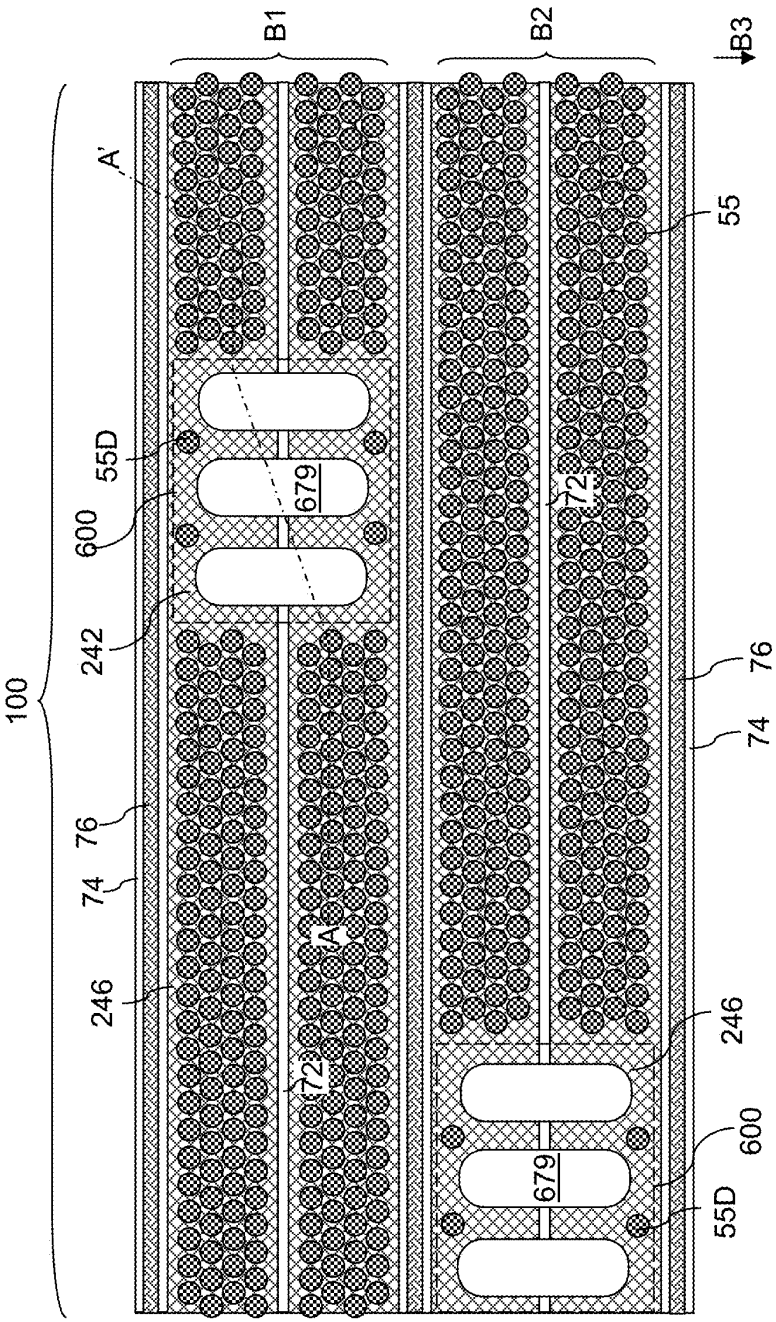

FIG. 57B

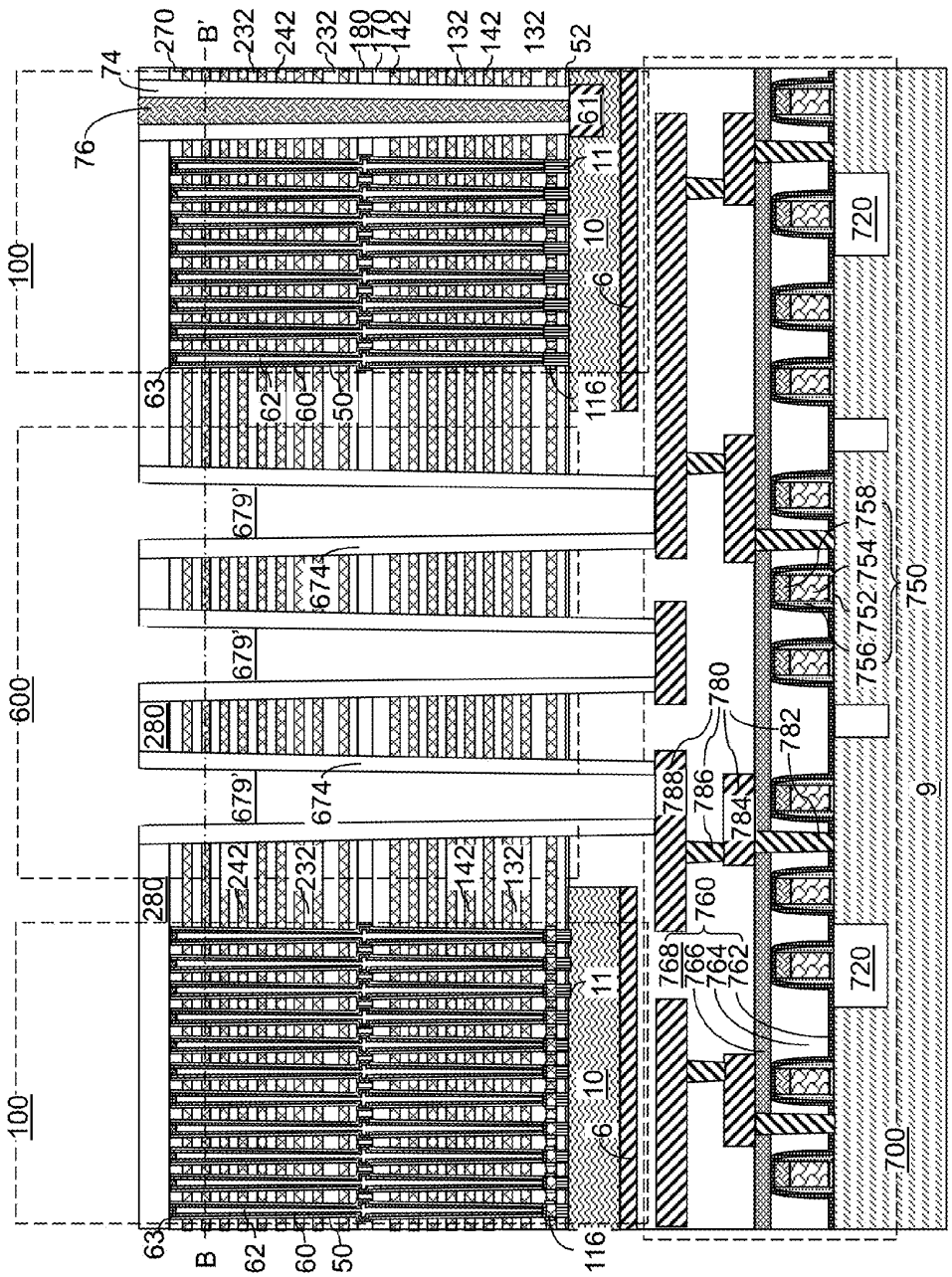
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FIG. 58A

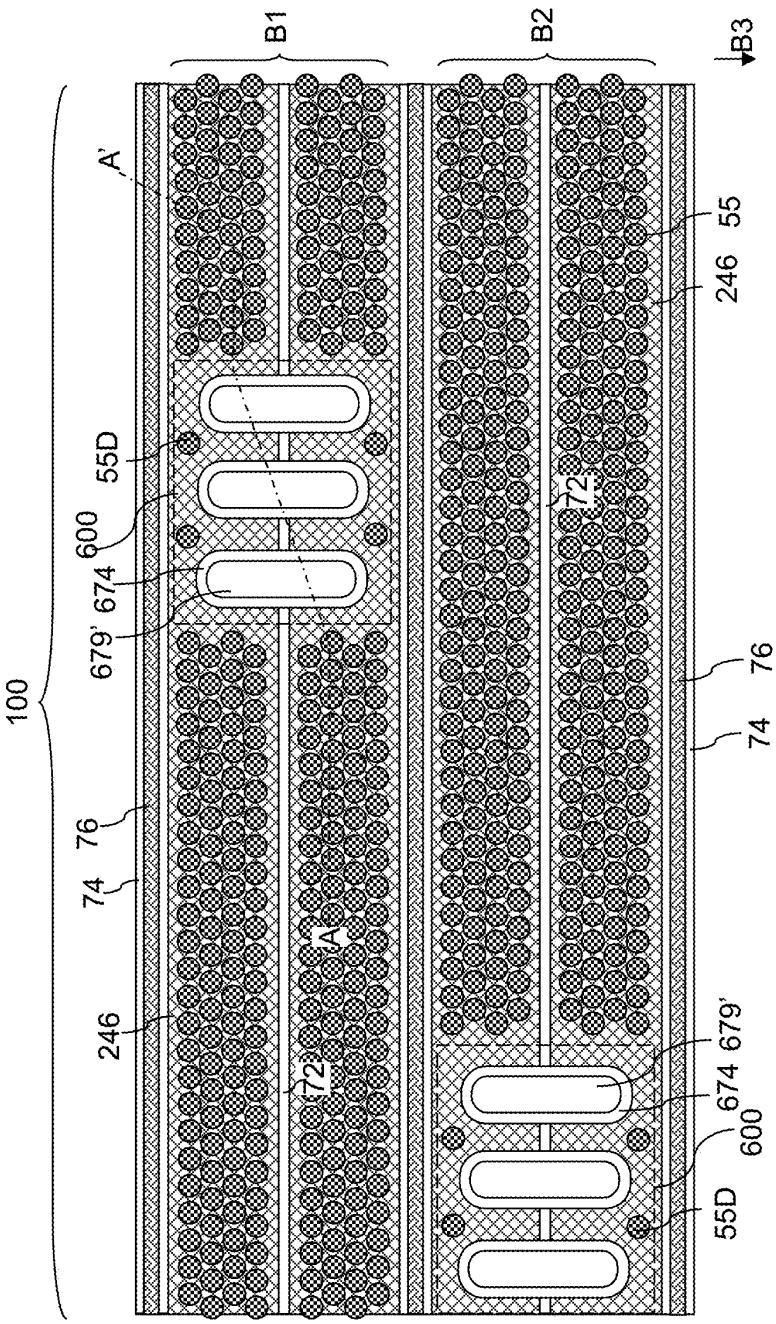

FIG. 58B

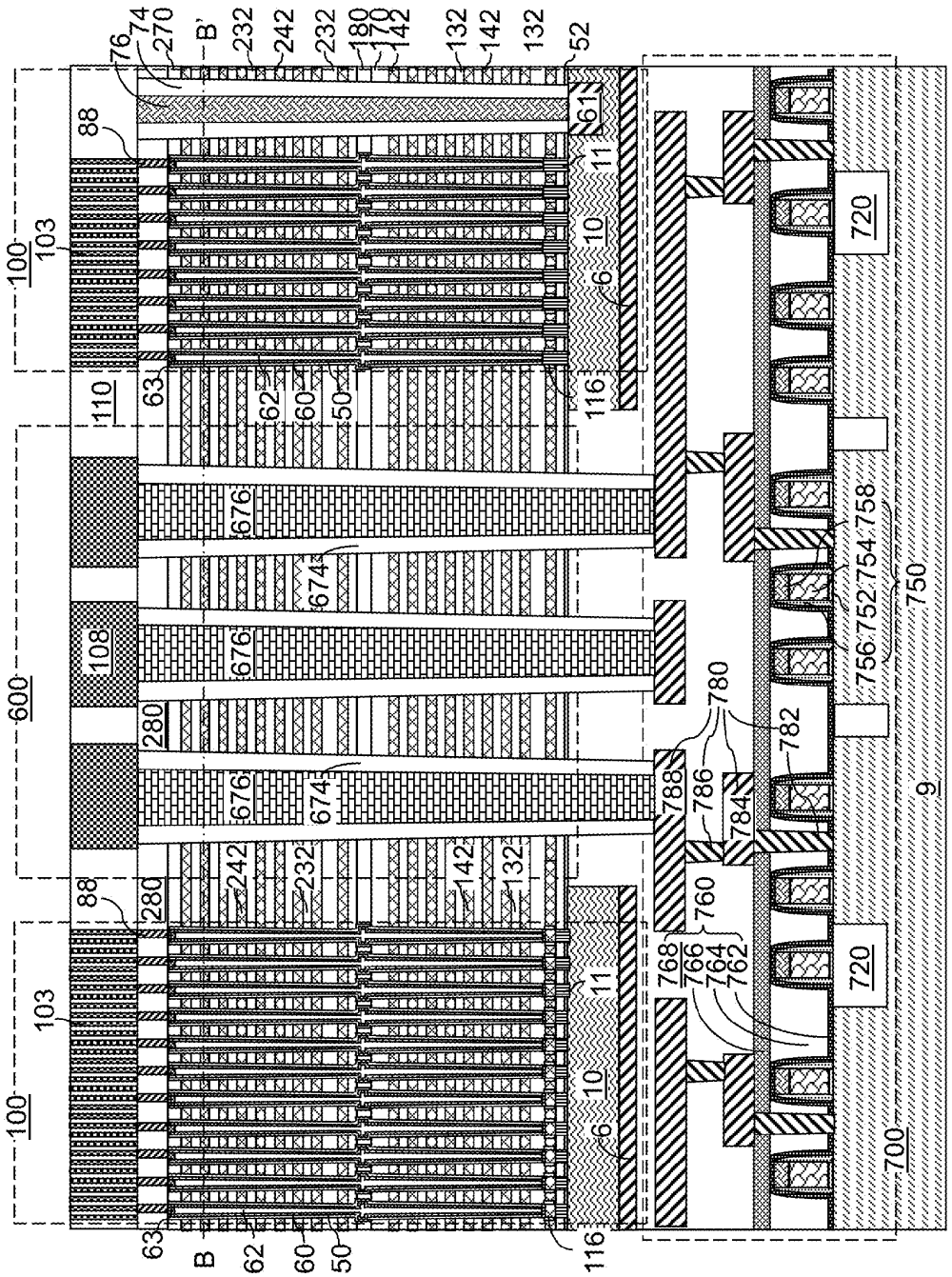
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FIG. 59A

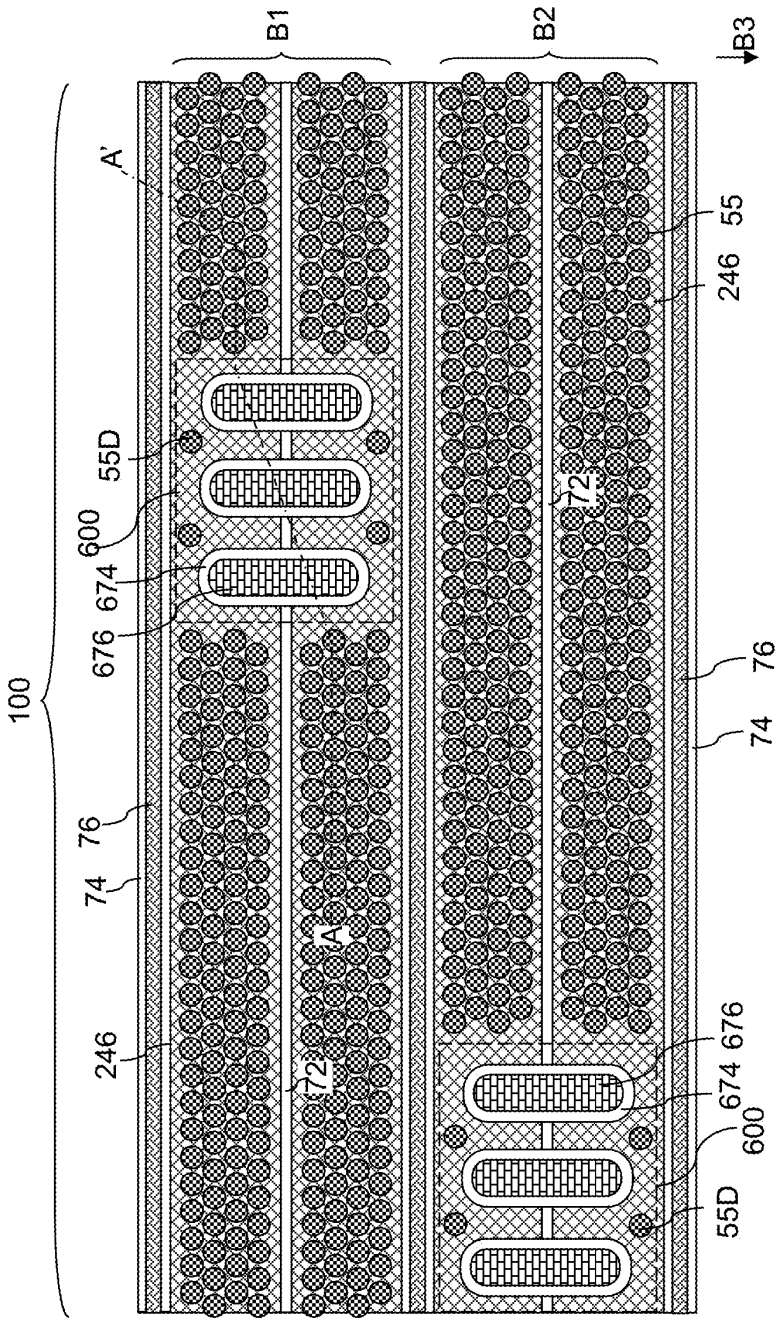

FIG. 59B

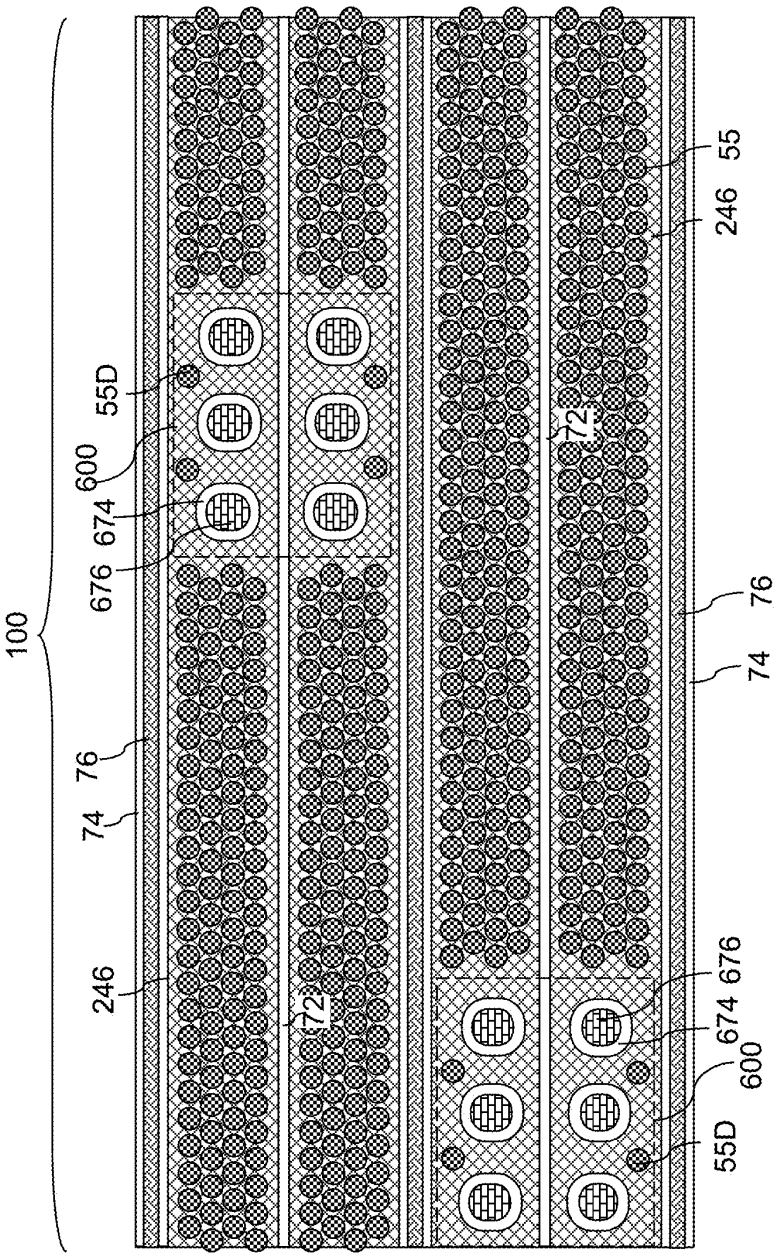

FIG. 60

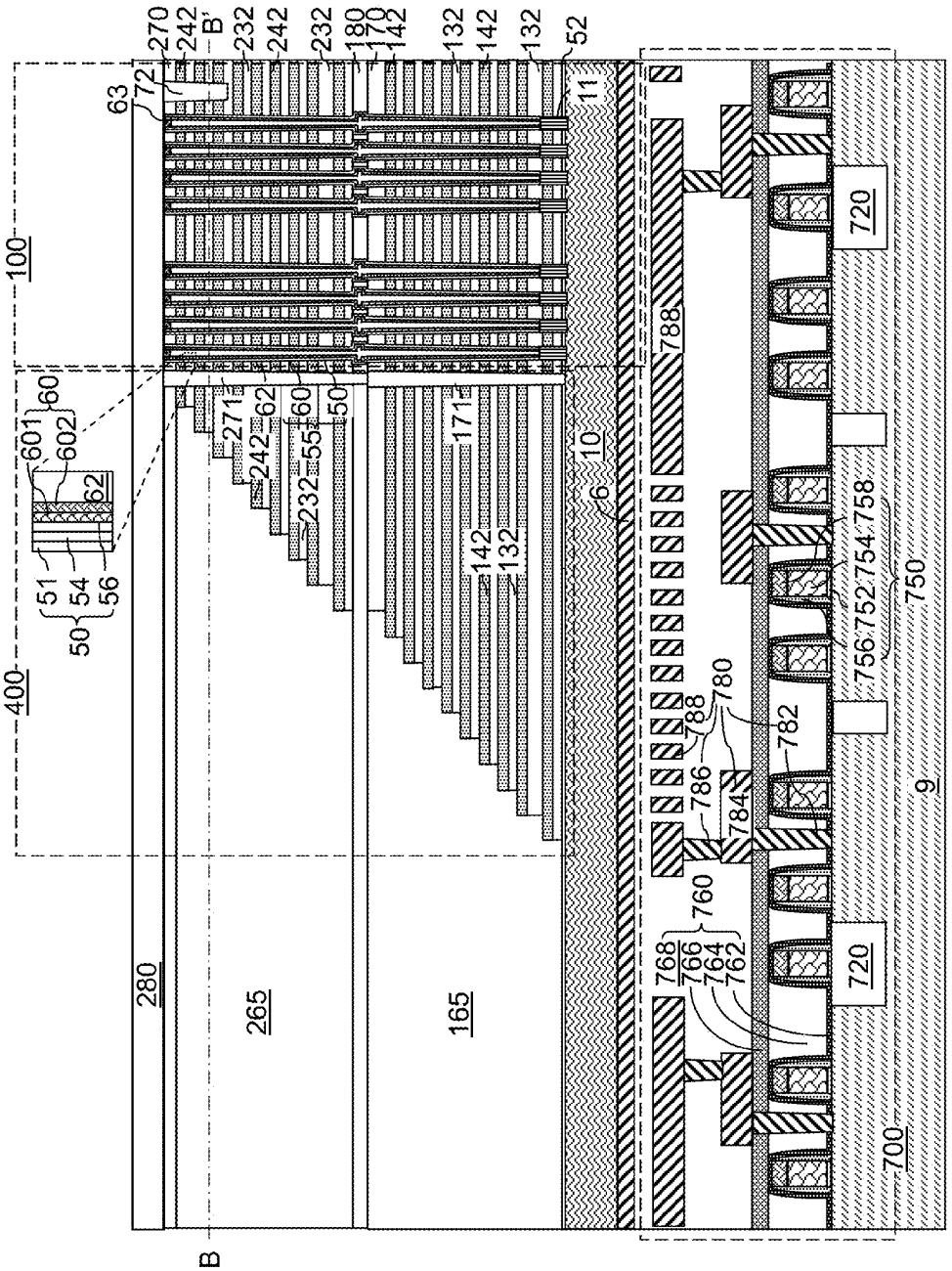
270
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FIG. 61A

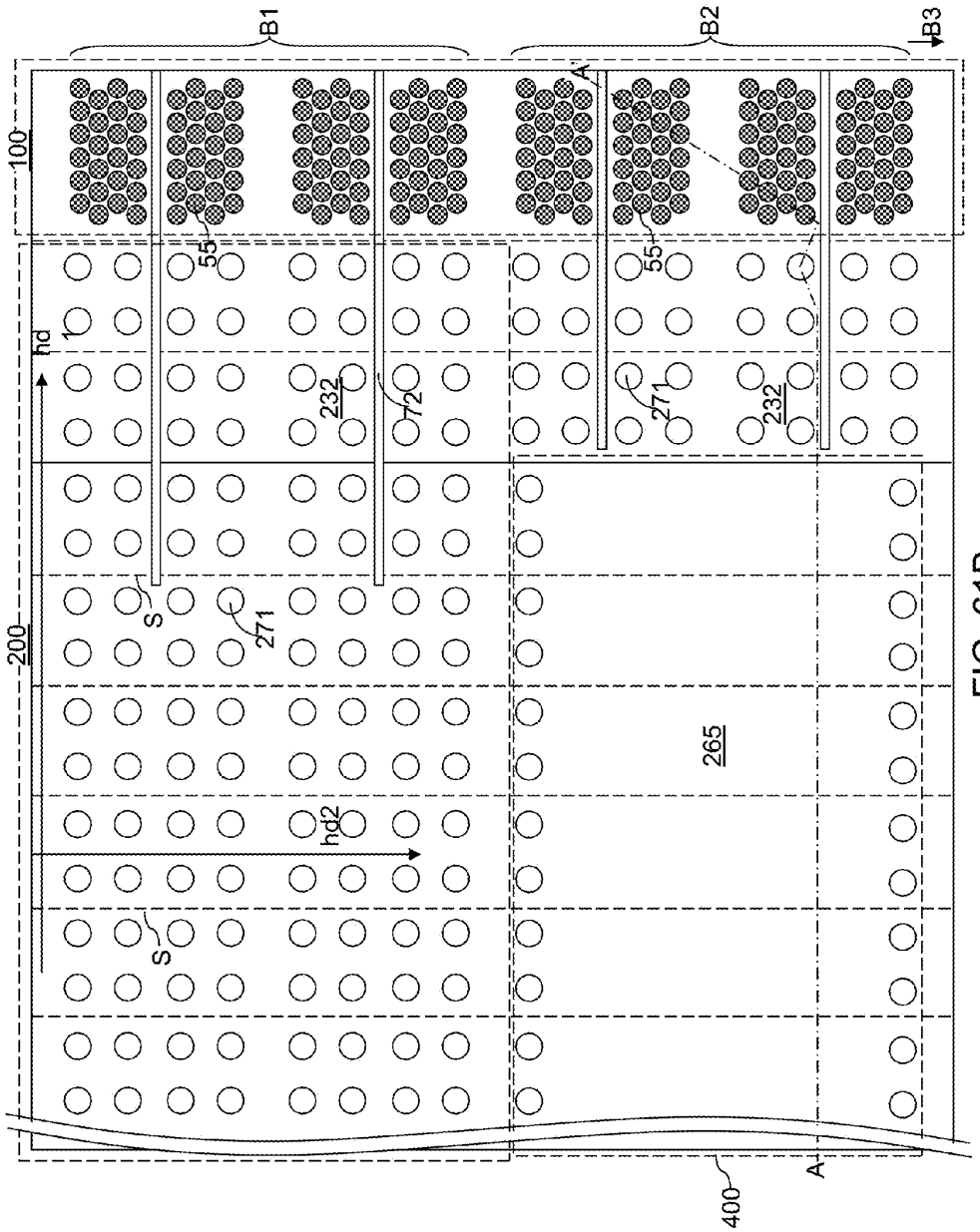

FIG. 61B

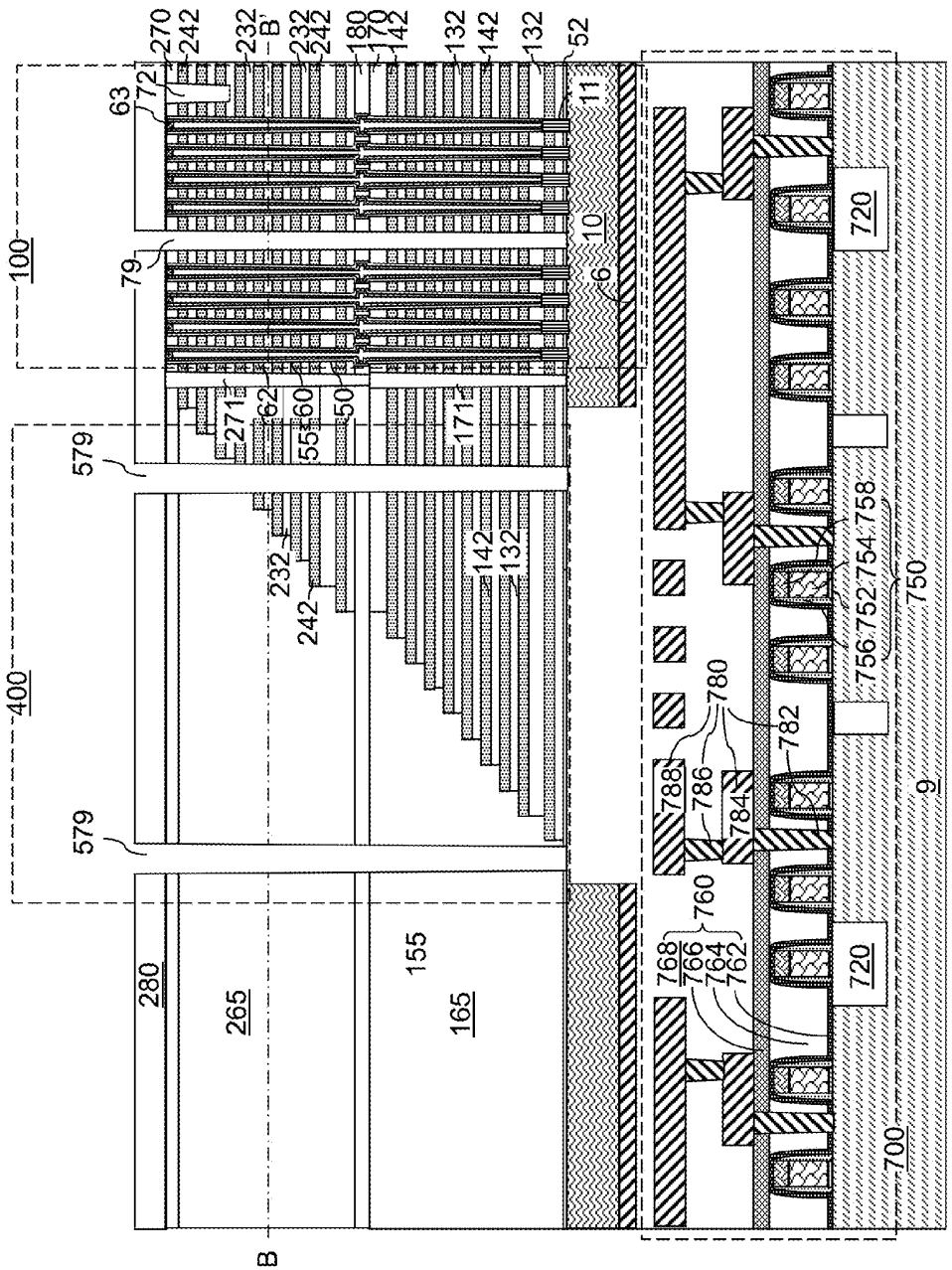
100
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FIG. 62A

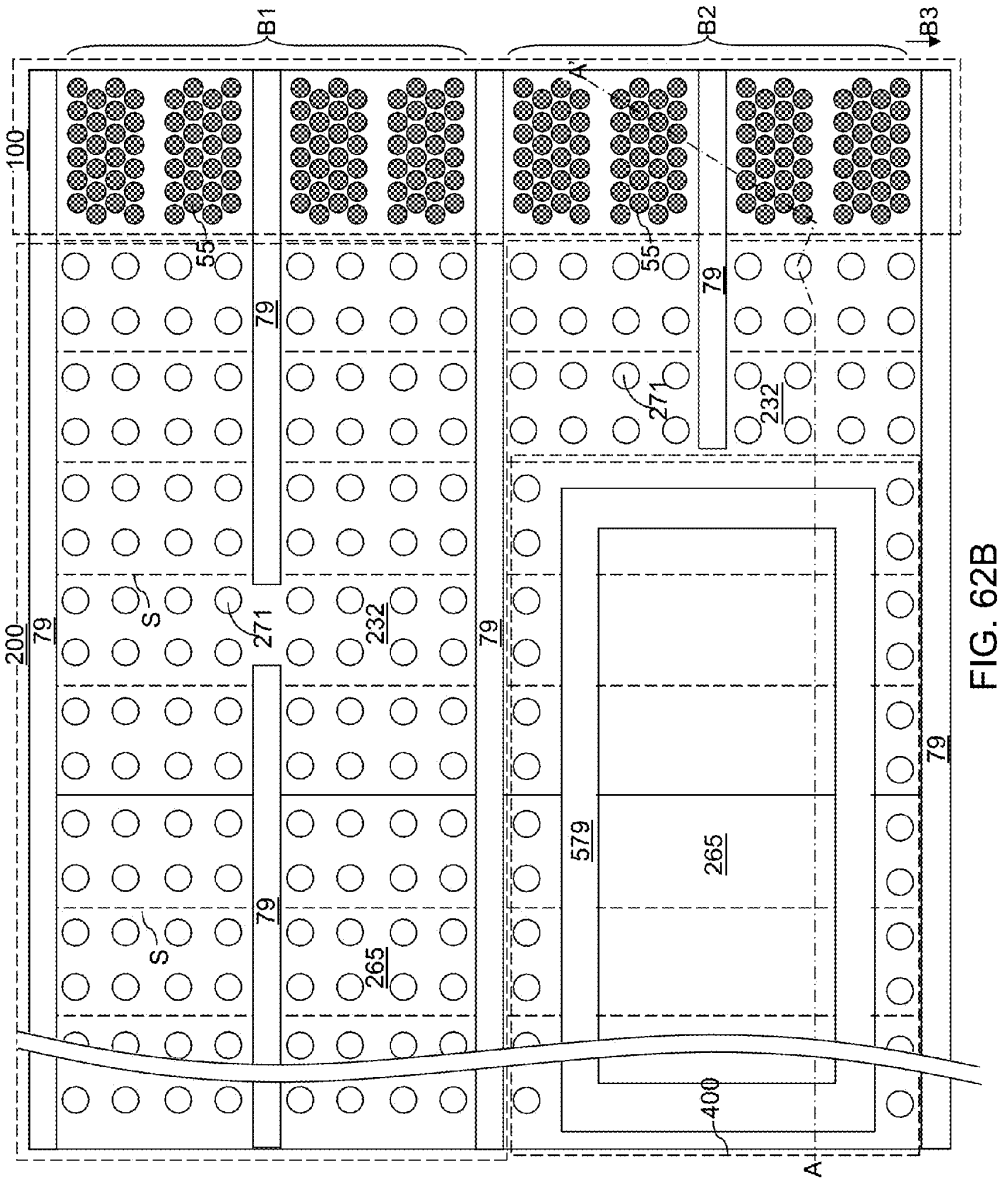

FIG. 62B

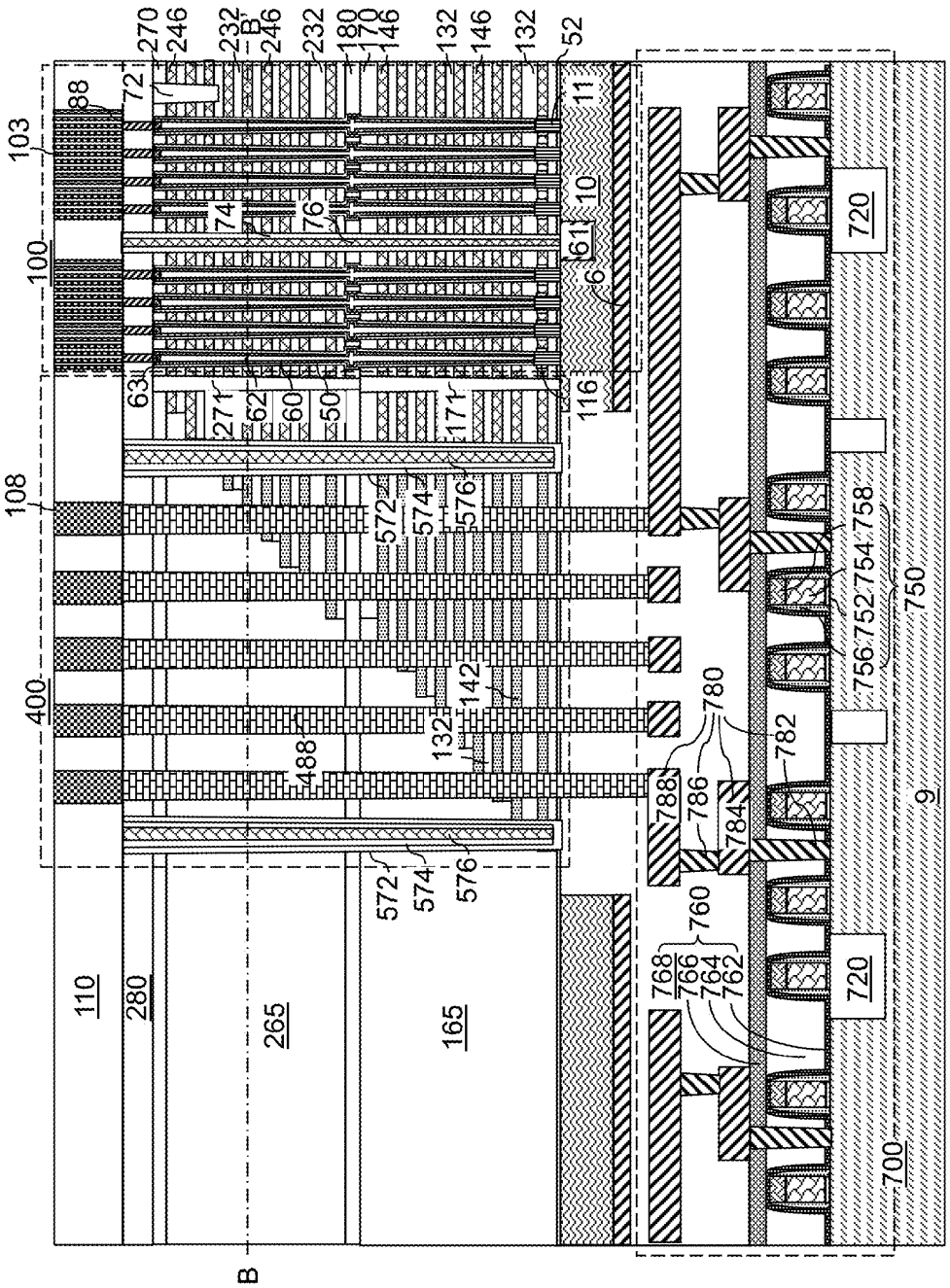
270
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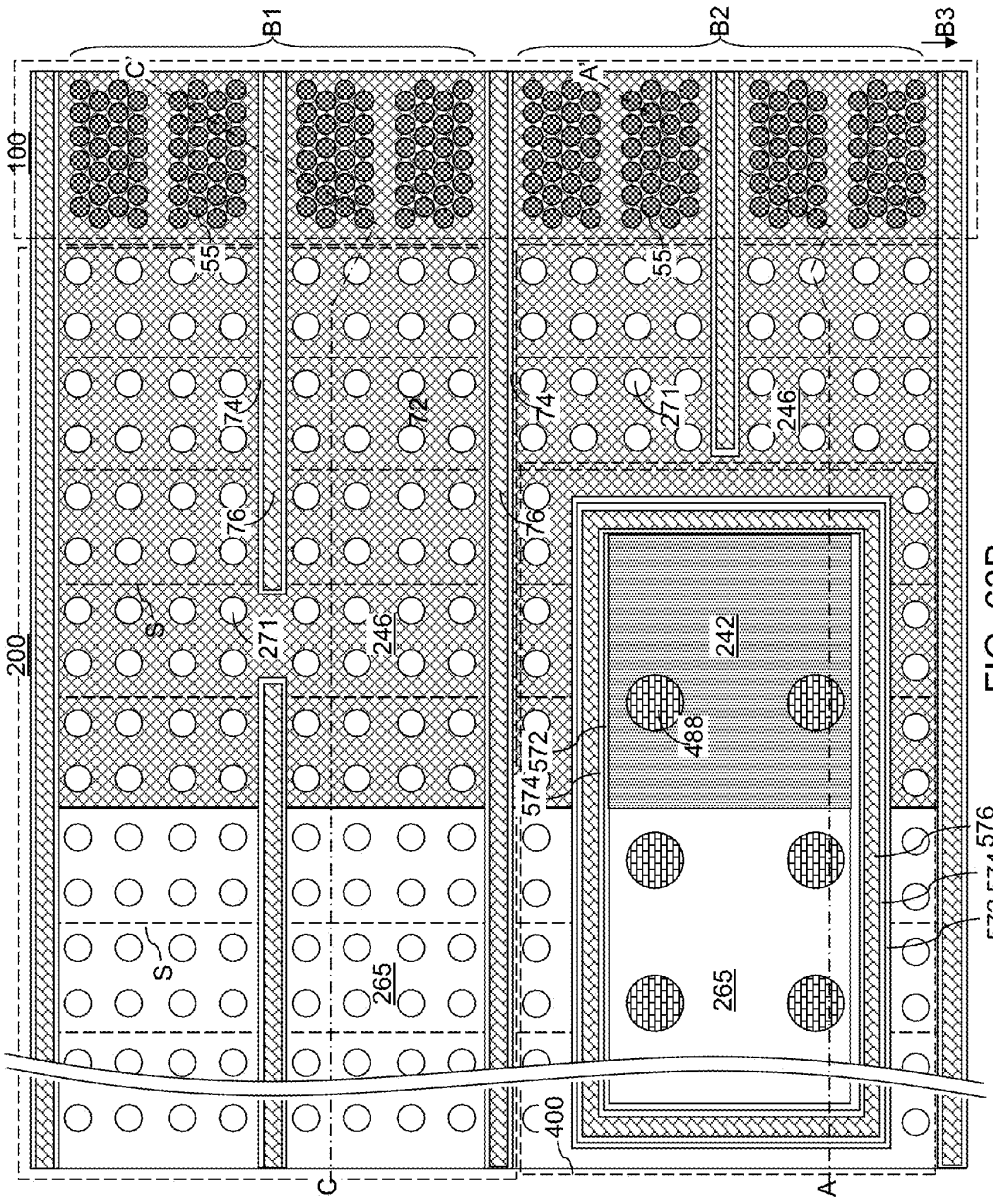
FIG. 63A


B1
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246
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576
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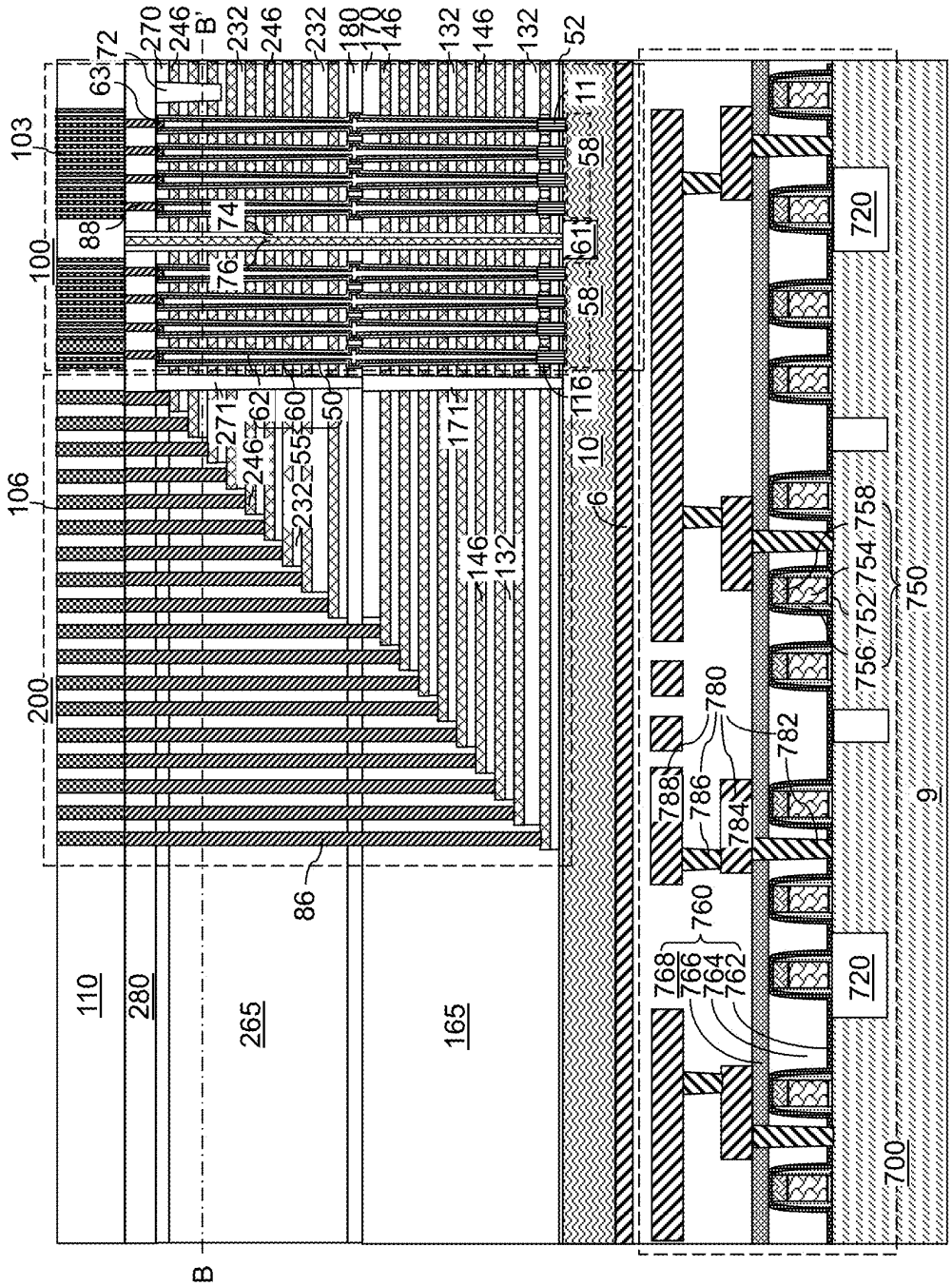
400
C
A

FIG. 63B



103
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FIG. 63C

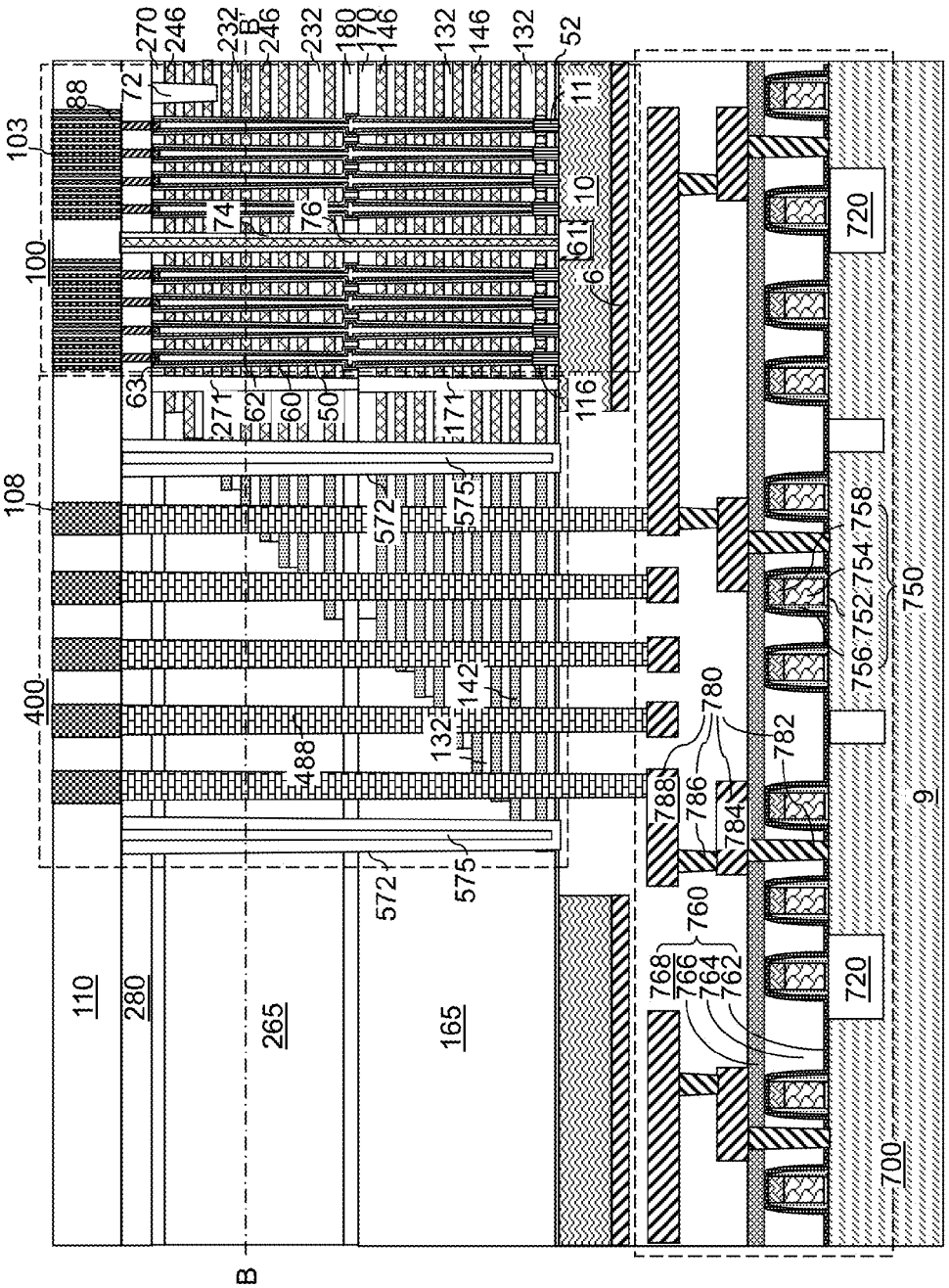
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FIG. 64

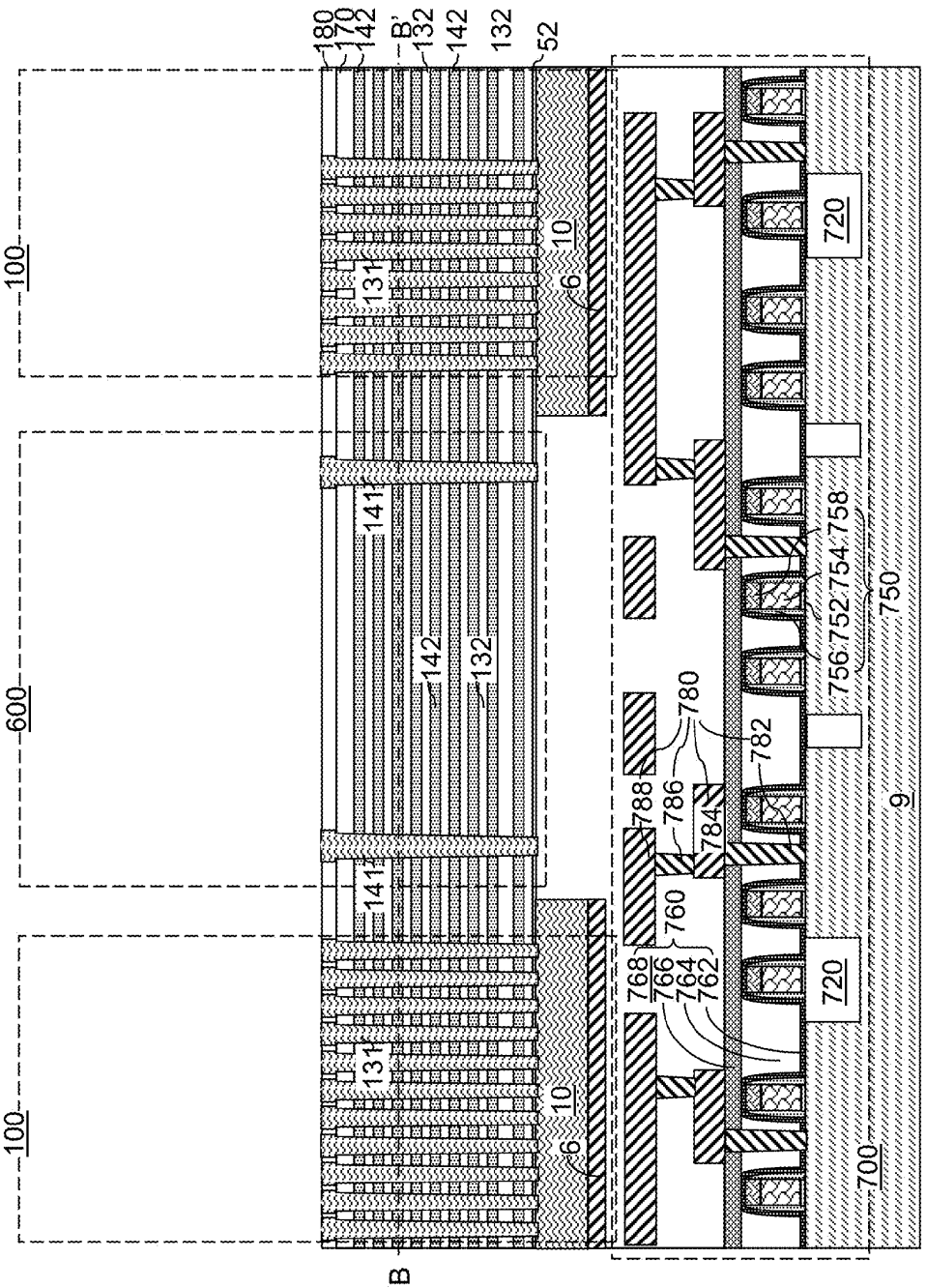
180
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FIG. 65A

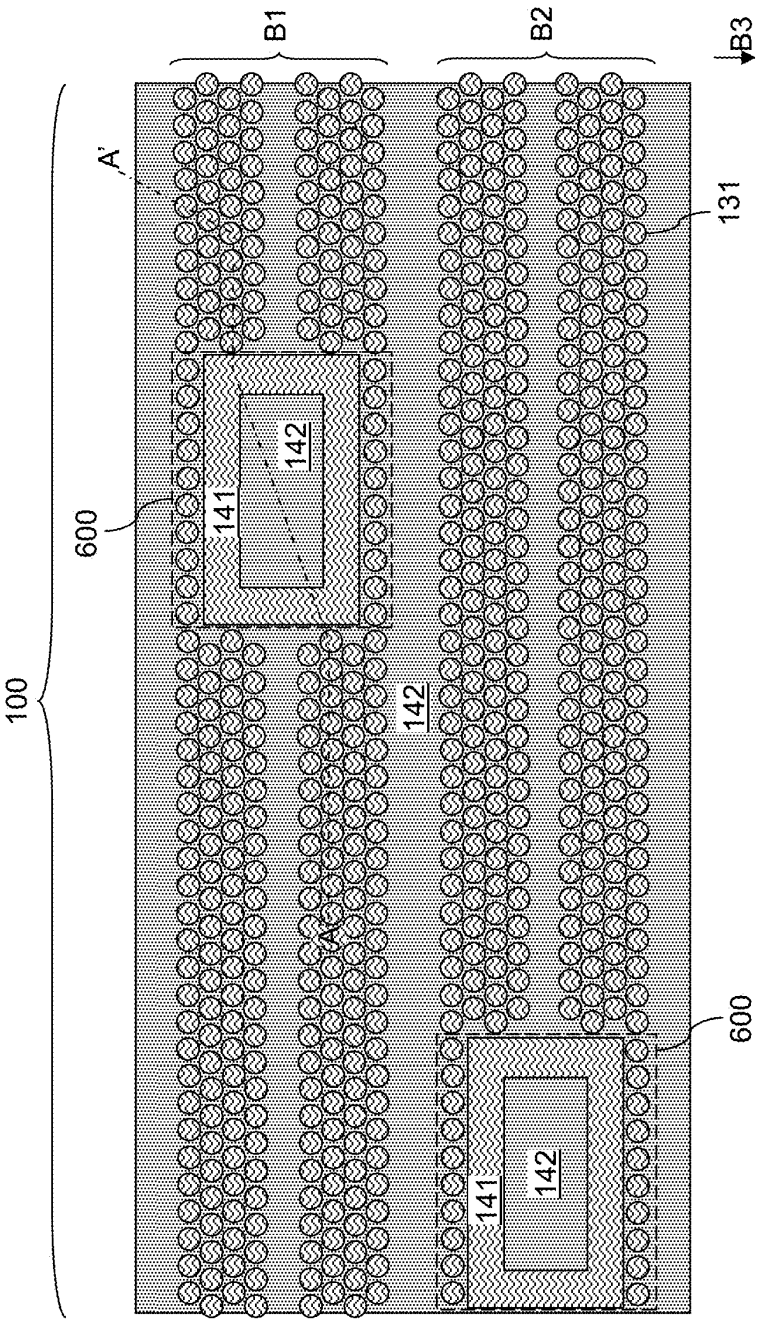

FIG. 65B

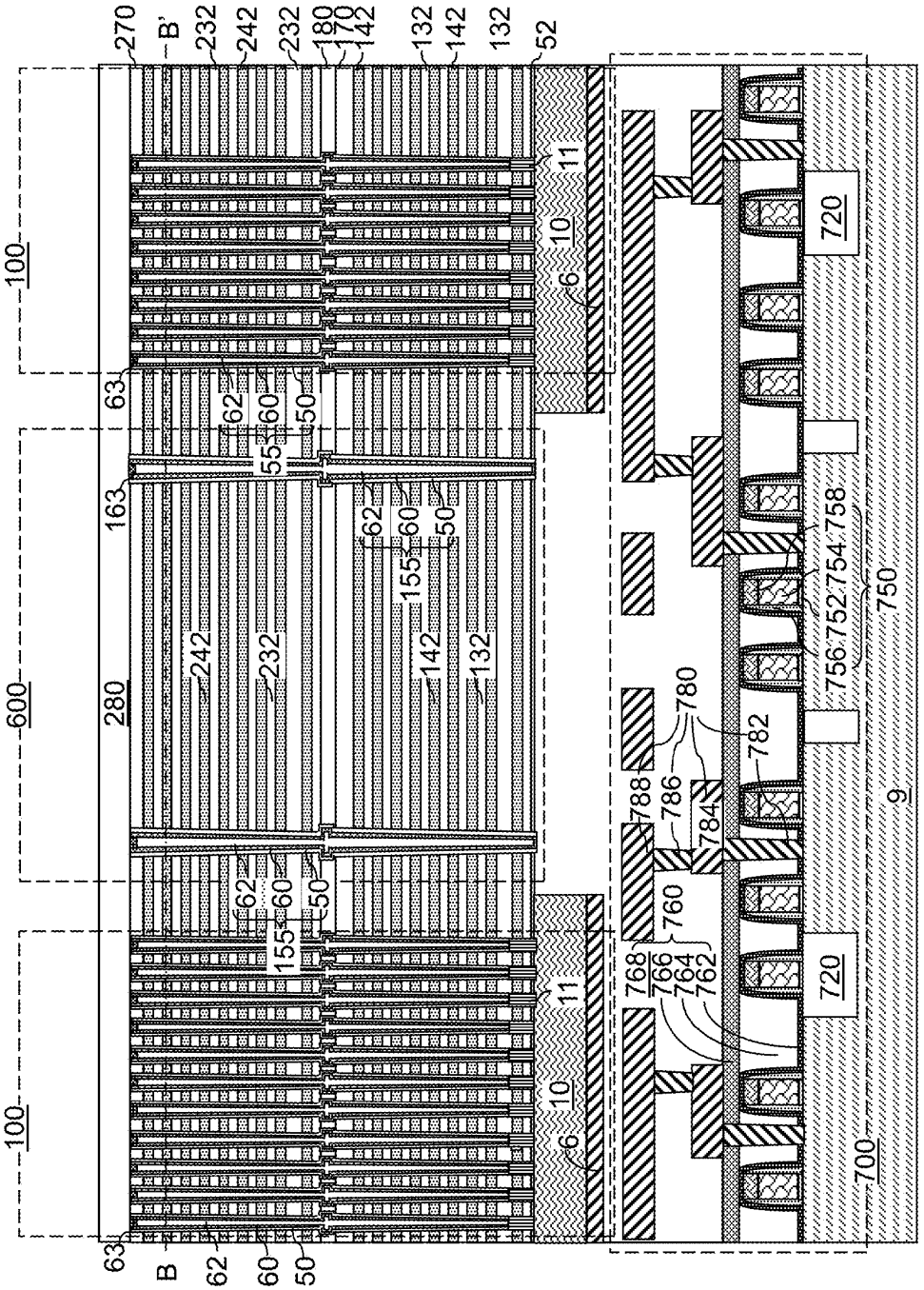
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FIG. 66A

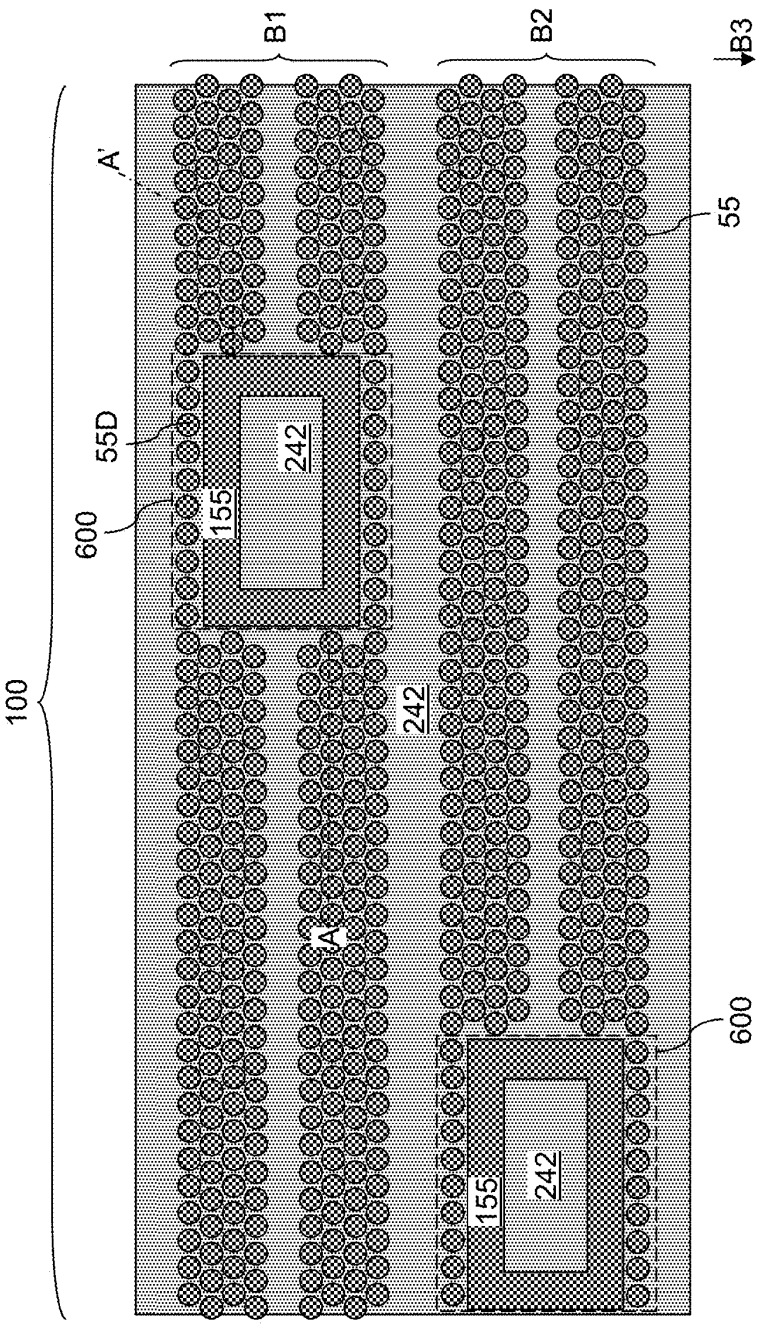

FIG. 66B

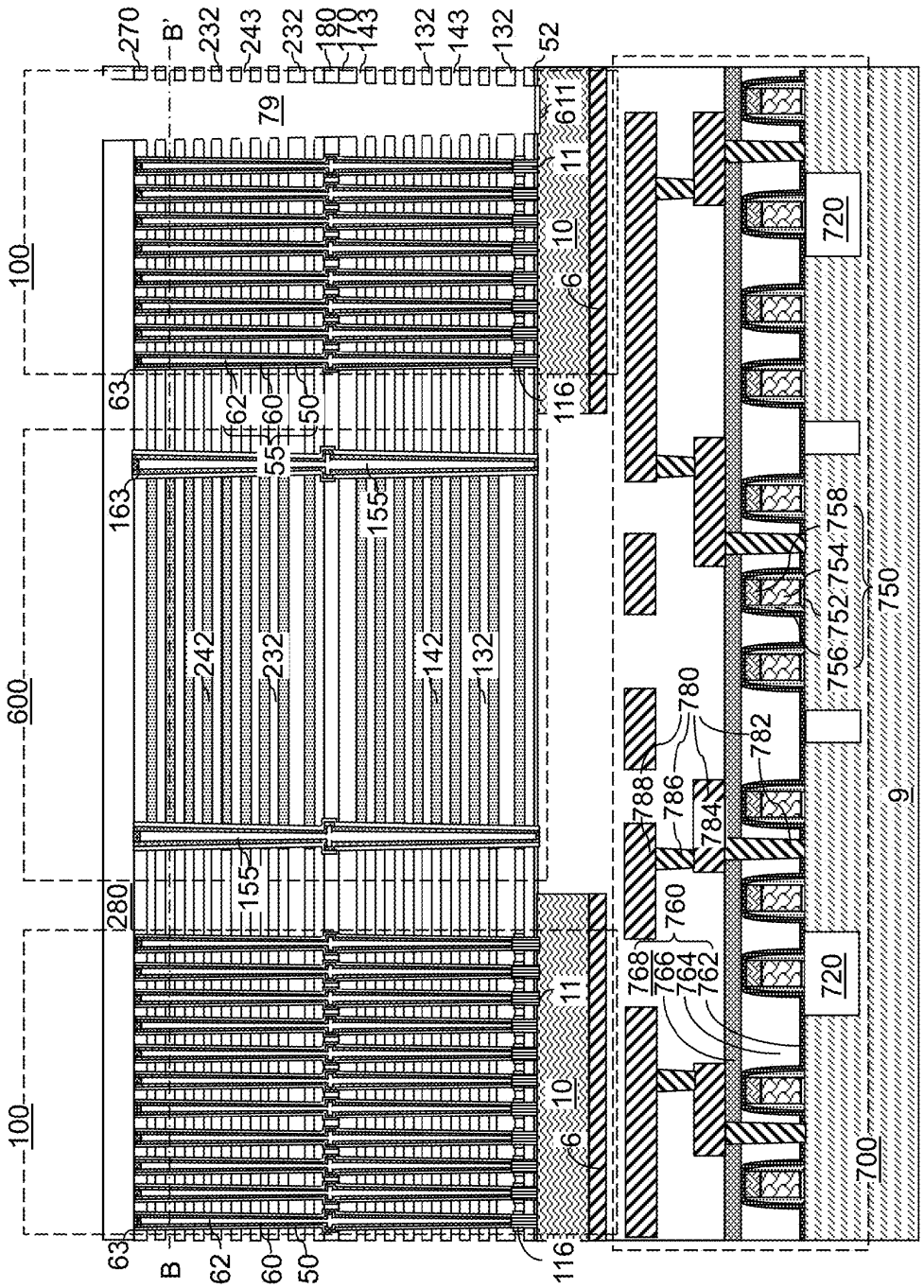
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FIG. 67A

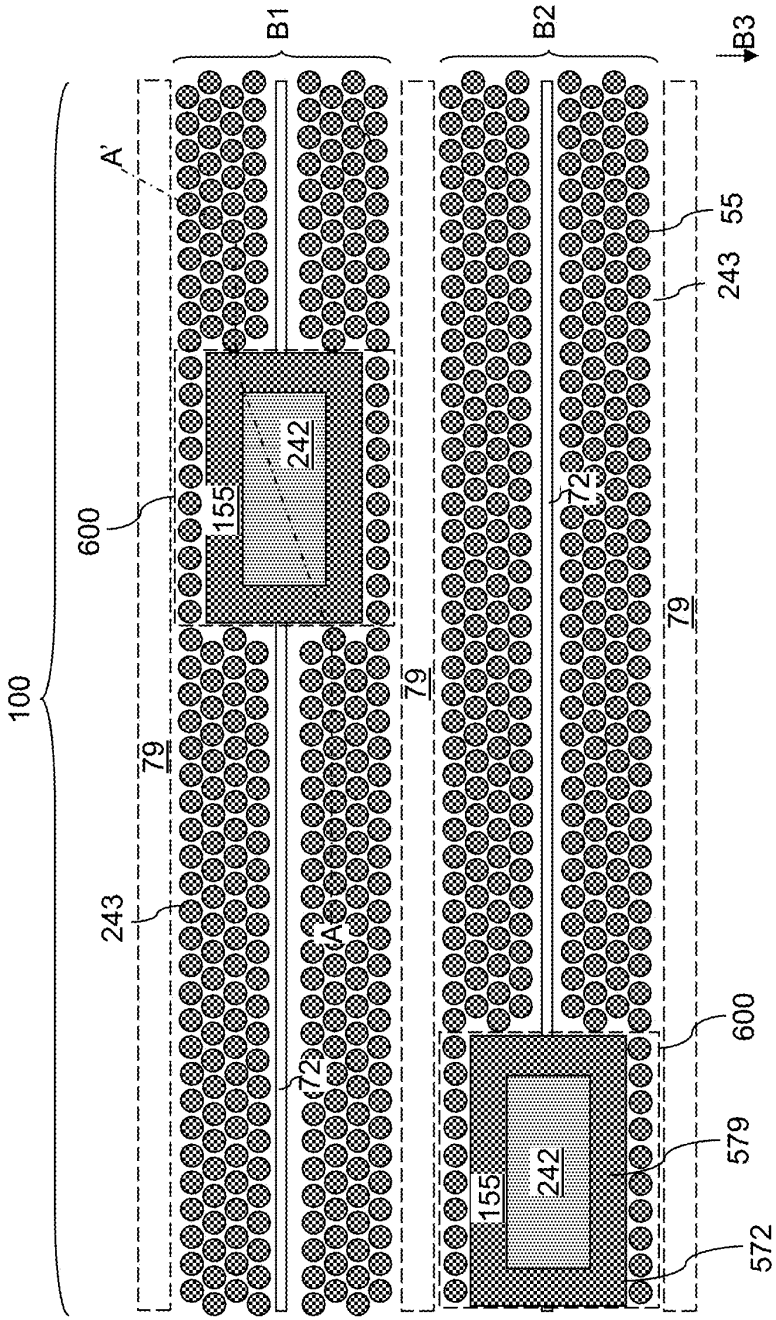

FIG. 67B

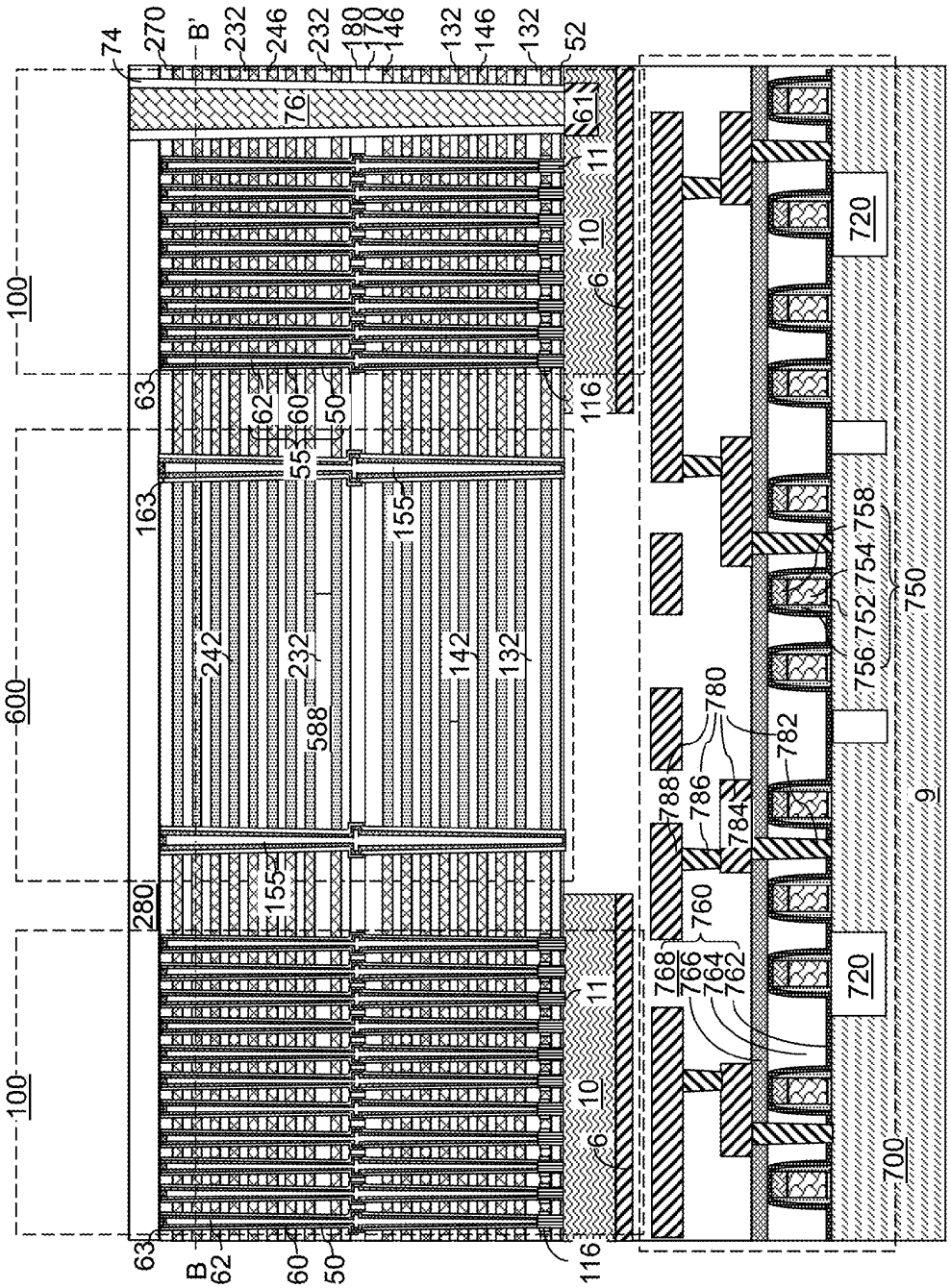
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FIG. 68A

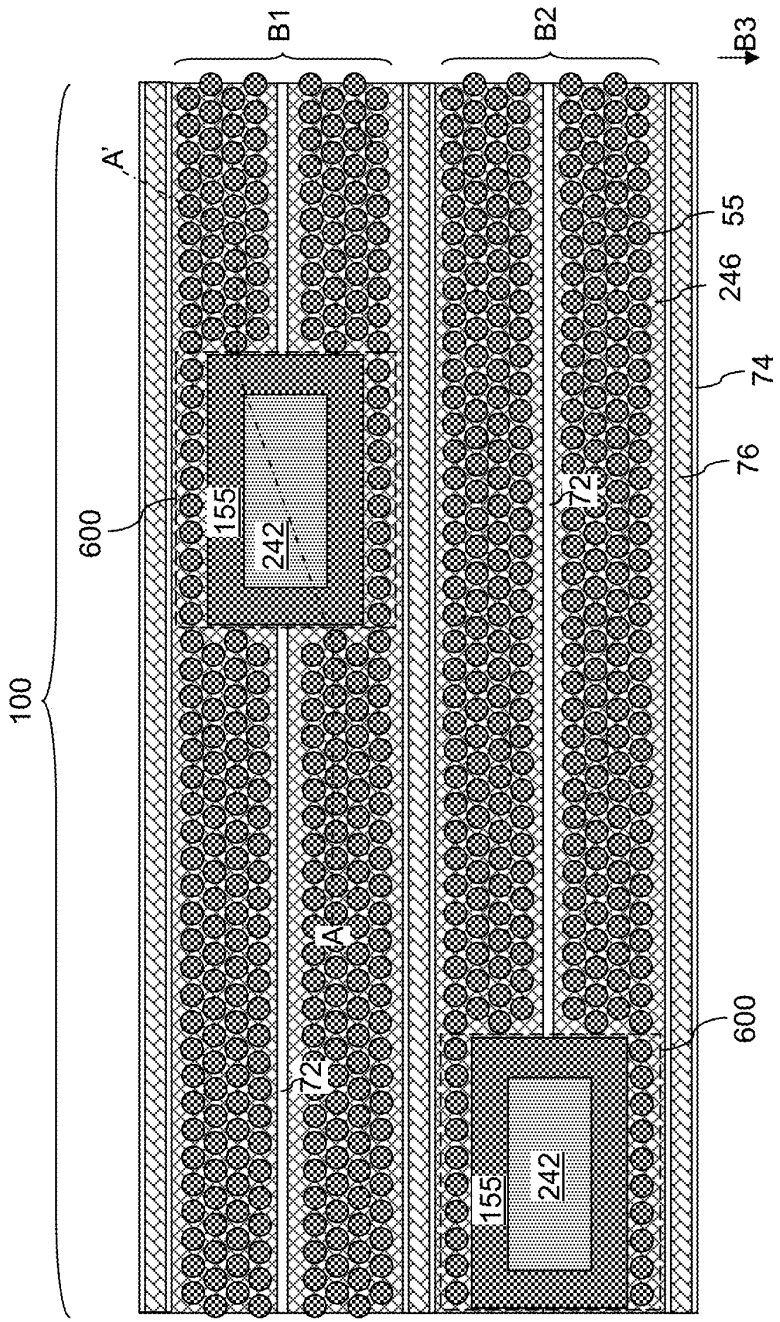

FIG. 68B

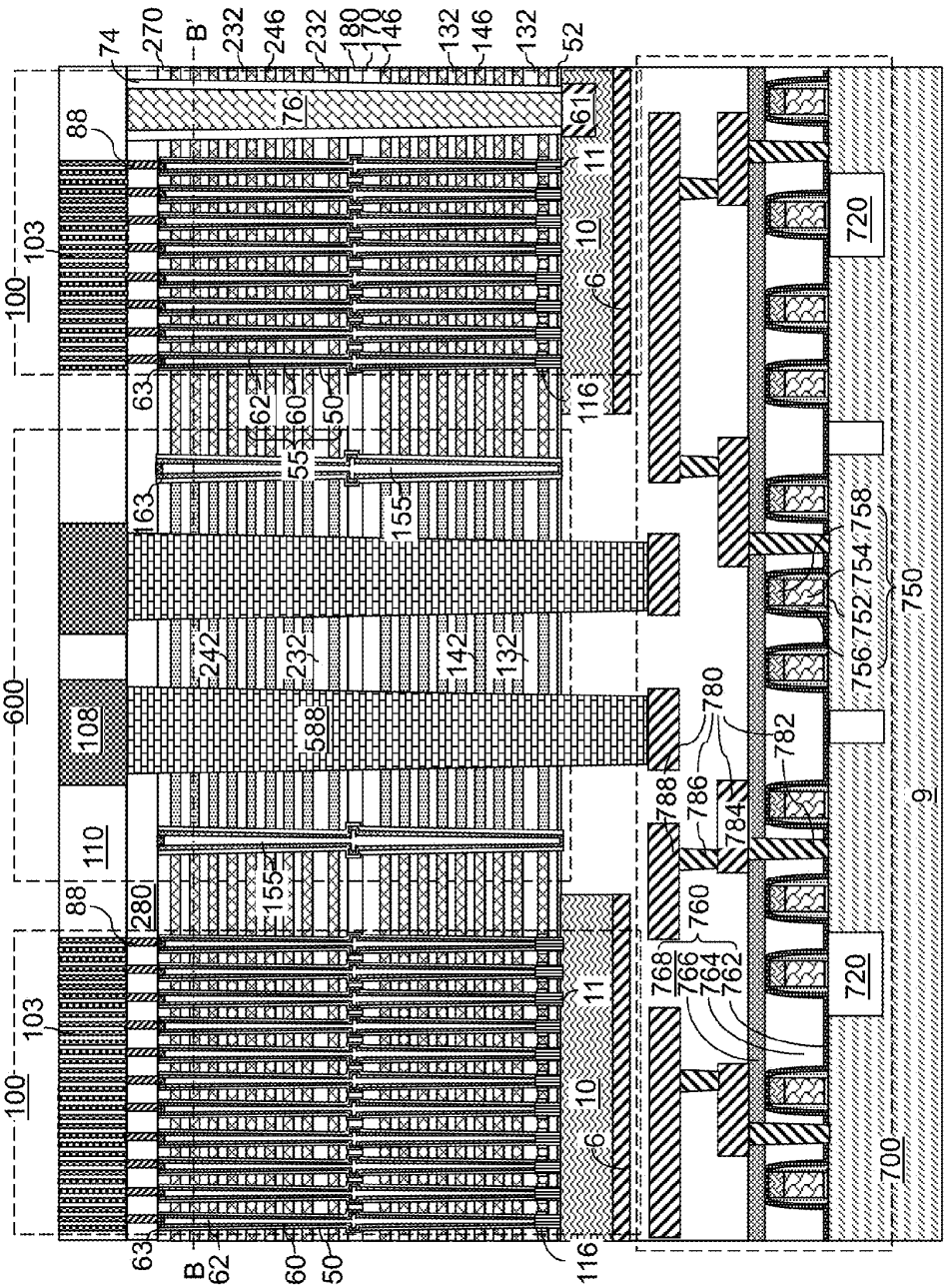
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FIG. 69A

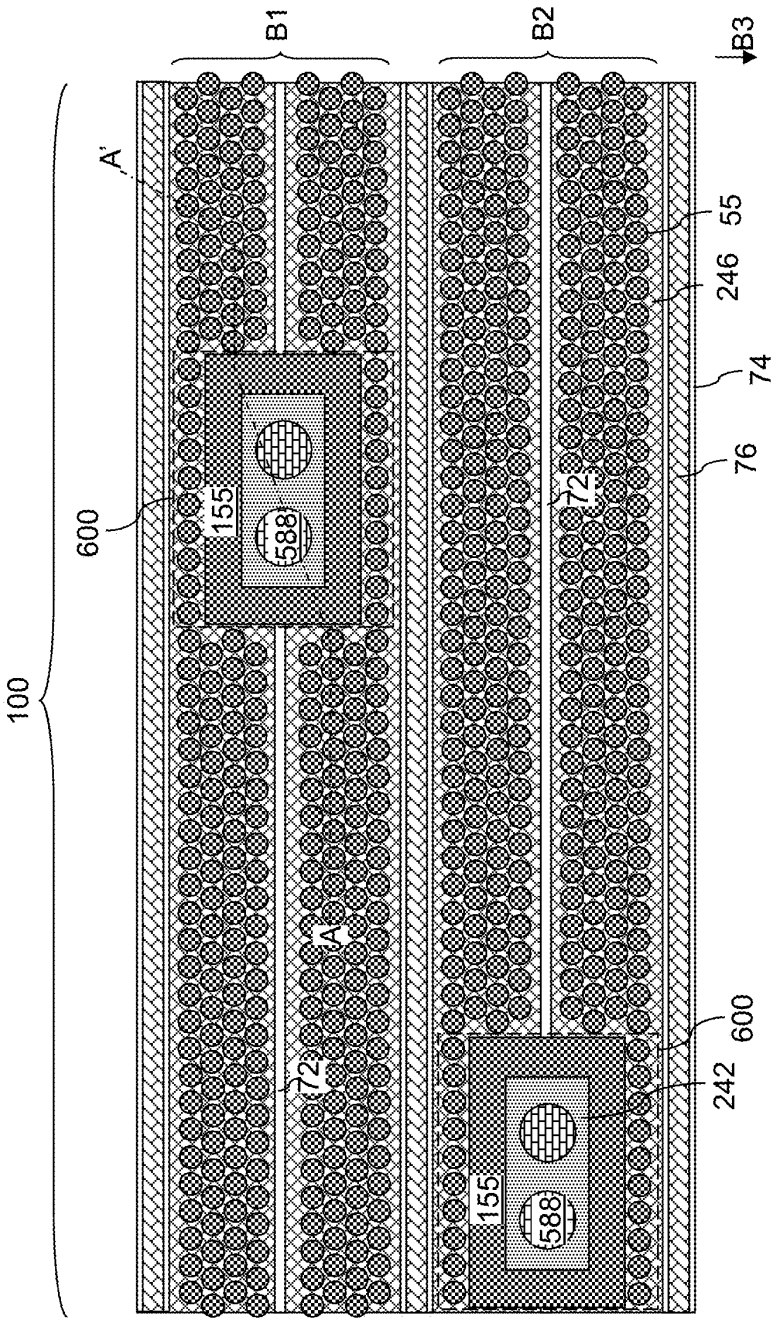

FIG. 69B

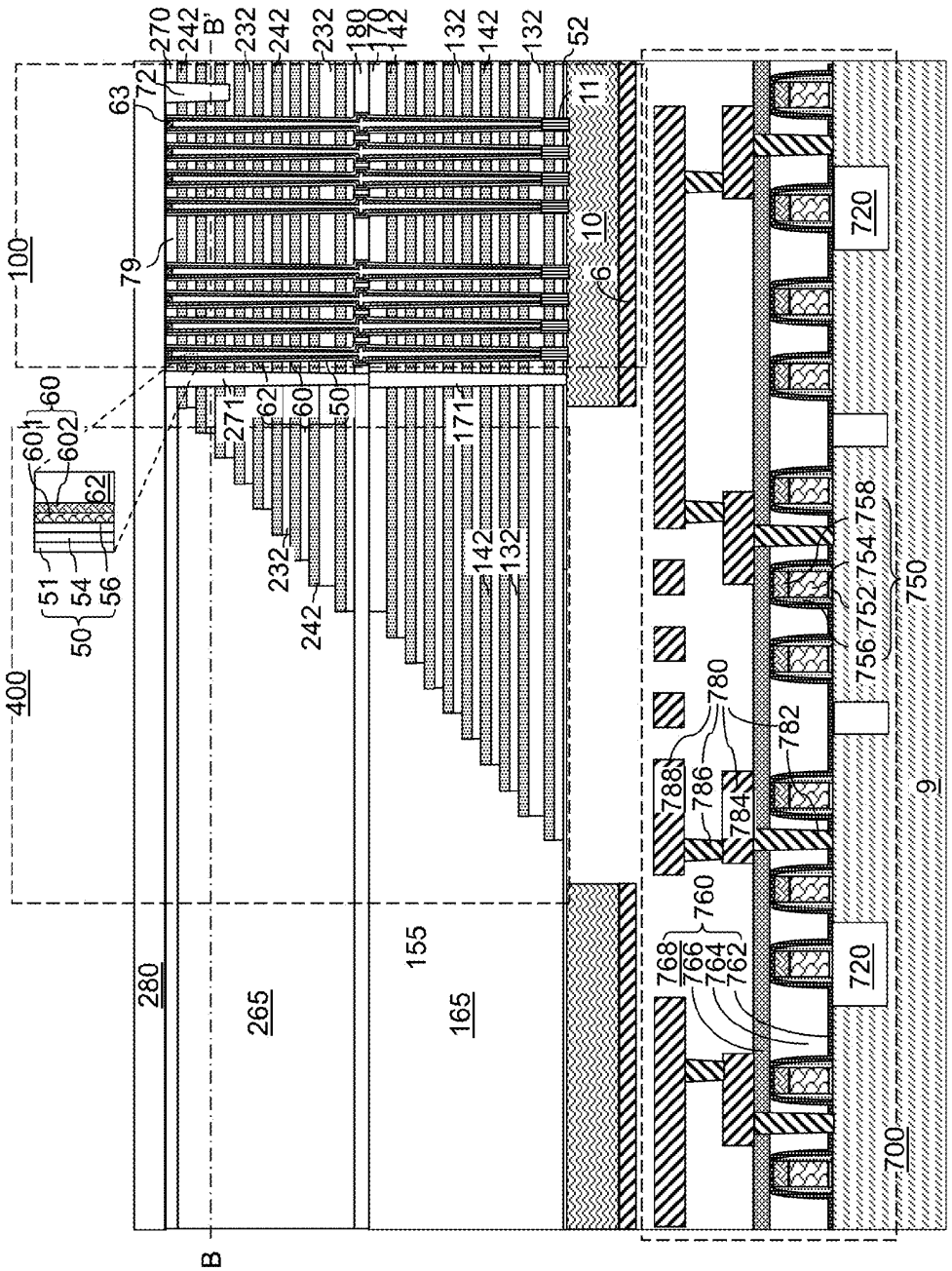
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FIG. 70A

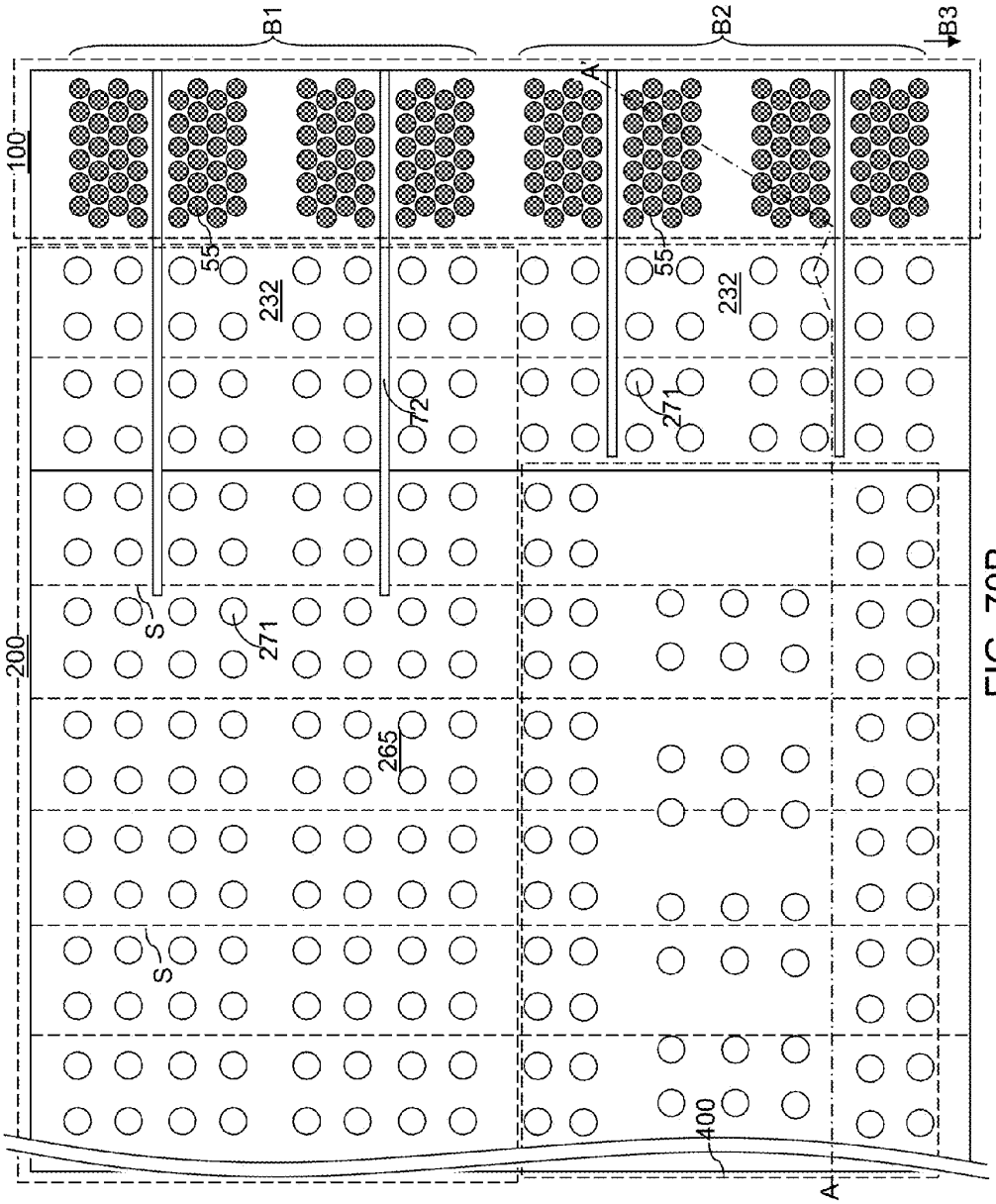

FIG. 70B

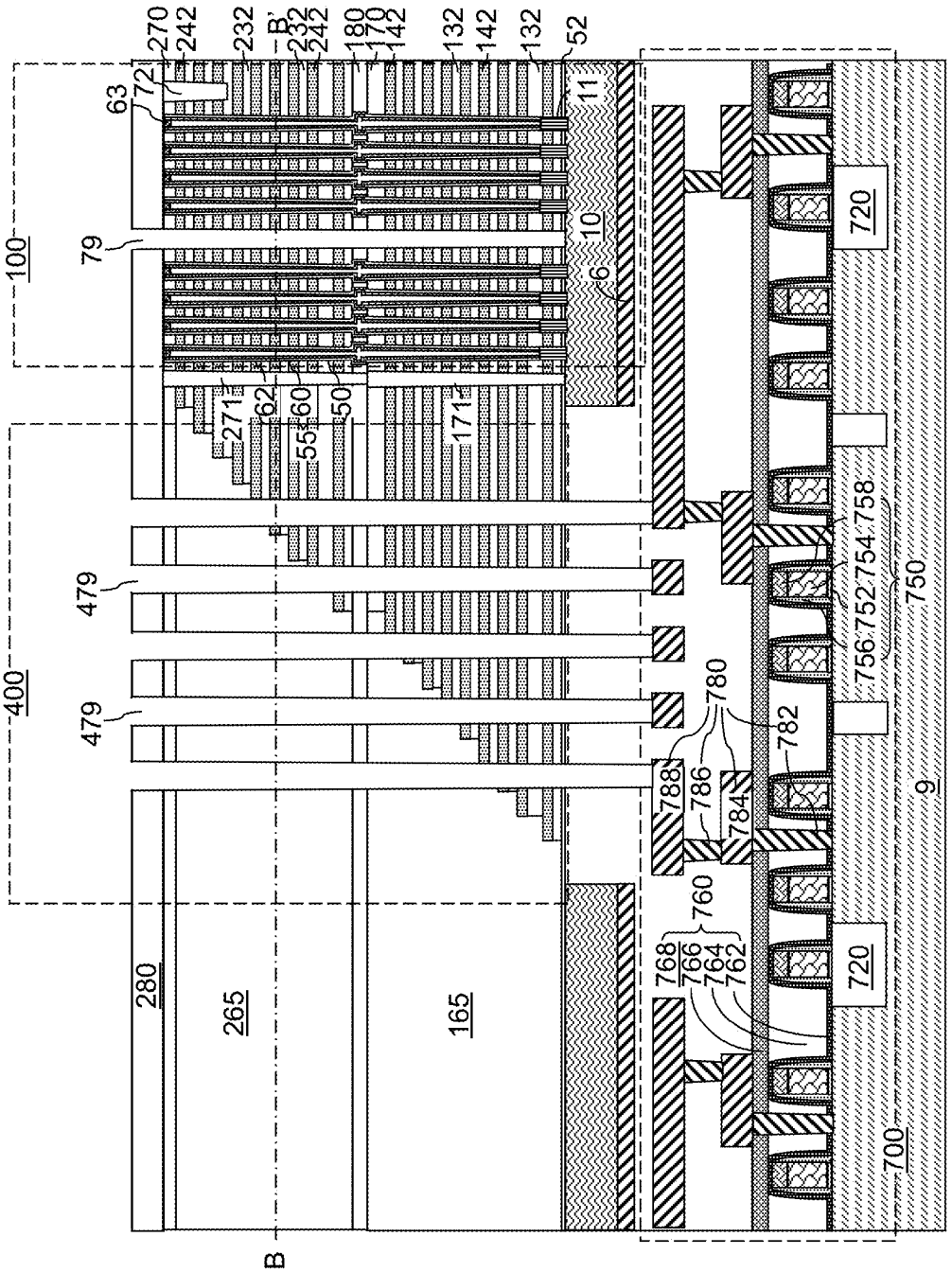
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FIG. 71A

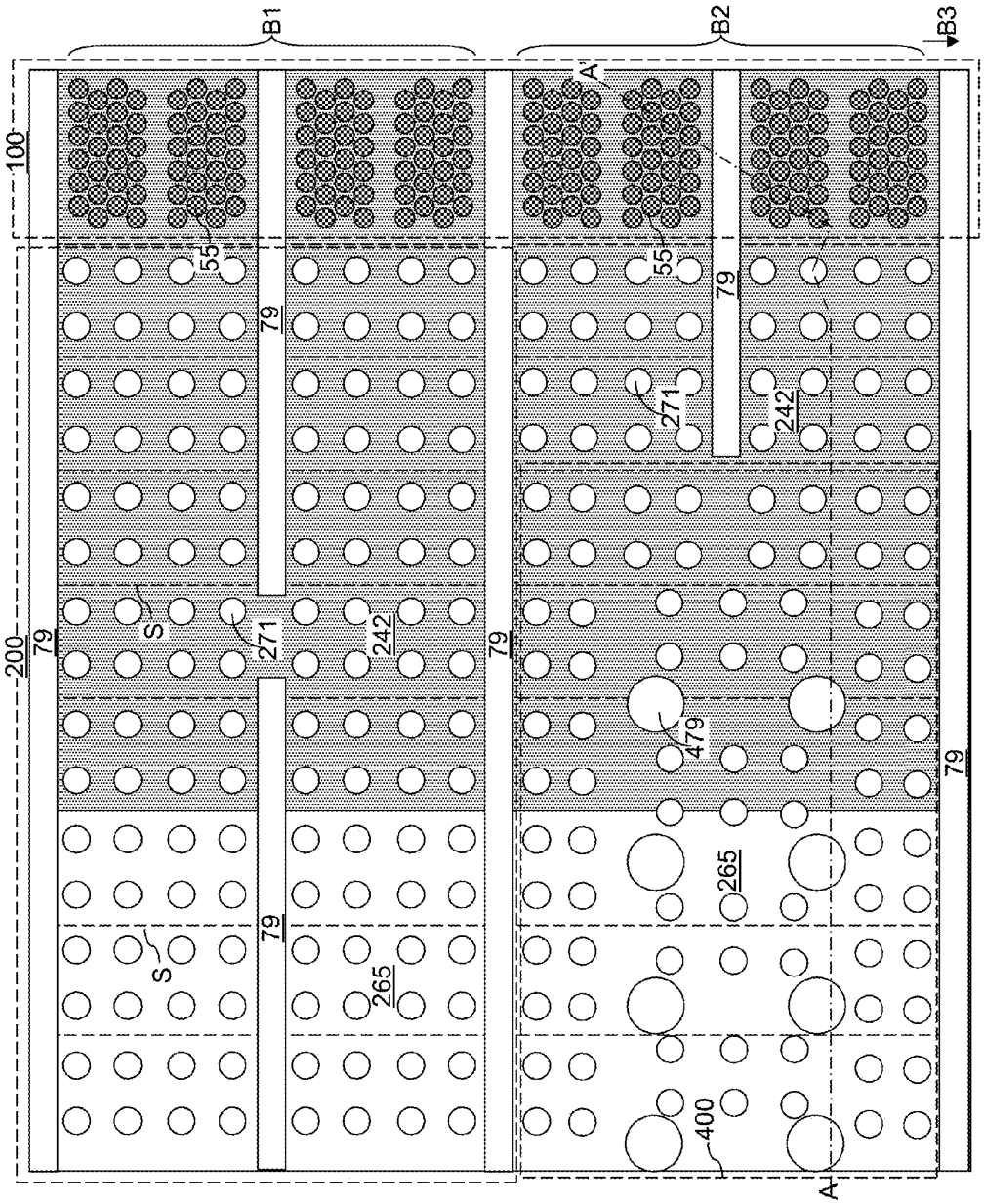

FIG. 71B

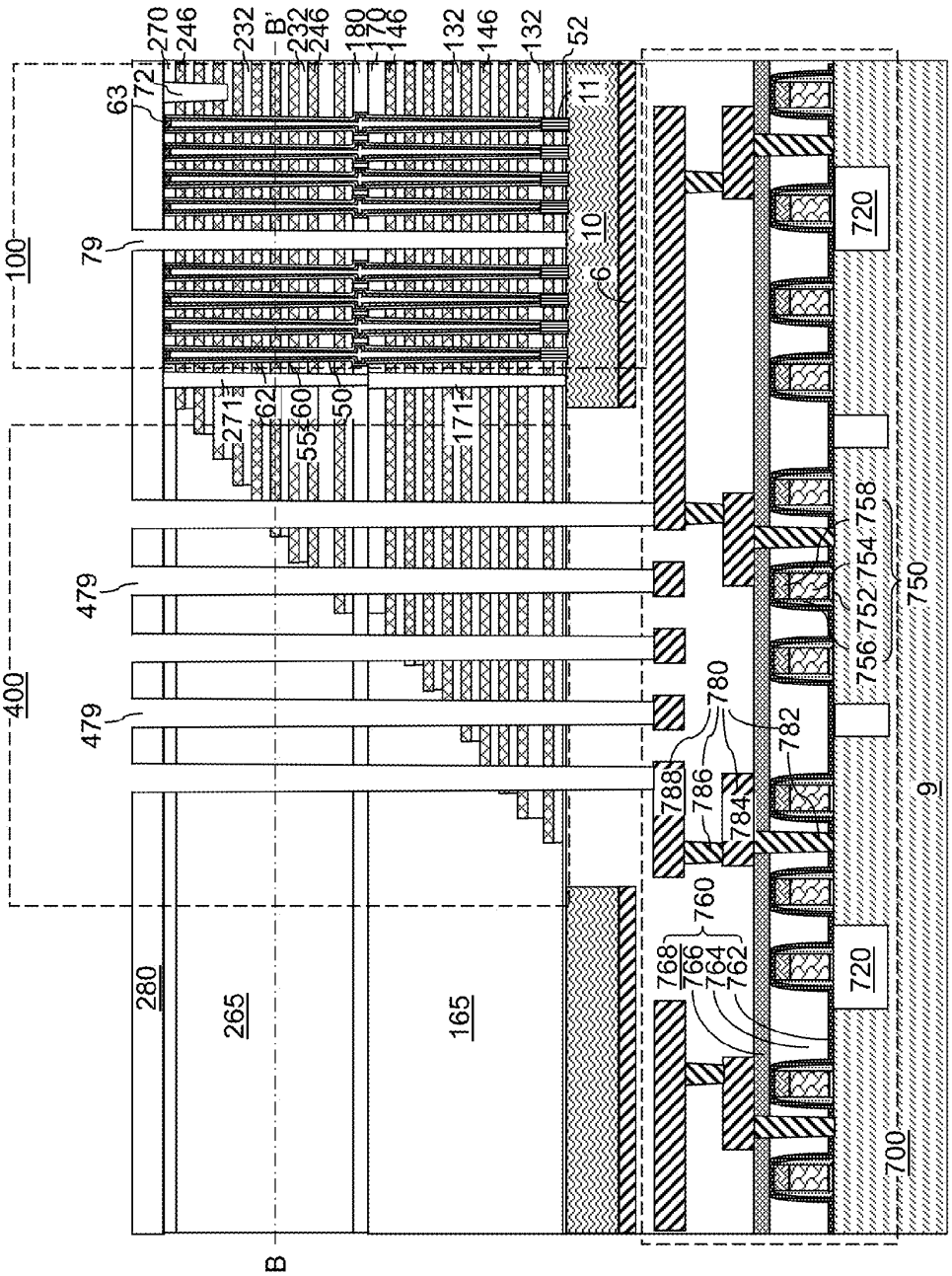
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FIG. 72A

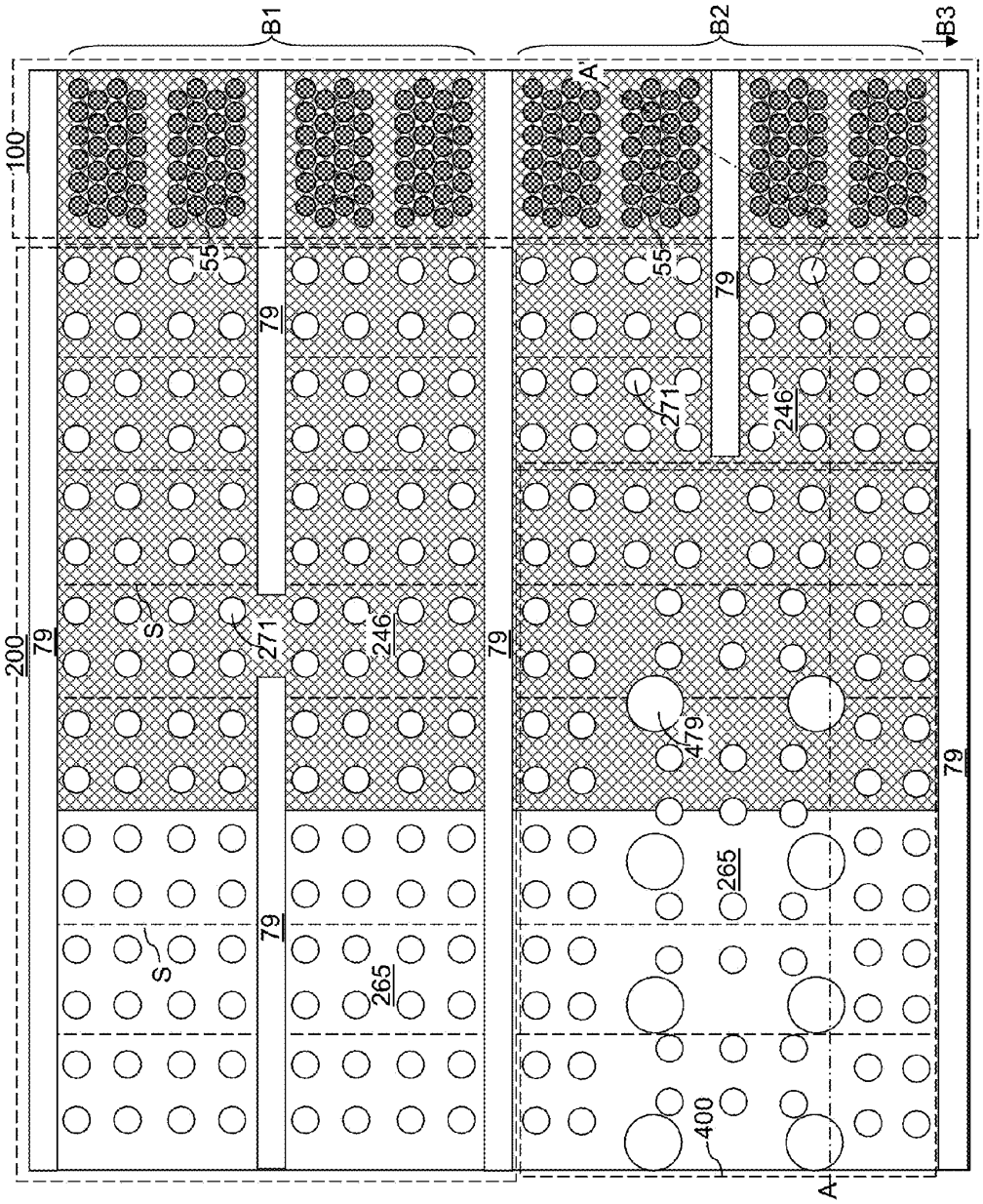

FIG. 72B

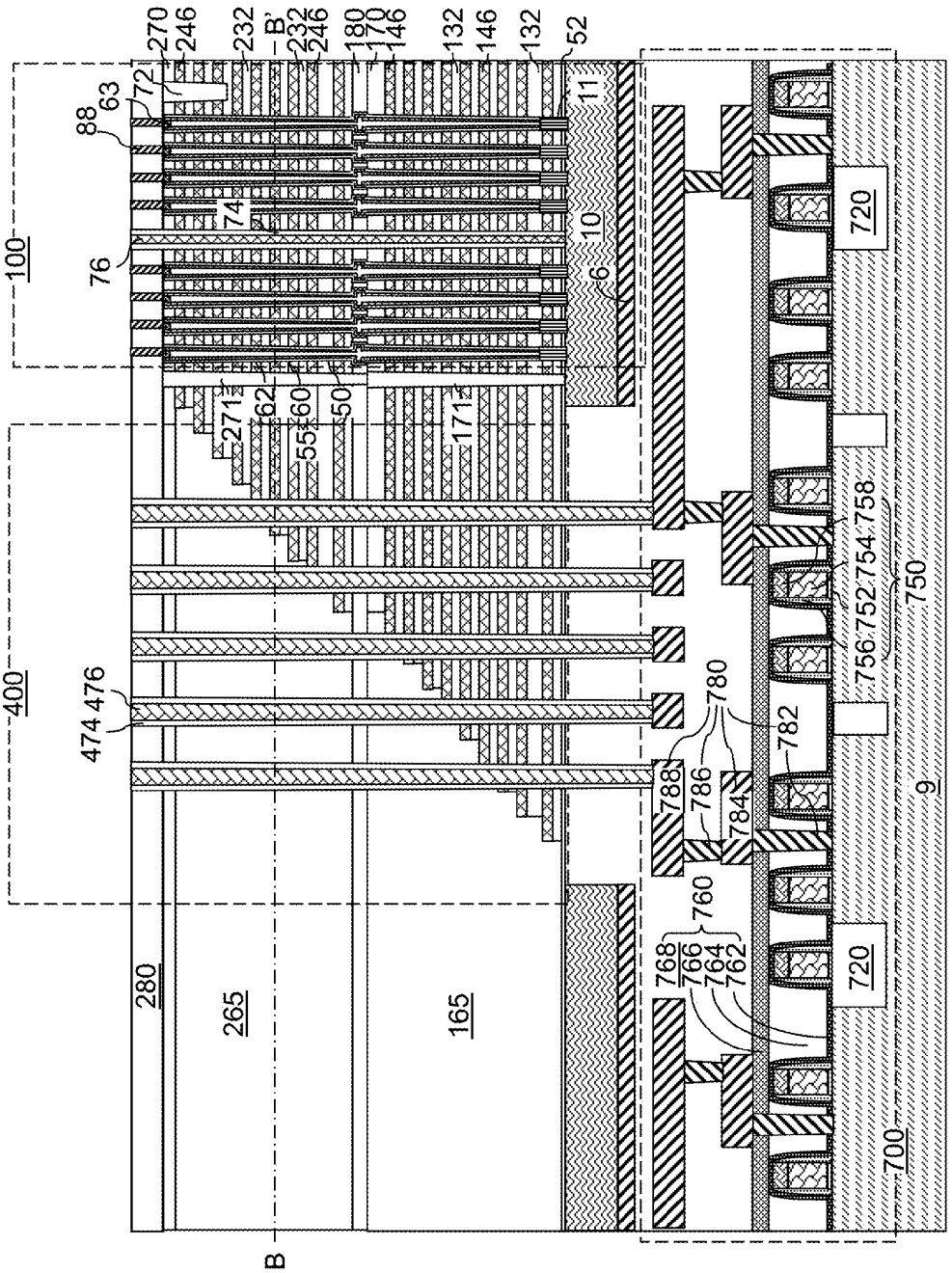
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FIG. 73A

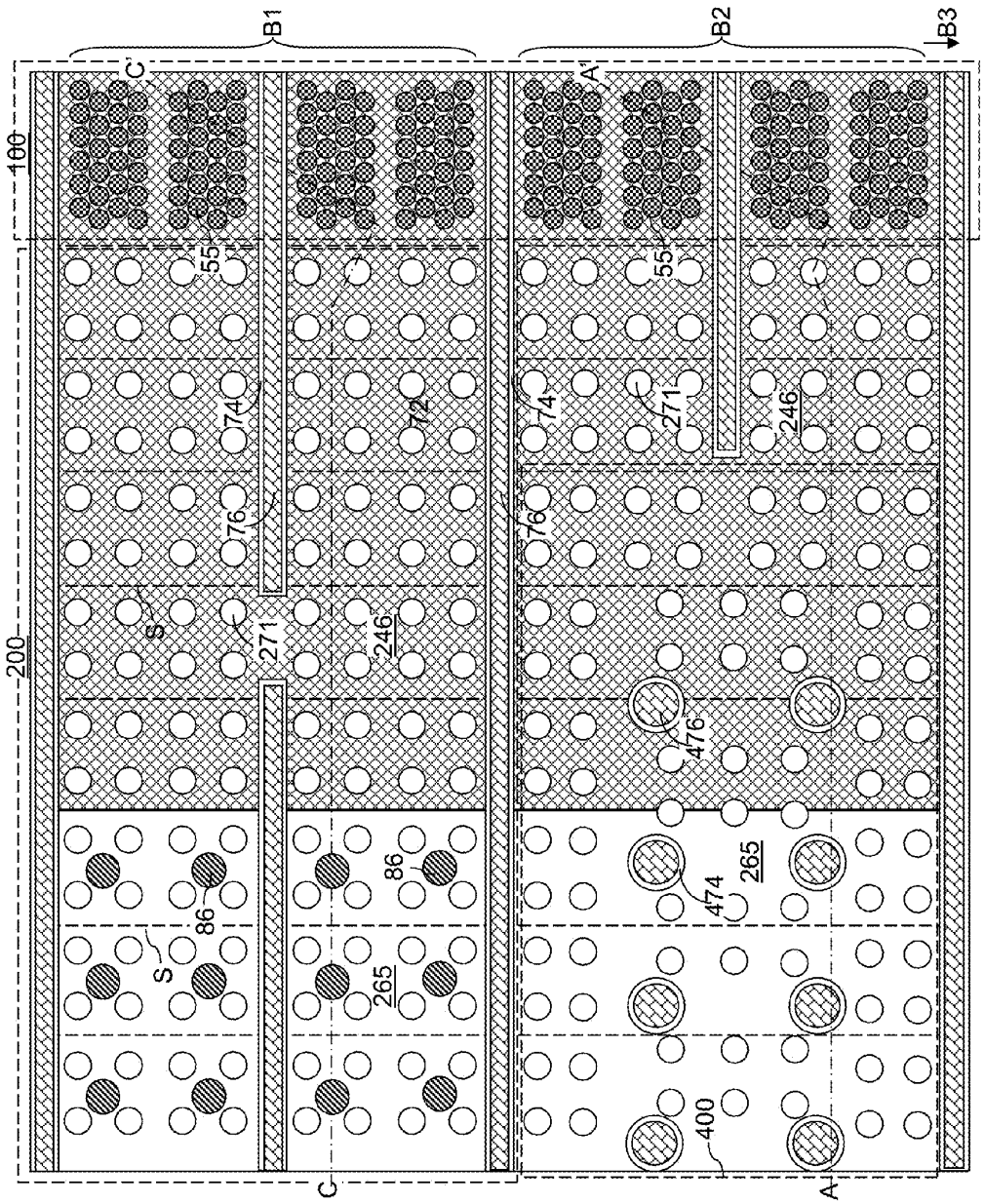

FIG. 73B

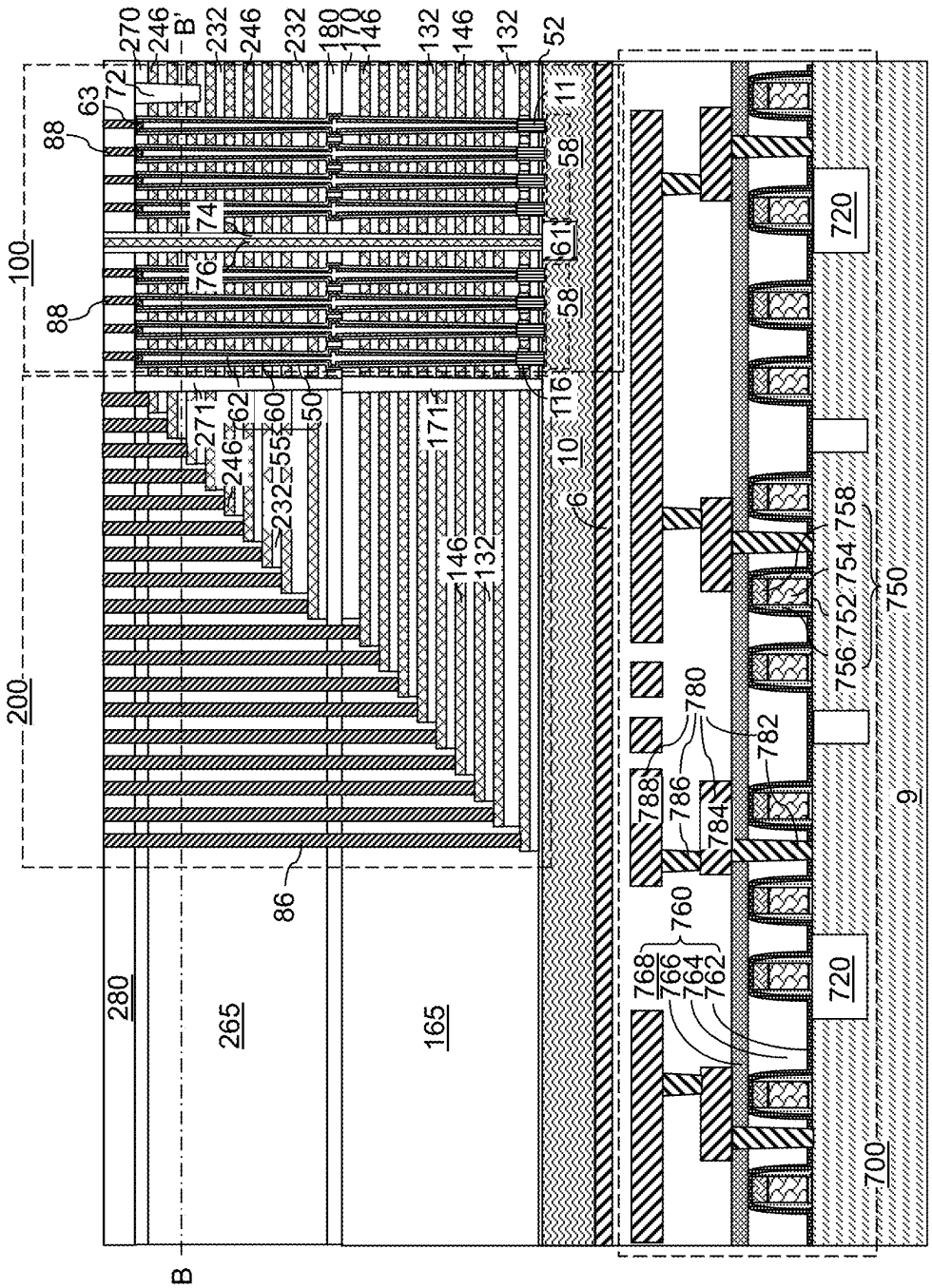
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FIG. 73C

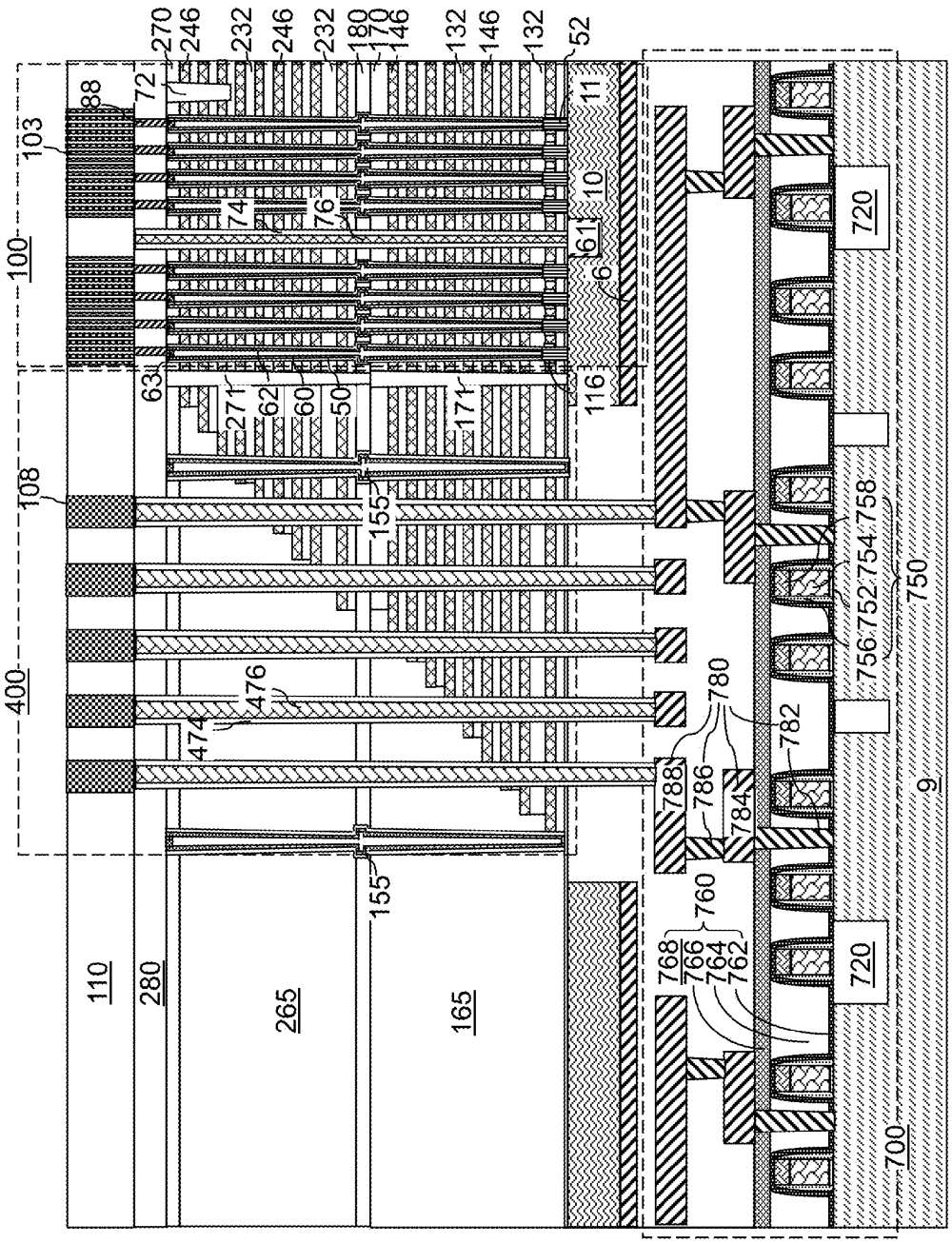
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FIG. 74

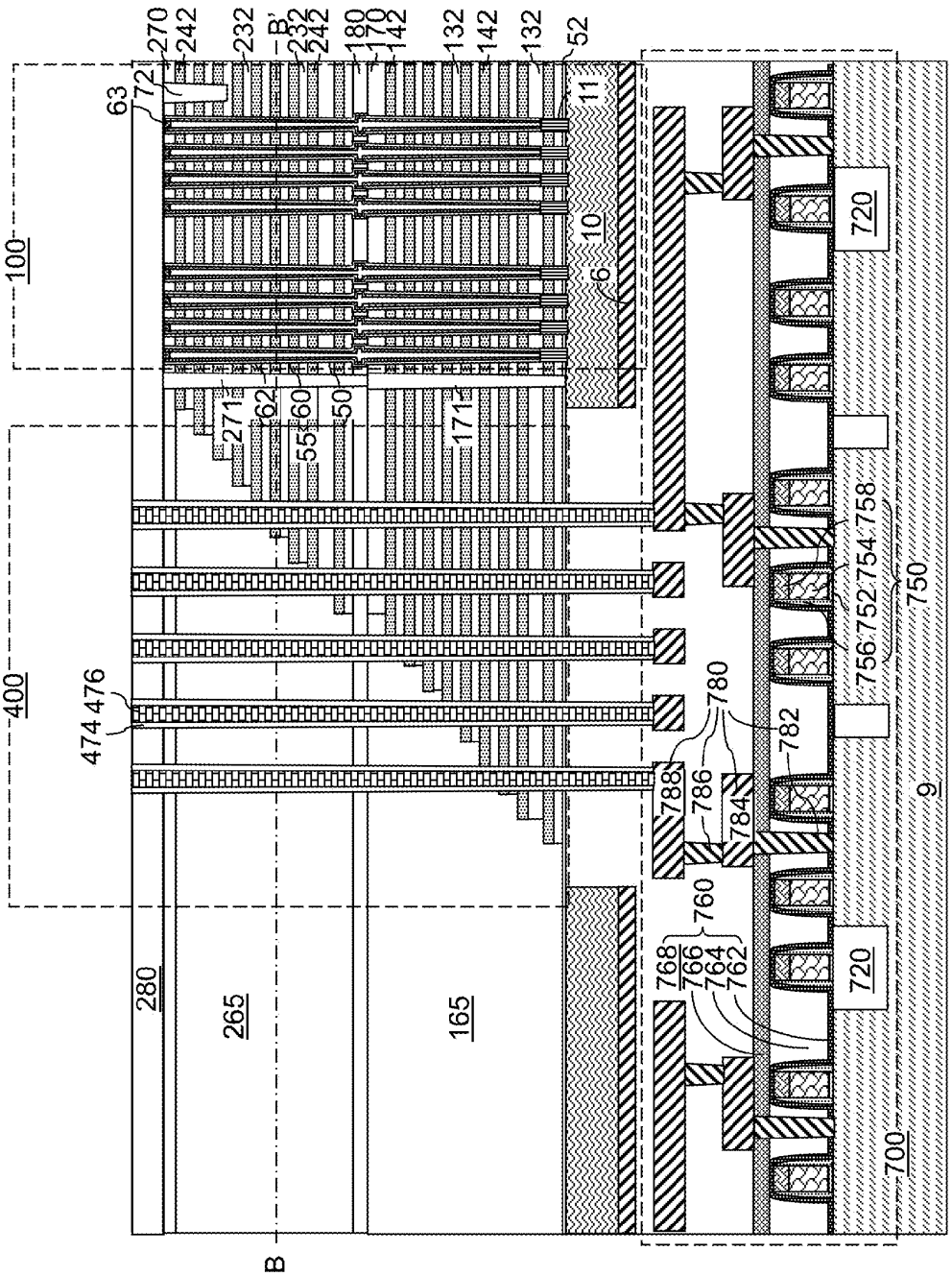
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FIG. 75A

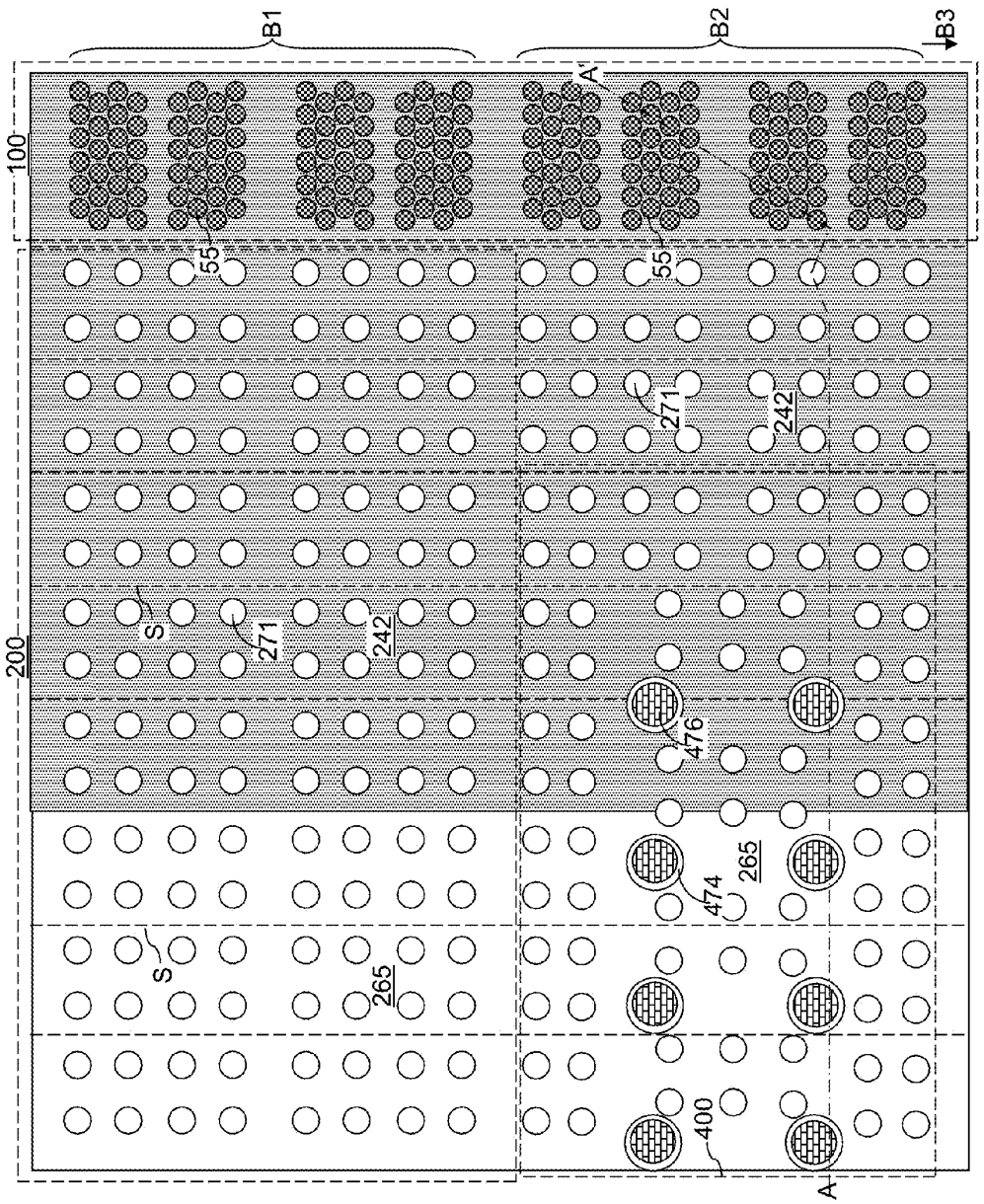

FIG. 75B

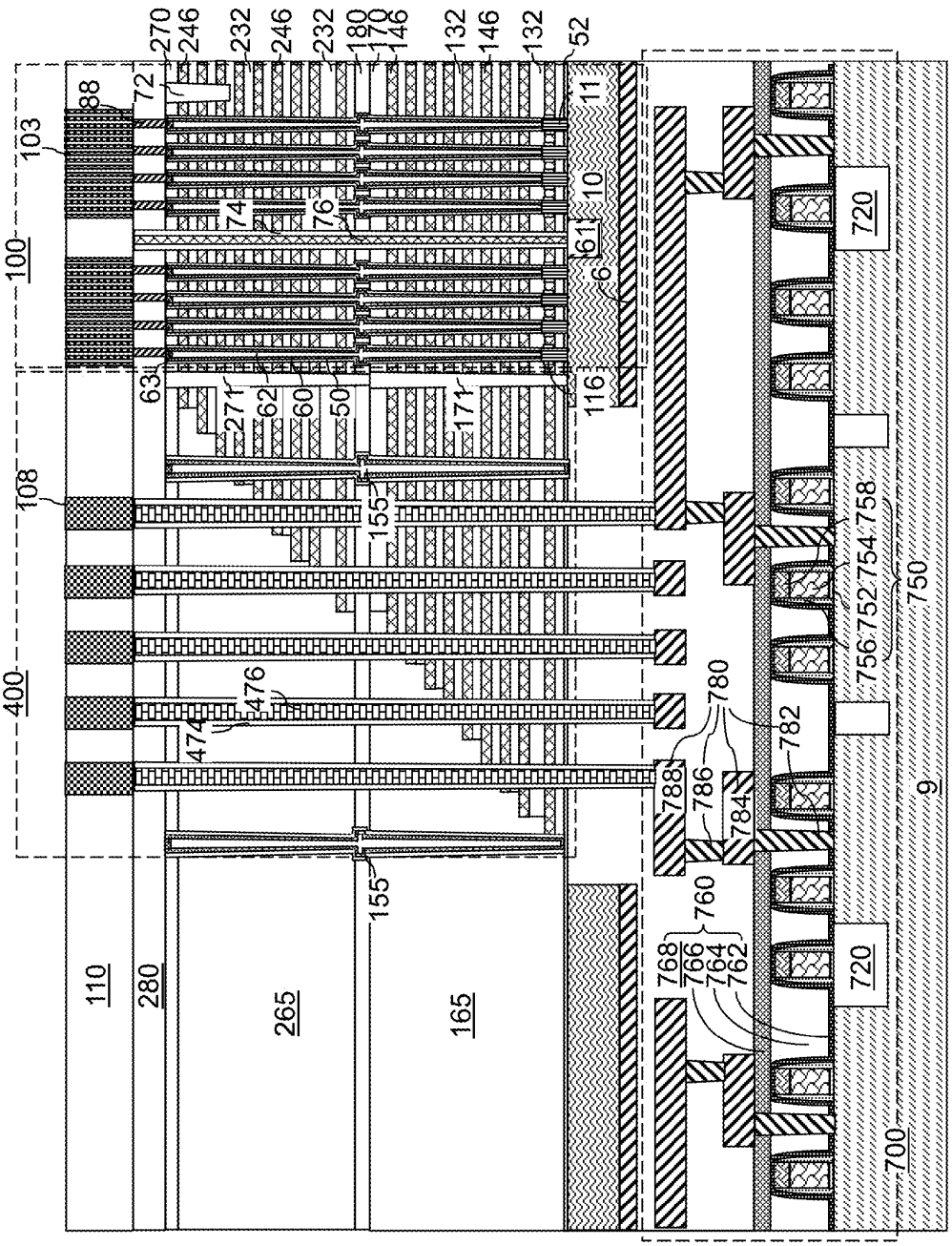
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FIG. 76

THROUGH-MEMORY-LEVEL VIA STRUCTURES FOR A THREE-DIMENSIONAL MEMORY DEVICE

RELATED APPLICATIONS

[0001] The present application claims the benefit of priority from U.S. Provisional Application Ser. No. 62/271,210 filed on Dec. 22, 2015, the entire content of which is incorporated herein by reference.

FIELD

[0002] The present disclosure relates generally to the field of semiconductor devices and specifically to three-dimensional non-volatile memory devices, such as vertical NAND strings and other three-dimensional devices, and methods of making the same.

BACKGROUND

[0003] Recently, ultra high density storage devices have been proposed using a three-dimensional (3D) stacked memory stack structure sometimes referred to as Bit Cost Scalable (BiCS) architecture. For example, a 3D NAND stacked memory device can be formed from an array of an alternating stack of insulating materials and spacer material layers that are formed as electrically conductive layer or replaced with electrically conductive layers. Memory openings are formed through the alternating stack, and are filled with memory stack structures, each of which includes a vertical stack of memory elements and a vertical semiconductor channel. A memory-level assembly including the alternating stack and the memory stack structures is formed over a substrate. The electrically conductive layers can function as word lines of a 3D NAND stacked memory device, and bit lines overlying an array of memory stack structures can be connected to drain-side ends of the vertical semiconductor channels. As three-dimensional memory devices scale to smaller device dimensions, the device area for peripheral devices can take up a significant portion of the total chip area. Thus, a method of providing various peripheral devices, such as word line driver circuits, without significantly increasing the total chip size is desired. Further, an efficient power distribution network in the array of memory stack structures can increase performance of three-dimensional memory devices. A method of enhancing power distribution without excessively increasing the footprint of a semiconductor chip is also desired.

SUMMARY

[0004] According to an aspect of the present disclosure, a three dimensional NAND memory device includes word line driver devices located on or over a substrate, an alternating stack of word lines and insulating layers located over the word line driver devices, a plurality of memory stack structures extending through the alternating stack, each memory stack structure including a memory film and a vertical semiconductor channel, and through-memory-level via structures which electrically couple the word lines in a first memory block to the word line driver devices. The through-memory-level via structures extend through a through-memory-level via region located between a staircase region of the first memory block and a staircase region of another memory block.

[0005] According to an aspect of the present disclosure a semiconductor structure is provided, which includes: a memory-level assembly located over a semiconductor substrate and including at least one alternating stack and memory stack structures vertically extending through the at least one alternating stack, wherein the at least one alternating stack includes alternating layers of respective insulating layers and respective electrically conductive layers; a plurality of laterally-elongated contact via structures that vertically extend through the memory-level assembly, laterally extend along a first horizontal direction, and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks, wherein the plurality of blocks comprises a set of three neighboring blocks including, in order, a first block, a second block, and third block arranged along a second horizontal direction that is perpendicular to the first horizontal direction; and a through-memory-level via region located on a lengthwise end of the second block and between a staircase region of the first block and a staircase region of the third block. Each staircase region of the first and third blocks includes terraces in which each underlying electrically conductive layer extends farther along the first horizontal direction than any overlying electrically conductive layer in the memory-level assembly. The through-memory-level via region comprises through-memory-level via structures that vertically extend at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane including a bottommost surface of the memory-level assembly.

[0006] According to another aspect of the present disclosure, a method of forming a semiconductor structure is provided. A memory-level assembly is formed over a semiconductor substrate. The memory-level assembly includes at least one alternating stack and memory stack structures vertically extending through the at least one alternating stack. The at least one alternating stack includes alternating layers of respective insulating layers and respective electrically conductive layers, and the at least one alternating stack comprises staircase regions that include terraces in which each underlying electrically conductive layer extends farther along a first horizontal direction than any overlying electrically conductive layer in the memory-level assembly. A plurality of laterally-elongated contact via structures is formed through the memory-level assembly. The plurality of laterally-elongated contact via structures laterally extends along the first horizontal direction and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks. The plurality of blocks comprises a set of three neighboring blocks including, in order, a first block, a second block, and third block arranged along a second horizontal direction that is perpendicular to the first horizontal direction and including a respective first staircase region, a second staircase region, and a third staircase region, respectively. The second staircase region is removed. Through-memory-level via structures are formed in an area of the removed second staircase region while the first and third staircase regions remain intact. Each of the through-memory-level via structures vertically extends at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane including a bottommost surface of the memory-level assembly.

[0007] According to yet another aspect of the present disclosure, a three dimensional NAND memory device,

comprises word line driver devices located over a substrate, an alternating stack of word lines and insulating layers located over the word line driver devices, a plurality of memory stack structures extending through the alternating stack, each memory stack structure comprising a memory film and a vertical semiconductor channel, and through-memory-level via structures which electrically couple the word lines in a first memory block to the word line driver devices. The through-memory-level via structures extend through a dielectric fill material portion located between a staircase region of the first memory block and a staircase region of another memory block.

[0008] According to yet another aspect of the present disclosure, a semiconductor structure is provided, which includes: word line switching devices comprising field effect transistors and located on a semiconductor substrate; and a memory-level assembly overlying the semiconductor substrate and comprising at least one alternating stack and memory stack structures vertically extending through the at least one alternating stack. Each of the at least one alternating stack comprises alternating layers of respective insulating layers and respective electrically conductive layers that comprise word lines for the memory stack structures. A plurality of laterally-elongated contact via structures vertically extends through the memory-level assembly, laterally extends along a first horizontal direction, and laterally divides the memory-level assembly into a plurality of laterally spaced-apart blocks. The plurality of blocks comprises a set of three neighboring blocks including, in order, a first block, a second block, and third block arranged along a second horizontal direction that is perpendicular to the first horizontal direction. A through-memory-level via region is located directly above an area of the word line switching devices on a lengthwise end of the second block and between a staircase region of the first block and a staircase region of the third block, each staircase region of the first and third blocks including terraces in which each underlying electrically conductive layer extends farther along the first horizontal direction than any overlying electrically conductive layer within the memory-level assembly, and the through-memory-level via region comprises through-memory-level via structures, each of which providing an electrically conductive path between a respective word line switching device and a respective word line.

[0009] According to still another aspect of the present disclosure, a method of forming a semiconductor structure is provided. Word line switching devices comprising field effect transistors are formed on a semiconductor substrate. A memory-level assembly is formed over a semiconductor substrate, the memory-level assembly including at least one alternating stack and memory stack structures vertically extending through the at least one alternating stack. Each of the at least one an alternating stack includes alternating layers of respective insulating layers and respective electrically conductive layers, and the at least one alternating stack comprises staircase regions that include terraces in which each underlying electrically conductive layer extends farther along a first horizontal direction than any overlying electrically conductive layer in the memory-level assembly. A plurality of laterally-elongated contact via structures is formed through the memory-level assembly. The plurality of laterally-elongated contact via structures laterally extends along the first horizontal direction and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks. The plurality of blocks comprises a set of three neighboring blocks including, in order, a first block including a first staircase region, a second block, and third block arranged along a second horizontal direction that is perpendicular to the first horizontal direction and including a first staircase region, a second staircase region, and a third staircase region, respectively. Nodes of the word line switching devices are electrically connected to portions of the electrically conducive layers in the first and third staircase regions employing through-memory-level via structures formed in an area of the second staircase region.

[0010] According to even another aspect of the present disclosure, a semiconductor structure is provided, which includes: a memory-level assembly located over a semiconductor substrate and comprising at least one first alternating stack of electrically conductive layers and first portions of insulating layers, and further comprising memory stack structures vertically extending through the at least one first alternating stack, wherein each of the memory stack structures comprises a memory film and a vertical semiconductor channel, wherein the electrically conductive layers constitute word lines for the memory stack structures; an insulating moat trench structure vertically extending through the memory-level assembly and defining an area of a through-memory-level via region laterally offset from the at least one first alternating stack; at least one second alternating stack located in the through-memory-level via region, wherein the at least one second alternating stack includes alternating layers of dielectric spacer layers and second portions of the insulating layers, and each of the dielectric spacer layers is located at a same level as a respective electrically conductive layer; and through-memory-level via structures located within the through-memory-level via region and vertically extending from a first horizontal plane including a topmost surface of the memory-level assembly and a bottommost surface of the memory-level assembly and comprising a conductive material.

[0011] According to further another aspect of the present disclosure, a method of forming a semiconductor structure is provided. At least one alternating stack of insulating layers and dielectric spacer layers is formed over a semiconductor substrate. Memory stack structures are formed through the at least one alternating stack. Each of the memory stack structures comprises a memory film and a vertical semiconductor channel. A moat trench defining an area of a through-memory-level via region is formed through the at least one alternating stack. A portion of the at least one alternating stack is present within the through-memory-level via region. Portions of the dielectric spacer layers outside the through-memory-level via region are replaced with electrically conductive layers while the portion of the at least one alternating stack in the moat trench remains intact. The electrically conductive layers constitute word lines for the memory stack structures. Through-memory-level via structures are formed within the through-memory-level via region. The through-memory-level via structures vertically extend from a first horizontal plane including a topmost surface of a remaining portion of the at least one alternating stack and a bottommost surface of the at least one alternating stack.

[0012] According to yet further another aspect of the present disclosure, a semiconductor structure is provided, which includes: a memory-level assembly located over a semiconductor substrate and comprising at least one alternating stack of electrically conductive layers and first por-

tions of insulating layers, and further comprising memory stack structures vertically extending through the at least one alternating stack. Each of the memory stack structures comprises a memory film and a vertical semiconductor channel. The electrically conductive layers constitute word lines for the memory stack structures. A plurality of laterally-elongated contact via structures vertically extends through the memory-level assembly, laterally extends along a first horizontal direction, and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks within the memory-level assembly. At least one through-memory-level via structure is located in a through-memory-level via region in a block, wherein the through-memory-level via region is located between a pair of laterally-elongated contact via structures and between two groups of memory stack structures located in the block, wherein each of the at least one through-memory-level via structure vertically extends through the memory-level assembly.

[0013] According to still further another aspect of the present disclosure, a method of forming a semiconductor structure is provided. A memory-level assembly is formed over a semiconductor substrate. The memory-level assembly comprises at least one alternating stack of electrically conductive layers and first portions of insulating layers, and further comprises memory stack structures vertically extending through the at least one alternating stack. Each of the memory stack structures comprises a memory film and a vertical semiconductor channel. A plurality of laterally-elongated contact via structures is formed through the memory-level assembly. The plurality of laterally-elongated contact via structures laterally extends along a first horizontal direction, and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks within the memory-level assembly. At least one through-memory-level via structure is formed in a through-memory-level via region in a block. The through-memory-level via region is provided between a pair of laterally-elongated contact via structures and between two groups of memory stack structures located in the block and including through-memory-level via structures. Each of the at least one through-memory-level via structure vertically extends through the memory-level assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1**A is a vertical cross-sectional view of a first exemplary structure after formation of semiconductor devices, at least one lower level dielectric layer, and lower level metal interconnect structures on a semiconductor substrate according to a first embodiment of the present disclosure.

[0015] FIG. **1**B is a horizontal cross-sectional view of the first exemplary structure of FIG. **1**A along the horizontal plane B-B' in FIG. **1**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **1**A.

[0016] FIG. **2** is a vertical cross-sectional view of the first exemplary structure after formation of a planar semiconductor material layer and a first-tier alternating stack of first insulting layers and first spacer material layers according to the first embodiment of the present disclosure.

[0017] FIG. **3** is a vertical cross-sectional view of the first exemplary structure after patterning first-tier staircase regions on the first-tier alternating stack and forming a first-tier retro-stepped dielectric material portion according to the first embodiment of the present disclosure.

[0018] FIG. **4**A is a vertical cross-sectional view of the first exemplary structure after formation of first-tier support pillar structures and an inter-tier dielectric layer according to the first embodiment of the present disclosure.

[0019] FIG. **4**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **4**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **4**A.

[0020] FIG. **5**A is a vertical cross-sectional view of the first exemplary structure after formation of first-tier memory openings according to the first embodiment of the present disclosure.

[0021] FIG. **5**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **5**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **5**A.

[0022] FIG. **6** is a vertical cross-sectional view of the first exemplary structure after formation of sacrificial memory opening fill portions according to the first embodiment of the present disclosure.

[0023] FIG. **7** is a vertical cross-sectional view of the first exemplary structure after formation of a second-tier alternating stack of second insulating layers and second spacer material layers, a second-tier retro-stepped dielectric material portion, and a second insulating cap layer according to the first embodiment of the present disclosure.

[0024] FIG. **8**A is a vertical cross-sectional view of the first exemplary structure after formation of second-tier dielectric support pillars and drain-select-level shallow trench isolation structures according to the first embodiment of the present disclosure.

[0025] FIG. **8**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **8**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **8**A.

[0026] FIG. **9**A is a vertical cross-sectional view of the first exemplary structure after formation of memory openings according to the first embodiment of the present disclosure.

[0027] FIG. **9**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **9**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **9**A.

[0028] FIG. **10**A is a vertical cross-sectional view of the first exemplary structure after formation of memory stack structures and contact level dielectric layer according to the first embodiment of the present disclosure.

[0029] FIG. **10**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **10**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **10**A.

[0030] FIG. **11**A is a vertical cross-sectional view of the first exemplary structure after formation of a through-memory-level opening according to the first embodiment of the present disclosure.

[0031] FIG. **11**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **11**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **11**A.

[0032] FIG. **12**A is a vertical cross-sectional view of the first exemplary structure after formation of a dielectric fill material according to the first embodiment of the present disclosure.

[0033] FIG. **12**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **12**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **12**A.

[0034] FIG. **13**A is a vertical cross-sectional view of the first exemplary structure after formation of backside contact trenches according to the first embodiment of the present disclosure.

[0035] FIG. **13**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **13**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **13**A.

[0036] FIG. **14**A is a vertical cross-sectional view of the first exemplary structure after formation of backside recesses by removal of the spacer material layers according to the first embodiment of the present disclosure.

[0037] FIG. **14**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **14**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **14**A.

[0038] FIG. **14**C is a vertical cross-sectional view of the first exemplary structure along the zig-zag vertical plane C-C' in FIG. **14**B according to the first embodiment of the present disclosure.

[0039] FIG. **15**A is a vertical cross-sectional view of the first exemplary structure after formation of electrically conductive layers, insulating spacers, and backside contact via structures according to the first embodiment of the present disclosure.

[0040] FIG. **15**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **15**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **15**A.

[0041] FIG. **15**C is a vertical cross-sectional view of the first exemplary structure along the zig-zag vertical plane C-C' in FIG. **15**B according to the first embodiment of the present disclosure.

[0042] FIG. **16**A is a vertical cross-sectional view of the first exemplary structure after formation of through-memory-level via structures, word line contact via structures, and upper level via structures according to the first embodiment of the present disclosure.

[0043] FIG. **16**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **16**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **16**A.

[0044] FIG. **16**C is a vertical cross-sectional view of the first exemplary structure along the zig-zag vertical plane C-C' in FIG. **16**B according to the first embodiment of the present disclosure.

[0045] FIG. **17**A is a vertical cross-sectional view of the first exemplary structure after formation of upper level line structures according to the first embodiment of the present disclosure.

[0046] FIG. **17**B is a horizontal cross-sectional view of the first exemplary structure along the horizontal plane B-B' in FIG. **17**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **17**A. Patterns of the upper level line structures are overlaid in dotted shapes.

[0047] FIG. **17**C is a vertical cross-sectional view of the first exemplary structure along the zig-zag vertical plane C-C' in FIG. **17**B according to the first embodiment of the present disclosure.

[0048] FIG. **17**D is a top-down view of the first exemplary structure according to the first embodiment of the present disclosure.

[0049] FIGS. **17**E and **17**F are top-down views of an alternative exemplary structure according to the first embodiment of the present disclosure.

[0050] FIG. **18** is a vertical cross-sectional view of a second exemplary structure after formation of semiconductor devices, lower level metal interconnect structures, and at least one lower level dielectric layer according to a second embodiment of the present disclosure.

[0051] FIG. **19**A is a vertical cross-sectional view of the second exemplary structure after formation of through-memory-level via structures and upper level metal interconnect structures according to the second embodiment of the present disclosure.

[0052] FIG. **19**B is cutaway plan view of the metal interconnect structures according to the second embodiment of the present disclosure.

[0053] FIG. **20** is a vertical cross-sectional view of an modification of the second exemplary structure after formation of semiconductor devices, lower level metal interconnect structures, and at least one lower level dielectric layer according to the second embodiment of the present disclosure.

[0054] FIG. **21** is a vertical cross-sectional view of the modification of the second exemplary structure after formation of a first tier structure including sacrificial memory opening fill portions and first-tier support pillar structures according to the second embodiment of the present disclosure.

[0055] FIG. **22** is a vertical cross-sectional view of the modification of the second exemplary structure after formation of a second tier structure after formation of a second tier structure, memory stack structures, second-tier support pillar structures, a contact level dielectric layer, and backside contact trenches according to the second embodiment of the present disclosure.

[0056] FIG. **23** is a vertical cross-sectional view of the modification of the second exemplary structure after formation of through-memory-level via structures according to the second embodiment of the present disclosure.

[0057] FIG. **24**A is a vertical cross-sectional view of a third exemplary structure after formation of a first-tier alternating stack, first-tier support pillar structures, sacrificial memory opening fill portions, and sacrificial backside contact trench fill portions according to the third embodiment of the present disclosure.

[0058] FIG. **24**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in FIG. **24**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **24**A.

[0059] FIG. **25**A is a vertical cross-sectional view of the third exemplary structure after formation of a second-tier alternating stack, second-tier support pillar structures, drain-select-level shallow trench structures, memory openings, and a moat trench according to the third embodiment of the present disclosure.

[0060] FIG. **25**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in

FIG. **25**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **25**A.

[0061] FIG. **26**A is a vertical cross-sectional view of the third exemplary structure after formation of memory stack structures and an insulating moat trench structure according to the third embodiment of the present disclosure.

[0062] FIG. **26**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in FIG. **26**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **26**A.

[0063] FIG. **27**A is a vertical cross-sectional view of the third exemplary structure after formation of backside contact trenches according to the third embodiment of the present disclosure.

[0064] FIG. **27**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in FIG. **27**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **27**A.

[0065] FIG. **28**A is a vertical cross-sectional view of the third exemplary structure after formation of laterally-elongated contact via structures according to the third embodiment of the present disclosure.

[0066] FIG. **28**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in FIG. **28**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **28**A.

[0067] FIG. **29**A is a vertical cross-sectional view of the third exemplary structure after formation of through-memory-level via structures according to the third embodiment of the present disclosure.

[0068] FIG. **29**B is a horizontal cross-sectional view of the third exemplary structure along the horizontal plane B-B' in FIG. **29**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **29**A.

[0069] FIG. **29**C is a vertical cross-sectional view of the third exemplary structure along the zig-zag vertical plane C-C' in FIG. **29**B according to the third embodiment of the present disclosure.

[0070] FIG. **30** is a vertical cross-sectional view of the third exemplary structure after formation of upper level metal interconnect structures according to the third embodiment of the present disclosure.

[0071] FIG. **31**A is a vertical cross-sectional view of a modification of the third exemplary structure after formation of an insulating moat trench structure according to the third embodiment of the present disclosure.

[0072] FIG. **31**B is a horizontal cross-sectional view of the modification of the third exemplary structure along the horizontal plane B-B' in FIG. **31**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **31**A.

[0073] FIG. **32**A is a vertical cross-sectional view of the modification of the third exemplary structure after formation of memory stack structures, laterally-elongated contact via structures, and through-memory-level via structures according to the third embodiment of the present disclosure.

[0074] FIG. **32**B is a horizontal cross-sectional view of the modification of the third exemplary structure along the horizontal plane B-B' in FIG. **32**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **32**A.

[0075] FIG. **33**A is a vertical cross-sectional view of a fourth exemplary structure after formation of a first-tier alternating stack, a second-tier alternating stack, and memory stack structures according to a fourth embodiment of the present disclosure.

[0076] FIG. **33**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **33**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **33**A.

[0077] FIG. **34**A is a horizontal cross-sectional view of the fourth exemplary structure after formation of through-memory-level openings and backside contact trenches according to the fourth embodiment of the present disclosure.

[0078] FIG. **34**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **34**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **34**A.

[0079] FIG. **35**A is a vertical cross-sectional view of the fourth exemplary structure after deposition and patterning of an insulating liner layer according to the fourth embodiment of the present disclosure.

[0080] FIG. **35**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **35**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **35**A.

[0081] FIG. **36**A is a vertical cross-sectional view of the fourth exemplary structure after formation of backside recesses according to the fourth embodiment of the present disclosure.

[0082] FIG. **36**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **36**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **36**A.

[0083] FIG. **37**A is a vertical cross-sectional view of the fourth exemplary structure after formation of electrically conductive layers according to the fourth embodiment of the present disclosure.

[0084] FIG. **37**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **37**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **37**A.

[0085] FIG. **38**A is a vertical cross-sectional view of the fourth exemplary structure after formation of insulating moat trench structures and laterally-elongated contact via structures according to the fourth embodiment of the present disclosure.

[0086] FIG. **38**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **38**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **38**A.

[0087] FIG. **39**A is a vertical cross-sectional view of the fourth exemplary structure after formation of through-memory-level via structures according to the fourth embodiment of the present disclosure.

[0088] FIG. **39**B is a horizontal cross-sectional view of the fourth exemplary structure along the horizontal plane B-B' in FIG. **39**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **39**A.

[0089] FIG. **40** is a vertical cross-sectional view of the fourth exemplary structure after formation of upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0090] FIG. **41** is a vertical cross-sectional view of a first modification of the fourth exemplary structure after forma-

tion of patterned insulating liner layers according to the fourth embodiment of the present disclosure.

[0091] FIG. **42** is a vertical cross-sectional view of the first modification of the fourth exemplary structure after formation of insulating moat trench structures, laterally-elongated contact via structures, and through-memory-level via structures according to the fourth embodiment of the present disclosure.

[0092] FIG. **43** is a vertical cross-sectional view of the first modification of the fourth exemplary structure after formation of upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0093] FIG. **44**A is a vertical cross-sectional view of a second modification of the fourth exemplary structure after formation of a first-tier alternating stack, a second-tier alternating stack, memory stack structures, and drain-select-level shallow trench isolation structures according to the fourth embodiment of the present disclosure.

[0094] FIG. **44**B is a horizontal cross-sectional view of the second modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **44**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **44**A.

[0095] FIG. **45**A is a vertical cross-sectional view of the second modification of the fourth exemplary structure after formation of through-memory-level openings and backside contact trenches according to the fourth embodiment of the present disclosure.

[0096] FIG. **45**B is a horizontal cross-sectional view of the second modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **45**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **45**A.

[0097] FIG. **46**A is a vertical cross-sectional view of the second modification of the fourth exemplary structure after replacement of sacrificial material layers with electrically conductive layers according to the fourth embodiment of the present disclosure.

[0098] FIG. **46**B is a horizontal cross-sectional view of the second modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **46**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **46**A.

[0099] FIG. **47**A is a vertical cross-sectional view of the second modification of the fourth exemplary structure after deposition of a conformal insulating layer and an anisotropic etch that removes horizontal portions of the conformal insulating layer and deepens the through-memory-level openings according to the fourth embodiment of the present disclosure.

[0100] FIG. **47**B is a horizontal cross-sectional view of the second modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **47**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **47**A.

[0101] FIG. **48**A is a vertical cross-sectional view of the second modification of the fourth exemplary structure after formation of laterally-elongated contact via structures and through-memory-level via structures according to the fourth embodiment of the present disclosure.

[0102] FIG. **48**B is a horizontal cross-sectional view of the second modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **48**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **48**A.

[0103] FIG. **49** is a vertical cross-sectional view of the second modification of the fourth exemplary structure after formation of upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0104] FIG. **50**A is a vertical cross-sectional view of a third modification of the fourth exemplary structure after formation of a first-tier alternating stack, a second-tier alternating stack, memory stack structures, and drain-select-level shallow trench isolation structures according to the fourth embodiment of the present disclosure.

[0105] FIG. **50**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **50**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **50**A.

[0106] FIG. **51**A is a vertical cross-sectional view of the third modification of the fourth exemplary structure after formation of through-memory-level openings according to the fourth embodiment of the present disclosure.

[0107] FIG. **51**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **51**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **51**A.

[0108] FIG. **52**A is a vertical cross-sectional view of the third modification of the fourth exemplary structure after replacement of sacrificial material layers with electrically conductive layers according to the fourth embodiment of the present disclosure.

[0109] FIG. **52**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **52**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **52**A.

[0110] FIG. **53**A is a vertical cross-sectional view of the third modification of the fourth exemplary structure after formation of insulating liners according to the fourth embodiment of the present disclosure.

[0111] FIG. **53**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **53**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **53**A.

[0112] FIG. **54**A is a vertical cross-sectional view of the third modification of the fourth exemplary structure after formation of through-memory-level via structures according to the fourth embodiment of the present disclosure.

[0113] FIG. **54**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **54**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **54**A.

[0114] FIG. **55**A is a vertical cross-sectional view of the third modification of the fourth exemplary structure after formation of laterally-elongated contact via structures and upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0115] FIG. **55**B is a horizontal cross-sectional view of the third modification of the fourth exemplary structure along

the horizontal plane B-B' in FIG. **55**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **55**A.

[0116] FIG. **56**A is a vertical cross-sectional view of a fourth modification of the fourth exemplary structure after formation of memory stack structures and laterally-elongated contact via structures according to the fourth embodiment of the present disclosure.

[0117] FIG. **56**B is a horizontal cross-sectional view of the fourth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **56**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **56**A.

[0118] FIG. **57**A is a vertical cross-sectional view of the fourth modification of the fourth exemplary structure after formation of through-memory-level openings according to the fourth embodiment of the present disclosure.

[0119] FIG. **57**B is a horizontal cross-sectional view of the fourth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **57**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **57**A.

[0120] FIG. **58**A is a vertical cross-sectional view of the fourth modification of the fourth exemplary structure after formation of insulating liners according to the fourth embodiment of the present disclosure.

[0121] FIG. **58**B is a horizontal cross-sectional view of the fourth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **58**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **58**A.

[0122] FIG. **59**A is a vertical cross-sectional view of the fourth modification of the fourth exemplary structure after formation of through-memory-level via structures and upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0123] FIG. **59**B is a horizontal cross-sectional view of the fourth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **59**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **59**A.

[0124] FIG. **60** is a horizontal cross-sectional view of a fifth modification of the fourth exemplary structure according to the fourth embodiment of the present disclosure.

[0125] FIG. **61**A is a vertical cross-sectional view of a second modification of the third exemplary structure after formation of memory stack structures according to the third embodiment of the present disclosure.

[0126] FIG. **61**B is a horizontal cross-sectional view of the second modification of the third exemplary structure of FIG. **61**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **61**A.

[0127] FIG. **62**A is a vertical cross-sectional view of the second modification of the third exemplary structure after simultaneous formation of backside contact trenches and moat trenches according to the third embodiment of the present disclosure.

[0128] FIG. **62**B is a horizontal cross-sectional view of the second modification of the third exemplary structure of FIG. **62**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **62**A.

[0129] FIG. **63**A is a vertical cross-sectional view of the second modification of the third exemplary structure after formation of upper level line structures according to the third embodiment of the present disclosure.

[0130] FIG. **63**B is a horizontal cross-sectional view of second modification of the third exemplary structure along the horizontal plane B-B' in FIG. **63**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **63**A.

[0131] FIG. **63**C is a vertical cross-sectional view of the second modification of the third exemplary structure along the zig-zag vertical plane C-C' in FIG. **63**B according to the third embodiment of the present disclosure.

[0132] FIG. **64** is a vertical cross-sectional view of a third modification of the third exemplary structure after formation of upper level line structures according to the third embodiment of the present disclosure.

[0133] FIG. **65**A is a vertical cross-sectional view of a sixth modification of the fourth exemplary structure after formation of sacrificial memory opening fill portions and sacrificial moat trench fill portions according to the fourth embodiment of the present disclosure.

[0134] FIG. **65**B is a horizontal cross-sectional view of the sixth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **65**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **65**A.

[0135] FIG. **66**A is a vertical cross-sectional view of the sixth modification of the fourth exemplary structure after formation of memory stack structures and dummy memory stack structures according to the fourth embodiment of the present disclosure.

[0136] FIG. **66**B is a horizontal cross-sectional view of the sixth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **66**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **66**A.

[0137] FIG. **67**A is a vertical cross-sectional view of the sixth modification of the fourth exemplary structure after formation of backside recesses according to the fourth embodiment of the present disclosure.

[0138] FIG. **67**B is a horizontal cross-sectional view of the sixth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **67**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **67**A.

[0139] FIG. **68**A is a vertical cross-sectional view of the sixth modification of the fourth exemplary structure after formation of electrically conductive layers and laterally-elongated contact via structures according to the fourth embodiment of the present disclosure.

[0140] FIG. **68**B is a horizontal cross-sectional view of the sixth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **68**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **68**A.

[0141] FIG. **69**A is a vertical cross-sectional view of the sixth modification of the fourth exemplary structure after formation of through-memory-level via structures and upper level metal interconnect structures according to the fourth embodiment of the present disclosure.

[0142] FIG. **69**B is a horizontal cross-sectional view of the sixth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **69**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **69**A.

[0143] FIG. **70**A is a vertical cross-sectional view of a seventh modification of the fourth exemplary structure after formation of memory stack structures and a contact level dielectric layer according to the fourth embodiment of the present disclosure.

[0144] FIG. **70**B is a horizontal cross-sectional view of the seventh modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **70**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **70**A.

[0145] FIG. **71**A is a vertical cross-sectional view of the seventh modification of the fourth exemplary structure after concurrent formation of backside contact trenches and through-memory-level via cavities according to the fourth embodiment of the present disclosure.

[0146] FIG. **71**B is a horizontal cross-sectional view of the seventh modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **71**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **71**A.

[0147] FIG. **72**A is a vertical cross-sectional view of the seventh modification of the fourth exemplary structure after replacement of the sacrificial material layers with electrically conductive layers according to the fourth embodiment of the present disclosure.

[0148] FIG. **72**B is a horizontal cross-sectional view of the seventh modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **72**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **72**A.

[0149] FIG. **73**A is a vertical cross-sectional view of the seventh modification of the fourth exemplary structure after formation of laterally-extending contact via structures and through-memory-stack via structures according to the fourth embodiment of the present disclosure.

[0150] FIG. **73**B is a horizontal cross-sectional view of the seventh modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **73**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **73**A.

[0151] FIG. **73**C is a vertical cross-sectional view of the seventh modification of the fourth exemplary structure along the zig-zag vertical plane C-C' in FIG. **73**B according to the fourth embodiment of the present disclosure.

[0152] FIG. **74** is a vertical cross-sectional view of the seventh modification of the fourth exemplary structure after formation of upper metal interconnect structures according to the fourth embodiment of the present disclosure.

[0153] FIG. **75**A is a vertical cross-sectional view of an eighth modification of the fourth exemplary structure after formation of through-memory-stack via structures according to the fourth embodiment of the present disclosure.

[0154] FIG. **75**B is a horizontal cross-sectional view of the eighth modification of the fourth exemplary structure along the horizontal plane B-B' in FIG. **75**A. The zig-zag vertical plane A-A' corresponds to the plane of the vertical cross-sectional view of FIG. **75**A.

[0155] FIG. **76** is a vertical cross-sectional view of the eighth modification of the fourth exemplary structure after formation of upper metal interconnect structures according to the fourth embodiment of the present disclosure.

DETAILED DESCRIPTION

[0156] As discussed above, the present disclosure is directed to three-dimensional non-volatile memory devices, such as vertical NAND strings and other three-dimensional devices, and methods of making the same, the various aspects of which are described below. The embodiments of the disclosure can be employed to form various semiconductor devices such as three-dimensional monolithic memory array devices comprising a plurality of NAND memory strings. The drawings are not drawn to scale. Multiple instances of an element may be duplicated where a single instance of the element is illustrated, unless absence of duplication of elements is expressly described or clearly indicated otherwise.

[0157] Ordinals such as "first," "second," and "third" are employed merely to identify similar elements, and different ordinals may be employed across the specification and the claims of the instant disclosure. As used herein, a first element located "on" a second element can be located on the exterior side of a surface of the second element or on the interior side of the second element. As used herein, a first element is located "directly on" a second element if there exist a physical contact between a surface of the first element and a surface of the second element. As used herein, an "in-process" structure or a "transient" structure refers to a structure that is subsequently modified.

[0158] As used herein, a "layer" refers to a material portion including a region having a thickness. A layer may extend over the entirety of an underlying or overlying structure, or may have an extent less than the extent of an underlying or overlying structure. Further, a layer may be a region of a homogeneous or inhomogeneous continuous structure that has a thickness less than the thickness of the continuous structure. For example, a layer may be located between any pair of horizontal planes between or at a top surface and a bottom surface of the continuous structure. A layer may extend horizontally, vertically, and/or along a tapered surface. A substrate may be a layer, may include one or more layers therein, and/or may have one or more layer thereupon, thereabove, and/or therebelow.

[0159] As used herein, a "memory level" or a "memory array level" refers to the level corresponding to a general region between a first horizontal plane (i.e., a plane parallel to the top surface of the substrate) including topmost surfaces of an array of memory elements and a second horizontal plane including bottommost surfaces of the array of memory elements. As used herein, a "through-memory-level" element refers to an element that vertically extends through a memory level.

[0160] As used herein, a "semiconductor material" refers to a material having electrical conductivity in the range from 1.0×10^{-6} S/cm to 1.0×10^{5} S/cm, and is capable of producing a doped material having electrical conductivity in a range from 1.0 S/cm to 1.0×10^{5} S/cm upon suitable doping with an electrical dopant. As used herein, an "electrical dopant" refers to a p-type dopant that adds a hole to a valence band within a band structure, or an n-type dopant that adds an electron to a conduction band within a band structure. As used herein, a "conductive material" refers to a material having electrical conductivity greater than 1.0×10^{5} S/cm. As used herein, an "insulating material" or a "dielectric material" refers to a material having electrical conductivity less than 1.0×10^{-6} S/cm. All measurements for electrical conductivities are made at the standard condition.

[0161] A monolithic three dimensional memory array is one in which multiple memory levels are formed above a single substrate, such as a semiconductor wafer, with no intervening substrates. The term "monolithic" means that layers of each level of the array are directly deposited on the layers of each underlying level of the array. In contrast, two dimensional arrays may be formed separately and then packaged together to form a non-monolithic memory device. For example, non-monolithic stacked memories have been constructed by forming memory levels on separate substrates and vertically stacking the memory levels, as described in U.S. Pat. No. 5,915,167 titled "Three Dimensional Structure Memory." The substrates may be thinned or removed from the memory levels before bonding, but as the memory levels are initially formed over separate substrates, such memories are not true monolithic three dimensional memory arrays. The substrate may include integrated circuits fabricated thereon, such as driver circuits for a memory device

[0162] The various three dimensional memory devices of the present disclosure include a monolithic three-dimensional NAND string memory device, and can be fabricated employing the various embodiments described herein. The monolithic three dimensional NAND string is located in a monolithic, three dimensional array of NAND strings located over the substrate. At least one memory cell in the first device level of the three dimensional array of NAND strings is located over another memory cell in the second device level of the three dimensional array of NAND strings.

[0163] Referring to FIGS. **1**A and **1**B, a first exemplary structure according to a first embodiment of the present disclosure is illustrated. The first exemplary structure includes a semiconductor substrate **9**, and semiconductor devices **710** formed thereupon. Shallow trench isolation structures **720** can be formed in an upper portion of the semiconductor substrate **9** to provide electrical isolation among the semiconductor devices. The semiconductor devices **710** can include, for example, field effect transistors including respective source regions **742**, drain regions **744**, channel regions **746** and gate structures **750**. The field effect transistors may be arranged in a CMOS configuration. Each gate structure **750** can include, for example, a gate dielectric **752**, a gate electrode **754**, a dielectric gate spacer **756** and a gate cap dielectric **758**. The semiconductor devices can include any semiconductor circuitry to support operation of a memory structure to be subsequently formed, which is typically referred to as a driver circuitry, which is also known as peripheral circuitry. As used herein, a peripheral circuitry refers to any, each, or all, of word line decoder circuitry, word line switching circuitry, bit line decoder circuitry, bit line sensing and/or switching circuitry, power supply/distribution circuitry, data buffer and/or latch, or any other semiconductor circuitry that can be implemented outside a memory array structure for a memory device. For example, the semiconductor devices can include word line switching devices for electrically biasing word lines of three-dimensional memory structures to be subsequently formed.

[0164] At least one dielectric layer is formed over the semiconductor devices, which is herein referred to as at least one lower level dielectric layer **760**. The at least one lower level dielectric layer **760** can include, for example, an optional dielectric liner **762** such as a silicon nitride liner that blocks diffusion of mobile ions and/or apply appropriate stress to underlying structures, a planarization dielectric layer **764** that is employed to provide a planar surface that is coplanar with the topmost surface of the dielectric liner **762** or the topmost surfaces of the gate structures **750**, an optional planar liner **766**, and at least one lower level interconnect dielectric layer **768** that collectively functions as a matrix for lower level metal interconnect structures **780** that provide electrical wiring among the various nodes of the semiconductor devices and landing pads for through-memory-level via structures to be subsequently formed. The lower level metal interconnect structures **780** can include various device contact via structures **782** (e.g., source and drain electrodes which contact the respective source and drain nodes of the device or gate electrode contacts), lower level metal lines **784**, lower level via structures **786**, and lower level topmost metal structures **788** that are configured to function as landing pads for through-memory-level via structures to be subsequently formed. The region of the semiconductor devices and the combination of the at least one lower level dielectric layer **760** and the lower level metal interconnect structures **780** is herein referred to an underlying peripheral device region **700**, which is located underneath a memory-level assembly to be subsequently formed and includes peripheral devices for the memory-level assembly. The lower level metal interconnect structures **780** are embedded in the at least one lower level dielectric layer **760**. In one embodiment, the topmost surfaces of the lower level topmost metal structures **788** may be located at or below a horizontal plane including the topmost surface of the at least one lower level dielectric layer **760**.

[0165] The lower level metal interconnect structures **780** can be electrically shorted to nodes (e.g., source **742**, drain **744** or gate electrodes **750**) of the semiconductor devices **710** (e.g., CMOS devices), and are located at the level of the at least one lower level dielectric layer **760**. The through-memory-level via structures (not shown in FIGS. **1**A and **1**B) can be subsequently formed directly on the lower level metal interconnect structures **780**. In one embodiment, the pattern of the lower level metal interconnect structures **780** can be selected such that the lower level topmost metal structures **788**, which are a subset of the lower level metal interconnect structures **780** located at the topmost portion of the lower level metal interconnect structures **780**, can provide landing pad structures within a through-memory-level via region **400**. The through-memory-level via region **400** is a region in which through-memory-level via structures that extend vertically through a memory-level assembly are subsequently formed.

[0166] The through-memory-level via region **400** can be located adjacent to a memory array region **100** in which an array of memory devices are subsequently formed, as shown in FIG. **1**B. A word line contact via region **200** can be located adjacent to the through-memory-level via region **400** and the memory array region **100**. In one embodiment, the through-memory-level via region **400** and the word line contact via region **200** can be located at a peripheral edge of the memory array region **100** that is perpendicular to a first horizontal direction h**1** (e.g., word line direction) and runs parallel to a second horizontal direction hd**2** (e.g., bit line direction). In one embodiment, the area of the first exemplary structure can be divided into multiple blocks (B**1**, B**2**, B**3**, . . .) that are laterally separated along the second horizontal direction hd**2** and can be one-to-one mapped with positive integers, i.e., can be indexed with positive integers. The same word

line in a given device level may be used as a control gate electrode for each memory cell in the same device level in each respective memory block.

[0167] Multiple instances of the through-memory-level via region **400** and the word line contact via region **200** can alternate along the second horizontal direction hd**2**. In an illustrative example, each instance of the through-memory-level via region **400** can be located within an area of a respective even numbered block (such as B**2**, B**4**, etc.), and each instance of the word line contact via region **200** can be located within an area of a respective odd numbered block (such as B**1**, B**3**, etc.). A neighboring pair of an odd-numbered block and an even-numbered block (such as B**1** and B**2**) can be periodically repeated along the second horizontal direction.

[0168] While a particular pattern for the lower level topmost metal structures **788** is illustrated herein, it is understood that the pattern for the lower level topmost metal structures **788** may be altered to optimize wiring in the underlying peripheral device region **700** as long as the lower level topmost metal structures **788** provide suitable landing pad areas for the through-memory-level via structures to be subsequently formed.

[0169] Referring to FIG. **2**, an optional planar conductive material layer **6** and a planar semiconductor material layer **10** can be formed over the underlying peripheral device region **700**. The optional planar conductive material layer **6** includes a conductive material such as a metal or a heavily doped semiconductor material. The optional planar conductive material layer **6**, for example, may include a tungsten layer having a thickness in a range from 3 nm to 100 nm, although lesser and greater thicknesses can also be employed. A metal nitride layer (not shown) may be provided as a diffusion barrier layer on top of the planar conductive material layer **6**. Layer **6** may function as a special source line in the completed device. Alternatively, layer **6** may comprise an etch stop layer and may comprise any suitable conductive, semiconductor or insulating layer.

[0170] The planar semiconductor material layer **10** can be formed over the at least one lower level dielectric layer **760**. The planar semiconductor material layer **10** includes a semiconductor material, which can include at least one elemental semiconductor material, at least one III-V compound semiconductor material, at least one II-VI compound semiconductor material, at least one organic semiconductor material, and/or other semiconductor materials known in the art. In one embodiment, the planar semiconductor material layer **10** can include a polycrystalline semiconductor material (such as polysilicon), or an amorphous semiconductor material (such as amorphous silicon) that is converted into a polycrystalline semiconductor material in a subsequent processing step (such as an anneal step). The planar semiconductor material layer **10** can be formed directly above a subset of the semiconductor devices on the semiconductor substrate **9** (e.g., silicon wafer). As used herein, a first element is located "directly above" a second element if the first element is located above a horizontal plane including a topmost surface of the second element and an area of the first element and an area of the second element has an areal overlap in a plan view (i.e., along a vertical plane or direction perpendicular to the top surface of the substrate **9**). In one embodiment, the planar semiconductor material layer **10** or portions thereof can be doped with electrical dopants, which may be p-type dopants or n-type dopants. The conductivity type of the dopants in the planar semiconductor material layer **10** is herein referred to as a first conductivity type. A dielectric pad layer **52** can be formed on the top surface of the planar semiconductor material layer **10**.

[0171] An alternating stack of first material layers and second material layers is subsequently formed. Each first material layer can include a first material, and each second material layer can include a second material that is different from the first material. In case at least another alternating stack of material layers is subsequently formed over the alternating stack of the first material layers and the second material layers, the alternating stack is herein referred to as a first-tier alternating stack. The level of the first-tier alternating stack is herein referred to as a first-tier level, and the level of the alternating stack to be subsequently formed immediately above the first-tier level is herein referred to as a second-tier level, etc.

[0172] The first-tier alternating stack can include first insulting layers **132** as the first material layers, and first spacer material layers as the second material layers. In one embodiment, the first spacer material layers can be sacrificial material layers that are subsequently replaced with electrically conductive layers. In another embodiment, the first spacer material layers can be electrically conductive layers that are not subsequently replaced with other layers. While the present disclosure is described employing embodiments in which sacrificial material layers are replaced with electrically conductive layers, embodiments in which the spacer material layers are formed as electrically conductive layers (thereby obviating the need to perform replacement processes) are expressly contemplated herein.

[0173] In one embodiment, the first material layers and the second material layers can be first insulating layers **132** and first sacrificial material layers **142**, respectively. In one embodiment, each first insulating layer **132** can include a first insulating material, and each first sacrificial material layer **142** can include a first sacrificial material. An alternating plurality of first insulating layers **132** and first sacrificial material layers **142** is formed over the planar semiconductor material layer **10**. As used herein, a "sacrificial material" refers to a material that is removed during a subsequent processing step.

[0174] As used herein, an alternating stack of first elements and second elements refers to a structure in which instances of the first elements and instances of the second elements alternate. Each instance of the first elements that is not an end element of the alternating plurality is adjoined by two instances of the second elements on both sides, and each instance of the second elements that is not an end element of the alternating plurality is adjoined by two instances of the first elements on both ends. The first elements may have the same thickness thereamongst, or may have different thicknesses. The second elements may have the same thickness thereamongst, or may have different thicknesses. The alternating plurality of first material layers and second material layers may begin with an instance of the first material layers or with an instance of the second material layers, and may end with an instance of the first material layers or with an instance of the second material layers. In one embodiment, an instance of the first elements and an instance of the second elements may form a unit that is repeated with periodicity within the alternating plurality.

[0175] The first-tier alternating stack (**132**, **142**) can include first insulating layers **132** composed of the first

material, and first sacrificial material layers **142** composed of the second material, which is different from the first material. The first material of the first insulating layers **132** can be at least one insulating material. Insulating materials that can be employed for the first insulating layers **132** include, but are not limited to silicon oxide (including doped or undoped silicate glass), silicon nitride, silicon oxynitride, organosilicate glass (OSG), spin-on dielectric materials, dielectric metal oxides that are commonly known as high dielectric constant (high-k) dielectric oxides (e.g., aluminum oxide, hafnium oxide, etc.) and silicates thereof, dielectric metal oxynitrides and silicates thereof, and organic insulating materials. In one embodiment, the first material of the first insulating layers **132** can be silicon oxide.

[0176] The second material of the first sacrificial material layers **142** is a sacrificial material that can be removed selective to the first material of the first insulating layers **132**. As used herein, a removal of a first material is "selective to" a second material if the removal process removes the first material at a rate that is at least twice the rate of removal of the second material. The ratio of the rate of removal of the first material to the rate of removal of the second material is herein referred to as a "selectivity" of the removal process for the first material with respect to the second material.

[0177] The first sacrificial material layers **142** may comprise an insulating material, a semiconductor material, or a conductive material. The second material of the first sacrificial material layers **142** can be subsequently replaced with electrically conductive electrodes which can function, for example, as control gate electrodes of a vertical NAND device. In one embodiment, the first sacrificial material layers **142** can be material layers that comprise silicon nitride.

[0178] In one embodiment, the first insulating layers **132** can include silicon oxide, and sacrificial material layers can include silicon nitride sacrificial material layers. The first material of the first insulating layers **132** can be deposited, for example, by chemical vapor deposition (CVD). For example, if silicon oxide is employed for the first insulating layers **132**, tetraethylorthosilicate (TEOS) can be employed as the precursor material for the CVD process. The second material of the first sacrificial material layers **142** can be formed, for example, CVD or atomic layer deposition (ALD).

[0179] The thicknesses of the first insulating layers **132** and the first sacrificial material layers **142** can be in a range from 20 nm to 50 nm, although lesser and greater thicknesses can be employed for each first insulating layer **132** and for each first sacrificial material layer **142**. The number of repetitions of the pairs of a first insulating layer **132** and a first sacrificial material layer **142** can be in a range from 2 to 1,024, and typically from 8 to 256, although a greater number of repetitions can also be employed. In one embodiment, each first sacrificial material layer **142** in the first-tier alternating stack (**132**, **142**) can have a uniform thickness that is substantially invariant within each respective first sacrificial material layer **142**.

[0180] A first insulating cap layer **170** is subsequently formed over the stack (**132**, **142**). The first insulating cap layer **170** includes a dielectric material, which can be any dielectric material that can be employed for the first insulating layers **132**. In one embodiment, the first insulating cap layer **170** includes the same dielectric material as the first insulating layers **132**. The thickness of the insulating cap layer **170** can be in a range from 20 nm to 300 nm, although lesser and greater thicknesses can also be employed.

[0181] Referring to FIG. **3**, the first insulating cap layer **170** and the first-tier alternating stack (**132**, **142**) can be patterned to form first stepped surfaces in each through-memory-level via region **400** and each word line contact via region **200**. Each of the through-memory-level via regions **400** and the word line contact via regions **200** can include a respective first stepped area SA**1** in which the first stepped surfaces are formed, and a second stepped area SA**2** in which additional stepped surfaces are to be subsequently formed in a second tier structure (to be subsequently formed over a first tier structure) and/or additional tier structures. The first stepped surfaces can be formed, for example, by forming a mask layer with an opening therein, etching a cavity within the levels of the first insulating cap layer **170**, and iteratively expanding the etched area and vertically recessing the cavity by etching each pair of a first insulating layer **132** and a first sacrificial material layer **142** located directly underneath the bottom surface of the etched cavity within the etched area. A dielectric material can be deposited to fill the first stepped cavity to form a first-tier retro-stepped dielectric material portion **165**. As used herein, a "retro-stepped" element refers to an element that has stepped surfaces and a horizontal cross-sectional area that increases monotonically as a function of a vertical distance from a top surface of a substrate on which the element is present. The first-tier alternating stack (**132**, **142**) and the first-tier retro-stepped dielectric material portion **165** collectively constitute a first tier structure, which is an in-process structure that is subsequently modified.

[0182] Referring to FIGS. **4**A and **4**B, first-tier support pillar structures **171** can be formed in portions of the first-tier alternating stack (**132**, **142**) in which memory stack structures are not formed at a sufficiently high density in subsequent processing steps. For example, the first-tier support pillar structures **171** can be formed in the through-memory-level via regions **400** and the word line contact via regions **200**. The first-tier support pillar structures **171** can be formed, for example, by forming via cavities through the first-tier alternating stack (**132**, **142**) and by filling the via cavities with a dielectric material such as silicon oxide and/or a dielectric metal oxide (such as aluminum oxide). Locations of steps S in the first-tier alternating stack (**132**, **142**) are illustrated in FIG. **4**B as dotted lines.

[0183] Optionally, an inter-tier dielectric layer **180** may be deposited over the first tier structure (**132**, **142**, **165**, **170**). The inter-tier dielectric layer **180** includes a dielectric material such as silicon oxide. The thickness of the inter-tier dielectric layer **180** can be in a range from 30 nm to 300 nm, although lesser and greater thicknesses can also be employed.

[0184] Referring to FIGS. **5**A and **5**B, first-tier memory openings **149** extending at least to a top surface of the planar semiconductor material layer **10** are formed through the first-tier alternating stack (**132**, **142**). The first-tier memory openings **149** can be formed in the memory array region **100** at locations at which memory stack structures including vertical stacks of memory elements are to be subsequently formed. For example, a lithographic material stack (not shown) including at least a photoresist layer can be formed over the first insulating cap layer **170** (and optionally layer **180**), and can be lithographically patterned to form openings within the lithographic material stack. The pattern in the

lithographic material stack can be transferred through the first insulating cap layer **170** (and optionally layer **180**), and through the entirety of the first-tier alternating stack (**132**, **142**) by at least one anisotropic etch that employs the patterned lithographic material stack as an etch mask. Portions of the first insulating cap layer **170** (and optionally layer **180**), and the first-tier alternating stack (**132**, **142**) underlying the openings in the patterned lithographic material stack are etched to form the first-tier memory openings **149**. In other words, the transfer of the pattern in the patterned lithographic material stack through the first insulating cap layer **170** and the first-tier alternating stack (**132**, **142**) forms the first-tier memory openings **149**.

[0185] In one embodiment, the chemistry of the anisotropic etch process employed to etch through the materials of the first-tier alternating stack (**132**, **142**) can alternate to optimize etching of the first and second materials in the first-tier alternating stack (**132**, **142**). The anisotropic etch can be, for example, a series of reactive ion etches or a single etch (e.g., $CF_4/O_2/Ar$ etch). The sidewalls of the first-tier memory openings **149** can be substantially vertical, or can be tapered. Subsequently, the patterned lithographic material stack can be subsequently removed, for example, by ashing.

[0186] Optionally, the portions of the first-tier memory openings **149** at the level of the inter-tier dielectric layer **180** can be laterally expanded by an isotropic etch. For example, if the inter-tier dielectric layer **180** comprises a dielectric material (such as borosilicate glass) having a greater etch rate than the first insulating layers **132** (that can include undoped silicate glass), an isotropic etch (such as a wet etch employing HF) can be employed to expand the lateral dimensions of the first-tier memory openings at the level of the inter-tier dielectric layer **180**. The portions of the first-tier memory openings **149** located at the level of the inter-tier dielectric layer **180** may be optionally widened to provide a larger landing pad for second-tier memory openings to be subsequently formed through a second-tier alternating stack (to be subsequently formed prior to formation of the second-tier memory openings).

[0187] Sacrificial memory opening fill portions **131** can be formed in the first-tier memory openings **149**. For example, a sacrificial fill material layer is deposited in the first-tier memory openings **149**. The sacrificial fill material layer includes a sacrificial material which can be subsequently removed selective to the materials of the first insulator layers **132** and the first sacrificial material layers **142**. In one embodiment, the sacrificial fill material layer can include a semiconductor material such as silicon (e.g., a-Si or polysilicon), a silicon-germanium alloy, germanium, a III-V compound semiconductor material, or a combination thereof. Optionally, a thin etch stop layer (such as a silicon oxide layer having a thickness in a range from 1 nm to 3 nm) may be employed prior to depositing the sacrificial fill material layer. The sacrificial fill material layer may be formed by a non-conformal deposition or a conformal deposition method. In another embodiment, the sacrificial fill material layer can include amorphous silicon or a carbon-containing material (such as amorphous carbon or diamond-like carbon) that can be subsequently removed by ashing.

[0188] Portions of the deposited sacrificial material can be removed from above the first insulating cap layer **170** (and optionally layer **180** if present). For example, the sacrificial fill material layer can be recessed to a top surface of the first insulating cap layer **170** (and optionally layer **180** if present) employing a planarization process. The planarization process can include a recess etch, chemical mechanical planarization (CMP), or a combination thereof. The top surface of the first insulating layer **170** (and optionally layer **180** if present) can be employed as an etch stop layer or a planarization stop layer. Each remaining portion of the sacrificial material in a first-tier memory opening **149** constitutes a sacrificial memory opening fill portion **131**. The top surfaces of the sacrificial memory opening fill portions **131** can be coplanar with the top surface of the inter-tier dielectric layer **180**. The sacrificial memory opening fill portion **131** may, or may not, include cavities therein.

[0189] Referring to FIG. **7**, a second tier structure can be formed over the first tier structure (**132**, **142**, **170**, **131**). The second tier structure can include an additional alternating stack of insulating layers and spacer material layers, which can be sacrificial material layers. For example, a second alternating stack (**232**, **242**) of material layers can be subsequently formed on the top surface of the first alternating stack (**132**, **142**). The second stack (**232**, **242**) includes an alternating plurality of third material layers and fourth material layers. Each third material layer can include a third material, and each fourth material layer can include a fourth material that is different from the third material. In one embodiment, the third material can be the same as the first material of the first insulating layer **132**, and the fourth material can be the same as the second material of the first sacrificial material layers **142**.

[0190] In one embodiment, the third material layers can be second insulating layers **232** and the fourth material layers can be second spacer material layers that provide vertical spacing between each vertically neighboring pair of the second insulating layers **232**. In one embodiment, the third material layers and the fourth material layers can be second insulating layers **232** and second sacrificial material layers **242**, respectively. The third material of the second insulating layers **232** may be at least one insulating material. The fourth material of the second sacrificial material layers **242** may be a sacrificial material that can be removed selective to the third material of the second insulating layers **232**. The second sacrificial material layers **242** may comprise an insulating material, a semiconductor material, or a conductive material. The fourth material of the second sacrificial material layers **242** can be subsequently replaced with electrically conductive electrodes which can function, for example, as control gate electrodes of a vertical NAND device.

[0191] In one embodiment, each second insulating layer **232** can include a second insulating material, and each second sacrificial material layer **242** can include a second sacrificial material. In this case, the second stack (**232**, **242**) can include an alternating plurality of second insulating layers **232** and second sacrificial material layers **242**. The third material of the second insulating layers **232** can be deposited, for example, by chemical vapor deposition (CVD). The fourth material of the second sacrificial material layers **242** can be formed, for example, CVD or atomic layer deposition (ALD).

[0192] The third material of the second insulating layers **232** can be at least one insulating material. Insulating materials that can be employed for the second insulating layers **232** can be any material that can be employed for the first insulating layers **132**. The fourth material of the second sacrificial material layers **242** is a sacrificial material that

can be removed selective to the third material of the second insulating layers **232**. Sacrificial materials that can be employed for the second sacrificial material layers **242** can be any material that can be employed for the first sacrificial material layers **142**. In one embodiment, the second insulating material can be the same as the first insulating material, and the second sacrificial material can be the same as the first sacrificial material.

[0193] The thicknesses of the second insulating layers **232** and the second sacrificial material layers **242** can be in a range from 20 nm to 50 nm, although lesser and greater thicknesses can be employed for each second insulating layer **232** and for each second sacrificial material layer **242**. The number of repetitions of the pairs of a second insulating layer **232** and a second sacrificial material layer **242** can be in a range from 2 to 1,024, and typically from 8 to 256, although a greater number of repetitions can also be employed. In one embodiment, each second sacrificial material layer **242** in the second stack (**232**, **242**) can have a uniform thickness that is substantially invariant within each respective second sacrificial material layer **242**.

[0194] Second stepped surfaces in the second stepped area SA**2** can be formed in the through-memory-level via regions **400** and the word line contact via regions **200** employing a same set of processing steps as the processing steps employed to form the first stepped surfaces in the first stepped area SA**1** with suitable adjustment to the pattern of at least one masking layer. A second-tier retro-stepped dielectric material portion **265** can be formed over the second stepped surfaces in the through-memory-level via regions **400** and the word line contact via regions **200**.

[0195] A second insulating cap layer **270** can be subsequently formed over the second alternating stack (**232**, **242**). The second insulating cap layer **270** includes a dielectric material that is different from the material of the second sacrificial material layers **242**. In one embodiment, the second insulating cap layer **270** can include silicon oxide. In one embodiment, the first and second sacrificial material layers (**142**, **242**) can comprise silicon nitride.

[0196] Generally speaking, at least one alternating stack of insulating layers (**132**, **232**) and spacer material layers (such as sacrificial material layers (**142**, **242**)) can be formed over the planar semiconductor material layer **10**, and at least one retro-stepped dielectric material portion (**165**, **265**) can be formed over the staircase regions on the at least one alternating stack (**132**, **142**, **232**, **242**).

[0197] Referring to FIGS. **8**A and **8**B, second-tier support pillar structures **271** can be formed in portions of the second-tier alternating stack (**132**, **142**) that overlie the first-tier support pillar structures **171**. For example, the second-tier support pillar structures **271** can be formed directly on top surfaces of the first-tier support pillar structures **171** in the through-memory-level via regions **400** and the word line contact via regions **200**. The second-tier support pillar structures **271** can be formed, for example, by forming via cavities through the second-tier alternating stack (**232**, **242**) and by filling the via cavities with a dielectric material such as silicon oxide and/or a dielectric metal oxide (such as aluminum oxide).

[0198] Optionally, drain-select-level shallow trench isolation structures **72** can be formed through a subset of layers in an upper portion of the second-tier alternating stack (**232**, **242**). The second sacrificial material layers **242** that are cut by the select-drain-level shallow trench isolation structures **72** correspond to the levels in which drain-select-level electrically conductive layers are subsequently formed. The drain-select-level shallow trench isolation structures **72** divide blocks (B**1**, B**2**, B**3**, . . .) into multiple sub-blocks along the first horizontal direction hd**1**. The drain-select-level shallow trench isolation structures **72** include a dielectric material such as silicon oxide. Locations of steps S in the first-tier alternating stack (**132**, **142**) and the second-tier alternating stack (**232**, **242**) are illustrated in FIG. **8**B as dotted lines. The staircase regions in the first, second and third memory block ascend in a same diagonal direction (e.g., from left to right).

[0199] Referring to FIGS. **9**A and **9**B, second-tier memory openings extending through the second tier structure (**232**, **242**, **270**) are formed in areas overlying the sacrificial memory opening fill portions **131**. A photoresist layer can be applied over the second tier structure (**232**, **242**, **270**), and can be lithographically patterned to form a same pattern as the pattern of the sacrificial memory opening fill portion **131**, i.e., the pattern of the first-tier memory openings. The lithographic mask employed to pattern the first-tier memory openings **149** can be employed to pattern the second-tier memory openings. An anisotropic etch can be performed to transfer the pattern of the lithographically patterned photoresist layer through the second tier structure (**232**, **242**, **270**). In one embodiment, the chemistry of the anisotropic etch process employed to etch through the materials of the second-tier alternating stack (**232**, **242**) can alternate to optimize etching of the alternating material layers in the second-tier alternating stack (**232**, **242**). The anisotropic etch can be, for example, a series of reactive ion etches. The patterned lithographic material stack can be removed, for example, by ashing after the anisotropic etch process.

[0200] A top surface of an underlying sacrificial memory opening fill portion **131** can be physically exposed at the bottom of each second-tier memory opening. After the top surfaces of the sacrificial memory opening fill portions **131** are physically exposed, an etch process can be performed, which removes the sacrificial material of the sacrificial memory opening fill portions **131** selective to the materials of the second-tier alternating stack (**232**, **242**) and the first-tier alternating stack (**132**, **142**) (e.g., $C_4F_8/O_2/Ar$ etch).

[0201] Upon removal of the sacrificial memory opening fill portions **131**, each vertically adjoining pair of a second-tier memory opening and a first-tier memory opening **149** forms a continuous cavity that extends through the first-tier alternating stack (**132**, **142**) and the second-tier alternating stack (**232**, **242**). The continuous cavities are herein referred to as memory openings **49**. A top surface of the planar semiconductor material layer **10** can be physically exposed at the bottom of each memory opening **49**.

[0202] Referring to FIGS. **10**A and **10**B, pedestal channel portions **11** can be optionally formed at the bottom of each memory opening **49** by a selective semiconductor deposition process. The selective semiconductor deposition grows a semiconductor material only from semiconductor surfaces, i.e., the physically exposed surfaces of the planar semiconductor material layer **10**, and suppresses growth of the semiconductor material from insulator surfaces. During a selective semiconductor deposition process, a reactant (such as silane, dichlorosilane, trichlorosilane, disilane, etc.) can be flowed into a deposition chamber simultaneously with, or alternately with, an etchant (such as hydrogen chloride). Because a semiconductor material is deposited at a greater

deposition rate on semiconductor surfaces than on insulator surfaces, a selective growth can be achieved by setting the etch rate between the deposition rate of the semiconductor material on semiconductor surfaces and the deposition rate of the semiconductor material on insulator surfaces. In one embodiment, the top surfaces of the pedestal channel portions **11** can extend across the levels of the source select levels in which source-select-level electrically conductive layers can be subsequently formed.

[0203] Memory stack structures **55** can be formed in the memory openings **49**. In an illustrative example, each memory stack structure **55** can include a memory film **50**, a vertical semiconductor channel **60**, and an optional dielectric core **62**. In one embodiment, each memory film **50** can include an optional blocking dielectric layer **51**, a memory material layer **54**, and a tunneling dielectric layer **56** as illustrated in the inset. In one embodiment, each vertical semiconductor channel **60** can include a first semiconductor channel **601** and a second semiconductor channel **602**. While the memory openings **49** and support openings for the first-tier support pillar structures **171** are shown as being made in separate steps in FIGS. **5**A and **4**A, respectively, in another embodiment, the memory openings **49** and the support openings for the first-tier support pillar structures **171** are formed in the same step. In this embodiment, the first-tier support pillar structures **171** which comprise dummy memory stack structures which are not electrically connected to bit lines may be formed in the support openings at the same time as the memory stack structures **55** are formed in the memory openings **49**.

[0204] The blocking dielectric layer **51** includes a blocking dielectric layer material such as silicon oxide, a dielectric metal oxide (such as aluminum oxide), or a combination thereof. Alternatively, the blocking dielectric layer **51** may be omitted during this processing step and instead be formed through backside recesses as will be described in more detail below. In one embodiment, the memory material layer **54** can be a charge trapping material including a dielectric charge trapping material, which can be, for example, silicon nitride.

[0205] The memory material layer **54** can be formed as a single memory material layer of homogeneous composition, or can include a stack of multiple memory material layers. The multiple memory material layers, if employed, can comprise a plurality of spaced-apart floating gate material layers that contain conductive materials (e.g., metal such as tungsten, molybdenum, tantalum, titanium, platinum, ruthenium, and alloys thereof, or a metal silicide such as tungsten silicide, molybdenum silicide, tantalum silicide, titanium silicide, nickel silicide, cobalt silicide, or a combination thereof) and/or semiconductor materials (e.g., polycrystalline or amorphous semiconductor material including at least one elemental semiconductor element or at least one compound semiconductor material). Alternatively or additionally, the memory material layer **54** may comprise an insulating charge trapping material, such as one or more silicon nitride segments. Alternatively, the memory material layer **54** may comprise conductive nanoparticles such as metal nanoparticles, which can be, for example, ruthenium nanoparticles. The memory material layer **54** can be formed, for example, by chemical vapor deposition (CVD), atomic layer deposition (ALD), physical vapor deposition (PVD), or any suitable deposition technique for storing electrical charges therein. The thickness of the memory material layer **54** can be in a range from 2 nm to 20 nm, although lesser and greater thicknesses can also be employed.

[0206] The tunneling dielectric layer **56** includes a dielectric material through which charge tunneling can be performed under suitable electrical bias conditions. The charge tunneling may be performed through hot-carrier injection or by Fowler-Nordheim tunneling induced charge transfer depending on the mode of operation of the monolithic three-dimensional NAND string memory device to be formed. The tunneling dielectric layer **56** can include silicon oxide, silicon nitride, silicon oxynitride, dielectric metal oxides (such as aluminum oxide and hafnium oxide), dielectric metal oxynitride, dielectric metal silicates, alloys thereof, and/or combinations thereof. In one embodiment, the tunneling dielectric layer **56** can include a stack of a first silicon oxide layer, a silicon oxynitride layer, and a second silicon oxide layer, which is commonly known as an ONO stack. The thickness of the tunneling dielectric layer **56** can be in a range from 2 nm to 20 nm, although lesser and greater thicknesses can also be employed.

[0207] A first semiconductor channel layer can be deposited over the memory films **50** by a conformal deposition method such as low pressure chemical vapor deposition (LPCVD). The thickness of the first semiconductor channel layer can be in a range from 2 nm to 10 nm, although lesser and greater thicknesses can also be employed. The first semiconductor channel layer and the memory films **50** can be anisotropically etched to remove horizontal portions thereof. A horizontal bottom portion of each memory film **50** can be removed from the bottom of each memory opening. Each remaining portion of the first semiconductor channel layer constitutes a first semiconductor channel **601**. The first semiconductor channels can include a semiconductor material such as at least one elemental semiconductor material, at least one III-V compound semiconductor material, at least one II-VI compound semiconductor material, at least one organic semiconductor material, or other semiconductor materials known in the art. In one embodiment, the first semiconductor channels **601** can include amorphous silicon or polysilicon.

[0208] A second semiconductor channel layer can be deposited on the first semiconductor channels **601** (i.e., the remaining vertical portions of the first semiconductor channel layer) and on top surface of the epitaxial channel portions **11** (or of the substrate semiconductor layer **10** in case the epitaxial channel portions **11** are not present). The second semiconductor channel layer includes a semiconductor material, which can be any semiconductor material that can be employed for the first semiconductor channel layer. The first and second semiconductor channel layers can have a doping of the first conductivity type (i.e., the same conductivity type as the substrate semiconductor layer **10**) or can be substantially intrinsic, i.e., having a dopant concentration that does not exceed $1.0\times10^{17}/cm^3$. In one embodiment, the second semiconductor channel layer can include amorphous silicon or polysilicon. The thickness of the second semiconductor channel layer can be in a range from 2 nm to 10 nm, although lesser and greater thicknesses can also be employed.

[0209] A dielectric material can be deposited in cavities surrounded by the second semiconductor channel layer, and subsequently recessed below the top surface of the second insulating cap layer **270**. Each remaining portion of the dielectric material in the memory openings constitutes a

dielectric core **62**. A doped semiconductor material having a second conductivity type (which is the opposite of the first conductivity type) can be deposited over the dielectric cores **62** and within the cavities in the memory openings to form drain regions **63**. The doped semiconductor material can be, for example, doped polysilicon. Excess portions of the deposited semiconductor material can be removed from above the top surface of the second insulating tier cap layer **270**, for example, by chemical mechanical planarization (CMP) or a recess etch to form the drain region **63**. Each remaining portion of the second semiconductor channel layer constitutes a second semiconductor channel **602**. A combination of a first semiconductor channel **601** and a second semiconductor channel **602** inside a memory opening constitutes a vertical semiconductor channel **60**.

[0210] Each of the memory stack structures **55** comprises a memory film **50** and a vertical semiconductor channel **60** that is adjoined to a respective horizontal channel within the planar semiconductor material layer **10**. Each memory film **50** can include a blocking dielectric layer **51** contacting a sidewall of the memory opening, a plurality of charge storage regions (embodied as portions of a memory material layer **54** at each level of the sacrificial material layers (**142**, **242**)) located on an inner sidewall of the blocking dielectric layer **51**, and a tunneling dielectric layer **56** located inside the plurality of charge storage regions.

[0211] The first tier structure (**132**, **142**, **170**, **165**, **171**), the second tier structure (**232**, **242**, **270**, **265**, **271**), the inter-tier dielectric layer **180**, and the memory stack structures **55** collectively constitute a memory-level assembly. The memory-level assembly is formed over the planar semiconductor material layer **10** such that the planar semiconductor material layer **10** includes horizontal semiconductor channels electrically connected to vertical semiconductor channels **60** within the memory stack structures **55**.

[0212] A first contact level dielectric layer **280** can be formed over the memory-level assembly. The first contact level dielectric layer **280** is formed at a contact level through which various contact via structures are subsequently formed to the drain regions **63** and the various electrically conductive layers that replaces the sacrificial material layers (**142**, **242**) in subsequent processing steps.

[0213] Referring to FIGS. **11**A and **11**B, a through-memory-level opening **769** can be formed in each through-memory-level via region **400** through the memory-level assembly. For example, a through-memory-level opening **769** extending through the memory-level assembly can be formed in the area of the second staircase region. The through-memory-level openings **769** can be formed, for example, by applying a photoresist layer **767** over the first contact level dielectric layer **280**, lithographically patterning the photoresist layer **767** to form an opening over each through-memory-level via region **400**, and anisotropically etching the portions of the first contact level dielectric layer **280** and the memory-level assembly that underlie the openings in the photoresist layer. In one embodiment, the area of each opening can include a predominant portion (i.e., over 50%) of the total area of a respective through-memory-level via region **400**.

[0214] The through-memory-level openings **769** are formed only in the through-memory-level via regions **400**, and are not formed in the word line contact via regions **200** or in the memory array region **100**. The areas of the word line contact via regions **200** or in the memory array region **100** are covered with a masking layer, such as the patterned photoresist layer **767**.

[0215] The through-memory-level openings **769** can extend through the entirety of the memory-level assembly, the planar semiconductor material layer **10**, the optional planar conductive material layer **6**, and into the at least one lower level dielectric material layer **760**. In one embodiment, the bottom surface of each through-memory-level opening **769** may be located above the topmost surface of the lower level metal interconnect structures **780**. Alternatively, the topmost surface of the lower level metal interconnect structures **780** may be physically exposed in the through-memory-level openings **769**. In one embodiment, the through-memory-level openings **769** can comprise substantially vertical sidewalls that extend through the memory-level assembly and the planar semiconductor material layer **10**. As used herein, a sidewall is "substantially vertical" if the sidewall is vertical or deviates from a vertical plane by an angle less than 5 degrees.

[0216] Referring to FIGS. **12**A and **12**B, a dielectric fill material portion **430** is formed within each through-memory-level opening **769**, for example, by deposition of a dielectric fill material and removal of the excess dielectric fill material from above a horizontal plane including the top surface of the first contact level dielectric layer **280**. The dielectric fill material portion **430** includes a dielectric material such as undoped silicate glass (e.g., silicon oxide), doped silicate glass, or a spin-on glass (SOG). The dielectric fill material can be deposited by a conformal deposition process, a combination of a non-conformal deposition process and a reflow process, or a spin-on coating. Excess portions of the dielectric fill material can be removed by a recess etch, chemical mechanical planarization (CMP), or a combination thereof.

[0217] Referring to FIGS. **13**A and **13**B, backside contact trenches **79** are subsequently formed through the first contact level dielectric layer **280** and the memory-level assembly. For example, a photoresist layer can be applied an lithographically patterned over the first contact level dielectric layer **280** to form elongated openings that extend along the first horizontal direction hd**1** A subset of the openings in the patterned photoresist layer fall on the boundaries between blocks (B**0**, B**1**, B**2**, B**3**, . . .). An anisotropic etch is performed to transfer the pattern in the patterned photoresist layer through the first contact level dielectric layer **280** and the memory-level assembly to a top surface of the planar semiconductor material layer **10**. The photoresist layer can be subsequently removed, for example, by ashing.

[0218] The backside contact trenches **79** extend along the first horizontal direction hd**1**, and thus, are elongated along the first horizontal direction hd**1**. The backside contact trenches **79** include a first subset of backside contact trenches **79** that extend through a memory array region **100**, adjoining word line contact via regions **200**, and adjoining through-memory-level via regions **400**. The first subset of the backside contact trenches **79** is formed through the memory-level assembly, laterally extends along the first horizontal direction hd**1**, and laterally divides the memory-level assembly (which generally includes at least one alternating stack (**132**, **142**, **232**, **242**) into a plurality of laterally spaced-apart blocks (B**0**, B**1**, B**2**, B**3**, . . .).

[0219] Each block (B**0**, B**1**, B**2**, B**3**, . . .) includes a respective portion of the memory array region between a

neighboring pair of backside contact trenches **79** among the first subset of the backside contact trenches **79**. Each block (B**0**, B**1**, B**2**, B**3**, . . .) can include the respective portion of the memory array region **100**, a staircase region located on one lengthwise end of the respective portion of the memory array region **100** and including a word line contact via region **200**, and another staircase region located on another lengthwise end of the respective portion of the memory array region **100** and including a through-memory-level via region **400**. In one embodiment, the placement of the word line contact via regions **200** along consecutive blocks (B**0**, B**1**, B**2**, B**3**, . . .) can alternate between two opposite sides. In an illustrative example, every odd numbered block (B**1**, B**3**, etc.) has a respective word line contact via region **200** on one side (such as a left side), and every even numbered block (B**2**, B**4**, etc.) has a respective word line contact via region **200** on an opposite side (such as a right side). Likewise, the placement of the through-memory-level via regions **400** along consecutive blocks (B**0**, B**1**, B**2**, B**3**, . . .) can alternate between two opposite sides such that the through-memory-level via regions **400** do not overlap with the word line contact via regions **200**. In an illustrative example, every even numbered block (B**0**, B**2**, B**4**, etc.) has a respective through-memory-level via regions **400** on one side (such as the left side), and every odd numbered block (B**1**, B**3**, etc.) has a respective word line contact via region **200** on an opposite side (such as the right side).

[0220] In an illustrative example, the plurality of blocks can comprise a set of three neighboring blocks (e.g., B**1**, B**2**, B**3**) including, in order, a first block B**1**, a second block B**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1**. The first block B**1**, the second block B**2**, and the third block B**3** can include a first staircase region (such as the region of the word line contact via region **200** on the left side of Block B**1** illustrated in FIG. **10**B), a second staircase region (such as the region of the through-memory-level via region **400** on the left side of Block B**2** illustrated in FIG. **10**B), and a third staircase region (that is a replica of the word line contact via region **200** on the left side of Block B**3**), respectively. As discussed above, a neighboring pair of an odd-numbered block and an even-numbered block (such as B**1** and B**2**) can be periodically repeated along the second horizontal direction.

[0221] Optionally, a second subset of backside contact trenches **79** may be provided within each block (B**0**, B**1**, B**2**, B**3**, . . .). If employed, the second subset of backside contact trenches **79** can extend along the first horizontal direction hd**1**, and can be positioned to suitably divide each block into a plurality of sub-blocks. Backside contact trenches **79** may comprise sub-block boundaries within each memory block. Backside contact trenches **79** may be discontinuous to permit the same word line to extend in connecting region **778** between two adjacent sub-blocks in the same block. If the drain-contact-level shallow trench isolation structures **72** are employed, the drain-contact-level shallow trench isolation structures **72** can extend along the first horizontal direction hd**1** to divide a subset of layers in an upper portion of the second-tier alternating stack (**232**, **242**) within each sub-block or within each block. Various design optimizations can be employed to divide a block into sub-blocks or subordinate units.

[0222] Referring to FIGS. **14**A-**14**C, an etchant that selectively etches the materials of the first and second sacrificial material layers (**142**, **242**) with respect to the materials of the first and second insulating layers (**132**, **232**), the first and second insulating cap layers (**170**, **270**), and the material of the outermost layer of the memory films **50** can be introduced into the backside contact trenches **79**, for example, employing an isotropic etch process. First backside recesses **143** are formed in volumes from which the first sacrificial material layers **142** are removed. Second backside recesses **243** are formed in volumes from which the second sacrificial material layers **242** are removed. In one embodiment, the first and second sacrificial material layers (**142**, **242**) can include silicon nitride, and the materials of the first and second insulating layers (**132**, **232**), can be silicon oxide. In another embodiment, the first and second sacrificial material layers (**142**, **242**) can include a semiconductor material such as germanium or a silicon-germanium alloy, and the materials of the first and second insulating layers (**132**, **232**) can be selected from silicon oxide and silicon nitride.

[0223] The isotropic etch process can be a wet etch process employing a wet etch solution, or can be a gas phase (dry) etch process in which the etchant is introduced in a vapor phase into the backside contact trench **79**. For example, if the first and second sacrificial material layers (**142**, **242**) include silicon nitride, the etch process can be a wet etch process in which the exemplary structure is immersed within a wet etch tank including phosphoric acid, which etches silicon nitride selective to silicon oxide, silicon, and various other materials employed in the art. In case the sacrificial material layers (**142**, **242**) comprise a semiconductor material, a wet etch process (which may employ a wet etchant such as a KOH solution) or a dry etch process (which may include gas phase HCl) may be employed.

[0224] Each of the first and second backside recesses (**143**, **243**) can be a laterally extending cavity having a lateral dimension that is greater than the vertical extent of the cavity. In other words, the lateral dimension of each of the first and second backside recesses (**143**, **243**) can be greater than the height of the respective backside recess (**143**, **243**). A plurality of first backside recesses **143** can be formed in the volumes from which the material of the first sacrificial material layers **142** is removed. A plurality of second backside recesses **243** can be formed in the volumes from which the material of the second sacrificial material layers **242** is removed. Each of the first and second backside recesses (**143**, **243**) can extend substantially parallel to the top surface of the substrate **9**. A backside recess (**143**, **243**) can be vertically bounded by a top surface of an underlying insulating layer (**132** or **232**) and a bottom surface of an overlying insulating layer (**132** or **232**). In one embodiment, each of the first and second backside recesses (**143**, **243**) can have a uniform height throughout.

[0225] In one embodiment, a sidewall surface of each pedestal channel portion **11** can be physically exposed at each bottommost first backside recess **143** after removal of the first and second sacrificial material layers (**142**, **242**). Further, a top surface of the planar semiconductor material layer **10** can be physically exposed at the bottom of each backside contact trench **79**. An annular dielectric spacer **116** can be formed around each pedestal channel portion **11** by oxidation of a physically exposed peripheral portion of the pedestal channel portions **11**. Further, a semiconductor oxide potion **616** can be formed from each physically exposed

surface portion of the planar semiconductor material layer **10** concurrently with formation of the annular dielectric spacers **116**.

[0226] Referring to FIGS. **15**A-**15**C, a backside blocking dielectric layer (not shown) can be optionally deposited in the backside recesses (**143**, **243**) and the backside contact trenches **79** and over the first contact level dielectric layer **280**. The backside blocking dielectric layer can be deposited on the physically exposed portions of the outer surfaces of the memory stack structures **55**. The backside blocking dielectric layer includes a dielectric material such as a dielectric metal oxide, silicon oxide, or a combination thereof. If employed, the backside blocking dielectric layer can be formed by a conformal deposition process such as atomic layer deposition or chemical vapor deposition. The thickness of the backside blocking dielectric layer can be in a range from 1 nm to 60 nm, although lesser and greater thicknesses can also be employed.

[0227] At least one conductive material can be deposited in the plurality of backside recesses (**143**, **243**), on the sidewalls of the backside contact trench **79**, and over the first contact level dielectric layer **280**. The at least one conductive material can include at least one metallic material, i.e., an electrically conductive material that includes at least one metallic element.

[0228] A plurality of first electrically conductive layers **146** can be formed in the plurality of first backside recesses **143**, a plurality of second electrically conductive layers **246** can be formed in the plurality of second backside recesses **243**, and a continuous metallic material layer (not shown) can be formed on the sidewalls of each backside contact trench **79** and over the first contact level dielectric layer **280**. Thus, the first and second sacrificial material layers (**142**, **242**) can be replaced with the first and second conductive material layers (**146**, **246**), respectively. Specifically, each first sacrificial material layer **142** can be replaced with an optional portion of the backside blocking dielectric layer and a first electrically conductive layer **146**, and each second sacrificial material layer **242** can be replaced with an optional portion of the backside blocking dielectric layer and a second electrically conductive layer **246**. A backside cavity is present in the portion of each backside contact trench **79** that is not filled with the continuous metallic material layer **46**L.

[0229] The metallic material can be deposited by a conformal deposition method, which can be, for example, chemical vapor deposition (CVD), atomic layer deposition (ALD), electroless plating, electroplating, or a combination thereof. The metallic material can be an elemental metal, an intermetallic alloy of at least two elemental metals, a conductive nitride of at least one elemental metal, a conductive metal oxide, a conductive doped semiconductor material, a conductive metal-semiconductor alloy such as a metal silicide, alloys thereof, and combinations or stacks thereof. Non-limiting exemplary metallic materials that can be deposited in the backside recesses (**143**, **243**) include tungsten, tungsten nitride, titanium, titanium nitride, tantalum, tantalum nitride, cobalt, and ruthenium. In one embodiment, the metallic material can comprise a metal such as tungsten and/or metal nitride. In one embodiment, the metallic material for filling the backside recesses (**143**, **243**) can be a combination of titanium nitride layer and a tungsten fill material. In one embodiment, the metallic material can be deposited by chemical vapor deposition or atomic layer deposition.

[0230] Residual conductive material can be removed from inside the backside contact trenches **79**. Specifically, the deposited metallic material of the continuous metallic material layer can be etched back from the sidewalls of each backside contact trench **79** and from above the first contact level dielectric layer **280**, for example, by an anisotropic or isotropic etch. Each remaining portion of the deposited metallic material in the first backside recesses **143** constitutes a first electrically conductive layer **146**. Each remaining portion of the deposited metallic material in the second backside recesses **243** constitutes a second electrically conductive layer **246**. Each electrically conductive layer (**146**, **246**) can be a conductive line structure.

[0231] A subset of the second electrically conductive layers **246** located at the levels of the drain-select-level shallow trench isolation structures **72** constitutes drain select gate electrodes. A subset of the first electrically conductive layers **146** located at each level of the annular dielectric spacers **116** constitutes source select gate electrodes. A subset of the electrically conductive layer (**146**, **246**) located between the drain select gate electrodes and the source select gate electrodes can function as combinations of a control gate and a word line located at the same level. The control gate electrodes within each electrically conductive layer (**146**, **246**) are the control gate electrodes for a vertical memory device including the memory stack structure **55**.

[0232] Each of the memory stack structures **55** comprises a vertical stack of memory elements located at each level of the electrically conductive layers (**146**, **246**). A subset of the electrically conductive layers (**146**, **246**) can comprise word lines for the memory elements. The semiconductor devices in the underlying peripheral device region **700** can comprise word line switch devices configured to control a bias voltage to respective word lines. The memory-level assembly is located over the semiconductor substrate **9**. The memory-level assembly includes at least one alternating stack (**132**, **146**, **232**, **246**) and memory stack structures **55** vertically extending through the at least one alternating stack (**132**, **146**, **232**, **246**). Each of the at least one an alternating stack (**132**, **146**, **232**, **246**) includes alternating layers of respective insulating layers (**132** or **232**) and respective electrically conductive layers (**146** or **246**). The at least one alternating stack (**132**, **146**, **232**, **246**) comprises staircase regions that include terraces in which each underlying electrically conductive layer (**146**, **246**) extends farther along the first horizontal direction hd**1** than any overlying electrically conductive layer (**146**, **246**) in the memory-level assembly.

[0233] Dopants of a second conductivity type, which is the opposite of the first conductivity type of the planar semiconductor material layer **10**, can be implanted into a surface portion of the substrate semiconductor layer **10** to form a source region **61** underneath the bottom surface of each backside contact trench **79**. An insulating spacer **74** including a dielectric material can be formed at the periphery of each backside contact trench **79**, for example, by deposition of a conformal insulating material (such as silicon oxide) and a subsequent anisotropic etch. The first contact level dielectric layer **280** may be thinned due to a collateral etch during the anisotropic etch that removes the vertical portions of horizontal portions of the deposited conformal insulating material.

[0234] A conformal insulating material layer can be deposited in the backside contact trenches **79**, and can be anisotropically etched to form insulating spacers **74**. The insulating spacers **74** include an insulating material such as silicon oxide, silicon nitride, and/or a dielectric metal oxide. A cavity laterally extending along the first horizontal direction hd**1** is present within each insulating spacer **74**.

[0235] A backside contact via structure can be formed in the remaining volume of each backside contact trench **79**, for example, by deposition of at least one conductive material and removal of excess portions of the deposited at least one conductive material from above a horizontal plane including the top surface of the first contact level dielectric layer **280** by a planarization process such as chemical mechanical planarization or a recess etch. The backside contact via structures are electrically insulated in all lateral directions, and is laterally elongated along the first horizontal direction hd**1**. As such, the backside contact via structures are herein referred to as laterally-elongated contact via structures **76**. As used herein, a structure is "laterally elongated" if the maximum lateral dimension of the structure along a first horizontal direction is greater than the maximum lateral dimension of the structure along a second horizontal direction that is perpendicular to the first horizontal direction at least by a factor of 5.

[0236] Optionally, each laterally-elongated contact via structure **76** may include multiple backside contact via portions such as a lower backside contact via portion and an upper backside contact via portion. In an illustrative example, the lower backside contact via portion can include a doped semiconductor material (such as doped polysilicon), and can be formed by depositing the doped semiconductor material layer to fill the backside contact trenches **79** and removing the deposited doped semiconductor material from upper portions of the backside contact trenches **79**. The upper backside contact via portion can include at least one metallic material (such as a combination of a TiN liner and a W fill material), and can be formed by depositing the at least one metallic material above the lower backside contact via portions, and removing an excess portion of the at least one metallic material from above the horizontal plane including the top surface of the first contact level dielectric layer **280**. The first contact level dielectric layer **280** can be thinned and removed during a latter part of the planarization process, which may employ chemical mechanical planarization (CMP), a recess etch, or a combination thereof. Each laterally-elongated contact via structure **76** can be formed through the memory-level assembly and on a respective source region **61**. The top surface of each laterally-elongated contact via structure **76** can located above a horizontal plane including the top surfaces of the memory stack structures **55**.

[0237] The plurality of laterally-elongated contact via structures **76** laterally extend along the first horizontal direction hd**1** and laterally divide the at least one alternating stack (**132**, **146**, **232**, **246**) into a plurality of laterally spaced-apart blocks (B**0**, B**1**, B**2**, B**3**, . . .), wherein the plurality of blocks comprises a set of three neighboring blocks including, in order, a first block B**1**, a second block b**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1** and including a first staircase region (such as the word line contact via region **200** illustrated in FIG. **13**B), a second staircase region (such as the through-memory-level via region **400** illustrated in FIG. **13**B), and a third staircase region (that can be located below the through-memory-level via region **400** in the third block B**3** outside the area of FIG. **13**B), respectively.

[0238] Referring to FIGS. **16**A-**16**C, a second contact level dielectric layer **282** can be optionally formed over the first contact level dielectric layer **280**. The second contact level dielectric layer **282** includes a dielectric material such as silicon oxide or silicon nitride. The thickness of the second contact level dielectric layer **282** can be in a range from 30 nm to 300 nm, although lesser and greater thicknesses can also be employed.

[0239] Various contact via structures can be formed through the contact level dielectric layers (**280**, **282**), the dielectric fill material portion **430** and underlying dielectric materials on various nodes of the memory device in the memory-level assembly and on the lower level metal interconnect structures **780**. Specifically, through-memory-level via structures **488** can be formed through the dielectric fill material portion **430** and optionally through the contact level dielectric layers (**280**, **282**) to electrically contact (i.e., to be electrically coupled to) the lower level metal interconnect structures **780**. Word line contact via structures **86** can be formed through the contact level dielectric layers (**280**, **282**) and the second-tier retro-stepped dielectric material portion **265** in region **200**.

[0240] A subset of the word line contact via structures **86** contacting the second electrically conductive layers **246** extends through the second-tier retro-stepped dielectric material portion **265** in region **200**, and does not extend through the first-tier retro-stepped dielectric material portion **165**. Another subset of the word line contact via structures **86** contacting the first electrically conductive layers **146** extends through the second-tier retro-stepped dielectric material portion **265** and through the first-tier retro-stepped dielectric material portion **165** in region **200**.

[0241] Drain contact via structures **88** contacting the drain regions **63** can extend through the contact level dielectric layers (**280**, **282**) and the second insulating cap layer **270** in the device region **100**. A source connection via structure **91** can extend through the contact level dielectric layers (**280**, **282**) to provide electrical connection to the laterally-elongated contact via structures **76** in region **100**, **200** and/or **400**.

[0242] Each via structure (**488**, **86**, **88**, **91**) may be formed employing a respective set of patterning processes and fill processes. Alternatively, two or more types of via structures (**488**, **86**, **88**, **91**) may be formed employing a common set of patterning processes and fill processes provided that the anisotropic etch process therein can control vertical extent of cavities at target height levels for each type of cavities that are simultaneously formed.

[0243] In one embodiment, the word line contact via structures **86** can be formed through the at least one retro-stepped dielectric material portion (**165**, **265**) over the first staircase region (such as the illustrated word line contact via region **200** in FIG. **16**B) and third staircase regions (another instance of the word line contact via region **200** below the illustrated area of FIG. **16**B) and directly on respective portions of electrically conductive layers (**146**, **246**) in the first and third blocks (B**1**, B**3**) (e.g., in odd numbered blocks), while not forming any contact via structure over the second staircase region (such as the illustrated through-memory-level via region **400** in FIG. **16**B) (e.g., in even numbered blocks).

[0244] Each of the through-memory-level via structures **488** can be formed through the dielectric fill material portion **430** (e.g., in even numbered blocks). The through-memory-level via structures **488** may be formed separately from the other via structures (**86**, **88**, **91**) by patterning the dielectric fill material portion **430** and depositing a conductive material (e.g., TiN, WN, W, Al, Ti, Cu, etc.) into the openings in portion **430** to form the through-memory-level via structures **488**. Alternatively, the through-memory-level via structures **488** may be formed during the same pattering and deposition steps as one or more of the other via structures (**86**, **88**, **91**) and/or of the backside contact via structures **76**.

[0245] While odd and even numbered blocks are described above, it should be noted that regions **400** and **200** do not have to sequentially alternate on one side of region **100**. For example, a set of two adjacent regions **200** may be separated by one region **400** or a set of adjacent two regions **400** on a given side (e.g., left or right side) of region **100**. On one side (e.g., the left side) of the device region **100**, a subset of the through-memory-level via structures **488** can be formed in regions **400** in the areas of even-numbered staircase regions after these even-numbered staircase regions, such as the second staircase region, are removed, while the odd-numbered staircase regions such as the first and third staircase regions remain intact. As used herein, a region or a structure "remains intact" if no substantial change in structure is made to the region or to the structure. Each of the through-memory-level via structures **488** vertically extends at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane including a bottommost surface of the memory-level assembly.

[0246] In contrast, as shown in FIG. **17**E, on the opposite side (e.g., right side) of region **100**, subset of the through-memory-level via structures can be formed in regions **400** in the areas of odd-numbered staircase regions after these odd-numbered staircase regions, such as the first staircase region, are removed, while the even-numbered staircase regions, such as the second staircase region remains intact.

[0247] Thus, as shown in FIGS. **2** to **7**, a plurality of alternating respective sacrificial layers (**142**, **242**) and insulating layers (**132**, **232**) are deposited to form the at least one alternating stack. A plurality of backside trenches **79** are then formed which laterally extend along the first horizontal direction hd**1** through the at least one alternating stack, as shown in FIGS. **13**A-**13**B. The sacrificial layers (**142**, **242**) are selectively removed from the at least one alternating stack through the plurality of backside trenches **79** to form a plurality of backside recesses (**143**, **243**) between the insulating layers (**132**, **232**), as shown in FIGS. **14**A-**14**C.

[0248] The plurality of electrically conductive layers (**146**, **246**) are formed in the backside recesses through the plurality of backside trenches, the insulating spacers **74** are formed in the plurality of backside trenches **79**, and the plurality of laterally-elongated contact via structures **76** are formed in the plurality of backside trenches **79** over the insulating spacers **74**, as shown in FIGS. **15**A-**15**C.

[0249] The step of forming the plurality of electrically conductive layers in the backside recesses through the plurality of backside trenches occurs after to the steps of removing the second staircase region and forming the dielectric fill material portion **430**, shown in FIGS. **11**A-**12**B. The step of removing the second staircase region comprises removing the insulating layers and the sacrificial layers in the second staircase region to form the through-memory-level opening **769**. The electrically conductive layers **46** are not formed in the dielectric fill material portion **430** located in the through-memory-level opening **769**.

[0250] Referring to FIGS. **17**A-**17**F, a line level dielectric layer **110** can be formed over the contact level dielectric layers (**280**, **282**). Various metal interconnect structures (**108**, **103**, **101**) can be formed in the line level dielectric layer **110**. The metal interconnect structures (**108**, **103**, **101**) can include upper level metal interconnect structures **108** that are electrically coupled to (e.g., formed on or in physical contact with) respective pairs of a word line contact via structure **86** and a through-memory-level via structure **488**, bit lines **103** that extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**, and source connection line structures **101** that contact the source connection via structures **91** to provide electrically conductive paths for biasing the source regions **61** through the laterally-elongated contact via structures **76**. Drain side select gate electrode contact via structures **87** are located in regions **200** adjacent to the device region **100**. There may be two or more steps in each sub-block between adjacent backside contact trenches **79** in region **200** exposing two or more vertically separated word lines from adjacent device levels. In this case, there are two or more word line contact via structures **86** (e.g., two structures **86** as shown in FIGS. **17**E and **17**F) located parallel to each other in the same sub-block to contact the respective vertically separated word lines.

[0251] An exemplary layout for the upper level metal interconnect structures **108** is illustrated in FIGS. **17**B and **17**D. FIG. **17**D is a top-down view, and FIG. **17**B is a horizontal cross-sectional view in which the shapes of the upper level metal interconnect structures **108** and the bit lines **103** are illustrated in dotted lines. The upper level metal interconnect structures **108** can extend across neighboring blocks, i.e., straddle a respective laterally-elongated contact via structure **76**. For example, some of the upper level metal interconnect structures **108** can extend across the second block and one of the first and third blocks. FIGS. **17**E and **17**F illustrate another exemplary layout of the upper level metal interconnect structures. In this embodiment, some upper level metal interconnect structures **108** are electrically coupled to the lower level metal interconnect structures **780** by the through-memory-level via structures **488** located in region **400** and are electrically coupled to the word lines **46** by the word line contact via structures **86** in region **200**. Other upper level metal interconnect structures **208** are electrically coupled to the word lines **46** by the word line contact via structures **86** in region **200**, but are not electrically coupled to the lower level metal interconnect structures **780** by the through-memory-level via structure **488** located in region **400**. These upper level metal interconnect structures **208** may be electrically coupled to the driver circuit devices at a location other than region **400**. The bit lines **103** are formed over the memory-level assembly, and are electrically coupled to nodes (e.g., drain regions **63**) of the memory stack structures **55** by the drain contact via structures **88**. As used herein, a first element is electrically coupled to a second element if there exists any one of an electrical short (i.e., Ohmic contact), electron tunneling communication, or a resistive (i.e., Schottky) contact between the first element and the second element. In this case, the upper level metal interconnect structures **108** can

be electrically shorted to respective word lines as embodied as electrically conductive layers **46** by the word line contact via structures **86**.

[0252] The first exemplary structure includes a memory-level assembly located over a semiconductor substrate **9** and including at least one alternating stack (**132**, **146**, **232**, **246**) and memory stack structures **55** vertically extending through the at least one alternating stack (**132**, **146**, **232**, **246**). Each of the at least one an alternating stack (**132**, **146**, **232**, **246**) includes alternating layers of respective insulating layers (**132** or **232**) and respective electrically conductive layers (**146** or **246**). A plurality of laterally-elongated contact via structures **76** vertically extend through the memory-level assembly, laterally extend along a first horizontal direction hd**1**, and laterally divides the at least one alternating stack (**132**, **146**, **232**, **246**) into a plurality of laterally spaced-apart blocks (B**0**, B**1**, B**2**, B**3**, . . .). The plurality of blocks (B**0**, B**1**, B**2**, B**3**, . . .) comprise a set of at least three neighboring blocks including, in order, a first block B**1**, a second block B**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1**. A through-memory-level via region **400** is located on a lengthwise end of the second block B**2** and between a staircase region of the first block B**1** and a staircase region of the third block B**3**.

[0253] Each staircase region of the first and third blocks (B**1**, B**3**) includes terraces in which each underlying electrically conductive layer (**146** or **246**) extends farther along the first horizontal direction hd**1** than any overlying electrically conductive layer (**146** or **246**) in the memory-level assembly. The through-memory-level via region **400** comprises through-memory-level via structures **488** that vertically extend at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane including a bottommost surface of the memory-level assembly.

[0254] At least one lower level dielectric layer **760** overlies the semiconductor substrate **9**. A planar semiconductor material layer **10** overlies the at least one lower level dielectric layer **760**, and includes horizontal semiconductor channels **58** electrically connected to vertical semiconductor channels **60** within the memory stack structures **55**. Semiconductor devices **710** (e.g., CMOS transistors of the word line driver circuit(s)) can be located on the semiconductor substrate **9**. Lower level metal interconnect structures **780** can be electrically shorted to nodes (e.g., source, drain and/or gate electrode) of the semiconductor devices **710** and embedded in the at least one lower level dielectric layer **760** that underlies the planar semiconductor material layer **10**. The through-memory-level via structures **488** contact the lower level metal interconnect structures **780**.

[0255] Upper level metal interconnect structures **108** overlie the memory-level assembly, and are embedded in at least one upper level dielectric layer **110**. At least a portion of the upper level metal interconnect structures **108** are each electrically coupled to the respective lower level metal interconnect structure **780** by the respective through-memory-level via structure **488** located in region **400** and are electrically coupled to the respective word line **46** by the respective word line contact via structures **86** in region **200**. Bit lines **103** also overlie the memory-level assembly and are electrically coupled to nodes of the memory stack structures **55** (through drain regions **63**), and are embedded in at least one upper level dielectric layer **110**. Each of the memory stack structures **55** comprises a vertical stack of memory elements located at each level of the electrically conductive layers (**146**, **246**). The electrically conductive layers (**146**, **246**) comprise word lines for the memory elements. In one embodiment, the semiconductor devices can comprise word line switch devices configured to control a bias voltage to respective word lines.

[0256] In one embodiment, each of the through-memory-level via structures **488** can contact a respective underlying lower level metal interconnect structure **780**. In one embodiment, a subset of the semiconductor devices **710** on the semiconductor substrate **9** can be located underneath an area of the planar semiconductor material layer **10**, i.e., has an areal overlap with the overlying planar semiconductor material layer **10**.

[0257] In one embodiment, a dielectric fill material portion **430** can be located within the through-memory-level via region **400**. The dielectric fill material portion **430** can laterally surround the through-memory-level via structures **488**, and can vertically extend at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane located underneath a bottommost surface of the memory-level assembly.

[0258] The planar semiconductor material layer **10** underlies the memory-level assembly, and can include horizontal semiconductor channels **58** electrically connected to vertical semiconductor channels **60** within the memory stack structures **55**. The second horizontal plane is located underneath a bottom surface of the planar semiconductor material layer. In one embodiment, the dielectric fill material portion **430** can comprise substantially vertical sidewalls that extend through the memory-level assembly and the planar semiconductor material layer **10**.

[0259] In one embodiment, a plurality of laterally-elongated contact via structures **76** can vertically extend through the memory-level assembly, laterally extend along a first horizontal direction hd**1**, and laterally divide the memory-level assembly into a plurality of laterally spaced-apart blocks (B**0**, B**1**, B**2**, B**3**, . . .). The plurality of blocks can comprise, for example, a set of three neighboring blocks including, in order, a first block B**1**, a second block B**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1**. The dielectric fill material portion **430** can be located on a lengthwise end of the second block B**2** and between a staircase region of the first block B**1** and a staircase region of the third block B**3**. Each staircase region of the first and third blocks (B**1**, B**3**) can include terraces in which each underlying electrically conductive layer (**146** or **246**) extends farther along the first horizontal direction than any overlying electrically conductive layer (**146** or **246**) within the memory-level assembly.

[0260] Each of the memory stack structures **55** can comprise a memory film **50** and a vertical semiconductor channel **60** that is adjoined to a respective horizontal channel **58** within the planar semiconductor material layer **10** underlying the memory-level assembly. The word line contact via structures **86** can extend through a retro-stepped dielectric material portion (**265**, **165**) that overlies the staircase regions of the first and third blocks (B**1**, B**3**) in regions **200**, and can contact respective portions of electrically conductive layers (**146**, **246**) in the first and third blocks (B**1**, B**3**). The upper level metal interconnect structures **108** can electrically short respective pairs of a word line contact via structure **86** and

a through-memory-level via structure **488**, can overlie the memory-level assembly, and can straddle the second block B**2** in region **400** and one of the first and third blocks (B**1**, B**3**) in region **200**.

[0261] Referring to FIG. **18**, a second exemplary structure according to a second embodiment of the present disclosure is illustrated. Specifically, in this second embodiment, the word line switching devices **710** employed for the semiconductor devices of the second exemplary structure are located in region **400** rather than under region **100** as in the first embodiment. Otherwise, the steps and structure described above with respect to the first embodiment can be used in the second embodiment. The second exemplary structure can be derived from the first exemplary structure of FIGS. **1**A and **1**B by altering the semiconductor devices and the pattern of the lower level metal interconnect structures **780**.

[0262] In an illustrative example, the word line switching devices **710** can be field effect transistors in a CMOS configuration that are formed in the through-memory-level via regions **400**. Optionally, a subset of the word line switching devices may be formed outside the areas of the through-memory-level via regions **400**, such as a portion under the area of the memory array region **100** or under the areas of the word line contact via regions **200** and. The active regions **730** (source regions **742** and drain regions **744** shown in FIG. **1**A) of the word line switching devices can be laterally surrounded by a shallow trench isolation structures **720**.

[0263] The lower level metal interconnect structures **780** can be embedded in at least one lower level dielectric layer **760**, and can be electrically shorted to nodes of the word line switching devices located on or over the semiconductor substrate **9**. The lower level metal interconnect structures **780** can be configured such that the lower level topmost metal structures **788** provide suitable landing pads for through-memory-level via structures to be subsequently formed within each area of the through-memory-level via region **400**.

[0264] Referring to FIGS. **19**A-**19**B, the processing steps of FIG. **2**-FIGS. **17**A-**17**D are performed to form a planar semiconductor material layer **10**, a memory-level assembly, various contact via structures (**88**, **86**, **91**, **488**), a line level dielectric layer **110**, and metal interconnect structures (**108**, **101**) and bit lines **103** embedded in the line level dielectric layer **110**.

[0265] In one embodiment, the field effect transistors of the word line switching devices can be paired in a CMOS configuration as shown in FIG. **19**B to share a common power supply node, which can be a source region or a drain region **730** that is connected to a power supply metal interconnect structure **7802**. Gate structures **750** can straddle channel regions of the field effect transistors. Switched output node metal interconnect structures can be connected to an output node of each field effect transistor, which can be a drain region or the source region of the respective field effect transistor. The power supply metal interconnect structures **7802** and the switched output node metal interconnect structures are subsets of the lower level metal interconnect structures **780**. The word line switching devices can be arranged as a periodic array that is repeated along the second horizontal direction hd**2** with the periodicity of the width of two neighboring blocks (such as the width of the combination of the first block B**1** and the second block B**2**).

[0266] Specifically, as shown in FIG. **19**A, a planar semiconductor material layer **10** can be formed over the at least one lower level dielectric layer **760**. The memory-level assembly can be formed over the planar semiconductor material layer **10**, and the planar semiconductor material layer **10** can include horizontal semiconductor channels **58** electrically connected to vertical semiconductor channels **60** within the memory stack structures **55**. A memory-level assembly can be formed over the semiconductor substrate **9** and the planar semiconductor layer **10**. The memory-level assembly includes at least one alternating stack (**132**, **146**, **232**, **246**) and memory stack structures **55** vertically extending through the at least one alternating stack (**132**, **146**, **232**, **246**). Each of the at least one an alternating stack (**132**, **146**, **232**, **246**) includes alternating layers of respective insulating layers (**132** or **232**) and respective electrically conductive layers (**146** or **246**). Each of the memory stack structures **55** comprises a vertical stack of memory elements located at each level of the electrically conductive layers (**146**, **246**). The electrically conductive layers (**146**, **246**) comprise word lines for the memory elements.

[0267] The at least one alternating stack (**132**, **146**, **232**, **246**) comprises staircase regions that include terraces in which each underlying electrically conductive layer (**146**, **246**) extends farther along a first horizontal direction than any overlying electrically conductive layer (**146**, **246**) in the memory-level assembly. At least one retro-stepped dielectric material portion (**165**, **265**) can be formed over the staircase regions on the at least one alternating stack (**132**, **146**, **232**, **246**).

[0268] A plurality of laterally-elongated contact via structures **76** is formed through the memory-level assembly. The plurality of laterally-elongated contact via structures **76** laterally extends along the first horizontal direction hd**1** and laterally divides the at least one alternating stack (**132**, **146**, **232**, **246**) into a plurality of laterally spaced-apart blocks (B**1**, B**2**, B**3**, B**4**, . . .). The plurality of blocks (B**1**, B**2**, B**3**, B**4**, . . .) comprises a set of three neighboring blocks including, in order, a first block B**1** a second block B**2**, a third block B**3** and fourth block B**4** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1** and including a first staircase region (such as the word line contact via region **200** containing the remaining the staircases of the third and fourth blocks B**3** and B**4**), and a second staircase region (from which the staircases was removed, such as the through-memory-level via region **400** of the first and second blocks B**1** and B**2**), and a third staircase region (such as the word line contact via region **200** containing the remaining third staircase of the additional blocks, such as B**0** (not shown for clarity)), respectively.

[0269] A through-memory-level opening **769** extending through the memory-level assembly can be formed in the areas of removed staircase regions such as the second staircase region. The through-memory-level opening **769** can extend into the at least one lower level dielectric material layer **760**. The through-memory-level opening **769** can comprise substantially vertical sidewalls that extend through the memory-level assembly and the planar semiconductor material layer **10**. A dielectric fill material portion **430** can be formed in the through-memory-level opening **769**. These steps are then followed by forming the backside trenches **79**, replacing the sacrificial material layers (**142**, **242**) with electrically conductive layers (**146**, **246**) and

forming the insulating spacer **74** and the contact via structure (e.g., source electrode or local interconnect) **76** in the backside trenches **79**, as described above.

[0270] The word line contact via structures **86** can be formed on, and over, the portions of the electrically conducive layers (**146**, **246**) in the remaining staircase regions such as the first and third staircase regions, while not forming any contact via structure over removed staircase regions such as the second staircase region at the same time. The word line contact via structures **86** can be formed through the at least one retro-stepped dielectric material portion (**165**, **265**) over the remaining staircase regions such as the first and third staircase regions and directly on respective portions of electrically conductive layers (**146**, **246**) in the first and third blocks (B**1**, B**3**), while not forming any contact via structure over removed staircase regions such as the second staircase region B**2** at the same time.

[0271] Each of the through-memory-level via structures **488** can be formed through the dielectric fill material portion **430** as described in the prior embodiment. Each of the through-memory-level via structures **488** vertically extends at least from a first horizontal plane including a topmost surface of the memory-level assembly to a second horizontal plane including a bottommost surface of the memory-level assembly.

[0272] Nodes of the word line switching devices can be electrically connected to portions of the electrically conducive layers (**146**, **246**) in the remaining staircase regions such as the first and third staircase regions employing through-memory-level via structures **488** formed in the areas of removed staircase regions such as the second staircase region. For example, upper level metal interconnect structures **108** can be formed on the through-memory-level via structures **488** and over the memory-level assembly and on the word line contact via structures **86**. For example, the upper level metal interconnect structures **108** can be formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **488** over the memory-level assembly. At least one of the upper level metal interconnect structures **108** can extend across the second block B**2** and the third block B**3**. In one embodiment, each of the upper level metal interconnect structures **108** can straddle a respective laterally-elongated contact via structure **76** located between the first block B**1** and the third block B**3**.

[0273] Referring to FIG. **20**, a modification of the second exemplary structure is illustrated, which can be derived from the second exemplary structure of FIG. **18** by forming the optional dielectric pad layer **52** and a subset of the first-tier alternating stack (**132**, **142**) at the same level as the word line switching devices, the at least one lower level dielectric layer **760**, and the lower level metal interconnect structures **780**. For example, the word line switching devices and the lower level metal interconnect structures **780** can be formed in the through-memory-level via regions **400** and outside of the area of the memory array region **100**.

[0274] In one embodiment, the dielectric pad layer **52** and a subset of the first-tier alternating stack (**132**, **142**) can be formed on the substrate **9**. Subsequently, portions of the subset of the first-tier alternating stack (**132**, **142**) can be removed from outside the memory array region **100**, and staircase regions with terraces of the subset of the first-tier alternating stack (**132**, **142**) can be formed at peripheral portions of the memory array region **100** that adjoin the through-memory-stack via regions **400** or the word line contact via regions **200**. A lower level retro-stepped dielectric material portion **765** can be formed over each staircase region and removed in region **700**. The semiconductor devices **710**, the at least one lower level dielectric layer **760** and the lower level metal interconnect structures **780** are then formed over the substrate **9** in region **700**. The lower level retro-stepped dielectric material portions **765** can have top surfaces that are substantially at the same level as the top surface of the deposited subset of the first-tier alternating stack and the top surface of the at least one lower level dielectric layer **760**.

[0275] Referring to FIG. **21**, a complementary subset of the first-tier alternating stack (**132**, **142**) can be formed over the deposited subset of the first-tier alternating stack (**132**, **142**). The processing steps of FIGS. **3**, **4**A and **4**B, **5**A and **5**B, and **6**A and **6**B can be performed to form a first tier structure. Referring to FIG. **22**, the processing steps of FIGS. **7**A and **7**B through the processing steps of FIGS. **10**A and **10**B can be performed to form a second tier structure. In this embodiment the horizontal channel is located within the substrate **9** underlying the memory-level assembly because layer **10** may be omitted in this embodiment. Alternatively, layer **10** is formed directly on the substrate **9** outside region **10**.

[0276] Referring to FIG. **23**, the processing steps of FIGS. **11**A and **11**B through the processing steps of FIGS. **17**A-**17**D can be performed to electrically connect the nodes of the word line switching devices to portions of the electrically conducive layers (**146**, **246**) in the remaining staircase regions such as the first and third staircase regions employing through-memory-level via structures **488** formed in the areas of the removed staircase regions such as the second staircase region.

[0277] Referring to FIGS. **24**A and **24**B, a third exemplary structure according to a third embodiment of the present disclosure includes a moat trench which separates the first part of the alternating stack of insulating layers and sacrificial insulating material layers from the second part of the alternating stack of the insulating stack in which the sacrificial insulating material layers are replaced with electrically conductive word line layers. The a third exemplary structure can be derived from the first exemplary structure, the second exemplary structure, or modifications thereof by performing the processing steps up to formation of the first-tier alternating stack. As in the first and second embodiments, the lower level metal interconnect structures **780** can be electrically shorted to nodes of the semiconductor devices, and can be embedded in at least one lower level dielectric layer **760**, which is formed over the semiconductor substrate **9**. The layout for the pattern of the first-tier support pillar structures **171** can be optionally altered to optionally remove the first-tier support pillar structures **171** from a center portion of each through-memory-stack via region **400**. The processing steps of FIGS. **5**A, **5**B, and **6** can be performed with modification to the pattern employed to form the first-tier memory openings **149**. The optional planar conductive material layer **6** and the planar semiconductor material layer **10** may be patterned to form an opening **151** extending through these layers to the underlying insulating layer **760**. The opening **151** is located under region **400** and may be filled with another insulating material layer (e.g., a silicon oxide or doped silicate glass) **760**.

[0278] Specifically, concurrently with formation of the first-tier memory openings **149**, a first-tier moat trench can

be formed in each through-memory-stack via region **400**. For example, a photoresist layer can be applied after formation of the first insulating cap layer **170** or the inter-tier dielectric layer **180**, and can be lithographically patterned to form a patterned photoresist layer including the pattern of memory openings and the pattern of first-tier moat trenches to be formed through the first-tier alternating stack (**132**, **142**). An anisotropic etch is performed through the first-tier alternating stack (**132**, **142**) to form first-tier memory openings **149** and first-tier moat trenches.

[0279] Sacrificial memory opening fill portions **131** can be formed in the first-tier memory openings **149**, and sacrificial moat trench fill portions **141** can be formed in the first-tier moat trenches. For example, a sacrificial fill material layer is deposited in the first-tier memory openings **149** and the first-tier moat trenches, and excess portions of the sacrificial fill material layer can be removed from above the top surface of the inter-stack dielectric layer **180**. The sacrificial fill material can include the same material as in the first and second embodiments.

[0280] Each remaining portion of the sacrificial material in a first-tier memory opening **149** constitutes a sacrificial memory opening fill portion **131**. Each remaining portion of the sacrificial material in a first-tier moat trench constitutes a sacrificial moat trench fill portion **141**. The top surfaces of the sacrificial memory opening fill portions **131** and the sacrificial moat trench fill portions **141** can be coplanar with the top surface of the first insulating cap layer **170**. The sacrificial memory opening fill portion **131** may, or may not, include cavities therein.

[0281] Referring to FIGS. **25**A and **25**B, the processing steps of FIGS. **7**, **8**A, **8**B, **9**A, and **9**B can be performed with a modification to the pattern employed to form the second-tier openings. Specifically, the pattern for the first-tier moat trenches can be added to the pattern for the second-tier memory openings. After the anisotropic etch process that transfers the pattern in the photoresist layer through the second-tier alternating stack (**232**, **242**), second-tier moat trenches are formed over the first-tier moat trenches. The pattern of the second-tier moat trenches can be identical to the pattern of the first-tier moat trenches. The sacrificial memory opening fill portions **131** and the sacrificial moat trench fill portions **141** are then removed by selective etching or ashing (if portions **131** and **141** comprise a carbon based material). Each stack of a first-tier moat trench and a second-tier moat trench constitutes a moat trench **449**. Memory openings **49** extending through the at least one alternating stack (**132**, **142**, **232**, **242**) can be formed simultaneously with formation of the moat trenches **449**.

[0282] In one embodiment, each moat trench **449** can have a U-shaped horizontal cross-sectional shape such that two open ends of the U-shape include vertical sidewalls composed of surfaces of the at least one retro-stepped dielectric material portion (**165**, **265**). In this case, the two sides of each moat trench **449** can extend along the first horizontal direction hd**1** parallel to the lengthwise direction of the backside contact trenches **79**, can be adjoined to each other through a connecting portion of the moat trench **449**. The two sides extend parallel to the second lengthwise direction hd**2** at a proximal side of the moat trench **449**, and can extend along the first horizontal direction beyond the area of the bottommost layers of the first-tier alternating stack (**132**, **142**) at a distal side of the moat trench **449**. As used herein, a "proximal" side of the moat trench **449** refers to the side that is proximal to the memory array region **100**, and a "distal" side of the moat trench **449** refers to the side that is distal from the memory array region **100**.

[0283] In another embodiment, each moat trench **449** can have a closed shape (e.g., polygon, circle, oval, irregular shape, etc.) such that an area of the memory-level assembly is located inside each moat trench **449**, and a complementary area of the memory-level assembly is located outside each moat trench **449**. In this case, the moat trench **449** separates the inside of the moat trench **449** from the outside of the moat trench **449** with closed shape area that corresponds to the area of the moat trench **449**. As used herein, a closed shape is a shape having a closed outer periphery and an opening within the closed outer periphery that is defined by a closed inner periphery. The opening in the moat trench **449** is located above the opening **151** in layer **10**, and may have the same or similar shape and/or dimensions to the opening **151**.

[0284] The moat trench **449** defines the area of a corresponding through-memory-level via region **400**, and extends through the at least one alternating stack (**132**, **142**, **232**, **242**). A portion of the at least one alternating stack (**132**, **142**, **232**, **242**) is present within the through-memory-level via region **400**. Specifically, a portion of the at least one alternating stack (**132**, **142**, **232**, **242**) containing insulating sacrificial material layers (**142**, **242**) can be laterally enclosed within a set of inner sidewalls of the moat trench **449** in case the moat trench **449** has a closed shape, or within a combination of the set of inner sidewalls of the moat trench **449** and a vertical surface containing a plane that connects a pair of vertical edges of the moat trench **449** located at a distal end of the moat trench **449** in case the moat trench **449** is U-shaped.

[0285] Referring to FIGS. **26**A and **26**B, a subset of the processing steps of FIGS. **10**A and **10**B can be performed to form optional pedestal channel portions **11** and memory stack structures **55**. Drain regions **63** can be formed on top of each vertical semiconductor channel **60**.

[0286] In one embodiment, all of the surfaces of the moat trenches **449** can be dielectric surfaces. A selective semiconductor deposition process is employed to form the pedestal channel portions **11** such that the pedestal channel portions **11** grow only from the physically exposed semiconductor surfaces of the planar semiconductor material layer **10** at the bottom of each memory opening **49**, while no semiconductor material is deposited in the moat trenches **449**.

[0287] Concurrent with formation of the memory stack structures **55**, a dummy memory stack structure **155** is formed within each moat trench **449**. For example, a memory film **50** can be formed within each memory opening **49** simultaneously with formation of an insulating liner **50** in each moat trench **449** by depositing and anisotropically etching a stack of layers including at least one dielectric material layer (**51**, **54**, **56**). Subsequently, a conformal semiconductor material layer can be deposited on the memory films **50** and the insulating liners **50**, and portions of the conformal semiconductor material layer can be removed from above the at least one alternating stack (**132**, **142**, **232**, **242**) employing a planarization process. Each remaining portion of the conformal semiconductor material layer constitutes a vertical semiconductor channel **60**, which can be an active channel of a vertical field effect transistor if present within a memory stack structure **55** or a semicon-

ductor fill material portion **60** if present within a dummy memory stack structure **155** inside a moat trench **449**.

[0288] Each dummy memory stack structure **155** can have an identical set of elements as a memory stack structure **55**. A set of insulating films formed in the moat trenches **449** and having the same material stack as the memory film **50** is herein referred to as an insulating liner **50**. A dummy drain region **463** can be formed on top of each dummy memory stack structure **155**. The dummy memory stack structures **155** can be electrically isolated from all underlying elements and laterally surrounding elements. For example, each dummy memory stack structure **155** can contact a top surface of the at least one lower level dielectric layer **760** (such as the at least one lower level interconnect dielectric layer **768** which fills the opening **151**) and sidewalls of the at least one alternating stack (**132**, **142**, **232**, **242**), the inter-stack dielectric layer **180**, the first insulating cap layer **170**, and the second insulating cap layer **270**.

[0289] Each combination of a dummy memory stack structure **155** and a dummy drain region **463** constitutes an insulating moat trench structure (**155**, **463**) that fills a respective moat trench **449**. The area of each through-memory-level via region **400** includes an area defined by a closed inner periphery of a respective insulating moat trench structure (**155**, **463**).

[0290] Referring to FIGS. **27**A and **27**B, a complementary subset of the processing steps of FIGS. **13**A and **13**B can be performed to form a first contact level dielectric layer **280** and backside contact trenches **79**.

[0291] Referring to FIGS. **28**A and **28**B, the processing steps of FIGS. **14**B, **14**C, **15**B and **15**C can be performed to replace the sacrificial material layers (**142**, **242**) with electrically conductive layers (**246**, **246**). In one embodiment, the sacrificial material layers (**142**, **242**) can include dielectric spacer layers, i.e., dielectric material layers that vertical space the insulating layers (**132**, **232**). The insulating moat trench structures (**155**, **463**), either alone or in combination with the retro-stepped dielectric material portions (**165**, **265**), block the lateral propagation of etchants into the areas laterally enclosed by the insulating moat trench structures (**155**, **463**) such that no backside recess (**143**, **243**) are formed inside the region **400** surrounded by the moat trench structure (**155**, **463**). Portions of the dielectric spacer layers (i.e., the sacrificial material layers (**142**, **242**)) located outside the moat trench structure (i.e., outside the through-memory-level via regions **400**) are replaced with electrically conductive layers (**146**, **246**) while the portions of the at least one alternating stack (**132**, **142**, **232**, **242**) in each moat trench **449** remains intact. The electrically conductive layers (**146**, **246**) constitute word lines for the memory stack structures **55**, which are formed outside the moat trench structure (i.e., outside region **400**) but which are not formed inside the moat trench structure (i.e., inside region **400**).

[0292] Subsequently, a conformal insulating material layer is deposited and anisotropically etched within each backside contact trench **79** to form insulating spacers **74**. A laterally-extending contact via structure **76** within each backside contact trench **79**. A plurality of laterally-elongated contact via structures **76** extending along the first horizontal direction hd**1** laterally divides the memory-level assembly into a plurality of laterally spaced-apart blocks (B**1**, B**2**, B**3**, . . .). The plurality of blocks (B**1**, B**2**, B**3**, . . .) can comprise a set of three neighboring blocks including, in order, a first block B**1**, a second block B**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1**.

[0293] In case the moat trenches **449** are U-shaped, a remaining portion of the retro-stepped dielectric material portion (**265** or **165**) can continuously extend over portions of the electrically conductive layers (**146**, **246**) in the first staircase region (such as the illustrated word line contact via region **200** in the first block B**1** in FIG. **28**B) and remaining portions of the dielectric spacer layers (i.e., the sacrificial material layers (**142**, **242**)) in the second staircase region, such as the through-memory-level via region **400** in the second block B**2** in FIG. **28**B.

[0294] Referring to FIGS. **29**A-**29**C, through-memory-level via structures **488** can be formed in each through-memory-level via region **400**. For example, via cavities can be formed, which extend through the first contact level dielectric layer **280**, a remaining portion of the second-tier alternating stack of the second insulating layers **232** and the second sacrificial layers **242**, a remaining portion of the first-tier alternating stack of the first insulating layers **132** and the first sacrificial layers **142**, and an upper portion of the at least one lower level dielectric layer **760**. Generally, the through-memory-level via structures **488** can vertically extend from a first horizontal plane including a topmost surface of a remaining portion of the at least one alternating stack (**132**, **142**, **232**, **242**) and a bottommost surface of the at least one alternating stack (**132**, **142**, **232**, **242**). Various additional via structures (**86**, **87**, **88**) can be formed employing the same processing steps as the processing steps of FIGS. **16**A-**16**C. Since the alternating stack materials in region **400** are electrically insulating, the through-memory-level via structures **488** extending through the insulating layers of the alternating stack in region **400** are not short circuited to each other or to all word lines in the stack outside region **400**.

[0295] Referring to FIG. **30**, a line level dielectric layer **110** can be formed over the contact level dielectric layers (**280**, **282**). Various metal interconnect structures (**108**, **101**) and bit lines **103** can be formed in the line level dielectric layer **110** employing the processing steps of FIGS. **17**A-**17**D. As in the first and second embodiments, the bit lines **103** can overlie the memory-level assembly, can be electrically coupled to nodes (e.g., drain regions **63**) of the memory stack structures **55**, and can be embedded in at least one upper level dielectric layer such as the line level dielectric layer **110**. The through-memory-level via structures **488** can contact respective pairs of an upper level metal interconnect structure **108** and a lower level metal interconnect structure **780**. The upper level metal interconnect structures **108** interconnect respective pairs of via structures (**86**, **488**) and (**87**, **488**).

[0296] Referring to FIGS. **31**A and **31**B, a modification of the third exemplary structure can be derived from the third exemplary structure by forming the moat trenches **149** and the insulating moat trench structures **466** in separate steps from forming respective memory openings **49** and memory stack structures **55**. The method of making third exemplary structure can be derived from the method steps shown in FIGS. **8**A and **8**B by forming moat trenches prior to formation of second-tier memory openings. For example, a photoresist layer can be applied over the first exemplary structure of FIGS. **8**A and **8**B, and can be lithographically patterned to form openings corresponding to the pattern of the moat trenches illustrated in FIGS. **25**A and **25**B. An

anisotropic etch is performed through the second-tier alternating stack (**232**, **242**) and the first-tier alternating stack (**132**, **142**) to form the moat trenches.

[0297] The moat trenches can be subsequently filled with a dielectric material such as silicon oxide to form deep trench isolation structures, which are moat trench fill structures **466** filling the moat trenches. In one embodiment, the moat trench fill structures **466** can consist essentially of the dielectric material. In one embodiment, the area of a through-memory-level via region **400** can comprise a closed inner periphery of the insulating moat trench structure **466**.

[0298] Referring to FIGS. **32**A and **32**B, the processing steps of FIGS. **9**A to **15**C can be sequentially performed to replace the sacrificial material layers (**142**, **242**) with electrically conductive layers (**246**, **246**), and to form insulating spacers **74** and laterally-extending contact via structures **76**. Subsequently, through-memory-level via structures **488** can be formed in each through-memory-level via region **400** employing the processing steps of FIGS. **29**A-**29**C. Various additional via structures (**86**, **87**, **88**) can be formed employing the same processing steps as the processing steps of FIGS. **16**A-**16**C. Subsequently, a line level dielectric layer **110** can be formed over the contact level dielectric layers (**280**, **282**), and various interconnect structures (**108**, **101**) and bit lines **103** can be formed in the line level dielectric layer **110** employing the processing steps of FIGS. **17**A-**17**D.

[0299] The third exemplary structure illustrated in FIG. **30** and the modification illustrated in FIGS. **32**A and **32**B include a semiconductor structure, which includes a memory-level assembly located over a semiconductor substrate **9** and comprising at least one first alternating stack of electrically conductive layers (**146**, **246**) and first portions of insulating layers (**132**, **232**), and further comprising memory stack structures **55** vertically extending through the at least one first alternating stack. Each of the memory stack structures **55** comprises a memory film **50** and a vertical semiconductor channel **60**. The electrically conductive layers (**146**, **246**) constitute word lines for the memory stack structures **55**. The semiconductor structure further includes an insulating moat trench structure {**466** or (**155**, **463**)} vertically extending through the memory-level assembly and defining an area of a through-memory-level via region **400** laterally spaced from the at least one first alternating stack (**132**, **146**, **232**, **246**). The semiconductor structure further includes at least one second alternating stack located in the through-memory-level via region **400**. The at least one second alternating stack includes alternating layers of dielectric spacer layers (**142**, **242**) and second portions of the insulating layers (**132**, **232**), and each of the dielectric spacer layers (**142**, **242**) is located at a same level as a respective electrically conductive layer (**146**, **246**). The semiconductor structure further comprises through-memory-level via structures **488** located within the through-memory-level via region **400** and vertically extending from a first horizontal plane including a topmost surface of the memory-level assembly and a bottommost surface of the memory-level assembly and comprising a conductive material.

[0300] In one embodiment, the area of the through-memory-level via region **400** includes a closed inner periphery of the insulating moat trench structure {**466** or (**155**, **463**)}. In this case, the entire set of outer sidewalls of the at least one second alternating stack (**132**, **142**, **232**, **242**) can contact an inner sidewall of the insulating moat trench structure {**466** or (**155**, **463**)}.

[0301] In one embodiment, a plurality of laterally-elongated contact via structures **76** can extend along the first horizontal direction hd**1**, and can laterally divide the memory-level assembly into a plurality of laterally spaced-apart blocks (B**1**, B**2**, B**3**, . . .). In one embodiment, the plurality of blocks (B**1**, B**2**, B**3**, . . .) can comprise a set of three neighboring blocks including, in order, a first block B**1**, a second block B**2**, and third block B**3** arranged along a second horizontal direction hd**2** that is perpendicular to the first horizontal direction hd**1**. The insulating moat trench structure {**466** or (**155**, **463**)} can be located on a lengthwise end of the second block B**2** and between a staircase region of the first block B**1** and a staircase region of the third block B**3**. Each staircase region of the first and third blocks (B**1**, B**3**) can include terraces in which each underlying electrically conductive layer (**146**, **246**) extends farther along the first horizontal direction hd**1** than any overlying electrically conductive layer (**146**, **246**) within the memory-level assembly.

[0302] In one embodiment, stepped bottom surfaces of a retro-stepped dielectric material portion (**265** or **165**) can contact stepped top surfaces of the first and third staircase regions in respective first and third blocks (B**1**, B**3**). In one embodiment, an additional retro-stepped dielectric material portion (**265** or **165**) can be present within an inner sidewall of the insulating moat trench structure {**466** or (**155**, **463**)}. In this case, stepped bottom surfaces of the additional retro-stepped dielectric material portion can comprise the same material as the retro-stepped dielectric material portion (**165**, **265**), and can be laterally spaced from the retro-stepped dielectric material portion by the insulating moat trench structure {**466** or (**155**, **463**)}, and can contact stepped top surfaces of the at least one second alternating stack (**132**, **142**, **232**, **242**).

[0303] In one embodiment, the insulating moat trench structure {**466** or (**155**, **463**)} can be U-shaped. In this case, additional stepped bottom surfaces of the retro-stepped dielectric material portion (**165** or **265**) can contact stepped top surfaces of the at least one second alternating stack (**132**, **142**, **232**, **242**).

[0304] In one embodiment, each of the plurality of laterally-elongated contact via structures **76** can be laterally surrounded by an insulating spacer **74**. The insulating moat trench structure (**155**, **463**) can comprise an insulating liner **50** comprising a same material as a memory film **50** in a memory stack structure **55**.

[0305] In one embodiment, the plurality of laterally-elongated contact via structures **76** can comprise source lines contacting respective underlying source regions **61** that contact respective horizontal channels **58**.

[0306] In one embodiment, the insulating moat structure (**155**, **463**) can comprise a layer stack including a same set of layers as layers included in each of the memory stack structures **55**, i.e., the memory film **50** and the vertical semiconductor channel **60**.

[0307] In one embodiment, the insulating moat structure **466** can consist essentially of a dielectric fill material portion.

[0308] The semiconductor structure can further comprise semiconductor devices located on the semiconductor substrate **9**, lower level metal interconnect structures **780** electrically shorted to nodes of the semiconductor devices and

embedded in at least one lower level dielectric layer **760** that overlies the semiconductor substrate **9**, and a planar semiconductor material layer **10** overlying the at least one lower level dielectric layer **760** and including horizontal semiconductor channels **58** connected to vertical semiconductor channels **60** within the memory stack structures **55**.

[0309] In one embodiment, the semiconductor structure can further include upper level metal interconnect structures **108** overlying the memory-level assembly, electrically coupled to nodes of the memory stack structures **55**, and embedded in at least one upper level dielectric layer **110**. The through-memory-level via structures **488** can vertically extend through the memory-level assembly, and can contact respective pairs of an upper level metal interconnect structure **108** and a lower level metal interconnect structure **780**.

[0310] Referring to FIGS. **33**A and **33**B, a fourth exemplary structure according to a fourth embodiment of the present disclosure, which can be formed concurrently with formation of any of the first, second, and third exemplary structures or modifications thereof, or can be formed as a stand-alone structure. The fourth exemplary structure illustrated in FIGS. **33**A and **33**B can be formed employing the same processing steps as the processing steps employed to form the first exemplary structure of FIGS. **10**A and **10**B without forming the backside contact trenches **79**. Through-memory-level via regions **500** can be formed within the memory array region **100**. Each through-memory-level via region **500** can be formed entirely within a block (B**1**, B**2**, etc.). The through-memory-level via regions **500** can be formed without forming additional through-memory-level via regions **400** of the first, second, and third embodiments, or can be formed in addition to the through-memory-level via regions **400** of the first, second, and third embodiments through the same memory-level assembly.

[0311] Each of the at least one alternating stack of insulating layers (**132**, **232**) and sacrificial material layers (**142**, **242**) is an in-process alternating stack, which is modified in subsequent processing steps. While an embodiment is described herein in which the through-memory-level via regions **500** are formed within the memory array region **100**, embodiments are also contemplated herein in which additional, or substitutional, through-memory-level via regions **500** are formed in the staircase regions. Various dummy memory stack structures **55**D can be formed around the through-memory-level via regions **500**, which are not electrically connected as device components, but are employed for structural support during formation of backside recesses in subsequent processing steps.

[0312] Referring to FIGS. **34**A and **34**B, backside contact trenches **79** and moat trenches **579** can be simultaneously formed through the memory-level assembly. For example, a photoresist layer can be applied over the first contact level dielectric layer **280**, and can be lithographically patterned to form openings including the pattern of the backside contact trenches **79** as in the previous embodiments and the pattern of moat trenches, which can be the same as the pattern of moat trenches of the third embodiment or the modification thereof. An anisotropic etch is performed to transfer the pattern in the patterned photoresist layer through the memory-level assembly, thereby forming the backside contact trenches **79** and the moat trenches **579**. The photoresist layer can be subsequently removed, for example, by ashing. Each moat trench **579** can include an area of the through-memory-level via region **400** within an outer periphery thereof.

[0313] Referring to FIGS. **35**A and **35**B, an insulating liner layer **572**L can be deposited in the moat trenches **579** and the backside contact trenches **79**. The insulating liner layer **572**L includes a dielectric material such as silicon oxide, silicon nitride, and/or a dielectric metal oxide such as aluminum oxide. The insulating liner layer **572**L can be deposited as a conformal material layer by a conformal deposition method such as chemical vapor deposition or atomic layer deposition. The thickness of the insulating liner layer **572**L can be in a range from 3 nm to 60 nm, although lesser and greater thicknesses can also be employed.

[0314] A photoresist layer **577** can be applied over the insulating liner layer **572**L, and can be lithographically patterned to cover the insulating liner layer **572**L in the through-memory-level via regions **500**, while the insulating liner layer **572**L is not covered by the photoresist layer outside the through-memory-level via regions **500**. An etch process (which may be an isotropic etch or an anisotropic etch) can be employed to remove physically exposed portions of the insulating liner layer **572**L from outside the through-memory-level via regions **500**. A patterned insulating liner layer **572**L is formed on sidewalls of the moat trenches **579** and over portions of the first contact level dielectric layer **280** within the through-memory-level via regions **500**. Sidewalls of the backside contact trenches **76** are physically exposed to an ambient. As used herein, an "ambient" refers to any gaseous ambient that a semiconductor substrate can be physically exposed to during a manufacturing sequence, and includes air, vacuum, an inert environment, and reduced pressure environment. The photoresist layer **577** is subsequently removed, for example, by ashing.

[0315] Referring to FIGS. **36**A and **37**A, the processing steps of FIGS. **11**A and **11**B can be performed to remove the sacrificial material layers (**142**, **242**) selective to the insulating layers (**132**, **232**). Specifically, an etchant can be introduced through the backside contact trenches **79** to form backside recesses (**143**, **243**). A patterned insulating liner layer **572**L covers all sidewalls of each moat trench **579**, and prevents the etchant from etching the portion of the at least one alternating stack (**132**, **142**, **232**, **242**) enclosed therein. Thus, each portion of the at least one alternating stack (**132**, **142**, **232**, **242**) laterally enclosed by the vertical portion of a respective patterned insulating liner layer **572**L remains intact during formation of the backside recesses (**143**, **243**).

[0316] Referring to FIGS. **37**A and **37**B, the processing steps of FIGS. **12**A and **12**B can be performed to form the electrically conductive layers (**146**, **246**) in the backside recesses (**143**, **243**). The electrically conductive layers (**146**, **246**) can be formed by introducing a reactant through the backside contact trenches **79**, thereby forming the at least one alternating stack of insulating layers (**132**, **232**) and electrically conductive layers (**146**, **246**). A trench cavity **579'** is present within each patterned insulating liner layer **572**L. A remaining portion of the at least one in-process alternating stack (**132**, **142**, **232**, **242**) remains within each area enclosed by a moat trench **579**.

[0317] Referring to FIGS. **38**A and **38**B, the processing steps of FIGS. **13**A and **13**B can be performed to form insulating spacers **74** and laterally-elongated contact via structures **76**. Specifically, an insulating material layer can be conformally deposited and anisotropically etched to form

an insulating spacer **74** in each backside contact trench **79** and an inner insulating liner **574** in each trench cavity **579'**. An inner insulating liner **574** can be formed within each patterned insulating liner layer **572**L concurrently with formation of the insulating spacers **74**. The insulating spacers **74** and insulating liners (i.e., the inner insulating liners **574**) can be simultaneously formed in the backside contact trenches **79** and the moat trenches **579**, respectively. The inner insulating liners **574** and the insulating spacers **74** can include the same dielectric material, and can have the same thickness.

[0318] A conductive material is deposited to fill remaining volumes of the backside contact trenches **79** and the trench cavities **579'**. Excess portions of the conductive material can be removed from above the horizontal plane including the top surface of the first contact level dielectric layer **280** by a planarization process such as chemical mechanical planarization. Each remaining portion of the conductive material within an insulating spacer **74** constitutes a laterally-elongated contact via structure **76**. Each remaining portion of the conductive material within an inner insulating liner **574** constitutes a conductive fill portion **576**. The plurality of laterally-elongated contact via structures **76** and the conductive fill material portions **576** can be simultaneously formed on the insulating spacers **74** and the insulating liners, respectively. Horizontal portions of the patterned insulating liner layers **572**L can be removed from above the top surface of the first contact level dielectric layer **280**. Each remaining portion of the patterned insulating liner layers **572**L constitutes an outer insulating liner **572**.

[0319] A plurality of laterally-elongated contact via structures **76** is formed through the memory-level assembly. The plurality of laterally-elongated contact via structures **76** laterally extends along a first horizontal direction hd**1**, and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks (B**1**, B**2**, B**3**, . . .) within the memory-level assembly.

[0320] Referring to FIGS. **39**A and **39**B, at least one through-memory-level opening is formed through the memory-level assembly within the areas of each through-memory-level via region **500**. A lithographically patterned mask including openings in the areas of the through-memory-level via regions **500** can be employed during an anisotropic etch that etches the material of the at least one alternating stack (**132**, **142**, **232**, **242**) as originally formed at the processing steps of FIGS. **2** and **7** and the material of the at least one lower level dielectric layer **760**. A top surface of lower level metal interconnect structures **780** can be physically exposed at the bottom of each through-memory-level opening. A conductive material is deposited in the through-memory-level cavities, and excess portions of the conductive material can be removed from above the horizontal plane including the top surface of the first contact level dielectric layer **280**. Each remaining portion of the conductive material in the through-memory-level openings constitutes a through-memory-level via structure **588**, which can contact a respective underlying lower level metal interconnect structure **780**.

[0321] In one embodiment, at least one through-memory-level via structure **588** can be formed in a through-memory-level via region **500** in a block. The through-memory-level via region **500** can be provided between a pair of laterally-elongated contact via structures **76** and between two groups of memory stack structures **55** located in the block. The through-memory-level via region **500** can include through-memory-level via structures **588**. Each of the at least one through-memory-level via structure **588** vertically extends through the memory-level assembly.

[0322] Referring to FIG. **40**, drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that may be formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588**, bit lines **103** that extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**, and source connection line structures (not shown). Alternatively, the upper level metal interconnect structures **108** may comprise a source shunt line or a power strap that contact the through-memory-level via structure **588**. A source shunt line may be a shunt line which extends parallel to and between the bit lines **103**. A power strap may be any conductive line which connects the driver circuits to an external power source.

[0323] The fourth exemplary structure illustrated in FIG. **40** includes a semiconductor structure, which includes a memory-level assembly located over a semiconductor substrate **9** and comprising at least one first alternating stack of electrically conductive layers (**146**, **246**) and first portions of insulating layers (**132**, **232**), and further comprising memory stack structures **55** vertically extending through the at least one first alternating stack. Each of the memory stack structures **55** comprises a memory film **50** and a vertical semiconductor channel **60**. The electrically conductive layers (**146**, **246**) constitute word lines for the memory stack structures **55**. The semiconductor structure further includes an insulating moat trench structure (**572**, **574**, **576**) vertically extending through the memory-level assembly and defining an area of a through-memory-level via region **500** that is laterally offset from the at least one first alternating stack (**132**, **146**, **232**, **246**). The semiconductor structure further includes at least one second alternating stack located in the through-memory-level via region **500**. The at least one second alternating stack includes alternating layers of dielectric spacer layers (**142**, **242**) and second portions of the insulating layers (**132**, **232**), and each of the dielectric spacer layers (**142**, **242**) is located at a same level as a respective electrically conductive layer (**146**, **246**). The semiconductor structure further comprises through-memory-level via structures **588** located within the through-memory-level via region **500** and vertically extending from a first horizontal plane including a topmost surface of the memory-level assembly and a bottommost surface of the memory-level assembly and comprising a conductive material.

[0324] In one embodiment, a plurality of laterally-elongated contact via structures **76** extending along the first horizontal direction hd**1** can laterally divide the memory-level assembly into a plurality of laterally spaced-apart blocks, and each of the plurality of laterally-elongated contact via structures **76** can be laterally surrounded by an insulating spacer **74**. The insulating moat trench structure (**572**, **574**, **576**) can comprises a conductive fill portion **576** comprising the same conductive material as the plurality of laterally-elongated contact via structures **76**.

[0325] Referring to FIG. **41**, a first modification of the fourth exemplary structure is illustrated, which can be derived from the fourth exemplary structure illustrated in FIGS. **37**A and **37**B by increasing the thickness of the insulating liner layer **572**L. Specifically, the thickness of the insulating liner layers **572**L is increased such that the maximum width of the trench cavity **579'** after formation of the insulating liner layers **572**L is less than twice of the insulating material layer to be deposited to form insulating spacers in the backside contact trenches **79**.

[0326] Referring to FIG. **42**, an insulating material layer is deposited at a thickness such that the insulating material layer does completely fill the backside contact trenches **79**, while filling the mote trenches **579** completely. An anisotropic etch is performed to remove horizontal portions of the insulating material layer. Each remaining vertical portion of the insulating material layer in the backside contact trenches **79** constitutes an insulating spacer. Each remaining portion of the insulating material layer that fills the volume inside an insulating liner layer **572** constitutes an insulating material fill portion **575**. Subsequently, a conductive material is deposited and planarized to form laterally-extending contact via structures **76**. The remaining portion of each insulating liner layer **572**L constitutes an outer insulating liner **572**.

[0327] In one embodiment, insulating spacers **74** can be formed in the backside contact trenches **79** simultaneously with formation of the insulating material fill portions **575** in the moat trenches **579**. The plurality of laterally-elongated contact via structures **76** can be formed on the insulating spacers **74**. A remaining portion of the at least one in-process alternating stack (**132**, **142**, **232**, **242**) remains within an area enclosed by each moat trench **579**.

[0328] Subsequently, the processing steps of FIGS. **39**A and **39**B can be performed to form at least one through-memory-level via structure **588** inside each through-memory-level via region **500**.

[0329] Referring to FIG. **43**, drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that are either formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588** or which comprise a shunt line or power strap connected to structure **588**, bit lines **103** that extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**, and source connection line structures (not shown).

[0330] The first modification of the fourth exemplary structure illustrated in FIG. **43** includes a semiconductor structure, which includes a memory-level assembly located over a semiconductor substrate **9** and comprising at least one first alternating stack of electrically conductive layers (**146**, **246**) and first portions of insulating layers (**132**, **232**), and further comprising memory stack structures **55** vertically extending through the at least one first alternating stack. Each of the memory stack structures **55** comprises a memory film **50** and a vertical semiconductor channel **60**. The electrically conductive layers (**146**, **246**) constitute word lines for the memory stack structures **55**. The semiconductor structure further includes an insulating moat trench structure (**572**, **575**) vertically extending through the memory-level assembly and defining an area of a through-memory-level via region **500** that is laterally offset from the at least one first alternating stack (**132**, **146**, **232**, **246**). The semiconductor structure further includes at least one second alternating stack located in the through-memory-level via region **500**. The at least one second alternating stack includes alternating layers of dielectric spacer layers (**142**, **242**) and second portions of the insulating layers (**132**, **232**), and each of the dielectric spacer layers (**142**, **242**) is located at a same level as a respective electrically conductive layer (**146**, **246**). The semiconductor structure further comprises through-memory-level via structures **588** located within the through-memory-level via region **500** and vertically extending from a first horizontal plane including a topmost surface of the memory-level assembly and a bottommost surface of the memory-level assembly and comprising a conductive material.

[0331] In one embodiment, a plurality of laterally-elongated contact via structures **76** extending along the first horizontal direction hd**1** can laterally divide the memory-level assembly into a plurality of laterally spaced-apart blocks, and each of the plurality of laterally-elongated contact via structures **76** can be laterally surrounded by an insulating spacer **74**. The insulating moat trench structure (**572**, **575**) can consist essentially of dielectric materials.

[0332] Referring to FIGS. **44**A and **44**B, a second modification of the fourth exemplary structure can the same as the fourth exemplary structure illustrated in FIGS. **33**A and **33**B. The second modification of the fourth exemplary structure can be formed concurrently with formation of any of the first, second, and third exemplary structures or modifications thereof, or can be formed as a stand-alone structure. At least one in-process alternating stack of insulating layers (**132**, **232**) and dielectric spacer layers (which can be the sacrificial material layers (**142**, **242**)) can be formed over the semiconductor substrate **9** as in previously described embodiments.

[0333] Through-memory-level via regions **600** that do not include memory stack structures **55** at respect center regions thereof can be formed within the memory array region **100**. Each through-memory-level via region **600** can be formed entirely within a block (B**1**, B**2**, etc.). Dummy memory stack structures **55**D can be provided at a periphery of the through-memory-level via regions **600**. The dummy memory stack structures **55** are not active components of the semiconductor structure, but are employed to provide structural support during formation of the backside recesses (**143**, **243**). The through-memory-level via regions **600** can be formed without forming additional through-memory-level via regions **400** of the first, second, and third embodiments, or can be formed in addition to the through-memory-level via regions **400** of the first, second, and third embodiments through the same memory-level assembly.

[0334] Referring to FIGS. **45**A and **45**B, a photoresist layer **677** can be applied over the first contact level dielectric layer **280**, and can be lithographically patterned to form openings therein. The pattern of the openings include the pattern of the backside contact trenches **79** described above and the pattern of through-memory-level via structures to be subsequently formed in the through-memory-level regions **600**.

[0335] The pattern in the photoresist layer **677** can be transferred through the first contact level dielectric layer **280**

and through the in-process alternating stack of insulating layers (**132**, **232**) and dielectric spacer material layers (**142**, **242**) to form backside contact trenches **79** in the memory array region **100** and through-memory-level openings **679** in the through-memory-level via regions **600**. A top surface of the planar semiconductor layer **10** can be physically exposed at the bottom of each backside contact trench **79**. The backside contact trenches **79** can be formed concurrently with formation of the through-memory-level openings **679**.

[0336] A top surface of the at least one lower level dielectric layer **760** can be physically exposed at the bottom of each through-memory-level opening **679**. Top surfaces of the lower level metal interconnect structures **780** may, or may not, be physically exposed at the bottom of the through-memory-level openings **679**. In one embodiment, the width of the through-memory-level openings **679** can be greater than the width of the backside contact trenches **79**. In this case, more reactant can be supplied to the through-memory-level openings **679** during the anisotropic etch, and the bottom surfaces of the through-memory-level openings **679** can be located below the bottom surfaces of the backside contact trenches **79**.

[0337] Referring to FIGS. **46**A and **46**B, the photoresist layer **677** can be removed, for example, by ashing. The processing steps of FIGS. **11**A and **11**B can be performed to remove the sacrificial material layers (**142**, **242**) selective to the insulating layers (**132**, **232**). In this case, the backside contact trenches **79** and the through-memory-level openings **679** can be employed to introduce etchants that etch the sacrificial material layers (**142**, **242**) selective to the insulating layers (**132**, **232**). Subsequently, the processing steps of FIGS. **12**A and **12**B can be performed to form electrically conductive layers (**146**, **246**). Reactants can be introduced through the backside contact trenches **79** and the through-memory-level openings **679** to deposit the electrically conductive layers (**146**, **246**). Excess portions of the deposited conductive material can be removed from inside the backside contact trenches **79** and the through-memory-level openings **679** and from above the first contact level dielectric layer **280** employing an etch-back process. An alternating stack (**132**, **146**, **232**, **246**) of insulating layers (**232**, **232**) and electrically conductive layers (**146**, **246**) is thus formed.

[0338] Referring to FIGS. **47**A and **47**B, a conformal insulating material layer is deposited in the backside contact trenches **79** and the through-memory-level openings **689** by a conformal deposition process such as chemical vapor deposition or atomic layer deposition. The conformal insulating material layer includes a dielectric material such as silicon oxide, silicon nitride, a dielectric metal oxide, or a combination thereof.

[0339] An anisotropic etch is performed to remove horizontal portions of the conformal insulating material layer. In case top surfaces of the lower level metal interconnect structures **780** are not physically exposed at the bottom of the through-memory-level openings **679** prior to the anisotropic etch, the anisotropic etch may remove additional material of the at least one lower level dielectric layer **760** to physically expose top surfaces of the lower level metal interconnect structures **780**. In this case, the through-memory-level openings **679** can be extended downward while the conformal insulating material layer is anisotropically etched. A lower level metal interconnect structure **780** can be physically exposed at a bottom of one or more of the through-memory-level openings **679** during the anisotropic etch.

[0340] Each remaining portion of the conformal insulating material layer in a backside contact trench **79** constitutes an insulating spacer **74**. Each remaining portion of the conformal insulating material layer in a through-memory-level opening **679** constitutes an insulating liner **674**. The insulating spacers **74** and the insulating liners **674** are concurrently formed in the backside contact trenches **79** and the through-memory-level openings **679**, respectively, after formation of the electrically conductive layers (**146**, **246**). A backside cavity **79'** is present within each insulating spacer **74**. A through-memory-level cavity **679'** is present within each insulating liner **674**.

[0341] Referring to FIGS. **48**A and **48**B, at least one conductive material can be deposited in the backside cavities **79'** and the through-memory-level cavities **679'**. Excess portions of the at least one conductive material can be removed from above the horizontal plane including the top surface of the first contact level dielectric layer **280** by a planarization process such as chemical mechanical planarization. Each remaining portion of the at least one conductive material in a backside contact trench **79** constitutes a laterally elongated contact via structure **76**. Each remaining portion of the at least one conductive material in a through-memory-level opening **679** constitutes a through-memory-level via structure **676**. Each through-memory-level via structure **676** is a conductive fill material portion. The laterally-elongated contact via structures **76** and the through-memory-level via structures **676** can be formed simultaneously in the backside contact trenches **79** and within the through-memory-level openings **679**, respectively.

[0342] Referring to FIG. **49**, drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that are either formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588** or which comprise a shunt line or power strap connected to structure **588**, bit lines **103** that extend along the second horizontal direction and perpendicular to the first horizontal direction hd**1**, and source connection line structures (not shown).

[0343] Referring to FIGS. **50**A and **50**B, a third modification of the fourth exemplary structure can be the same as the second modification of the fourth exemplary structure illustrated in FIGS. **44**A and **44**B with an optional modification in the pattern for the drain-select-level shallow trench isolation structures **72**. A first-tier alternating stack (**132**, **242**), a second-tier alternating stack (**232**, **242**), memory stack structures **55**, and drain-select-level shallow trench isolation structures **72** can be formed as described above.

[0344] Referring to FIGS. **51**A and **51**B, a photoresist layer **677** can be applied and patterned only with the pattern of the through-memory-level openings **679** and without the pattern of the backside contact trenches **79** illustrated in FIGS. **45**A and **45**B. An anisotropic etch can be performed as in the processing steps of FIGS. **45**A and **45**B to transfer

the pattern in the photoresist layer **677** though the alternating stack (**132**, **142**, **232**, **242**) and into an upper portion of the at least one dielectric layer **760**. Through-memory-level openings **679** are formed in the through-memory-level regions **600** without forming backside contact trenches in the semiconductor structure.

[0345] Referring to FIGS. **52**A and **52**B, the photoresist layer **677** can be removed, for example, by ashing. The processing steps of FIGS. **11**A and **11**B can be performed to remove the sacrificial material layers (**142**, **242**) selective to the insulating layers (**132**, **232**). In this case, the through-memory-level openings **679** can be employed to introduce etchants that etch the sacrificial material layers (**142**, **242**) selective to the insulating layers (**132**, **232**). Subsequently, the processing steps of FIGS. **12**A and **12**B can be performed to form electrically conductive layers (**146**, **246**). Reactants can be introduced through the through-memory-level openings **679** to deposit the electrically conductive layers (**146**, **246**). Excess portions of the deposited conductive material can be removed from inside the through-memory-level openings **679** and from above the first contact level dielectric layer **280** employing an etch-back process. An alternating stack (**132**, **146**, **232**, **246**) of insulating layers (**232**, **232**) and electrically conductive layers (**146**, **246**) is thus formed.

[0346] Referring to FIGS. **53**A and **54**B, a conformal insulating material layer is deposited in the through-memory-level openings **689** by a conformal deposition process such as chemical vapor deposition or atomic layer deposition. The conformal insulating material layer includes a dielectric material such as silicon oxide, silicon nitride, a dielectric metal oxide, or a combination thereof.

[0347] An anisotropic etch is performed to remove horizontal portions of the conformal insulating material layer. In case top surfaces of the lower level metal interconnect structures **780** are not physically exposed at the bottom of the through-memory-level openings **679** prior to the anisotropic etch, the anisotropic etch may remove additional material of the at least one lower level dielectric layer **760** to physically expose top surfaces of the lower level metal interconnect structures **780**. In this case, the through-memory-level openings **679** can be extended downward while the conformal insulating material layer is anisotropically etched. A lower level metal interconnect structure **780** can be physically exposed at a bottom of one or more of the through-memory-level openings **679** during the anisotropic etch. Each remaining portion of the conformal insulating material layer in a through-memory-level opening **679** constitutes an insulating liner **674**. A through-memory-level cavity **679'** is present within each insulating liner **674**.

[0348] Referring to FIGS. **54**A and **54**B, at least one conductive material can be deposited in the through-memory-level cavities **679'**. Excess portions of the at least one conductive material can be removed from above the horizontal plane including the top surface of the first contact level dielectric layer **280** by a planarization process such as chemical mechanical planarization. Each remaining portion of the at least one conductive material in a through-memory-level opening **679** constitutes a through-memory-level via structure **676**. Each through-memory-level via structure **676** is a conductive fill material portion.

[0349] Referring to FIGS. **55**A and **55**B, a plurality of insulating spacers **74** and a plurality of laterally-extending contact via structures **76** located within a respective insulating spacer **74** can be formed. Backside contact trenches can be formed though the alternating stack (**132**, **146**, **232**, **246**) of the insulating layers (**132**, **232**) and electrically conductive layers (**146**, **246**) employing the pattern illustrated in FIG. **11**B. The insulating spacers **74** can be formed by deposition and an anisotropic etch of a dielectric material. Source regions **61** can be formed underneath each backside contact trench. The laterally-extending contact via structures **76** can be formed by deposition of at least one conductive material and removal of excess portions of the at least one conductive material employing a planarization process.

[0350] Subsequently, drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that are either formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588** or which comprise a shunt line or power strap connected to structure **588**, bit lines **103** that extend along the second horizontal direction and perpendicular to the first horizontal direction, and source connection line structures (not shown).

[0351] Referring to FIGS. **56**A and **56**B, a fourth modification of the fourth exemplary structure can be derived from the first exemplary structure illustrated in FIGS. **13**A and **13**B, or any of the second, third, and fourth exemplary structures or modifications thereof described above that corresponds to the processing steps of FIGS. **13**A and **13**B.

[0352] Through-memory-level via regions **600** that do not include memory stack structures **55** at respect center regions thereof can be formed within the memory array region **100**. Each through-memory-level via region **600** can be formed entirely within a block (B**1**, B**2**, etc.). Dummy memory stack structures **55**D can be provided at a periphery of the through-memory-level via regions **600**. The dummy memory stack structures **55** are not active components of the semiconductor structure, but are employed to provide structural support during formation of the backside recesses (**143**, **243**). The through-memory-level via regions **600** can be formed without forming additional through-memory-level via regions **400** of the first, second, and third embodiments, or can be formed in addition to the through-memory-level via regions **400** of the first, second, and third embodiments through the same memory-level assembly.

[0353] Referring to FIGS. **57**A and **57**B, a photoresist layer **677** can be applied and patterned with the pattern of the through-memory-level openings **679** illustrated in FIGS. **51**A and **51**B. An anisotropic etch can be performed to transfer the pattern in the photoresist layer **677** though the alternating stack (**132**, **146**, **232**, **246**) and into an upper portion of the at least one dielectric layer **760**. Through-memory-level openings **679** are formed in the through-memory-level regions **600** while a plurality of laterally-extending contact via structures **76** and insulating spacers **74** are present in the semiconductor structure. A top surface of an underlying lower level metal interconnect structure **780** may be physically exposed at the bottom of the through-memory-level openings **679**.

[0354] Referring to FIGS. **58**A and **58**B, the processing steps of FIGS. **53**A and **53**B can be performed to form

insulating liners **674** that laterally surround a respective through-memory-level cavity **679'**.

[0355] Referring to FIGS. **59**A and **59**B, drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that are either formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588** or which comprise a shunt line or power strap connected to structure **588**, bit lines **103** that extend along the second horizontal direction and perpendicular to the first horizontal direction, and source connection line structures (not shown).

[0356] Referring to FIG. **60**, a fifth modification of the fourth exemplary structure according to the fourth embodiment of the present disclosure is illustrated, which can be derived from any of the second, third, and fourth modifications of the fourth exemplary structure by patterning the through-memory-level openings **679** in a manner that does not divide the drain-contact-level shallow trench isolation structures **72**. In this case, the through-memory-level via structures **676** can be formed as a two-dimensional array.

[0357] Referring to FIGS. **61**A and **61**B, a second modification of the third exemplary structure can be derived from the structure of FIGS. **10**A and **10**B, or from the structure of FIG. **22**. The memory stack structures **55** and the first contact level dielectric layer **280** can be formed employing any of the methods described above.

[0358] Referring to FIGS. **62**A and **62**B, the processing steps of FIGS. **34**A and **34**B can be performed to simultaneously form backside contact trenches **79** and moat trenches **579** through the memory-level assembly. In this embodiment, the locations of the moat trenches **579** is selected to be outside the memory array region **100** and within each through-memory-level via region **400**, which can have the same locations as the through-memory-level via regions **400** in the first, second, and third embodiments.

[0359] For example, a photoresist layer can be applied over the first contact level dielectric layer **280**, and can be lithographically patterned to form openings including the pattern of the backside contact trenches **79** as in the previous embodiments and the pattern of moat trenches **579**. An anisotropic etch is performed to transfer the pattern in the patterned photoresist layer through the memory-level assembly, thereby forming the backside contact trenches **79** and the moat trenches **579**. The photoresist layer can be subsequently removed, for example, by ashing. Each moat trench **579** can include an area of the through-memory-level via region **400** within an outer periphery thereof.

[0360] Referring to FIGS. **63**A-**63**C, the processing steps of FIGS. **35**A and **35**B, **36**A and **36**B, **37**A and **37**B, **38**A and **38**B, **39**A and **39**B, and **40** can be sequentially performed to form a plurality of laterally-elongated contact via structures **76** through the memory-level assembly, and to fill each moat trench **579** with an insulating moat trench structure (**572**, **574**, **576**) that vertically extends through the memory-level assembly. Through-memory-level via structure **488** can be formed through each dielectric material assembly laterally enclosed by a respective insulating moat trench structure (**572**, **573**, **576**). Each dielectric material assembly can include the at least one alternating stack of insulating layers (**132**, **232**) and spacer dielectric layers (**142**, **242**), a second-tier retro-stepped dielectric material portion **265**, and an optional first-tier retro-stepped dielectric material portion **165**.

[0361] Various contact via structures (**88**, **86**), a line level dielectric layer **110**, and various metal interconnect structures and bit lines **103** extending through the line level dielectric layer **110** can be formed. The metal interconnect structures can include upper level metal interconnect structures **108**. In one embodiment, a subset of the upper level metal interconnect structures **108** can be electrically coupled to (e.g., formed on or in physical contact with) respective pairs of a word line contact via structure **86** and a through-memory-level via structure **488**. The bit lines **103** extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**. The word line interconnect structures **106** may include portions of the upper level metal interconnect structures **108** that are electrically shorted to the through-memory-level via structure **488**, and/or may include metal lines that are connected to the peripheral circuitry for driving the word lines of the memory stack structures **55** in the memory array region **100**. Alternatively or additionally, at least a subset of the through-memory-level via structure **488** may be employed for different purposes such as providing a power supply voltage, electrical ground, etc.

[0362] Referring to FIG. **64**, a third modification of the third exemplary structure can be derived from the second modification of the third exemplary structure by performing the processing steps of FIGS. **41** and **42** to form insulating moat trench structures (**572**, **575**), each of which includes a pair of an insulating liner **572** and an insulating material fill portion **575**.

[0363] Referring to FIGS. **65**A and **65**B, sixth modification of the fourth exemplary structure can be derived from the third exemplary structure of FIGS. **24**A and **24**B by forming first-tier moat trenches within the through-memory-level via region **600** illustrated in FIG. **44**B. Sacrificial moat trench fill portions **141** can be formed in the first-tier moat trenches employing the processing steps of FIGS. **24**A and **24**B.

[0364] Referring to FIGS. **66**A and **66**B, a second-tier alternating stack (**232**, **242**) and memory stack structures **55** and dummy memory stack structures **155** are formed by performing the processing steps of FIGS. **25**A, **25**B, **26**A, and **26**B. The dummy memory stack structures **155** are insulating moat trench structures that provide electrical isolation between the inside and the outside of the dummy memory stack structure **155**.

[0365] Referring to FIGS. **67**A and **67**B, the processing steps of FIGS. **27**A and **27**B, and a subset of the processing steps of FIGS. **28**A and **28**B can be performed to form backside recesses (**143**, **243**).

[0366] Referring to FIGS. **68**A and **68**B, the complementary subset of the processing steps of FIGS. **28**A and **28**B can be performed to form the electrically conductive layers (**146**, **246**) outside the through-memory-level via regions **600**. Insulating spacers **74** and laterally-extending contact via structures **76** can be formed in the backside contact trenches **79**.

[0367] Referring to FIGS. **69**A and **69**B, at least one through-memory-level opening is formed through the memory-level assembly within the areas of each through-

memory-level via region **600**. A lithographically patterned mask including openings in the areas of the through-memory-level via regions **600** can be employed during an anisotropic etch that etches the material of the at least one alternating stack (**132**, **142**, **232**, **242**) as originally formed at the processing steps of FIGS. **2** and **7** and the material of the at least one lower level dielectric layer **760**. A top surface of lower level metal interconnect structures **780** can be physically exposed at the bottom of each through-memory-level opening. A conductive material is deposited in the through-memory-level cavities, and excess portions of the conductive material can be removed from above the horizontal plane including the top surface of the first contact level dielectric layer **280**. Each remaining portion of the conductive material in the through-memory-level openings constitutes a through-memory-level via structure **588**, which can contact a respective underlying lower level metal interconnect structure **780**.

[0368] In one embodiment, at least one through-memory-level via structure **588** can be formed in a through-memory-level via region **600** in a block. The through-memory-level via region **600** can be provided between a pair of laterally-elongated contact via structures **76** and between two groups of memory stack structures **55** located in the block. The through-memory-level via region **600** can include through-memory-level via structures **588**. Each of the at least one through-memory-level via structure **588** vertically extends through the memory-level assembly.

[0369] Drain contact via structures **88** and word line contact via structures can be formed as in the first through third embodiments. A line level dielectric layer **110** can be formed over the first contact level dielectric layer **280**. Various metal interconnect structures can be formed can be formed in the line level dielectric layer **110** as in the first through third embodiments. The metal interconnect structures can include upper level metal interconnect structures **108** that are either formed on respective pairs of a word line contact via structure **86** and a through-memory-level via structure **588** or which comprise a shunt line or power strap connected to structure **588**, bit lines **103** that extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**, and source connection line structures (not shown).

[0370] Referring to FIGS. **70**A and **70**B, a seventh modification of the fourth exemplary structure can be derived from the first exemplary structure illustrated in FIGS. **10**A and **10**B. Memory stack structures **55** and a first contact level dielectric layer **280** can be formed employing methods described above. The pattern of the support pillar structures (**171**, **271**) may be modified to avoid areas of through-memory-level via structures to be subsequently formed.

[0371] Referring to FIGS. **71**A and **71**B, a photoresist layer is applied and lithographically patterned to form openings including the pattern of the backside contact trenches **79** described above and the pattern of through-memory-level via structures to be formed in each through-memory-level via regions **400**. The pattern in the photoresist layer is transferred through the memory-level assembly to simultaneously form backside contact trenches **79** and through-memory-level via cavities **479**. In one embodiment, the anisotropic etch can be selective to the semiconductor material of the planar semiconductor layer **10** to enable etching of the physically exposed portions of the at least one lower level dielectric layer **760**. In one embodiment, top surfaces of the lower level metal interconnect structures **780** can be physically exposed at the bottom of the through-memory-level via cavities **479**.

[0372] Referring to FIGS. **72**A and **72**B, the processing steps of FIGS. **52**A and **52**B can be performed to replace the sacrificial material layers (**142**, **242**) with electrically conductive layers (**146**, **246**). Each of the through-memory-level via cavities **479** and the backside contact trenches **79** can be employed to provide an etchant to remove the material of the sacrificial material layers (**142**, **242**) to form backside recesses (**143**, **243**), and to provide a reactant to deposit the conductive material of the electrically conductive layers (**146**, **246**).

[0373] Referring to FIGS. **73**A-**73**C, a conformal insulating material layer including a dielectric material (such as silicon oxide) can be deposited and anisotropically etched to simultaneously form insulating liners **474** in the through-memory-level via cavities **479** and insulating spacers **74** in the backside contact trenches **79**. Source regions **61** can be formed by implantation of electrical dopants in physically exposed portions of the planar semiconductor material layer **10**. A through-memory-level via structure **476** can be formed in each remaining volume of the through-memory-level via cavities **479**, and a laterally-extending contact via structure **76** can be formed in each remaining volume of the backside contact trenches **79** by deposition and planarization of at least one conductive material such as TiN and W. Various contact via structures (**86**, **88**) can be formed employing the methods described above.

[0374] Referring to FIG. **74**, a line level dielectric layer **110** and various metal interconnect structures and bit lines **103** extending through the line level dielectric layer **110** can be formed. The metal interconnect structures can include upper level metal interconnect structures **108**. In one embodiment, a subset of the upper level metal interconnect structures **108** can be electrically coupled to (e.g., formed on or in physical contact with) respective pairs of a word line contact via structure **86** and a through-memory-level via structure **476**. The bit lines **103** extend along the second horizontal direction hd**2** and perpendicular to the first horizontal direction hd**1**. The word line interconnect structures may include portions of the upper level metal interconnect structures **108** that are electrically shorted to the through-memory-level via structure **476**, and/or may include metal lines that are connected to the peripheral circuitry for driving the word lines of the memory stack structures **55** in the memory array region **100**. Alternatively or additionally, at least a subset of the through-memory-level via structure **476** may be employed for different purposes such as providing a power supply voltage, electrical ground, etc.

[0375] Referring to FIGS. **75**A and **75**B, an eighth modification of the fourth exemplary structure can be derived from the seventh modification of the fourth exemplary structure of FIGS. **70**A and **70**B by postponing formation of the backside contact trenches **79** until after formation of the insulating liners **474** and the through-memory-level via structures **476**.

[0376] Referring to FIG. **76**, backside contact trenches **79**, insulating spacers **74**, source regions **61**, laterally-extending contact via structures **76**, additional contact via structures **88**, a line level dielectric layer **110** and various metal interconnect structures **108** and bit lines **103** extending therethrough can be formed as described above.

[0377] The various through-memory-level via structures (**588**, **676**) of the fourth exemplary structure or modifications thereof can be employed to provide vertical electrically conductive paths inside selected areas of a memory array region **100**. The through-memory-level via structures (**588**, **676**) may be employed as a portion of a power distribution network, or can be employed to provide various control signals for a three-dimensional memory device in a manner that shortens the signal path, and thus, minimizes signal loss and capacitive coupling.

[0378] The fourth exemplary structure or any of the modifications thereof can include a semiconductor structure, which comprises a memory-level assembly located over a semiconductor substrate **9** and comprising at least one alternating stack of electrically conductive layers (**146**, **246**) and first portions of insulating layers (**132**, **232**), and further comprising memory stack structures **55** vertically extending through the at least one alternating stack. Each of the memory stack structures **55** comprises a memory film **50** and a vertical semiconductor channel **60**. The electrically conductive layers (**146**, **246**) constitute word lines for the memory stack structures **55**. A plurality of laterally-elongated contact via structures **76** vertically extends through the memory-level assembly, laterally extends along a first horizontal direction hd**1**, and laterally divides the at least one alternating stack into a plurality of laterally spaced-apart blocks (B**1**, B**2**, B**3**, . . .) within the memory-level assembly. At least one through-memory-level via structure (**588**, **676**) is located in a through-memory-level via region **400** in a block. The through-memory-level via region **400** is located between a pair of laterally-elongated contact via structures **76** and between two groups of memory stack structures **55** located in the block. Each of the at least one through-memory-level via structure (**588**, **676**) vertically extends through the memory-level assembly.

[0379] Semiconductor devices can be located on the semiconductor substrate **9**. Lower level metal interconnect structures **680** can be electrically shorted to nodes of the semiconductor devices, and can be embedded in at least one lower level dielectric layer **760** that overlies the semiconductor substrate **9**. The lower level metal interconnect structures **680** can contact the at least one through-memory-level via structure (**588**, **676**). A planar semiconductor material layer **10** can overlie the at least one lower level dielectric layer **760**, and can include horizontal semiconductor channels **58** connected to vertical semiconductor channels **60** within the memory stack structures **55**.

[0380] In one embodiment, each of the at least one through-memory-level via structure **676** can be laterally electrically isolated from the electrically conductive layers (**146**, **246**) by a respective insulating liner **674**. In one embodiment, a bottom portion of each sidewall of the at least one through-memory-level via structure (**588**, **676**) is in physical contact with the at least one lower level dielectric layer **760**. In some embodiments, each insulating liner **674** can have a lesser vertical extent than a respective through-memory-level via structure **676** enclosed by the insulating liner **674** as illustrated in FIG. **49**.

[0381] In one embodiment, each of the plurality of laterally-elongated contact via structures **76** is laterally electrically isolated from the at least one alternating stack (**132**, **246**, **232**, **246**) by an insulating spacer **74**. In one embodiment, each of the at least one through-memory-level via structure **676** is laterally electrically isolated from the at least one alternating stack (**132**, **246**, **232**, **246**) by an insulating liner **674** having a same material composition and a same thickness as the insulating spacer **74**.

[0382] The planar semiconductor material layer **10** can overlie the semiconductor substrate **9**, and can include horizontal semiconductor channels **58** connected to vertical semiconductor channels **60** within the memory stack structures **55**. The at least one through-memory-level via structure (**588**, **686**) can extend through an opening in the planar semiconductor material layer **10**. In one embodiment, the plurality of laterally-elongated contact via structures **76** can terminate on a top surface of the planar semiconductor material layer **10**. The plurality of laterally-elongated contact via structures **76** can comprise source lines contacting respective underlying source regions **61** that contact respective horizontal channels. **58** located within the planar semiconductor material layer **10**.

[0383] In some embodiments, at least one second alternating stack (**132**, **142**, **232**, **242**) can be located in the through-memory-level via region **400**. The at least one second alternating stack (**132**, **142**, **232**, **242**) includes alternating layers of dielectric spacer layers (**142**, **242**) and second portions of the insulating layers (**132**, **232**), and each of the dielectric spacer layers (**142**, **242**) is located at a same level as a respective electrically conductive layer (**146**, **246**). The through-memory-level via region **400** can comprise an insulating moat trench structure {(**572**, **574**, **576**), (**572**. **575**)} that laterally encloses the at least one second alternating stack (**132**, **142**, **232**, **242**).

[0384] Inner sidewalls of the insulating moat trench structure {(**572**, **574**, **576**), (**572**. **575**)} and sidewalls of the at least one through-memory-level via structure **588** are in physical contact with the at least one second alternating stack (**132**, **142**, **232**, **242**).

[0385] In one embodiment, the insulating moat trench structure (**572**, **574**, **576**) can comprise an outer insulating liner **572** and an inner insulating liner **574**. Each of the plurality of laterally-elongated contact via structures **76** can be laterally surrounded by an insulating spacer **74** that comprises a dielectric material having a same composition and a same thickness as the inner insulating liner **574**.

[0386] In one embodiment, the insulating moat trench structure (**572**, **574**, **576**) can comprise a conductive fill portion **576** having a same material composition as the plurality of laterally-elongated contact via structures **76**.

[0387] In one embodiment, the insulating moat trench structure (**572**, **575**) can consist of an outer insulating liner **572** and an inner insulating fill portion **565**, and each of the plurality of laterally-elongated contact via structures **76** can be laterally surrounded by an insulating spacer **74** that comprises a same dielectric material as the inner insulating fill portion **574**.

[0388] Each of the exemplary structures and modifications thereof can include a three-dimensional memory structure. The memory stack structures **55** can comprise memory elements of a vertical NAND device. The electrically conductive layers (**146**, **246**) can comprise, or can be electrically connected to, a respective word line of the vertical NAND device. The semiconductor substrate **9** can comprises a silicon substrate. The vertical NAND device can comprise an array of monolithic three-dimensional NAND strings over the silicon substrate. At least one memory cell in a first device level of the array of monolithic three-dimensional NAND strings is located over another memory cell in a

second device level of the array of monolithic three-dimensional NAND strings. The silicon substrate can contain an integrated circuit comprising the word line driver circuit and a bit line driver circuit for the memory device. The array of monolithic three-dimensional NAND strings can comprise a plurality of semiconductor channels, wherein at least one end portion (such as a vertical semiconductor channel **60**) of each of the plurality of semiconductor channels (**58**, **11**, **60**) extends substantially perpendicular to a top surface of the semiconductor substrate **9**, a plurality of charge storage elements (as embodied as portions of the memory material layer **54** located at each word line level), each charge storage element located adjacent to a respective one of the plurality of semiconductor channels (**58**, **11**, **60**), and a plurality of control gate electrodes (as embodied as a subset of the electrically conductive layers (**146**, **246**) having a strip shape extending substantially parallel to the top surface of the semiconductor substrate **9** (e.g., along the first horizontal direction hd**1**), the plurality of control gate electrodes comprise at least a first control gate electrode located in the first device level and a second control gate electrode located in the second device level.

[0389] The via contact structures located in regions **400**, **500** and/or **600** described above provide an electrical contact to the driver circuit devices located under the memory array to decrease the overall device size/footprint over the substrate and utilize device area that is not fully utilized in prior art devices, which decreases the device cost.

[0390] Although the foregoing refers to particular embodiments, it will be understood that the disclosure is not so limited. It will occur to those of ordinary skill in the art that various modifications may be made to the disclosed embodiments and that such modifications are intended to be within the scope of the disclosure. Where an embodiment employing a particular structure and/or configuration is illustrated in the present disclosure, it is understood that the present disclosure may be practiced with any other compatible structures and/or configurations that are functionally equivalent provided that such substitutions are not explicitly forbidden or otherwise known to be impossible to one of ordinary skill in the art. All of the publications, patent applications and patents cited herein are incorporated herein by reference in their entirety.

What is claimed is:

1. A three dimensional NAND memory device, comprising:

word line driver devices located on or over a substrate;

an alternating stack of word lines and insulating layers located over the word line driver devices;

a plurality of memory stack structures extending through the alternating stack, each memory stack structure comprising a memory film and a vertical semiconductor channel; and

through-memory-level via structures which electrically couple the word lines in a first memory block to the word line driver devices;

wherein the through-memory-level via structures extend through a through-memory-level via region located between a staircase region of the first memory block and a staircase region of another memory block.

2. The device of claim **1**, wherein the through-memory-level via structures extend through a dielectric fill material portion located in the through-memory-level via region.

3. The device of claim **1**, wherein the alternating stack of word lines and insulating layers and the plurality of memory stack structures are located over the word line driver devices.

4. The device of claim **2**, wherein the word line driver devices are located under the dielectric fill material portion located in the through-memory-level via region.

5. The device of claim **1**, wherein the through-memory-level via structures extend through at least one second alternating stack located in the through-memory-level via region.

6. The device of claim **5**, wherein:

the at least one second alternating stack includes alternating layers of dielectric spacer layers and second portions of the insulating layers, and each of the dielectric spacer layers is located at a same level as a respective word line; and

the at least one second alternating stack is at least partially surrounded by an insulating moat trench structure.

7. The device of claim **1**, wherein:

the through-memory-level via structures extend through the alternating stack of word lines and insulating layers which extends into the through-memory-level via region; and

each of the at least one through-memory-level via structures is laterally electrically isolated from the word lines by a respective insulating liner.

8. The device of claim **1**, further comprising:

word line contact via structures extending through a dielectric material portion that overlies the staircase region of the first memory block and contacting the word lines in the first memory block; and

upper level metal interconnect structures electrically shorting respective pairs of a word line contact via structure and a through-memory-level via structure, wherein the upper level metal interconnect structures overly the alternating stack, and straddle the first memory block and the dielectric fill material portion.

9. The device of claim **8**, wherein the through-memory-level via region is located in a second memory block at a first end of memory array region, and wherein no word line contact via structures are located in the through-memory-level via region in the second memory block at the first end of memory array region.

10. The device of claim **9**, further comprising:

a second staircase region in the second memory block at a second end of memory array region; and

second word line contact via structures extending through a dielectric material portion that overlies the staircase region of the second memory block and contacting the word lines in the second memory block.

11. The device of claim **1**, wherein the staircase region of the first memory block and the staircase region of another memory block ascend in a same diagonal direction.

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