FIG. 1

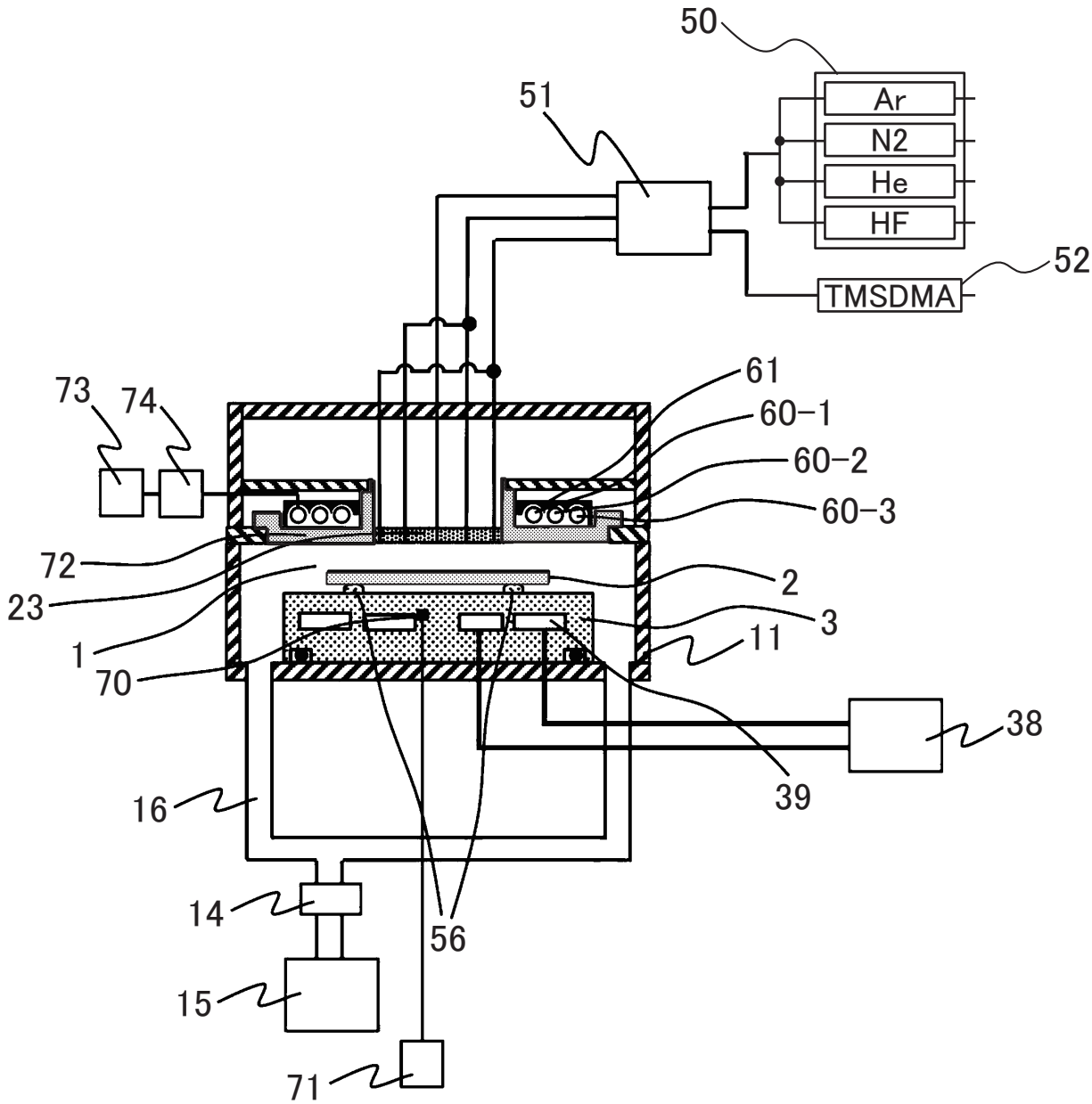

50
51
Ar
N2
He
HF
52
TMSDMA
73
74
61
60-1
60-2
60-3
72
23
1
70
2
3
11
38
39
16
14
56
15
71

FIG. 2

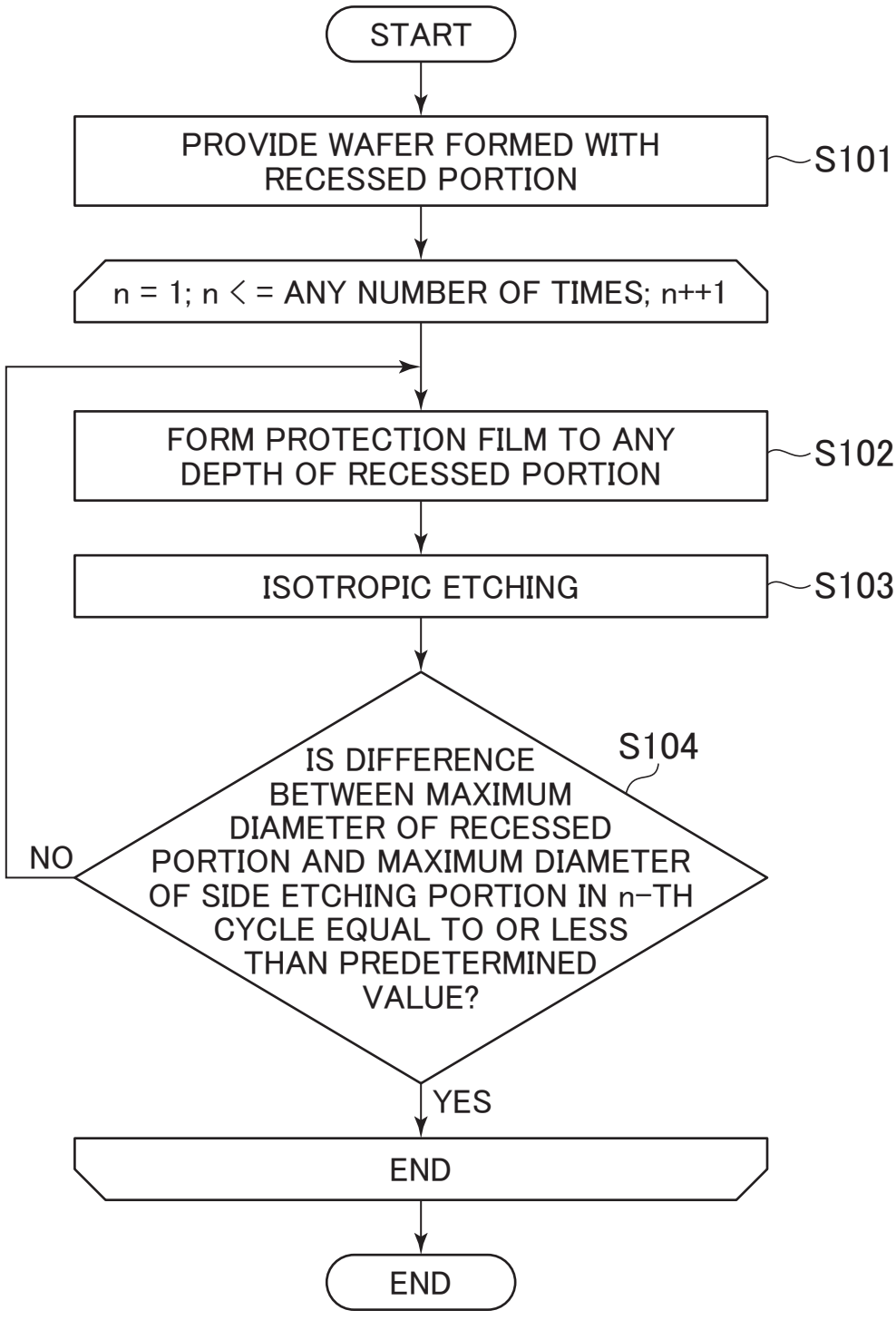

START
PROVIDE WAFER FORMED WITH RECESSED PORTION
S101
n = 1; n < = ANY NUMBER OF TIMES; n++1
FORM PROTECTION FILM TO ANY DEPTH OF RECESSED PORTION
S102
ISOTROPIC ETCHING
S103
S104
IS DIFFERENCE BETWEEN MAXIMUM DIAMETER OF RECESSED PORTION AND MAXIMUM DIAMETER OF SIDE ETCHING PORTION IN n-TH CYCLE EQUAL TO OR LESS THAN PREDETERMINED VALUE?
NO
YES
END
END

FIG. 3

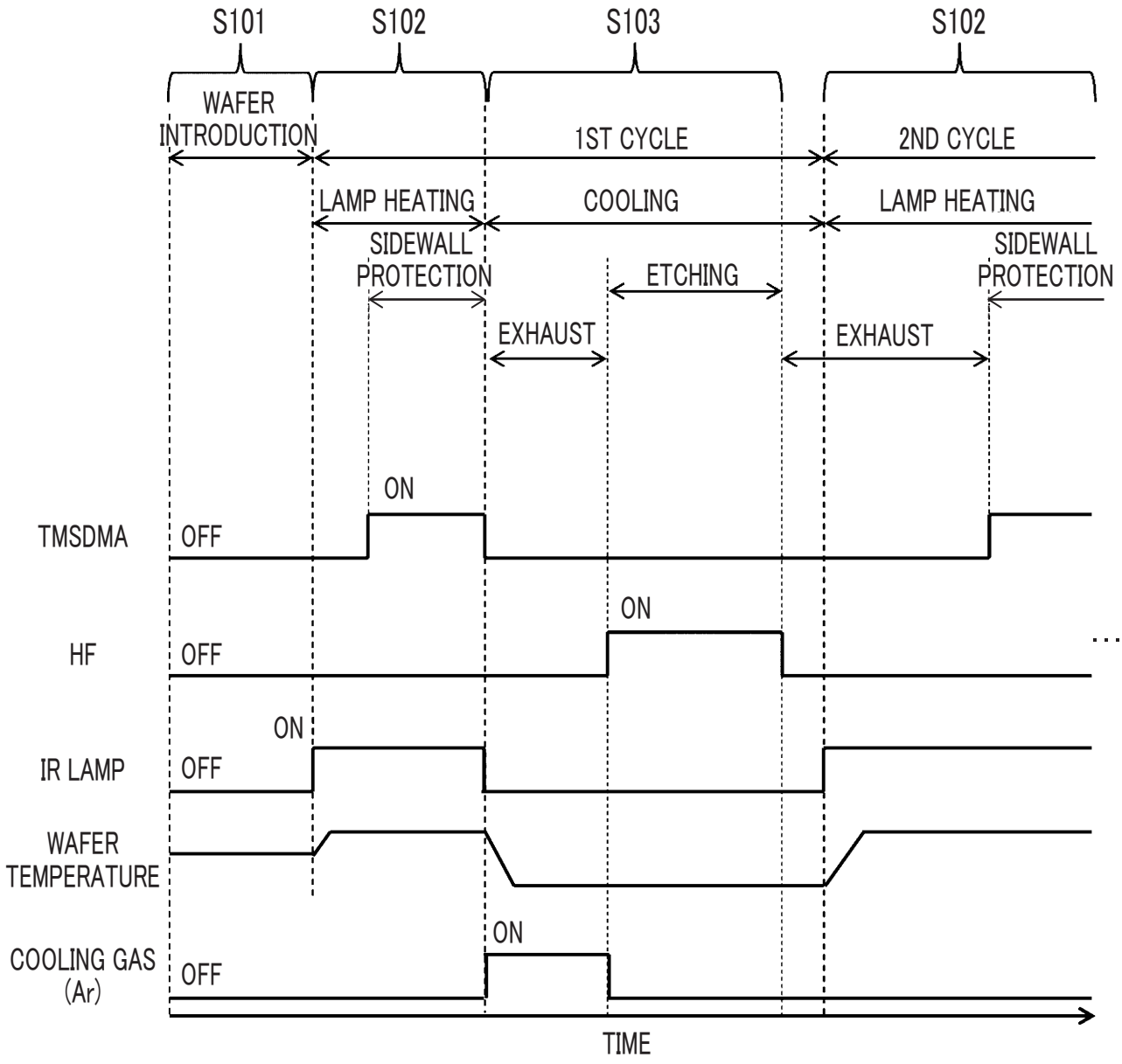

S101
S102
S103
S102
WAFER INTRODUCTION
1ST CYCLE
2ND CYCLE
LAMP HEATING
COOLING
LAMP HEATING
SIDEWALL PROTECTION
ETCHING
SIDEWALL PROTECTION
EXHAUST
EXHAUST
TMSDMA
ON
OFF
HF
ON
OFF
IR LAMP
ON
OFF
WAFER TEMPERATURE
COOLING GAS (Ar)
ON
OFF
TIME

FIG. 4

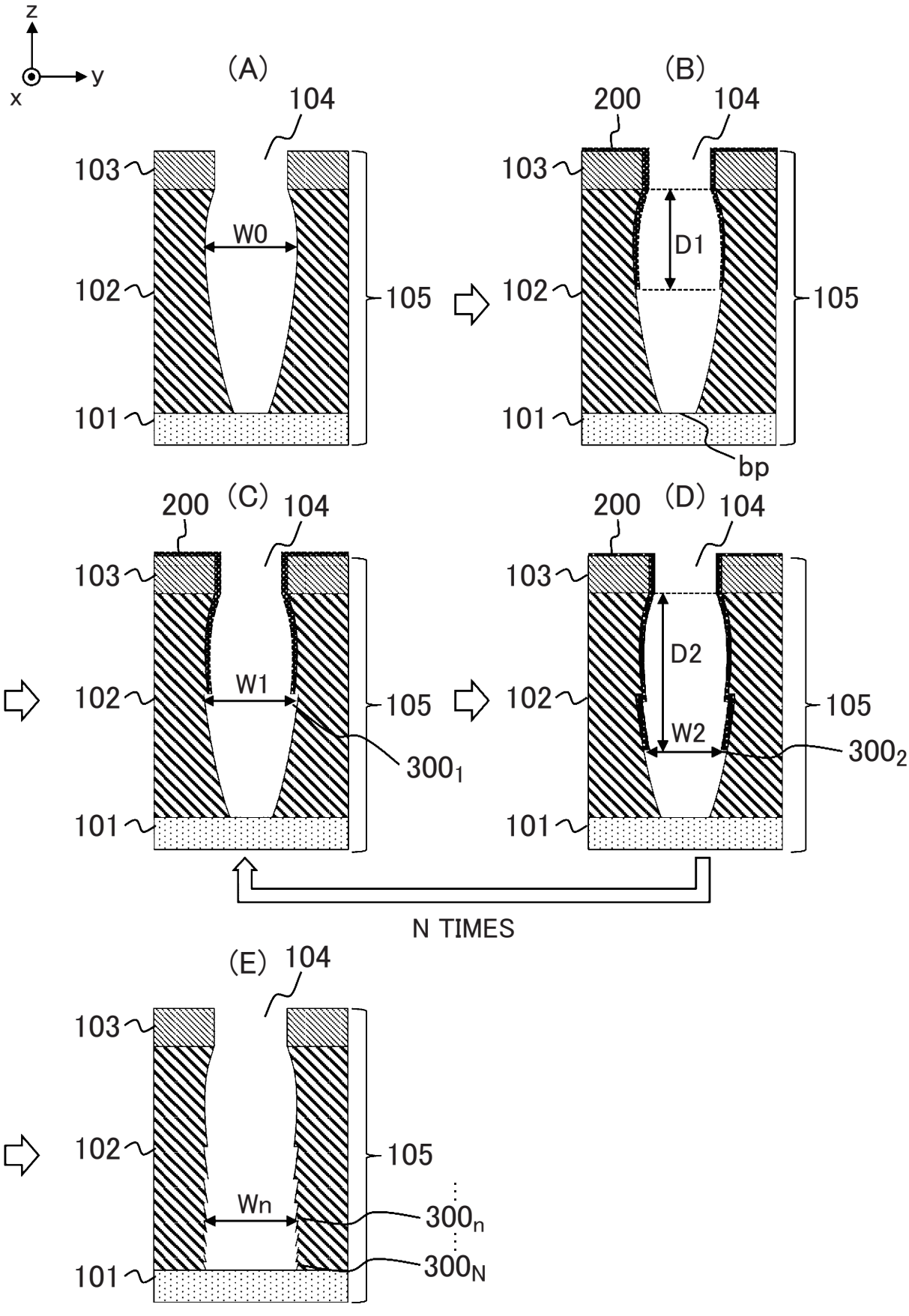

z
y
x
(A)
104
103
W0
102
105
101
(B)
200
104
103
D1
102
105
101
bp
200
(C)
104
103
W1
102
105
300$_1$
101
200
(D)
104
103
D2
102
105
W2
300$_2$
101
N TIMES
(E)
104
103
102
105
Wn
300$_n$
300$_N$
101

FIG. 5

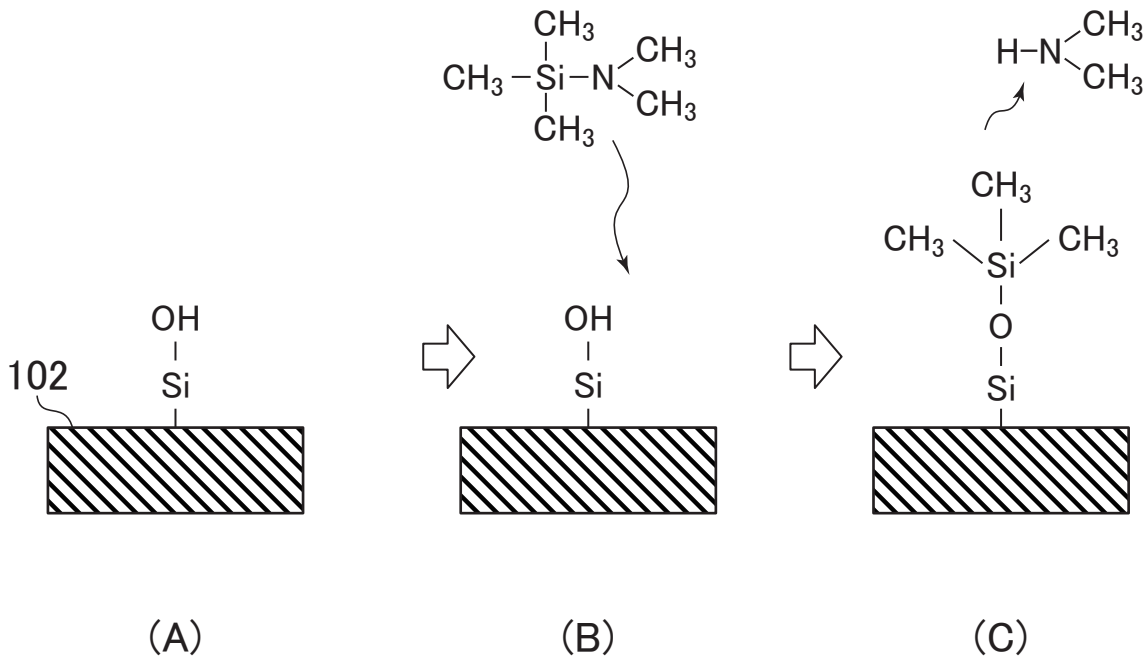

CH3
CH3
Si
N
CH3
CH3
CH3
H
N
CH3
CH3
OH
Si
102
OH
Si
CH3
CH3
Si
CH3
O
Si
(A)
(B)
(C)

FIG. 6

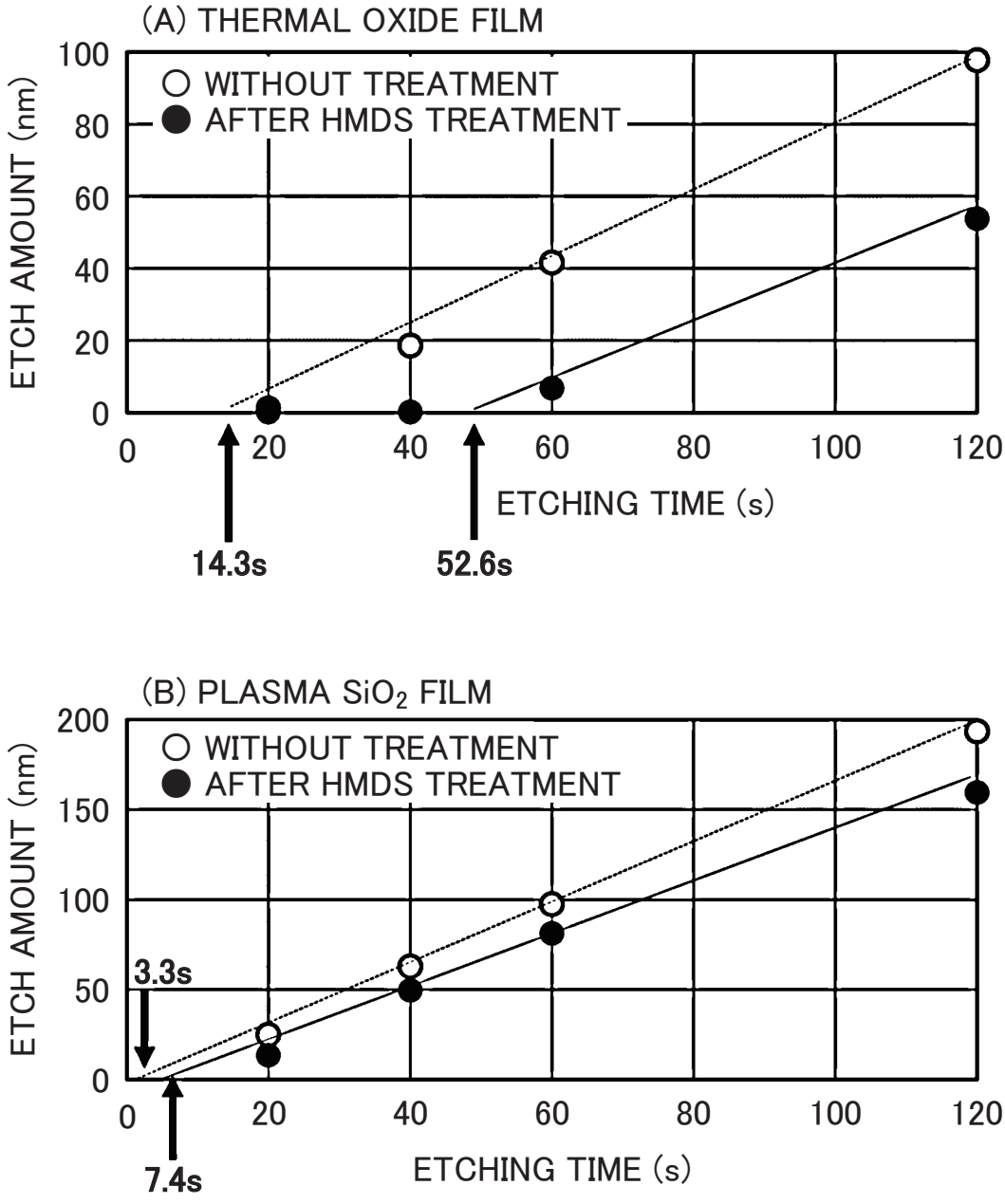

(A) THERMAL OXIDE FILM
ETCH AMOUNT (nm)
100
80
60
40
20
0
WITHOUT TREATMENT
AFTER HMDS TREATMENT
0
20
40
60
80
100
120
ETCHING TIME (s)
14.3s
52.6s
(B) PLASMA SiO2 FILM
ETCH AMOUNT (nm)
200
150
100
50
0
WITHOUT TREATMENT
AFTER HMDS TREATMENT
3.3s
7.4s
0
20
40
60
80
100
120
ETCHING TIME (s)

FIG. 7

ENDURANCE TIME OF PROTECTION FILM AGAINST HF GAS ETCHING OF PLASMA SiO_2 FILM (INCUBATION TIME)

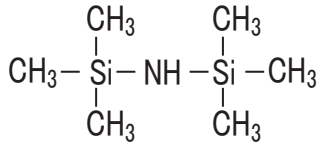
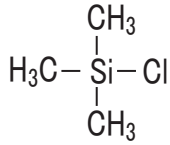
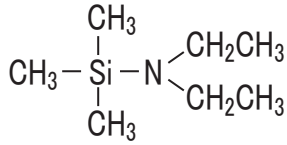
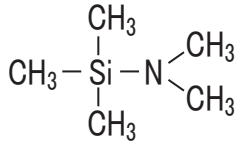
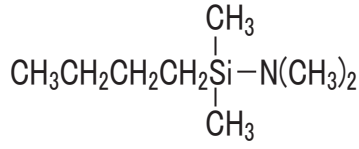
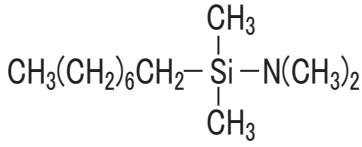
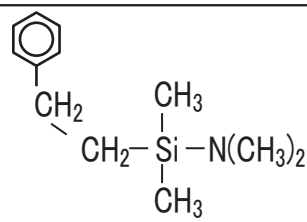
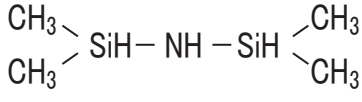
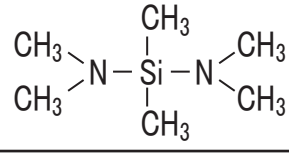
FIRST GAS TYPE	STRUCTURE	INCUBATION TIME (s)
NONE		3.3
HMDS HEXAMETHYLDISILAZANE		7.4
TMCS TRIMETHYLSILYL CHLORIDE		5.3
TMSDEA TRIMETHYLSILYLDIETHYLAMINE		16.7
TMSDMA TRIMETHYLSILYLDIMETHYLAMINE		18.6
BDDAS BUTHYLDIMETHYL (DIMETHYLAMINO) SILANE		6.0
ODDAS OCTYLDIMETHYL (DIMETHYLAMINO) SILANE		1.0
PDDAS PHENYLDIMETHYL (DIMETHYLAMINO) SILANE		7.2
TMDS TETRAMETHYLDISILAZANE		14.1
DMADMS DIMETHYLAMINODIMETHYLSILANE		20.7

FIG. 8

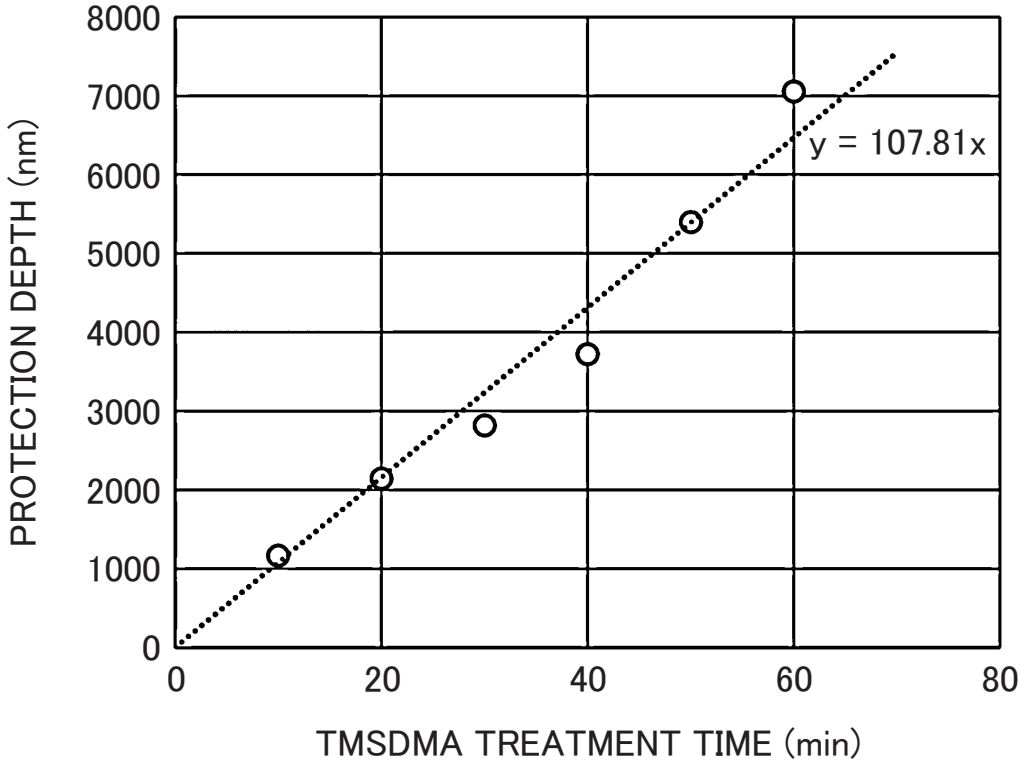

8000
7000
6000
5000
4000
3000
2000
1000
0
PROTECTION DEPTH (nm)
y = 107.81x
0
20
40
60
80
TMSDMA TREATMENT TIME (min)

FIG. 9

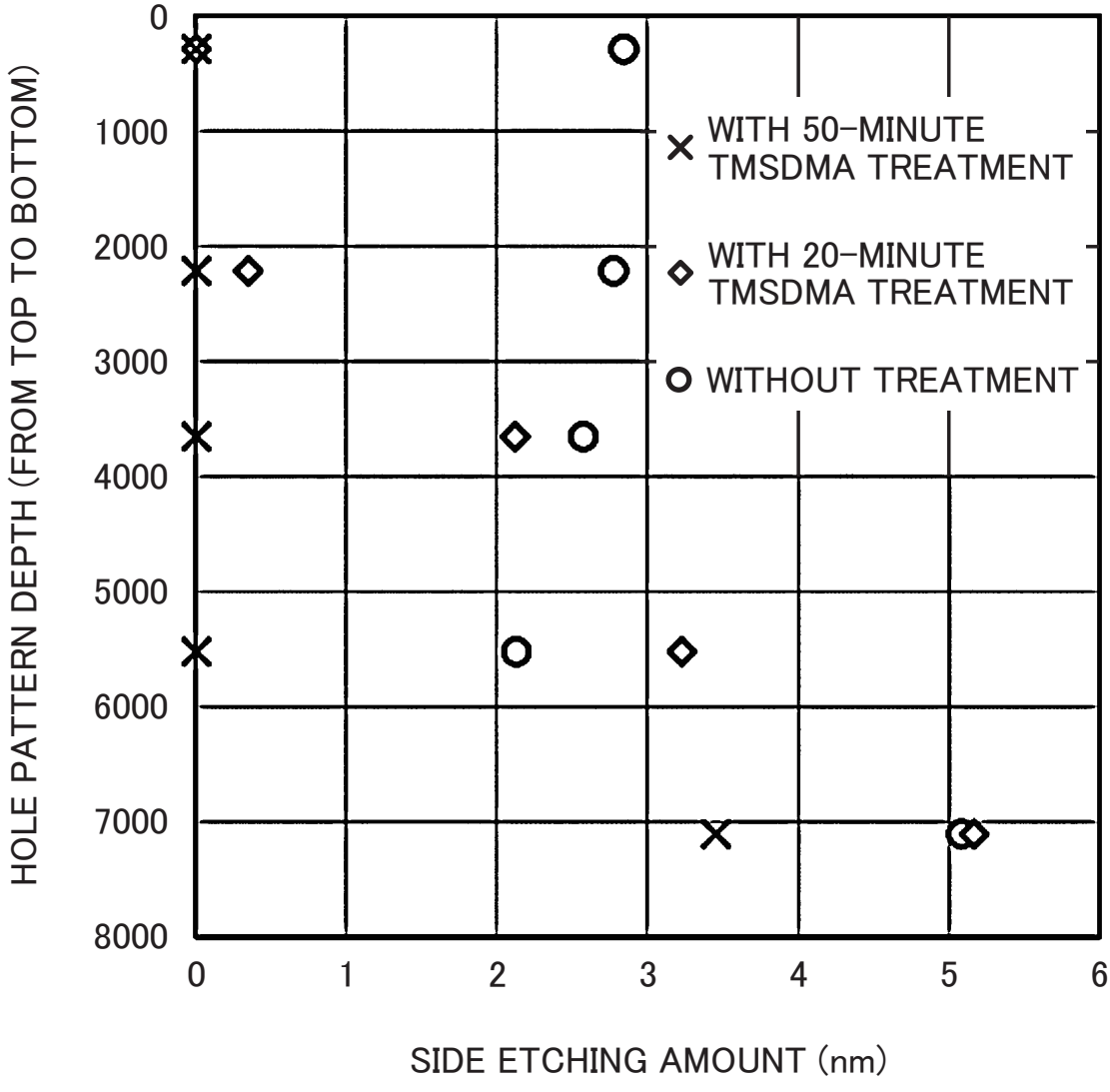

HOLE PATTERN DEPTH (FROM TOP TO BOTTOM)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5
6
SIDE ETCHING AMOUNT (nm)
WITH 50-MINUTE TMSDMA TREATMENT
WITH 20-MINUTE TMSDMA TREATMENT
WITHOUT TREATMENT

FIG. 10

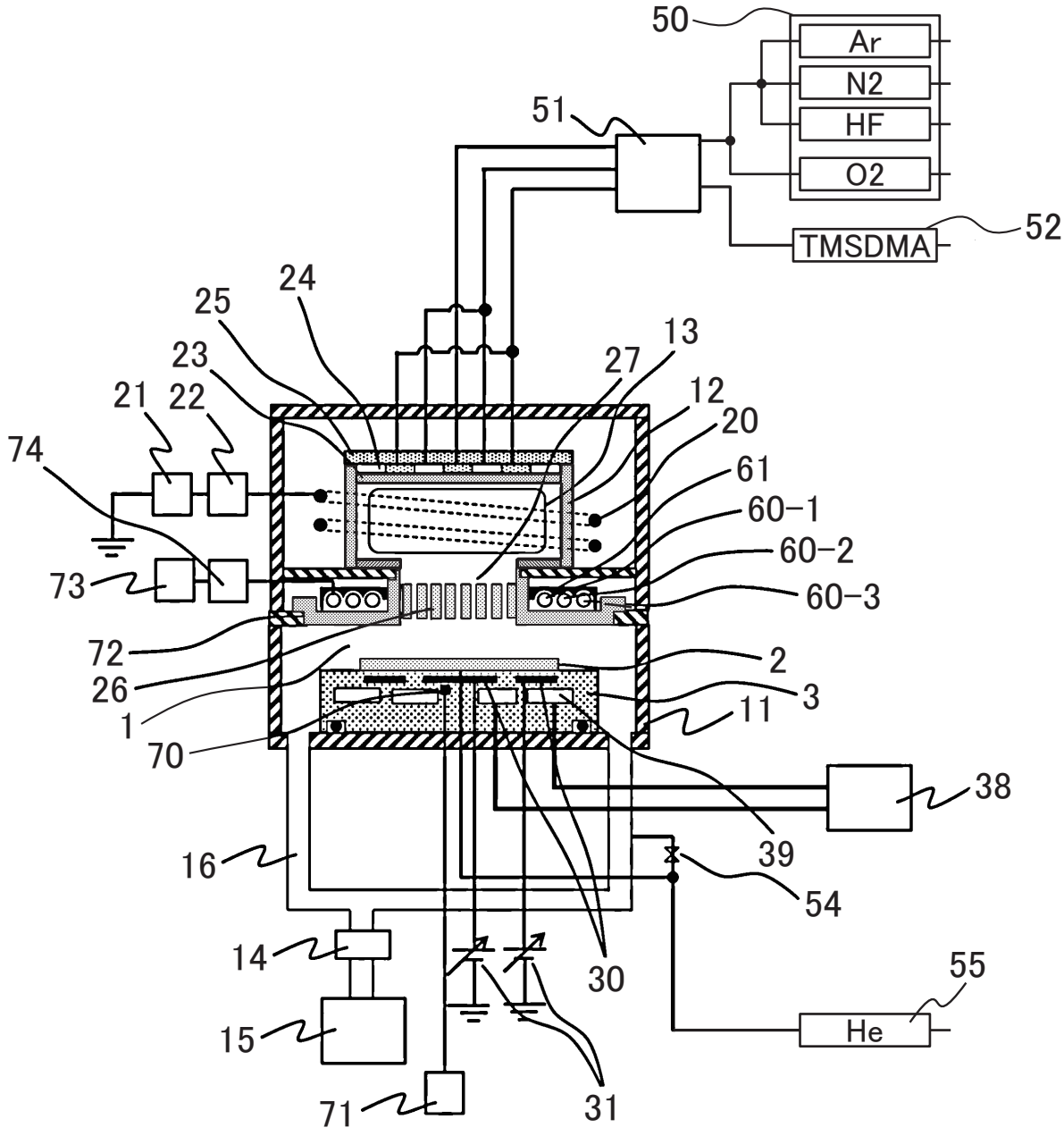

50
Ar
N2
HF
O2
51
52
TMSDMA
24
25
23
21
22
74
73
72
26
1
70
27
13
12
20
61
60-1
60-2
60-3
2
3
11
38
39
54
16
14
15
71
30
31
55
He

FIG. 11

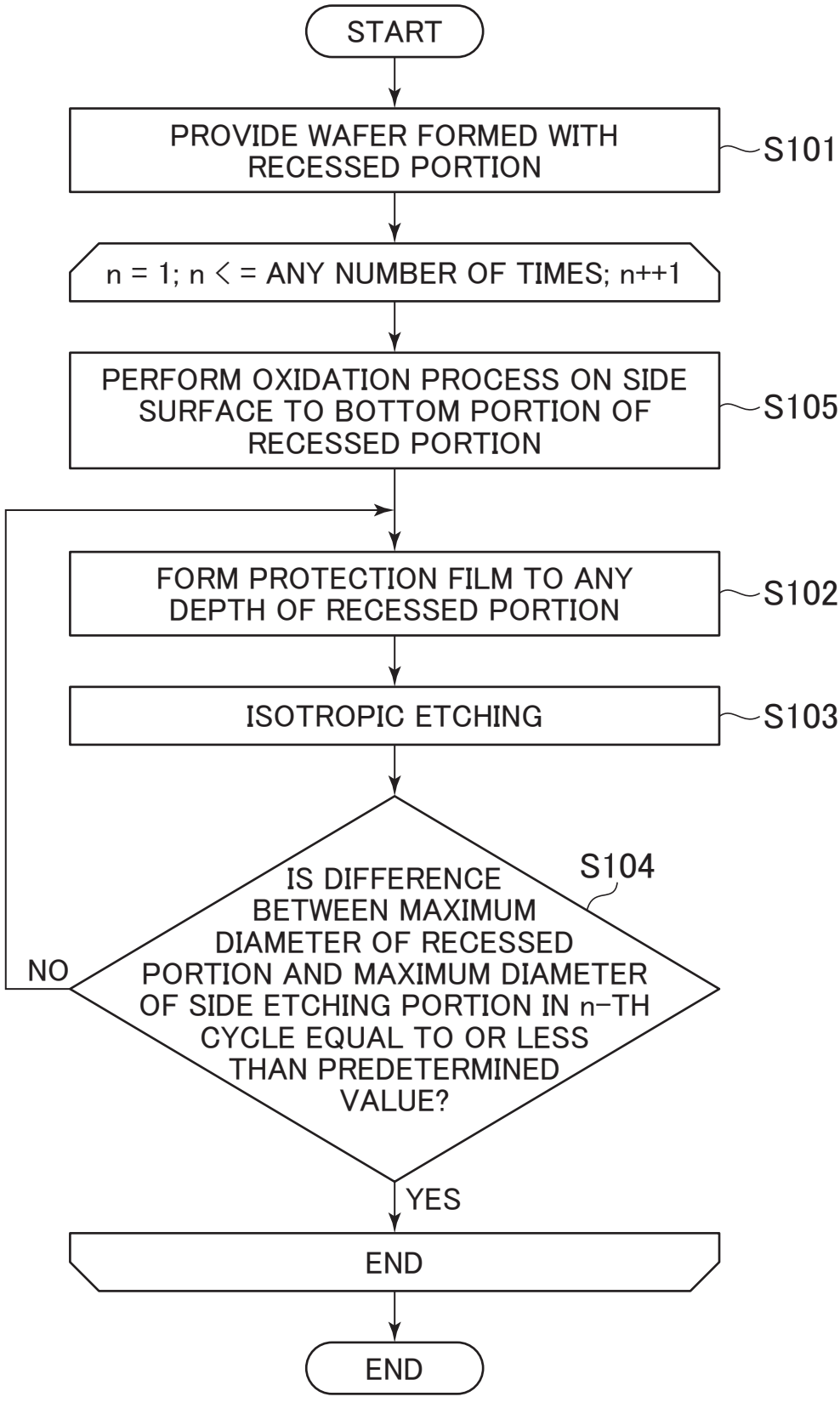

START
PROVIDE WAFER FORMED WITH RECESSED PORTION
S101
n = 1; n < = ANY NUMBER OF TIMES; n++1
PERFORM OXIDATION PROCESS ON SIDE SURFACE TO BOTTOM PORTION OF RECESSED PORTION
S105
FORM PROTECTION FILM TO ANY DEPTH OF RECESSED PORTION
S102
ISOTROPIC ETCHING
S103
S104
IS DIFFERENCE BETWEEN MAXIMUM DIAMETER OF RECESSED PORTION AND MAXIMUM DIAMETER OF SIDE ETCHING PORTION IN n-TH CYCLE EQUAL TO OR LESS THAN PREDETERMINED VALUE?
NO
YES
END
END

FIG. 12

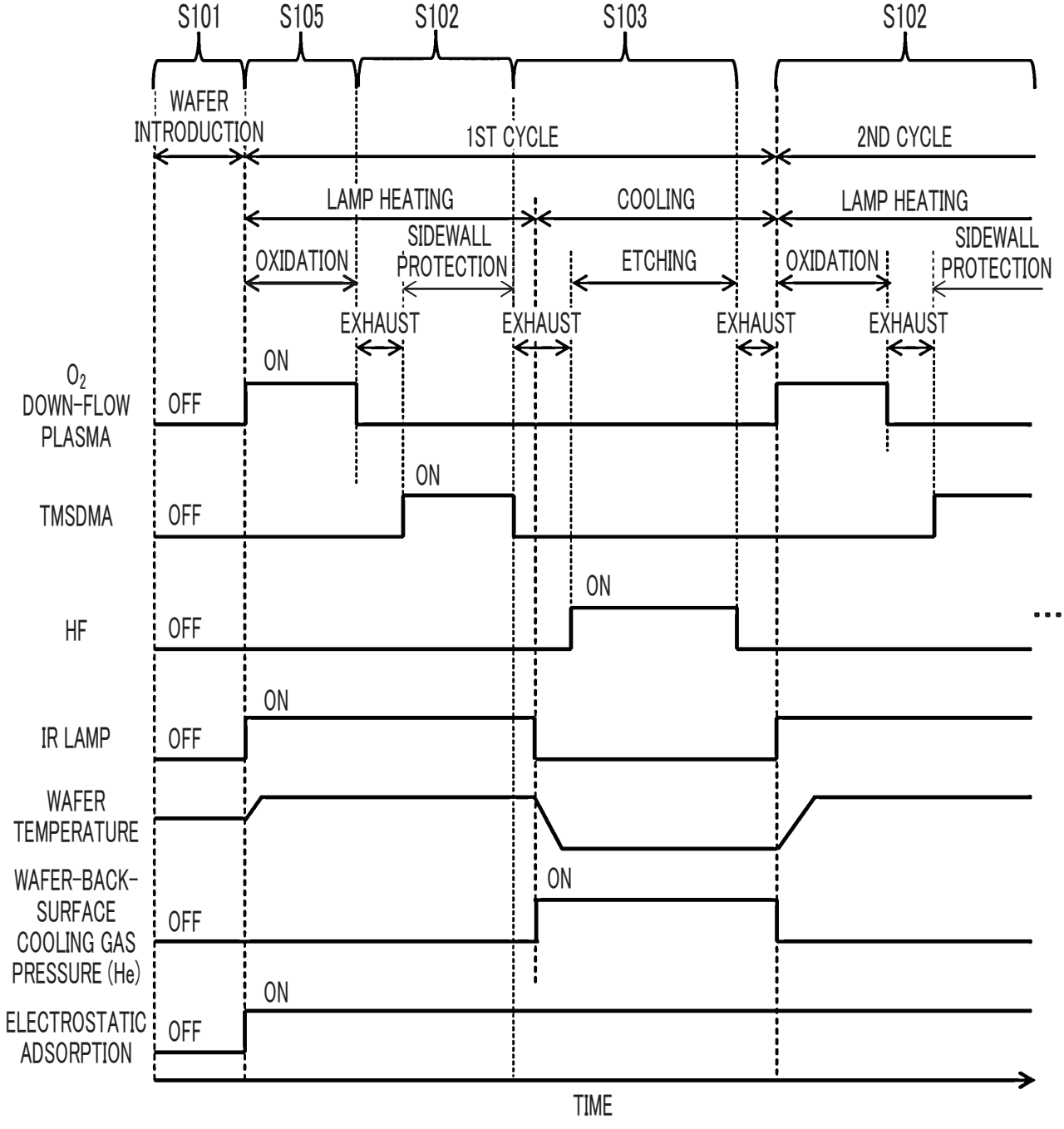

S101
S105
S102
S103
S102
WAFER INTRODUCTION
1ST CYCLE
2ND CYCLE
LAMP HEATING
COOLING
LAMP HEATING
OXIDATION
SIDEWALL PROTECTION
ETCHING
OXIDATION
SIDEWALL PROTECTION
EXHAUST
EXHAUST
EXHAUST
EXHAUST
O2 DOWN-FLOW PLASMA
TMSDMA
HF
IR LAMP
WAFER TEMPERATURE
WAFER-BACK-SURFACE COOLING GAS PRESSURE (He)
ELECTROSTATIC ADSORPTION
ON
OFF
TIME

FIG. 13

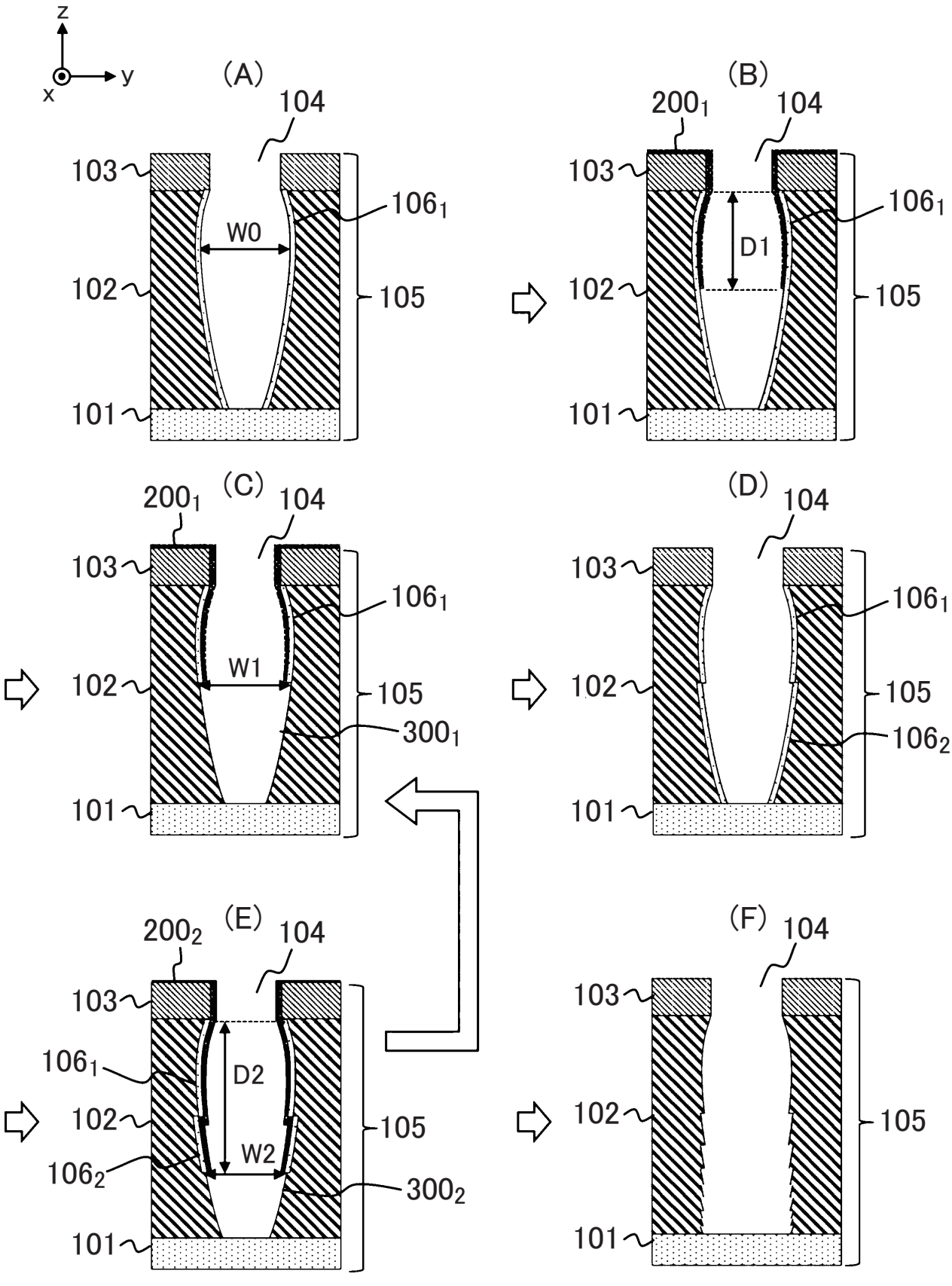

z
y
x
(A)
104
103
106_1
W0
102
105
101
(B)
200_1
104
103
106_1
D1
102
105
101
(C)
200_1
104
103
106_1
W1
102
105
300_1
101
(D)
104
103
106_1
102
105
106_2
101
(E)
200_2
104
103
106_1
D2
102
105
W2
106_2
300_2
101
(F)
104
103
102
105
101

FIG. 14

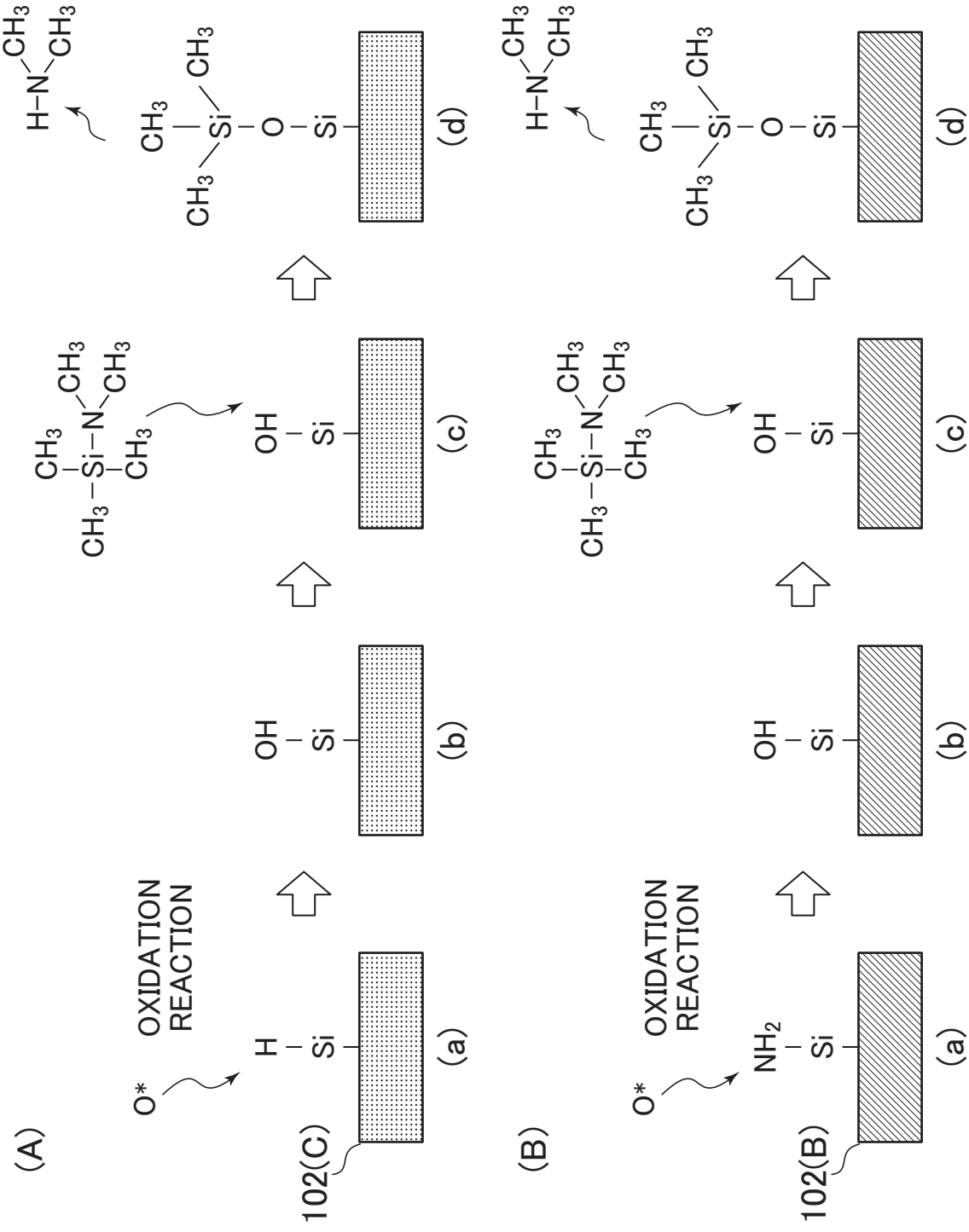
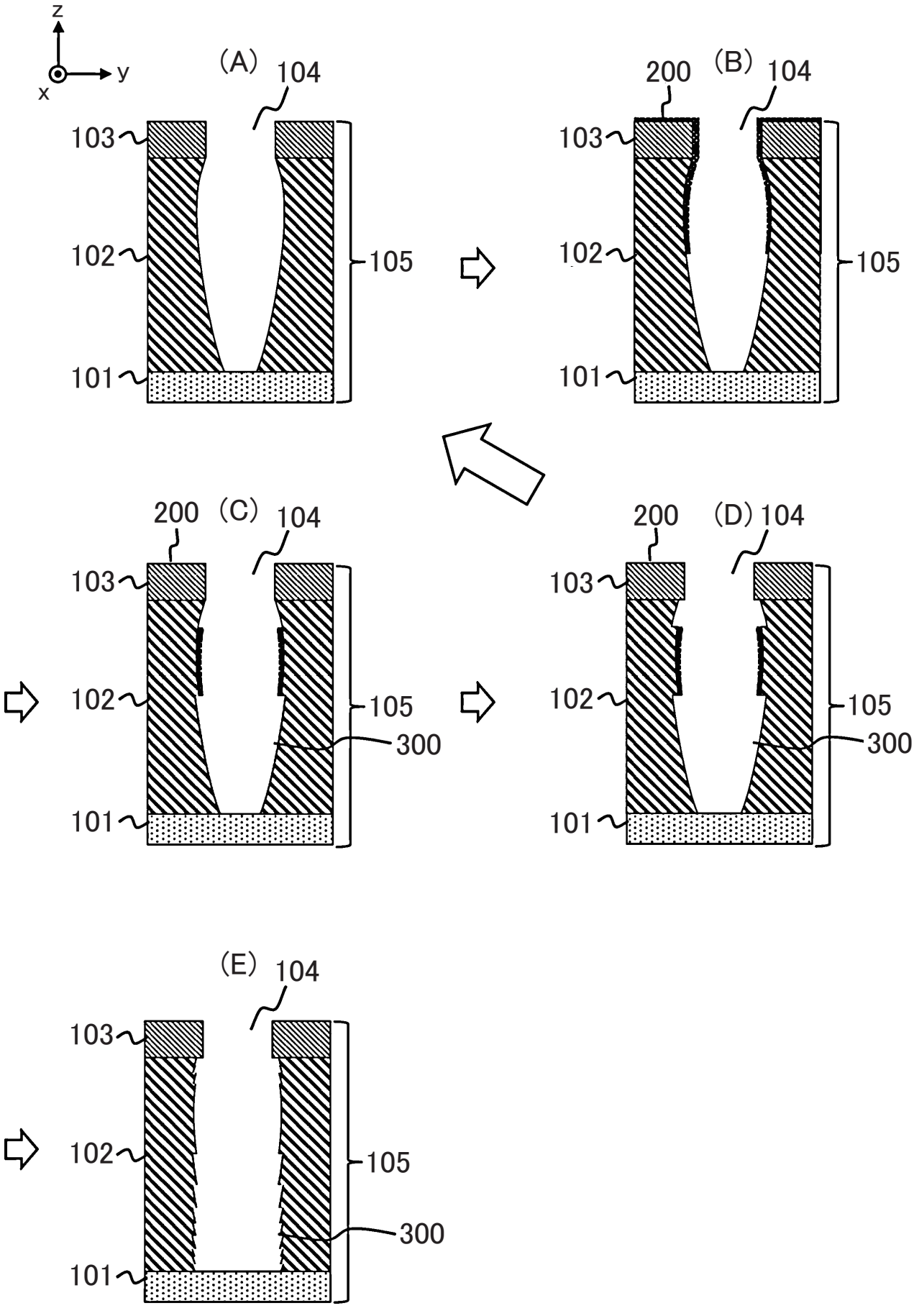

(A)
O*
OXIDATION REACTION
H – Si
102(C)
(a)
OH – Si
(b)
CH3 – Si(CH3)2 – N(CH3)2
OH – Si
(c)
H–N(CH3)2
CH3 – Si(CH3)2 – O – Si
(d)
(B)
O*
OXIDATION REACTION
NH2 – Si
102(B)
(a)
OH – Si
(b)
CH3 – Si(CH3)2 – N(CH3)2
OH – Si
(c)
H–N(CH3)2
CH3 – Si(CH3)2 – O – Si
(d)

FIG. 15


z
y
x
(A)
104
103
102
105
101
200
(B)
104
103
102
105
101
200
(C)
104
103
102
105
300
101
200
(D)
104
103
102
105
300
101
(E)
104
103
102
105
300
101