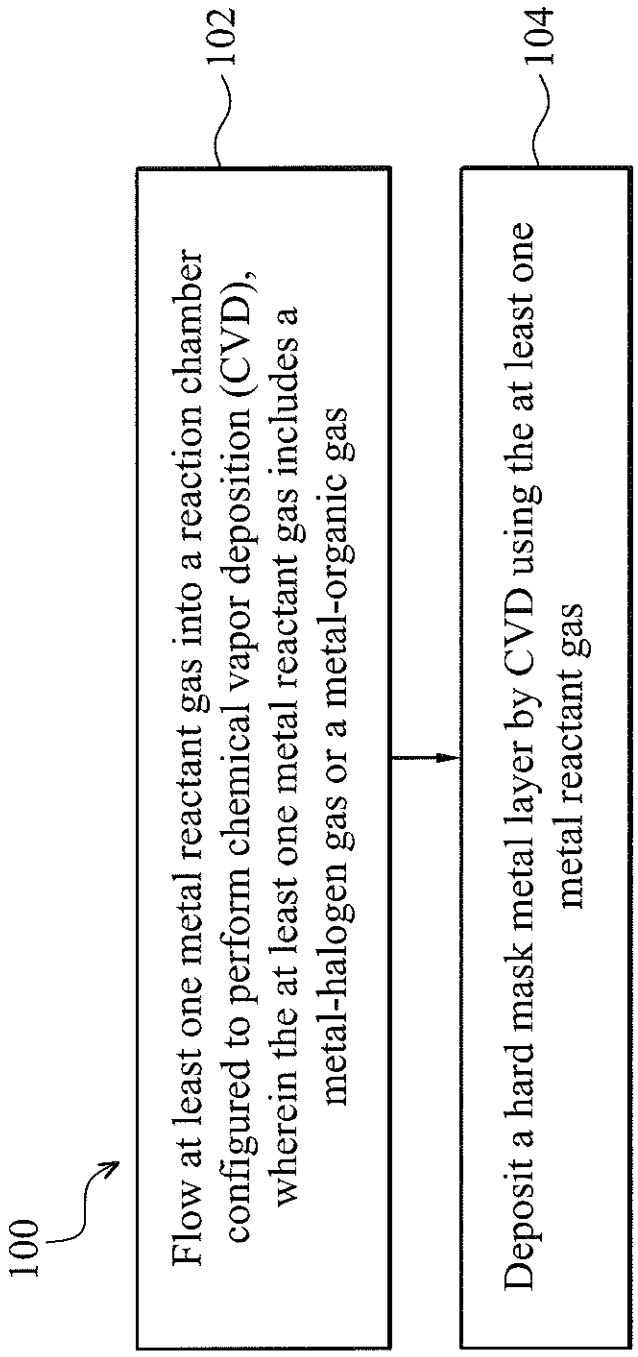

100
102
Flow at least one metal reactant gas into a reaction chamber configured to perform chemical vapor deposition (CVD), wherein the at least one metal reactant gas includes a metal-halogen gas or a metal-organic gas
104
Deposit a hard mask metal layer by CVD using the at least one metal reactant gas

FIG. 1

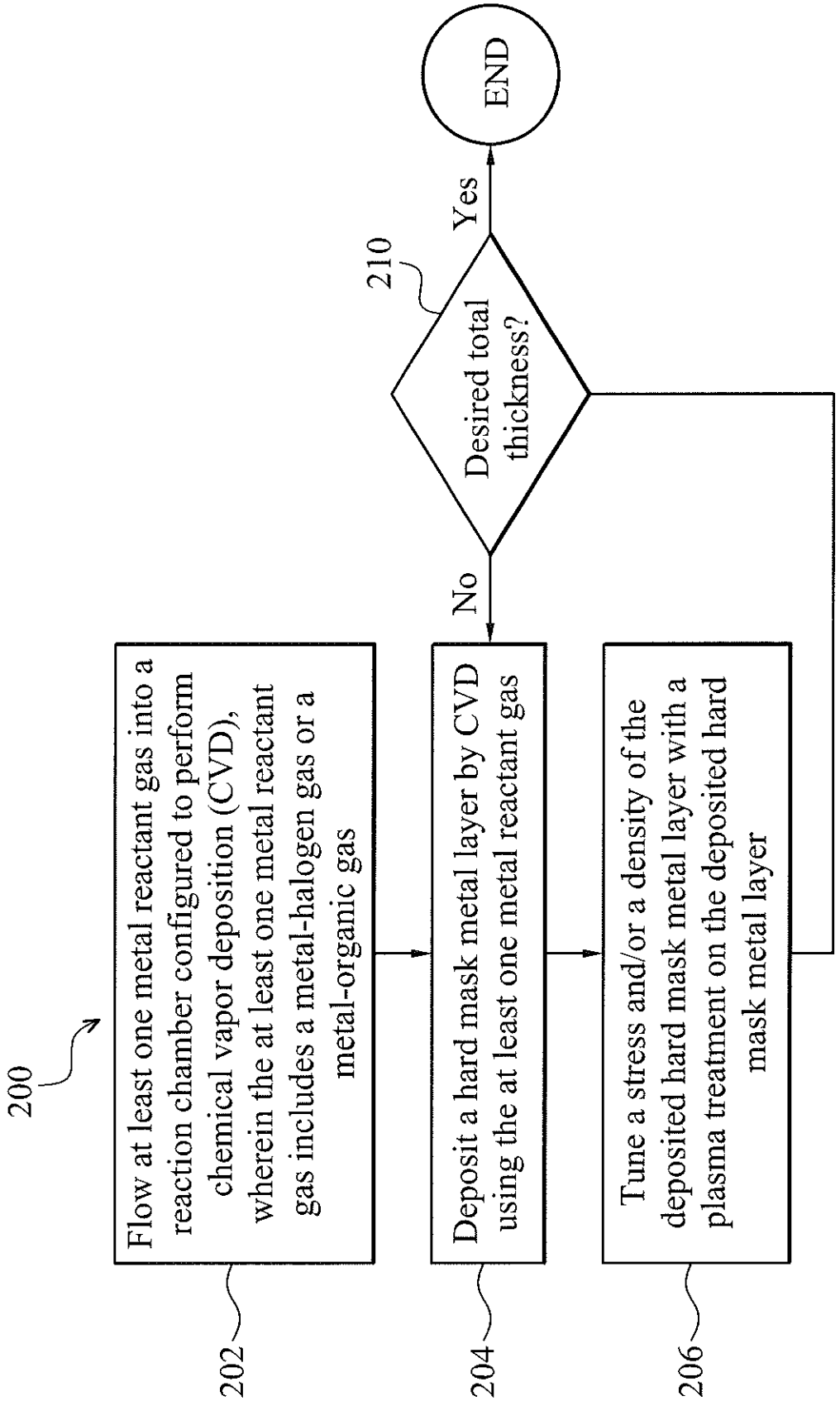
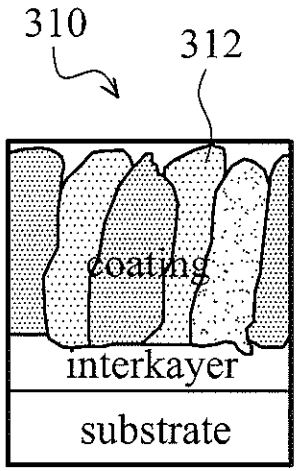
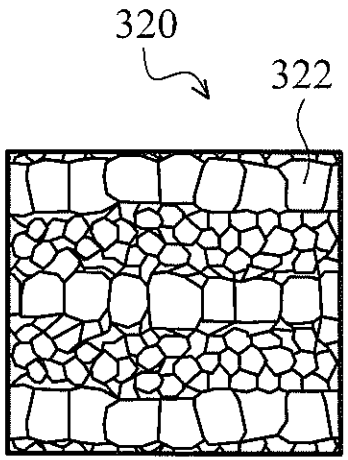

200
Flow at least one metal reactant gas into a reaction chamber configured to perform chemical vapor deposition (CVD), wherein the at least one metal reactant gas includes a metal-halogen gas or a metal-organic gas
202
Deposit a hard mask metal layer by CVD using the at least one metal reactant gas
204
Tune a stress and/or a density of the deposited hard mask metal layer with a plasma treatment on the deposited hard mask metal layer
206
210
Desired total thickness?
No
Yes
END

FIG. 2



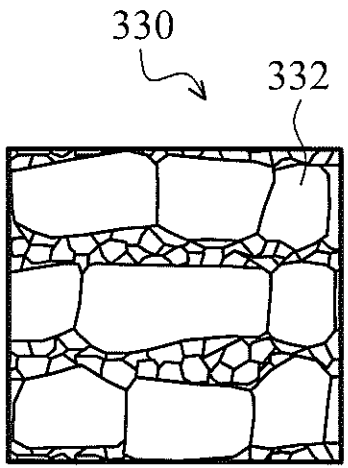
PVD

FIG. 3A



CVD without cyclic plasma treatment

FIG. 3B



CVD with cyclic plasma treatment

FIG. 3C

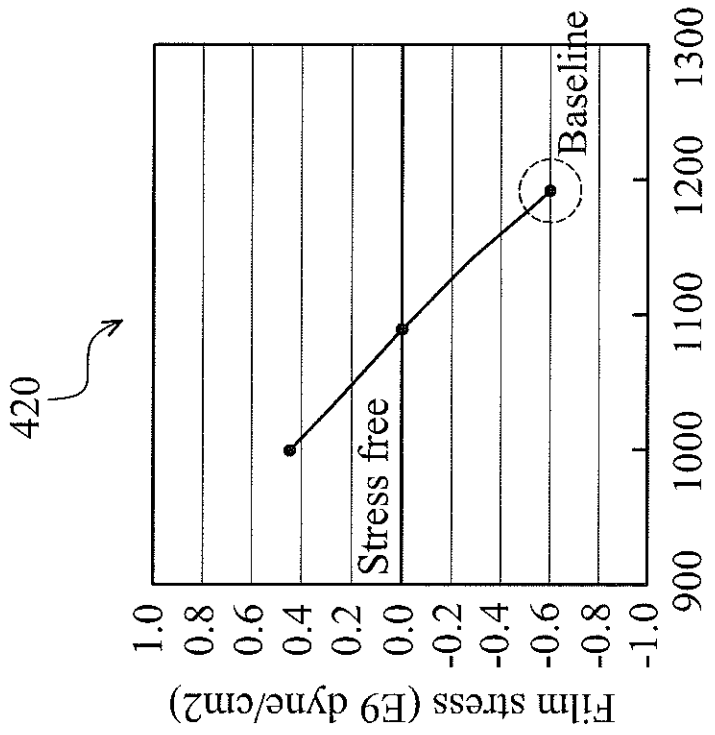

420
Film stress (E9 dyne/cm2)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Stress free
Baseline
900
1000
1100
1200
1300
Nitridation RF power (W)

FIG. 4B

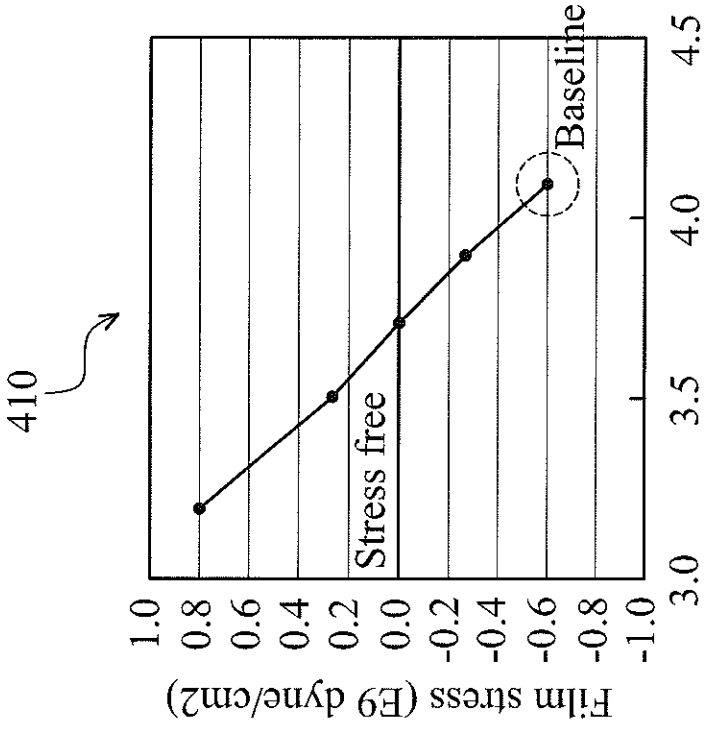

410
Film stress (E9 dyne/cm2)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Stress free
Baseline
3.0
3.5
4.0
4.5
Nitridation time (sec)

FIG. 4A

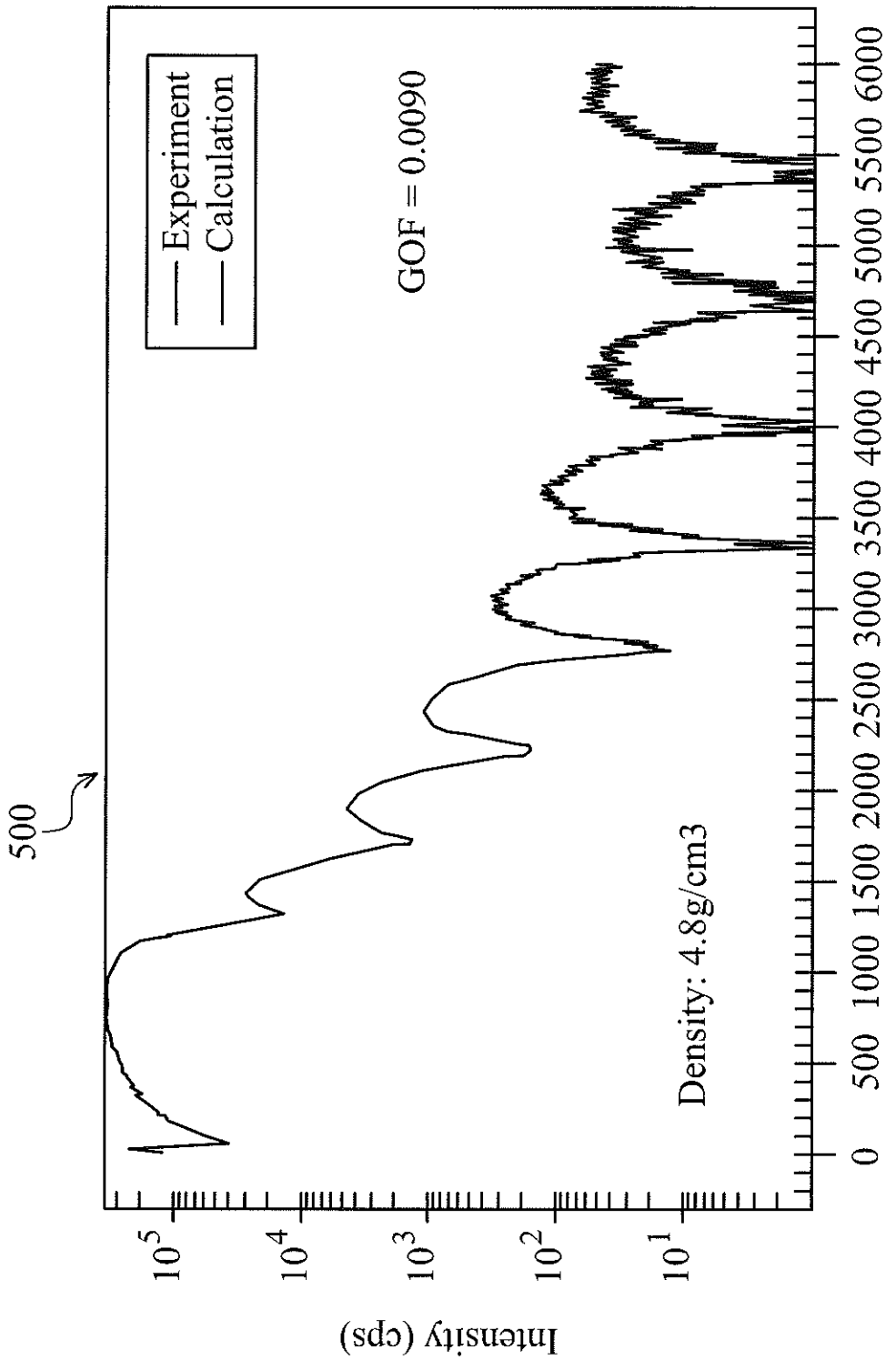

500
Experiment
Calculation
GOF = 0.0090
Density: 4.8g/cm3
Intensity (cps)
10^5
10^4
10^3
10^2
10^1
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000
Omege (sec)

FIG. 5

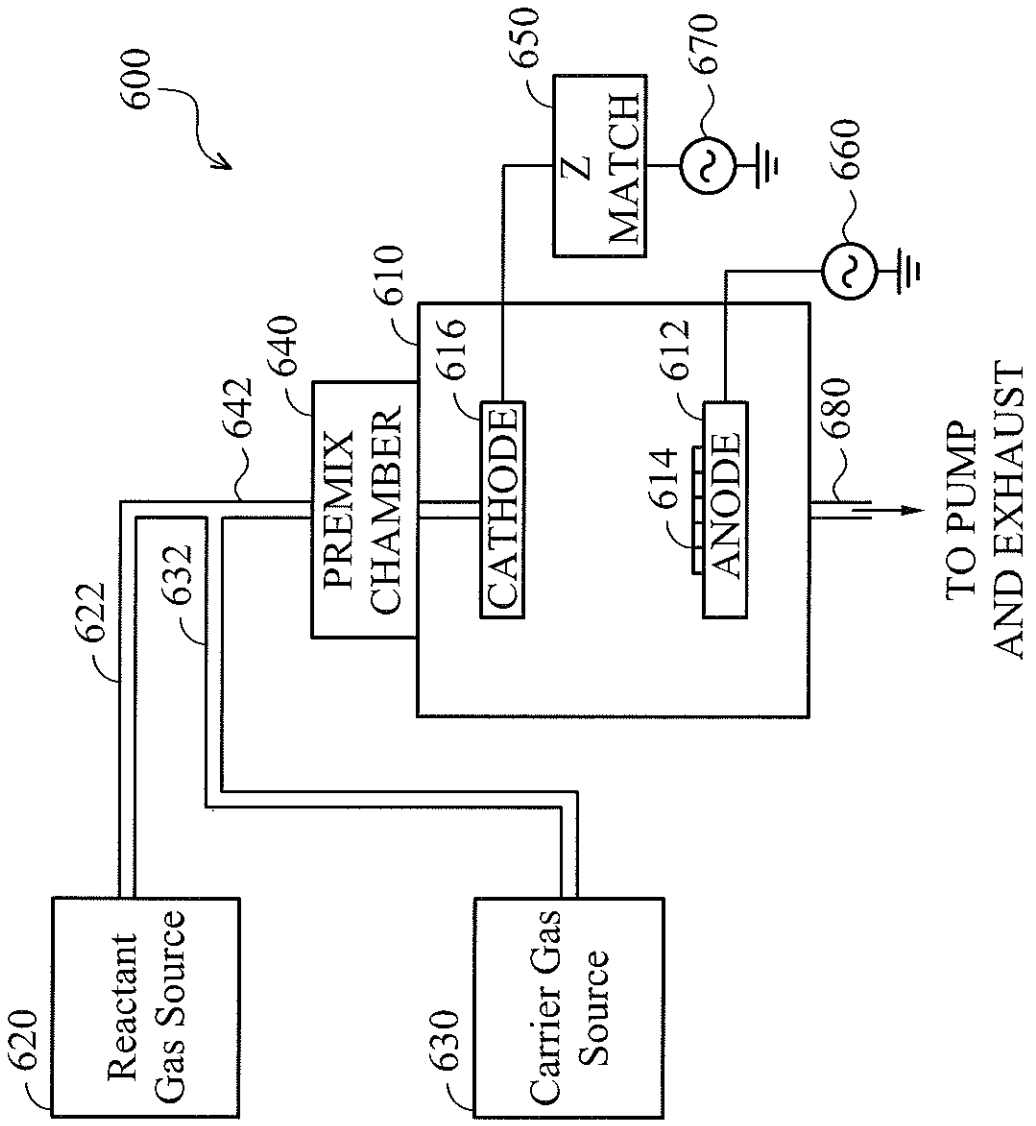

600
650
Z MATCH
670
660
610
640
642
616
612
PREMIX CHAMBER
CATHODE
ANODE
614
680
622
632
TO PUMP AND EXHAUST
620
Reactant Gas Source
630
Carrier Gas Source

FIG. 6