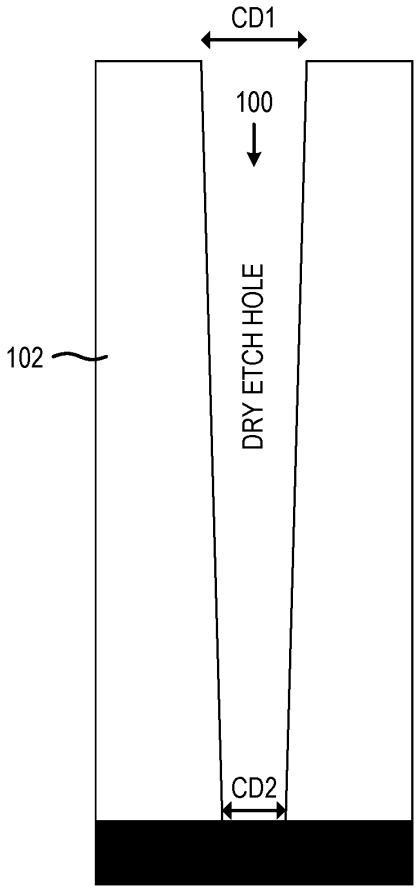



FIG. 1A

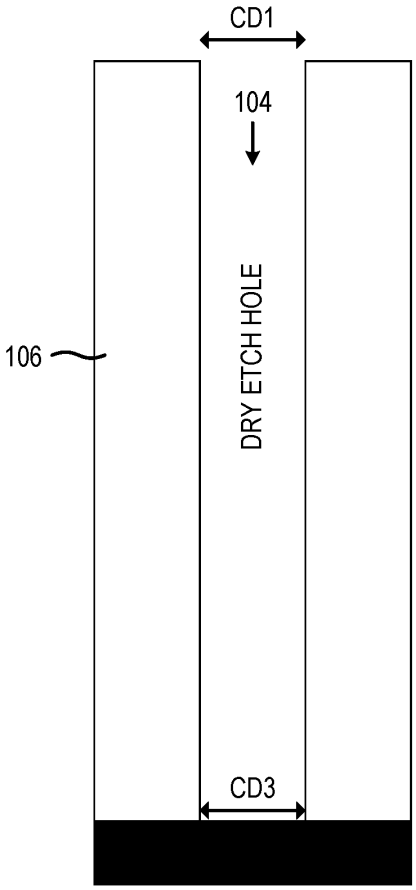



FIG. 1B

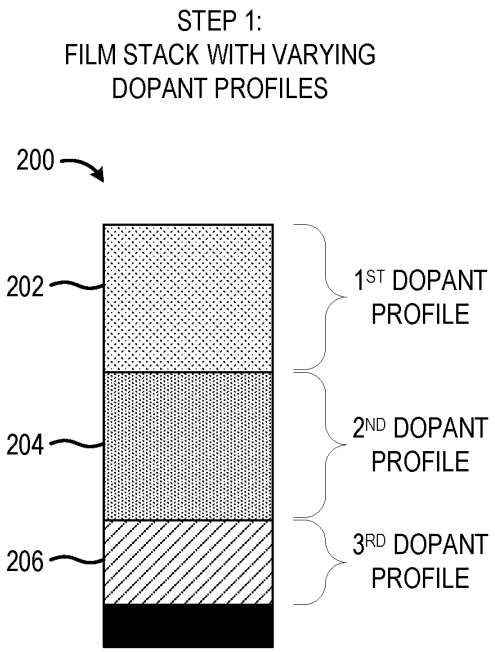

STEP 1:
FILM STACK WITH VARYING
DOPANT PROFILES
200
202
204
206
1ST DOPANT
PROFILE
2ND DOPANT
PROFILE
3RD DOPANT
PROFILE

FIG. 2A

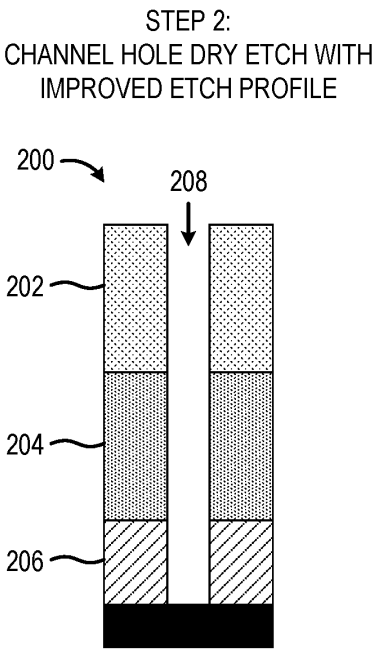

STEP 2:
CHANNEL HOLE DRY ETCH WITH
IMPROVED ETCH PROFILE
200
208
202
204
206

FIG. 2B

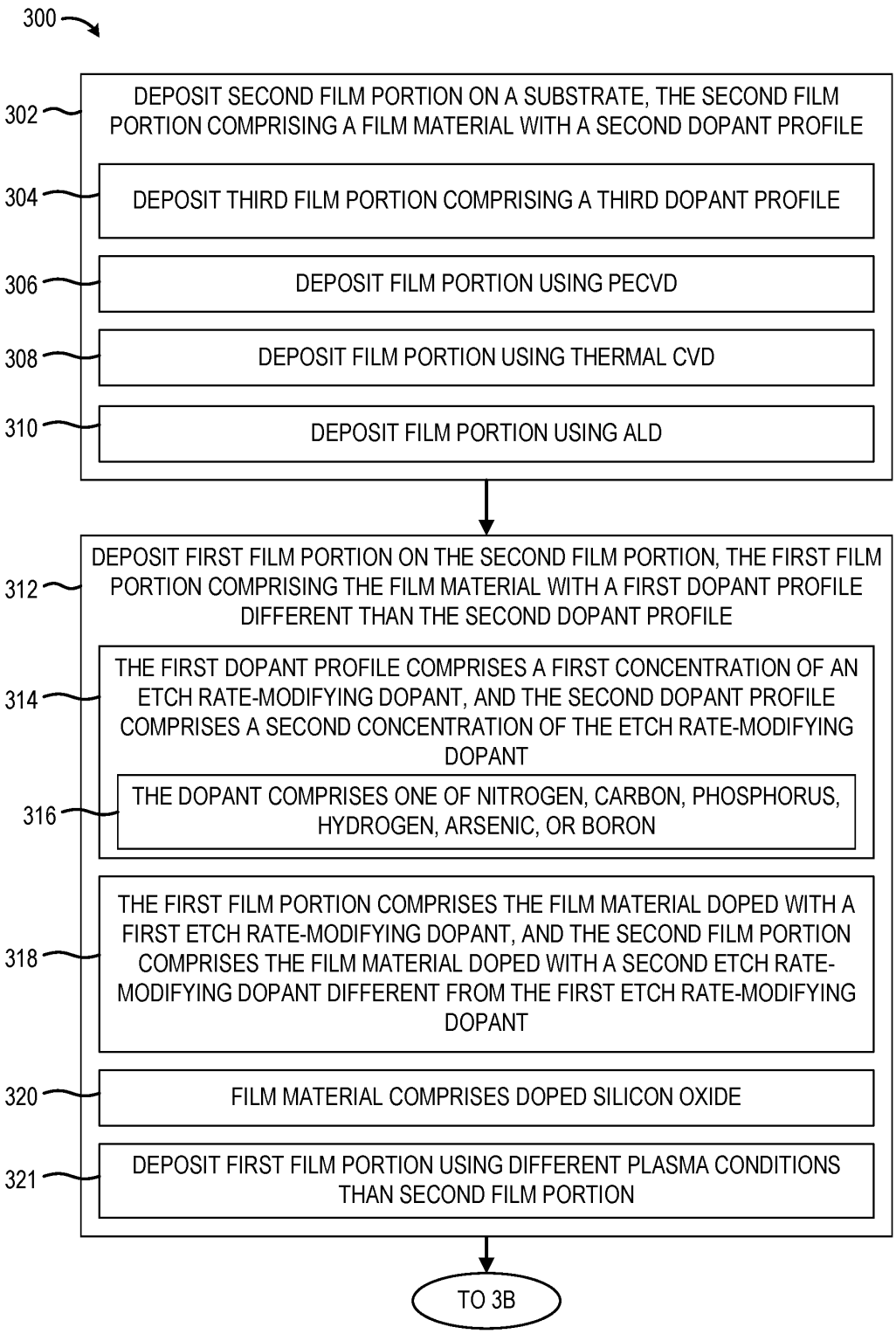

300
302
DEPOSIT SECOND FILM PORTION ON A SUBSTRATE, THE SECOND FILM PORTION COMPRISING A FILM MATERIAL WITH A SECOND DOPANT PROFILE
304
DEPOSIT THIRD FILM PORTION COMPRISING A THIRD DOPANT PROFILE
306
DEPOSIT FILM PORTION USING PECVD
308
DEPOSIT FILM PORTION USING THERMAL CVD
310
DEPOSIT FILM PORTION USING ALD
312
DEPOSIT FIRST FILM PORTION ON THE SECOND FILM PORTION, THE FIRST FILM PORTION COMPRISING THE FILM MATERIAL WITH A FIRST DOPANT PROFILE DIFFERENT THAN THE SECOND DOPANT PROFILE
314
THE FIRST DOPANT PROFILE COMPRISES A FIRST CONCENTRATION OF AN ETCH RATE-MODIFYING DOPANT, AND THE SECOND DOPANT PROFILE COMPRISES A SECOND CONCENTRATION OF THE ETCH RATE-MODIFYING DOPANT
316
THE DOPANT COMPRISES ONE OF NITROGEN, CARBON, PHOSPHORUS, HYDROGEN, ARSENIC, OR BORON
318
THE FIRST FILM PORTION COMPRISES THE FILM MATERIAL DOPED WITH A FIRST ETCH RATE-MODIFYING DOPANT, AND THE SECOND FILM PORTION COMPRISES THE FILM MATERIAL DOPED WITH A SECOND ETCH RATE-MODIFYING DOPANT DIFFERENT FROM THE FIRST ETCH RATE-MODIFYING DOPANT
320
FILM MATERIAL COMPRISES DOPED SILICON OXIDE
321
DEPOSIT FIRST FILM PORTION USING DIFFERENT PLASMA CONDITIONS THAN SECOND FILM PORTION
TO 3B

FIG. 3A

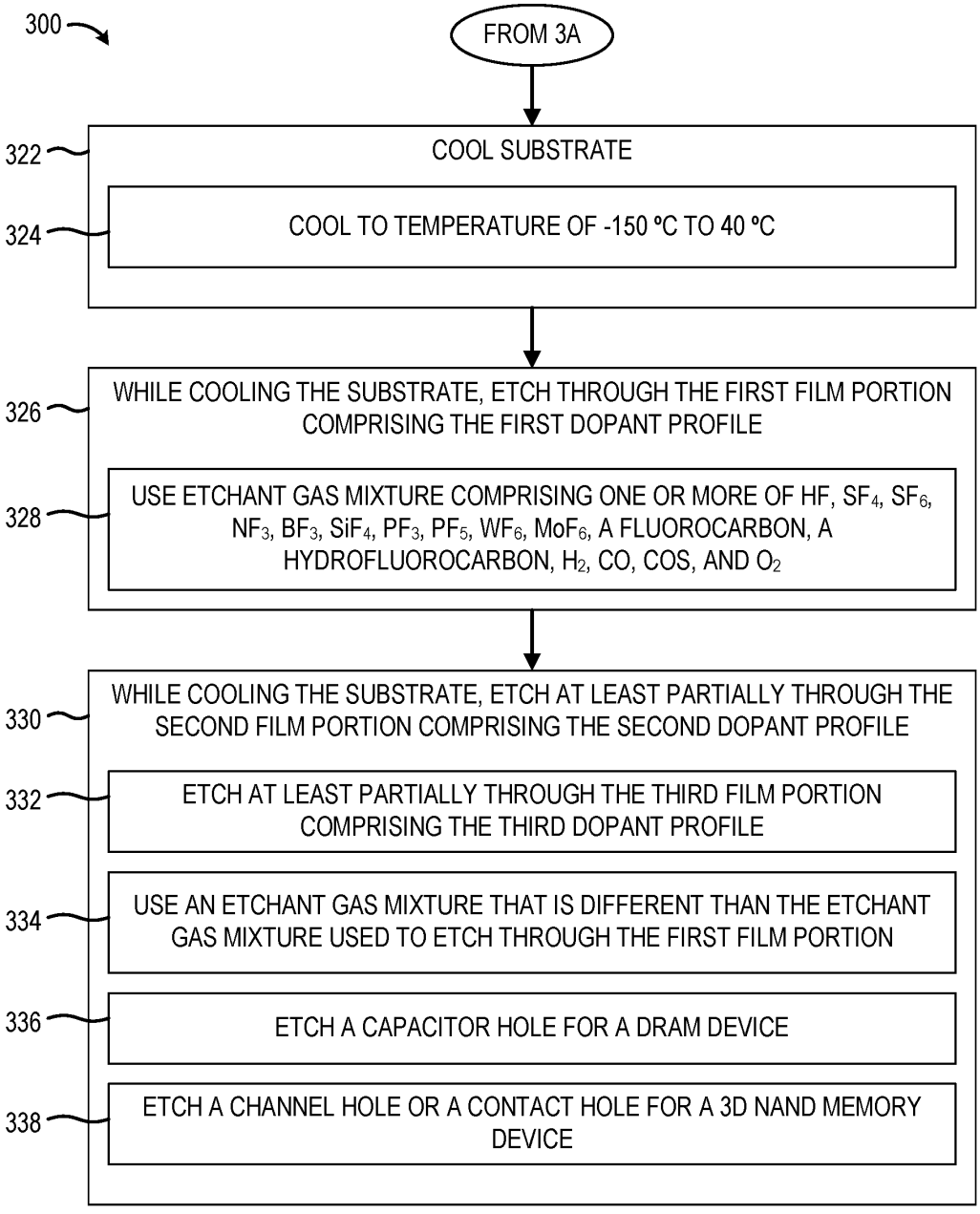

300
FROM 3A
322
COOL SUBSTRATE
324
COOL TO TEMPERATURE OF -150 °C TO 40 °C
326
WHILE COOLING THE SUBSTRATE, ETCH THROUGH THE FIRST FILM PORTION COMPRISING THE FIRST DOPANT PROFILE
328
USE ETCHANT GAS MIXTURE COMPRISING ONE OR MORE OF HF, $SF_4$, $SF_6$, $NF_3$, $BF_3$, $SiF_4$, $PF_3$, $PF_5$, $WF_6$, $MoF_6$, A FLUOROCARBON, A HYDROFLUOROCARBON, $H_2$, CO, COS, AND $O_2$
330
WHILE COOLING THE SUBSTRATE, ETCH AT LEAST PARTIALLY THROUGH THE SECOND FILM PORTION COMPRISING THE SECOND DOPANT PROFILE
332
ETCH AT LEAST PARTIALLY THROUGH THE THIRD FILM PORTION COMPRISING THE THIRD DOPANT PROFILE
334
USE AN ETCHANT GAS MIXTURE THAT IS DIFFERENT THAN THE ETCHANT GAS MIXTURE USED TO ETCH THROUGH THE FIRST FILM PORTION
336
ETCH A CAPACITOR HOLE FOR A DRAM DEVICE
338
ETCH A CHANNEL HOLE OR A CONTACT HOLE FOR A 3D NAND MEMORY DEVICE

FIG. 3B

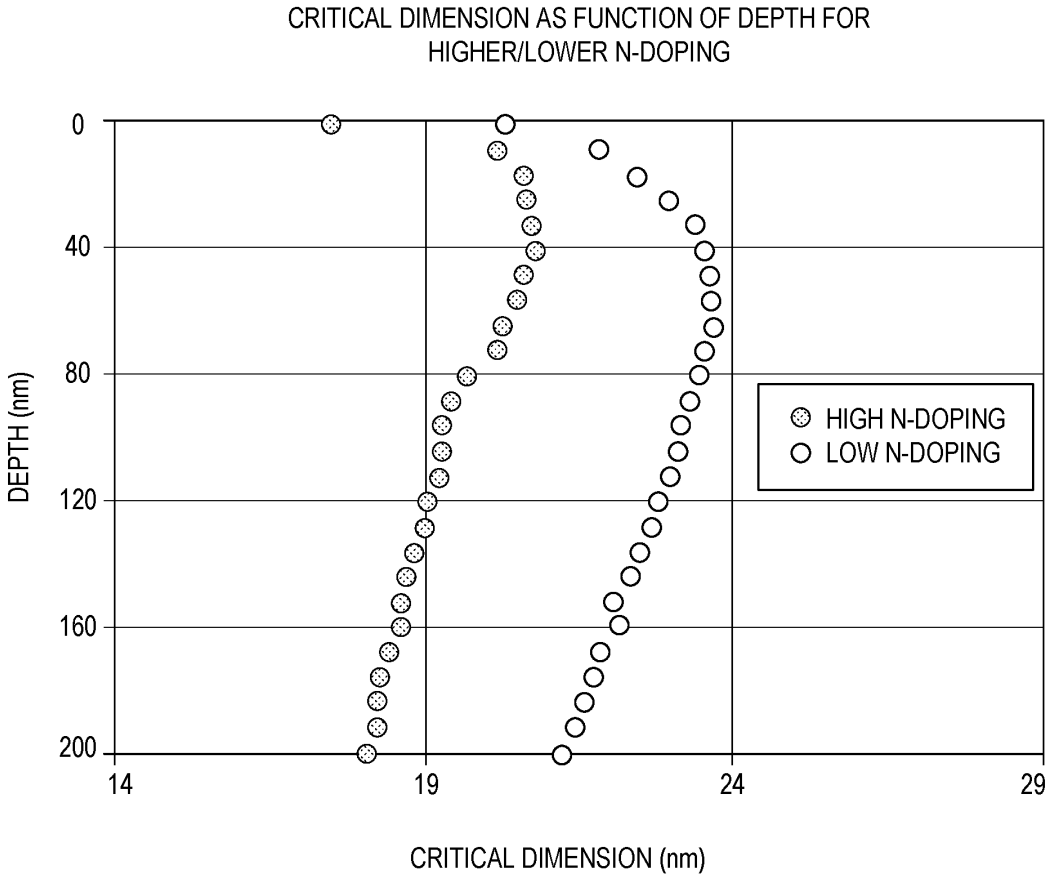

CRITICAL DIMENSION AS FUNCTION OF DEPTH FOR
HIGHER/LOWER N-DOPING
DEPTH (nm)
0
40
80
120
160
200
14
19
24
29
CRITICAL DIMENSION (nm)
HIGH N-DOPING
LOW N-DOPING

FIG. 4

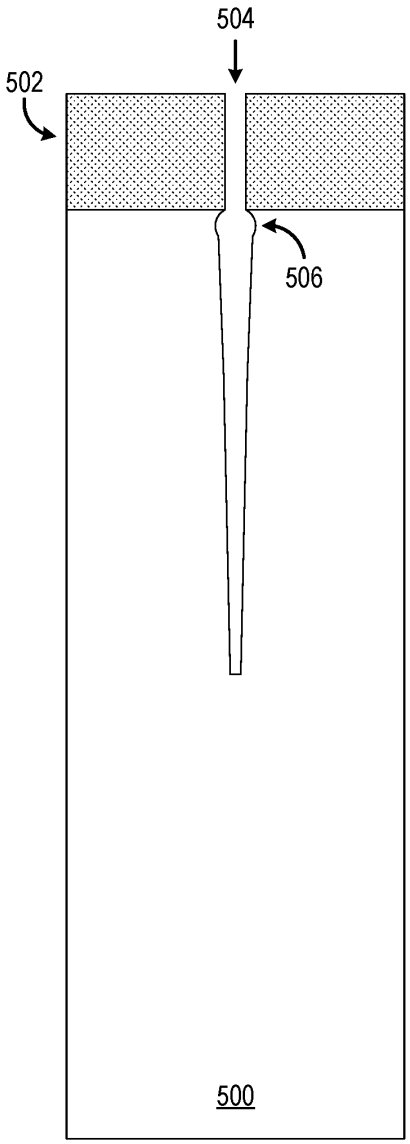



FIG. 5A

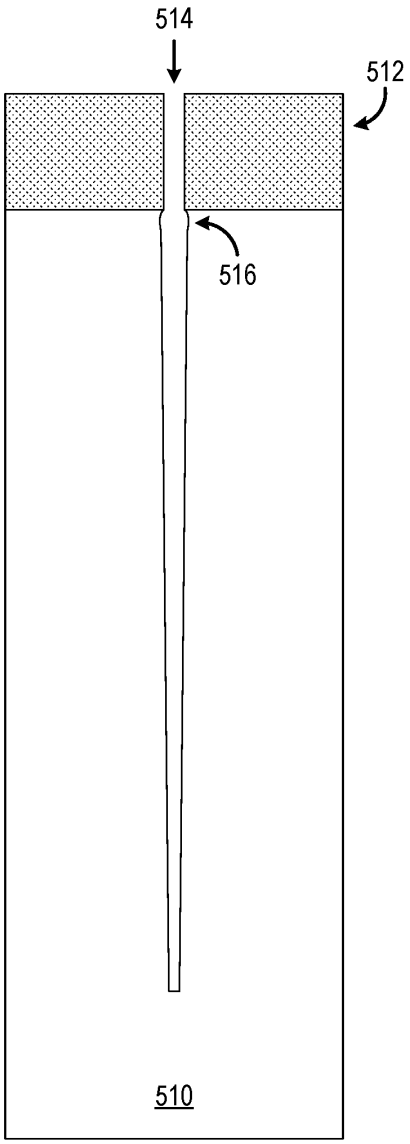



FIG. 5B

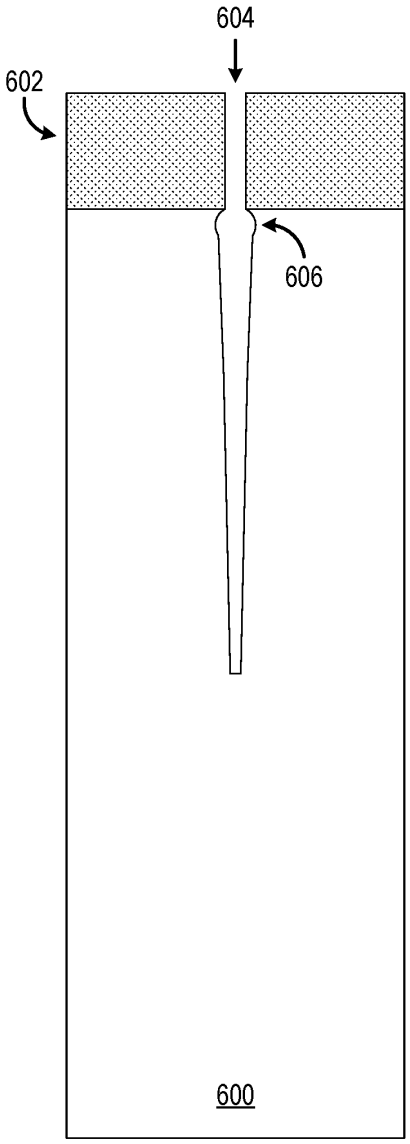



FIG. 6A

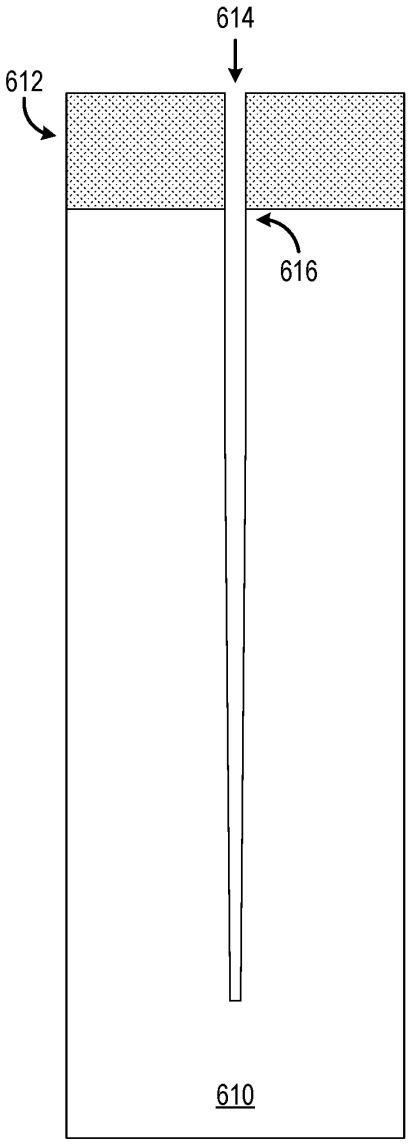



FIG. 6B

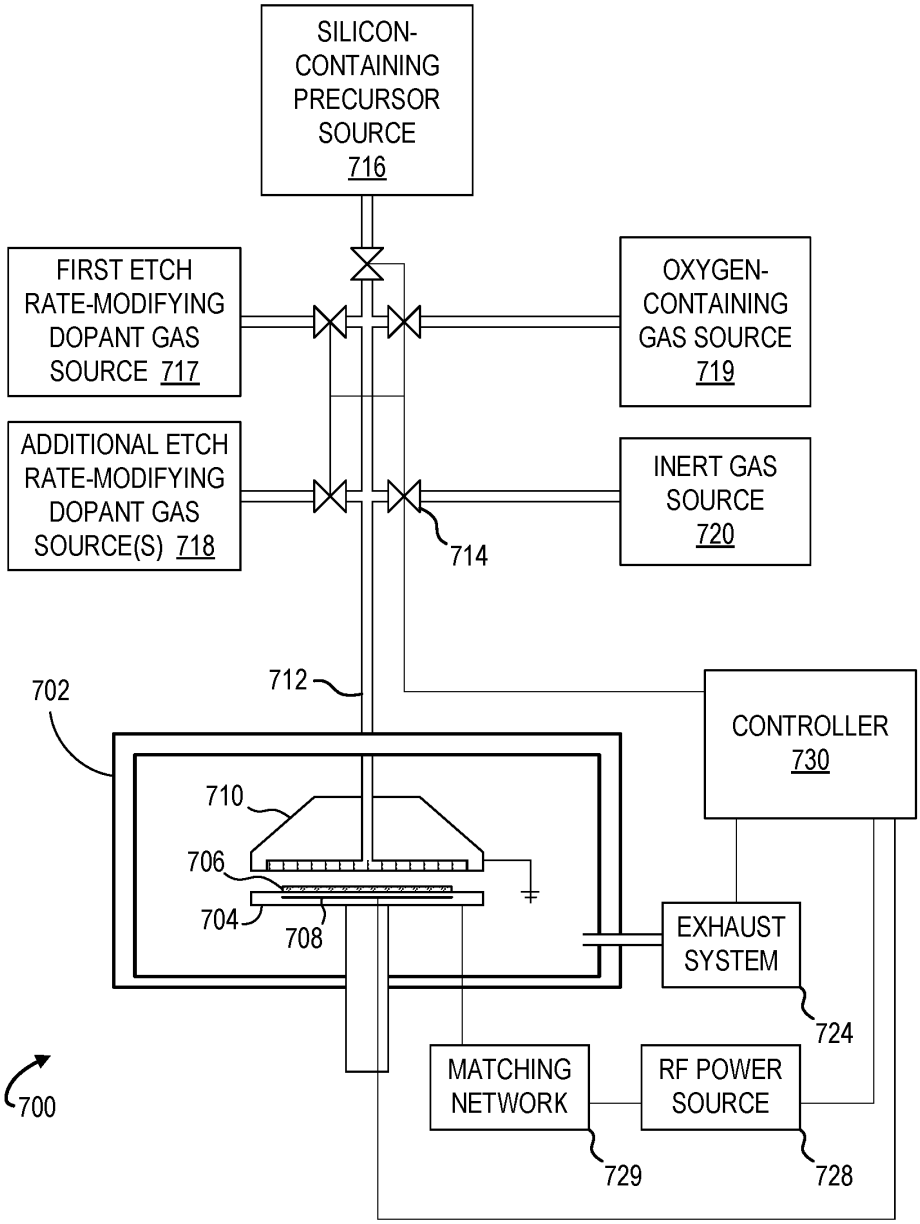

SILICON-CONTAINING PRECURSOR SOURCE 716
FIRST ETCH RATE-MODIFYING DOPANT GAS SOURCE 717
OXYGEN-CONTAINING GAS SOURCE 719
ADDITIONAL ETCH RATE-MODIFYING DOPANT GAS SOURCE(S) 718
INERT GAS SOURCE 720
714
712
702
CONTROLLER 730
710
706
704
708
EXHAUST SYSTEM
724
MATCHING NETWORK
RF POWER SOURCE
729
728
700

FIG. 7

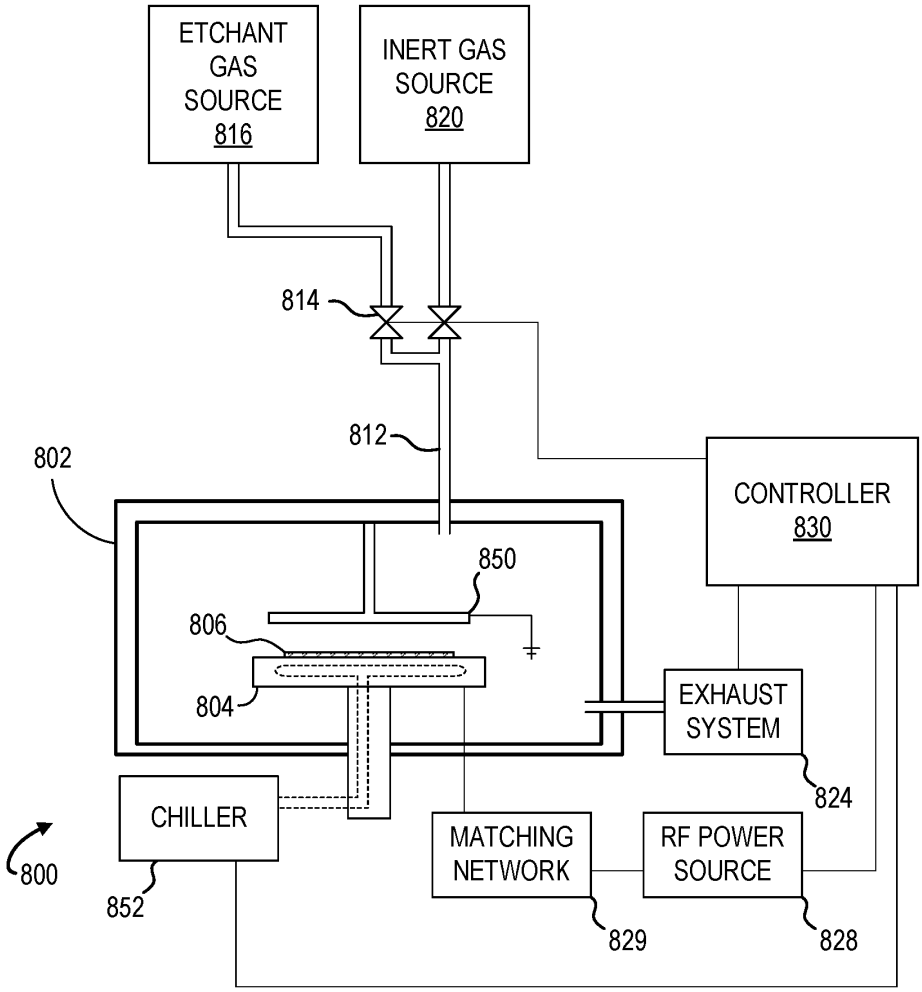

ETCHANT GAS SOURCE 816
INERT GAS SOURCE 820
814
812
802
CONTROLLER 830
850
806
804
EXHAUST SYSTEM
824
CHILLER
800
852
MATCHING NETWORK
829
RF POWER SOURCE
828

FIG. 8

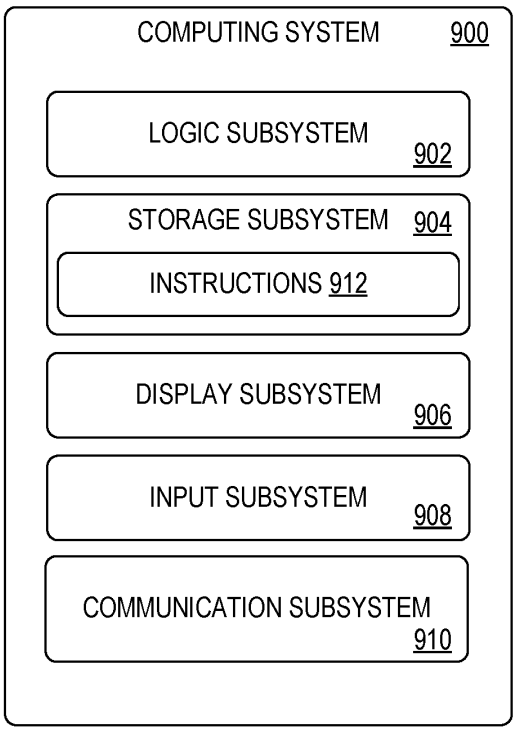

COMPUTING SYSTEM 900
LOGIC SUBSYSTEM 902
STORAGE SUBSYSTEM 904
INSTRUCTIONS 912
DISPLAY SUBSYSTEM 906
INPUT SUBSYSTEM 908
COMMUNICATION SUBSYSTEM 910

FIG. 9