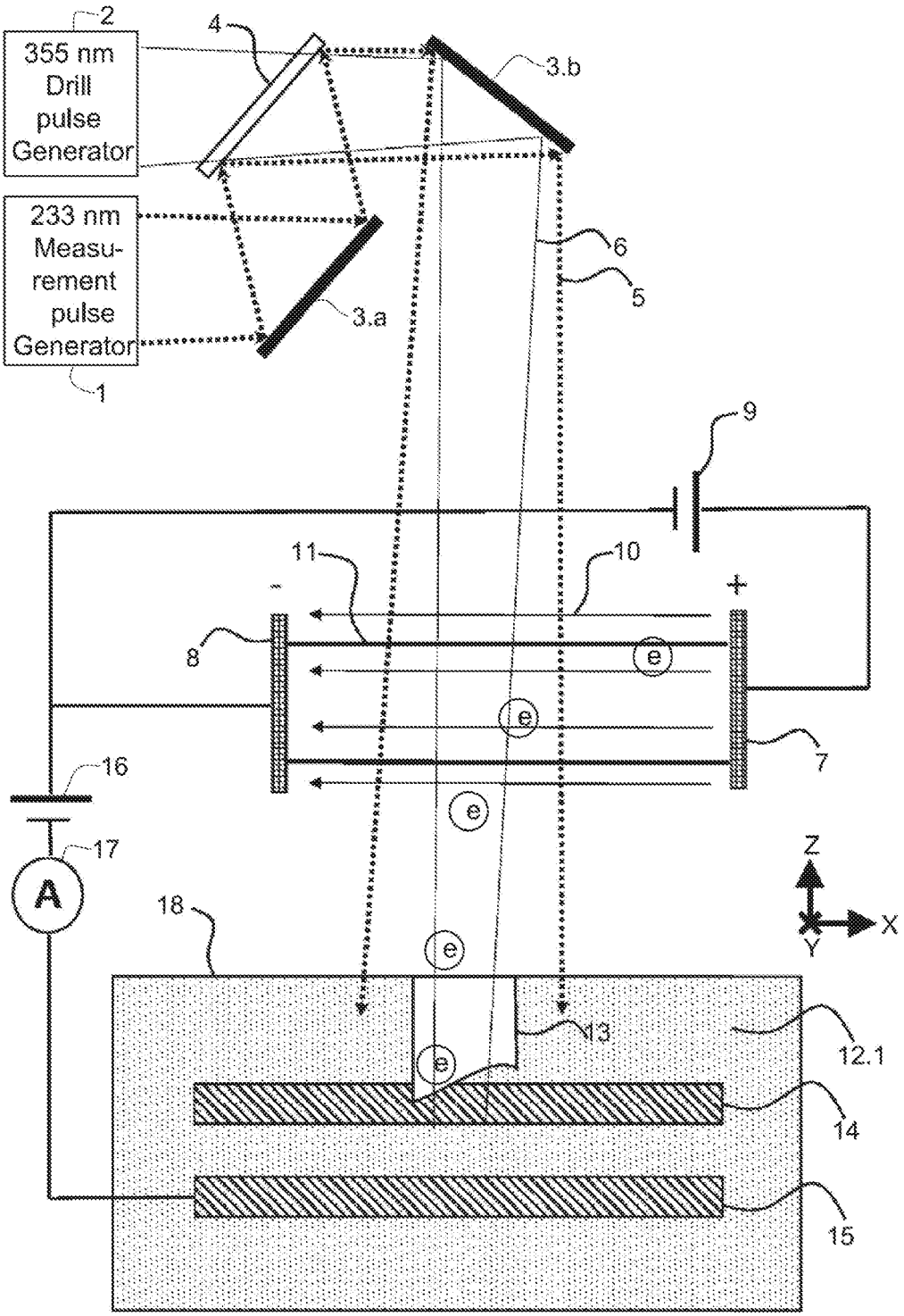

2
355 nm
Drill
pulse
Generator
4
3.b
233 nm
Measu-
rement
pulse
Generator
3.a
1
6
5
9
11
10
-
+
8
e
e
e
e
7
16
17
A
18
Z
X
Y
13
12.1
14
15

FIG. 1

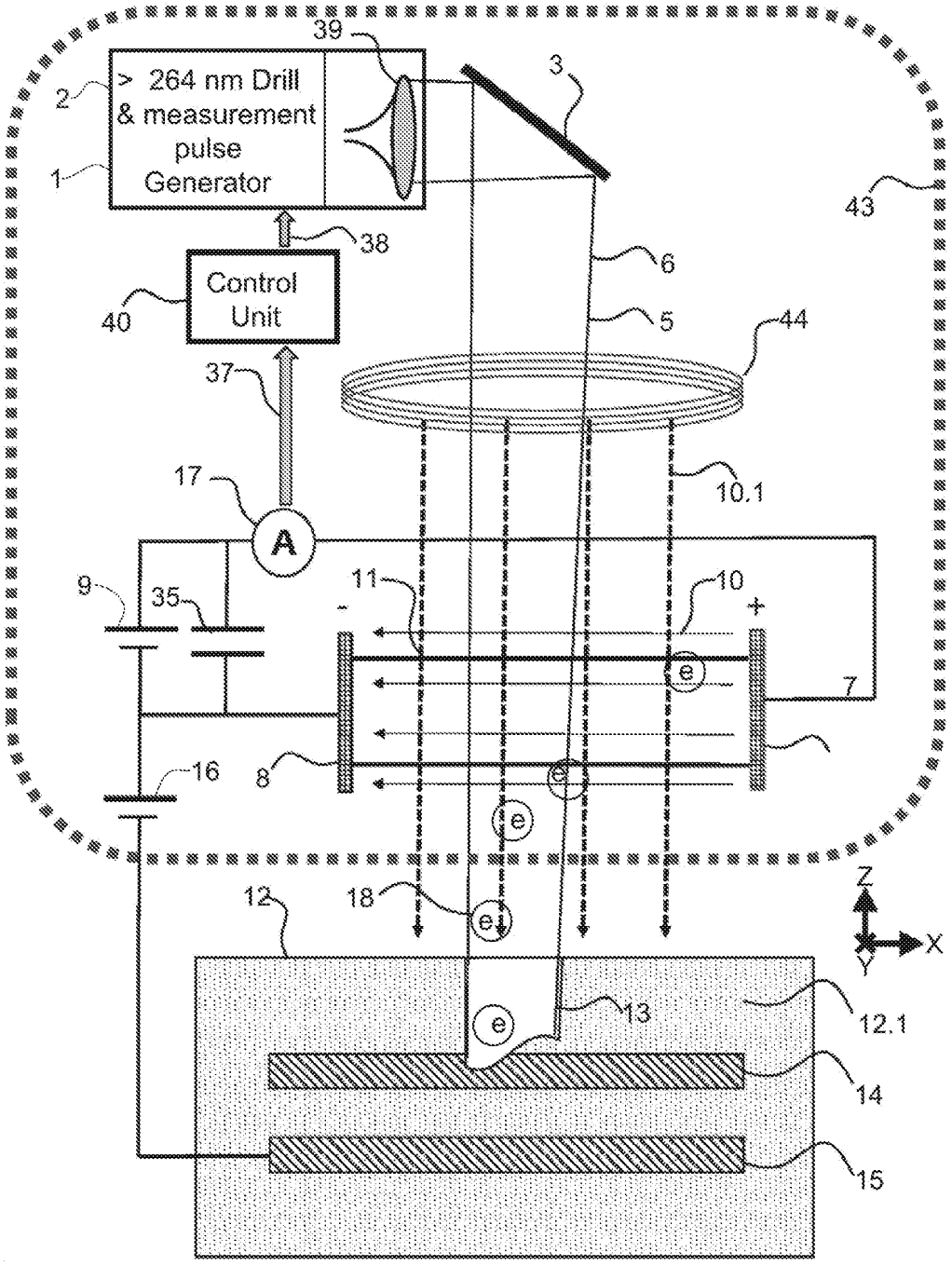

39
2
> 264 nm Drill
& measurement
pulse
Generator
1
3
43
38
6
Control
Unit
40
5
44
37
17
10.1
A
9
35
11
10
-
+
e
7
16
8
12
18
Z
X
Y
13
12.1
14
15

FIG. 2

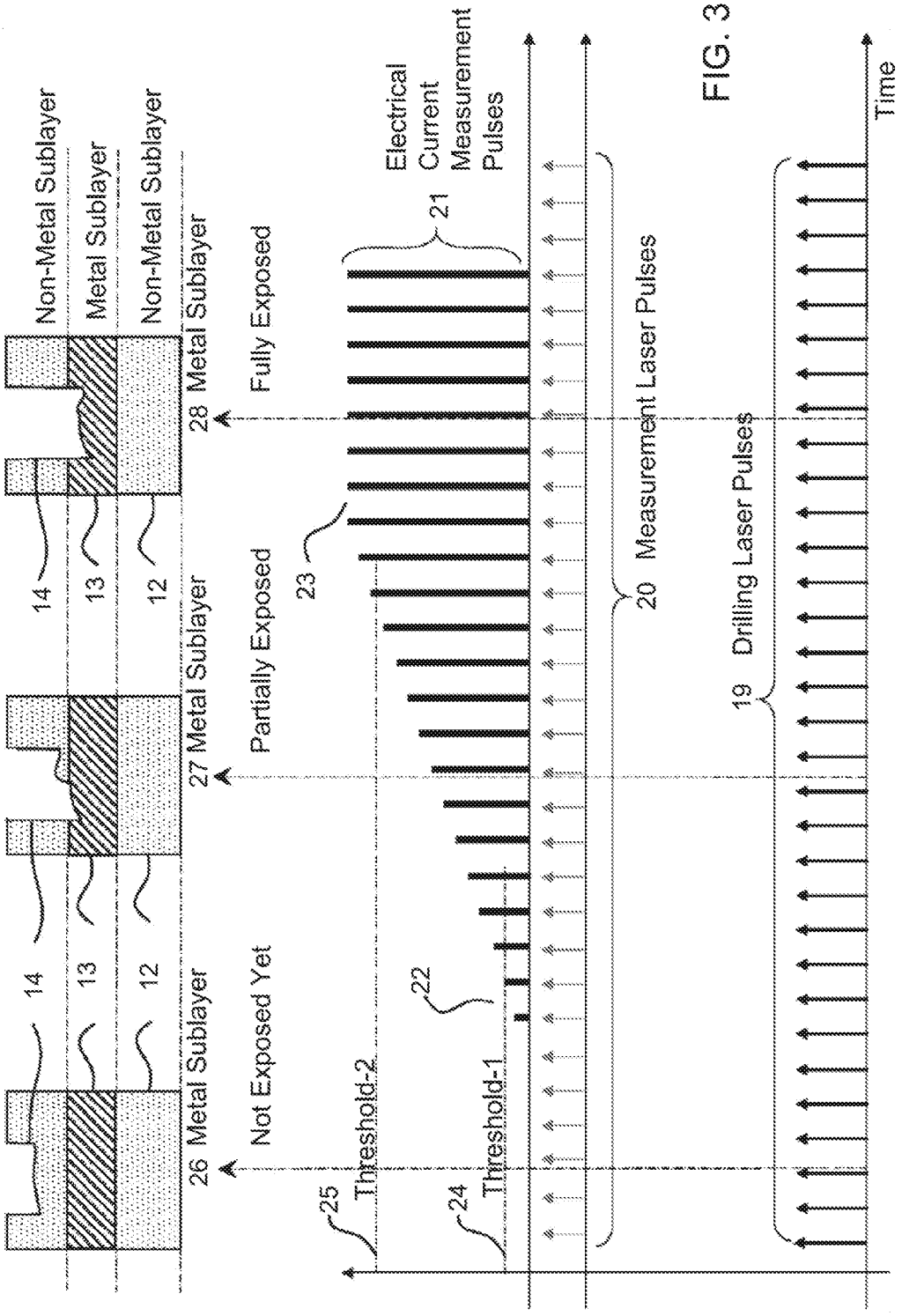

Non-Metal Sublayer
Metal Sublayer
Non-Metal Sublayer
14
13
12
26 Metal Sublayer
27 Metal Sublayer
28 Metal Sublayer
Not Exposed Yet
Partially Exposed
Fully Exposed
25 Threshold-2
24 Threshold-1
22
23
21 Electrical Current Measurement Pulses
20 Measurement Laser Pulses
19 Drilling Laser Pulses
Time

FIG. 3

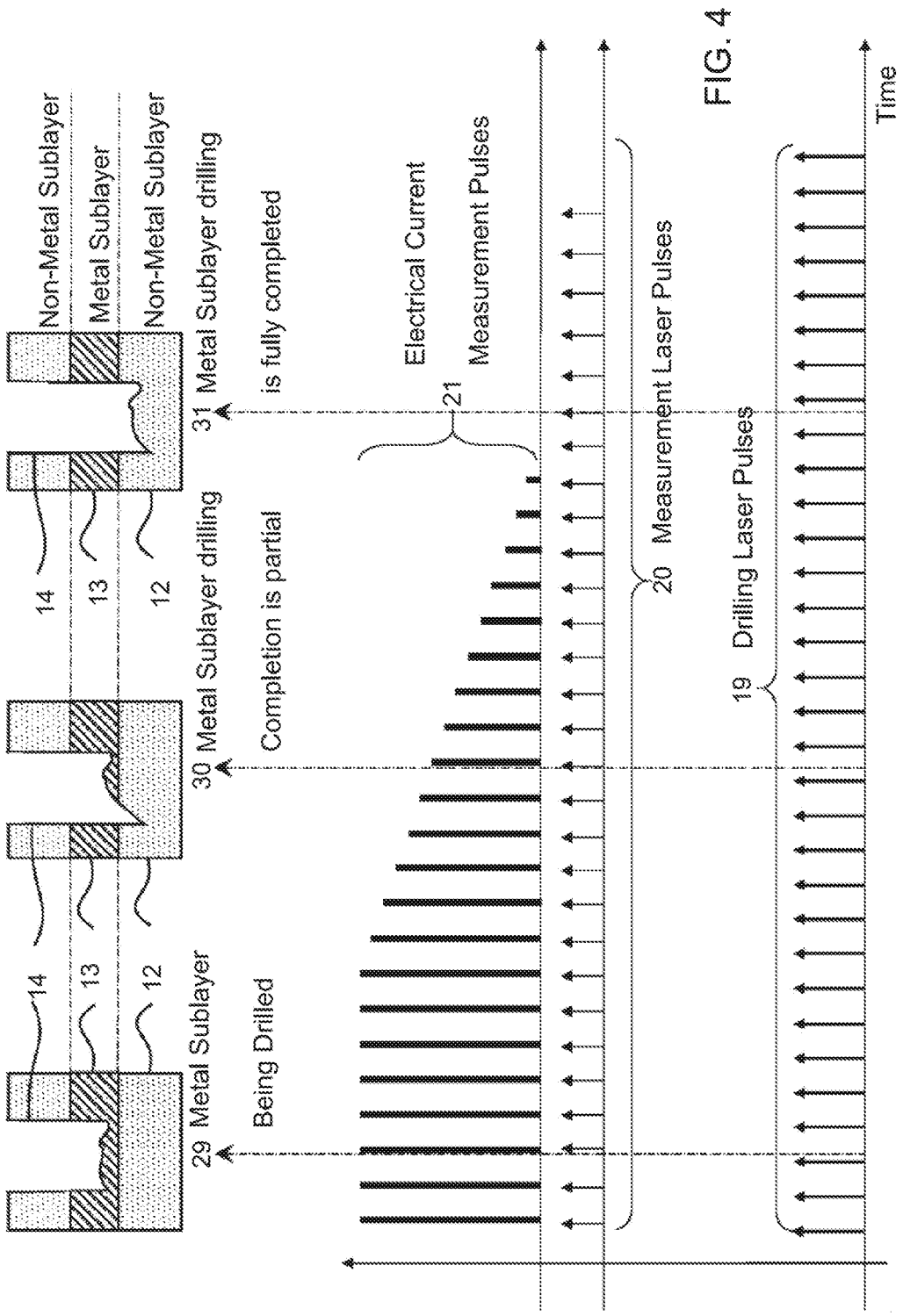

Non-Metal Sublayer
Metal Sublayer
Non-Metal Sublayer
14
13
12
29 Metal Sublayer
Being Drilled
30 Metal Sublayer drilling
Completion is partial
31 Metal Sublayer drilling
is fully completed
Electrical Current
Measurement Pulses
21
20 Measurement Laser Pulses
19 Drilling Laser Pulses
Time

FIG. 4

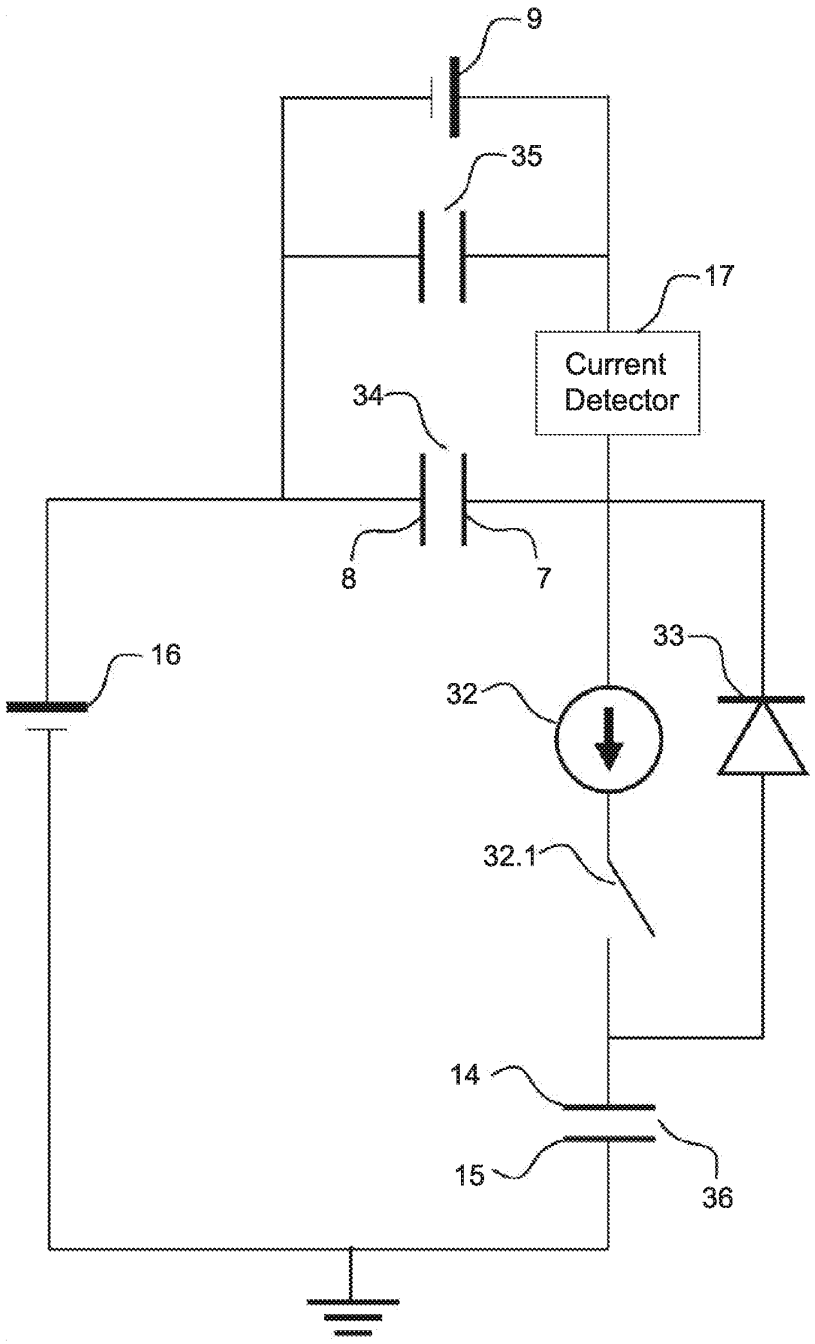
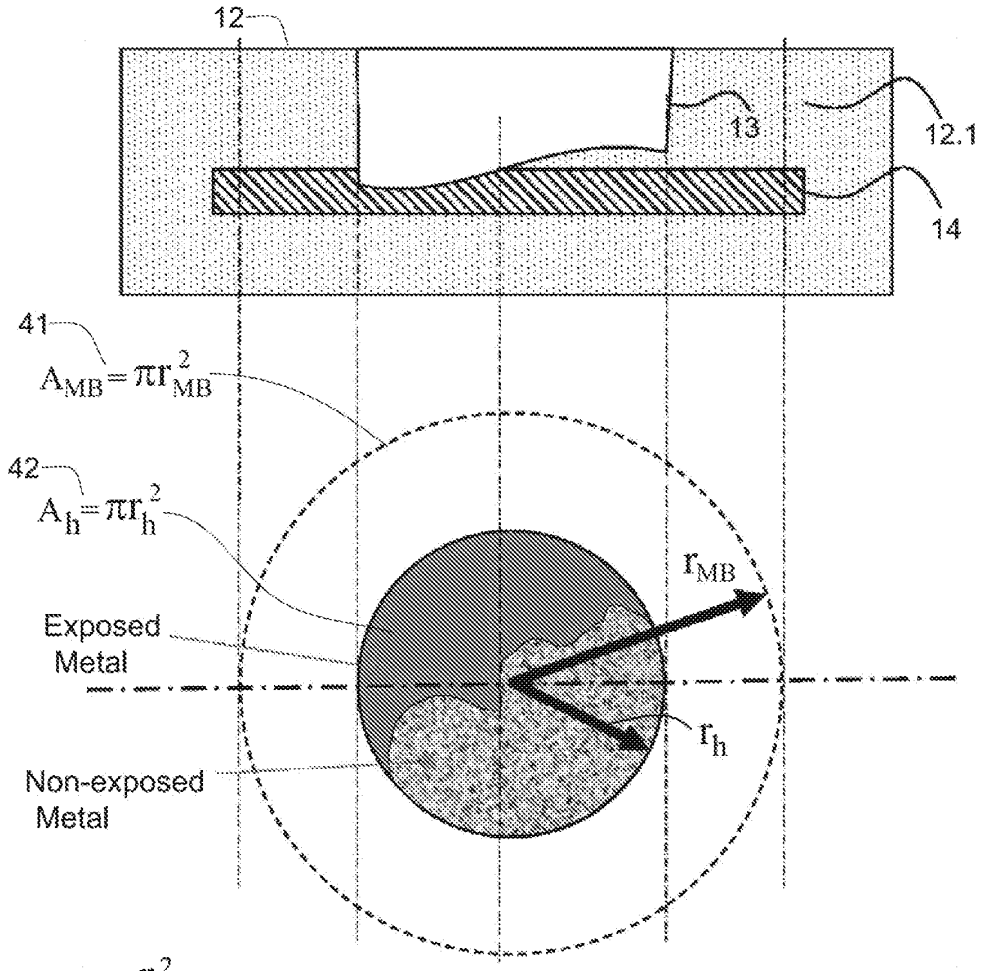


FIG. 5



$$I(t)=\frac{r_h^2}{r_{MB}^2}\cdot ER\cdot q_e\cdot LI_{MB}(t)\cdot CE(V)$$

I*(t)*	is the measured electric current [A*mpere*]
ER	is the E***xposure*** R***atio*** or metal in hole [any number between 0 to 1]
qe	is the electron electric charge [C*oulomb*]
LI*(t)*	is the instantaneous measurement L***ight*** I***ntensity*** [photons per second]
CE*(V)*is	is the C***ollection*** E***fficiency*** of the free electrons which depends on offset voltage between anode and workpiece [any number between 0 to 1]

At a certain moment in time:

$$I = K\cdot EB$$

FIG. 6

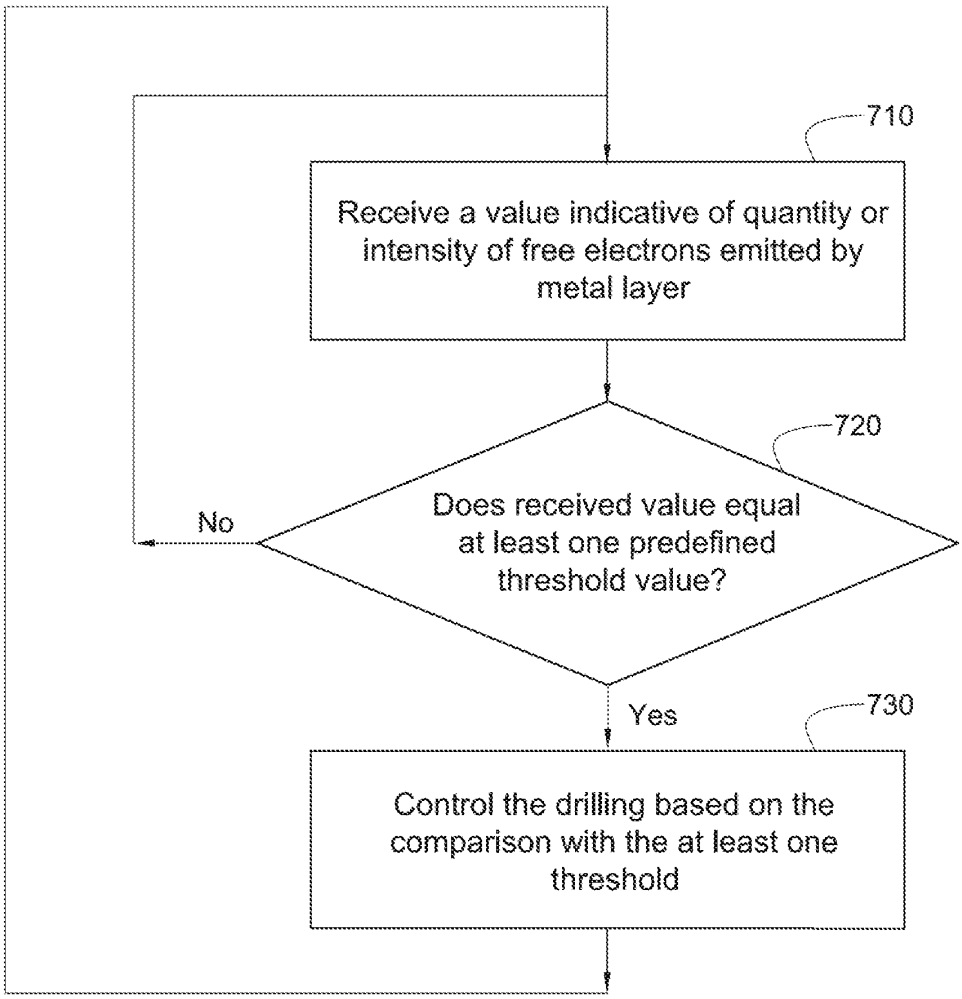

710
Receive a value indicative of quantity or intensity of free electrons emitted by metal layer
720
Does received value equal at least one predefined threshold value?
No
Yes
730
Control the drilling based on the comparison with the at least one threshold

FIG. 7

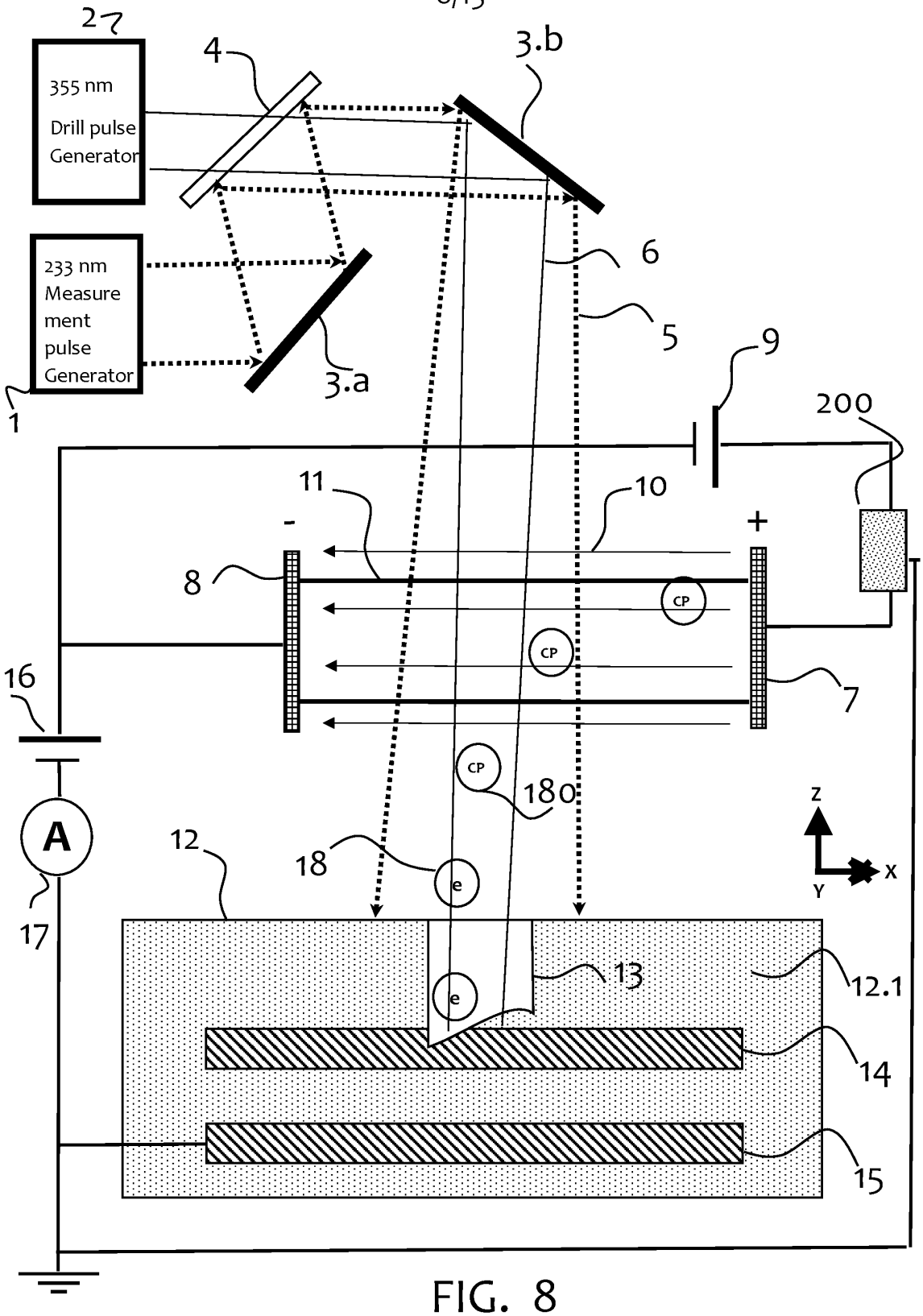

27
355 nm
Drill pulse
Generator
233 nm
Measure
ment
pulse
Generator
1
4
3.b
3.a
6
5
9
200
11
10
-
+
8
CP
CP
CP
7
16
A
17
180
12
18
e
e
13
12.1
14
15
Z
X
Y

FIG. 8

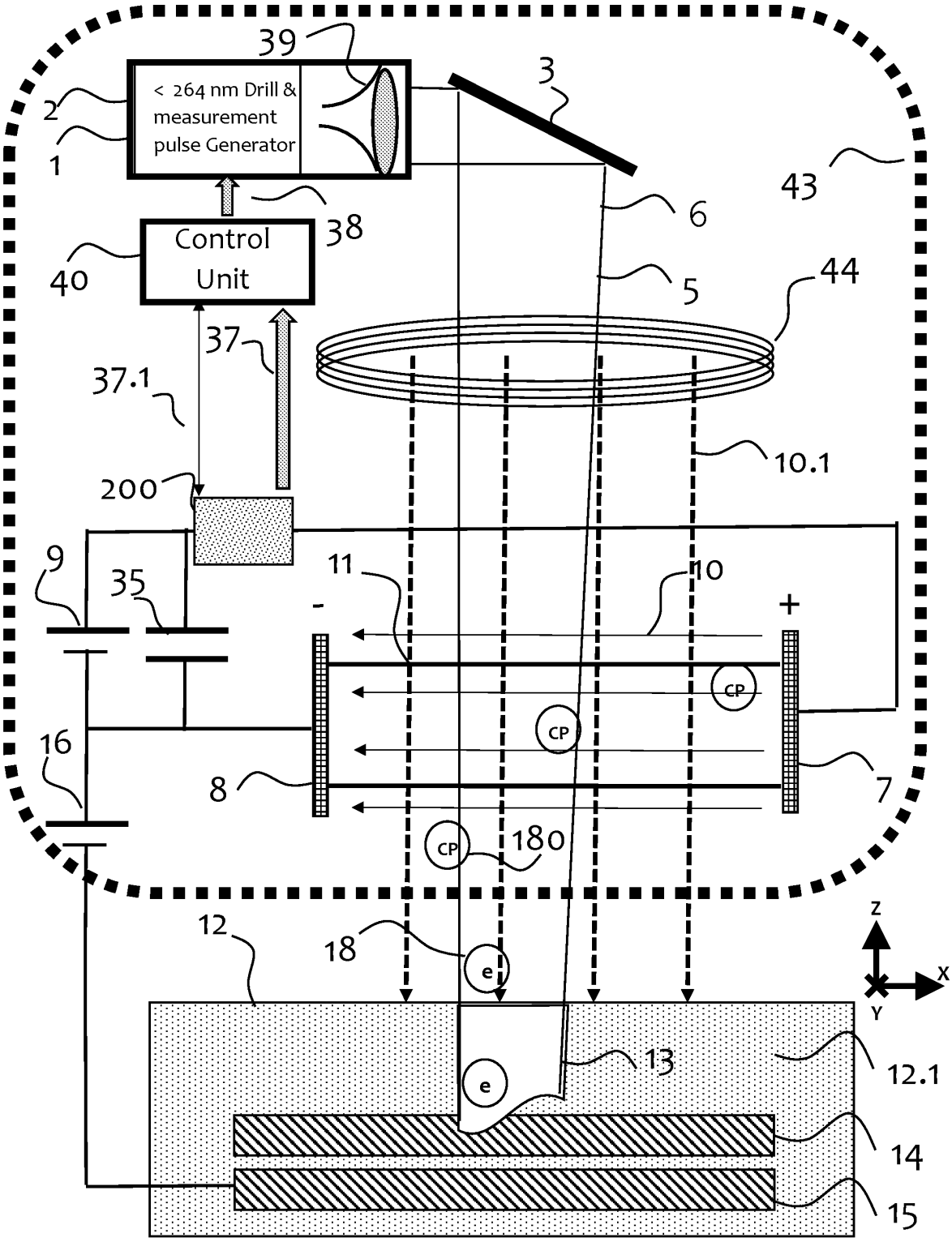
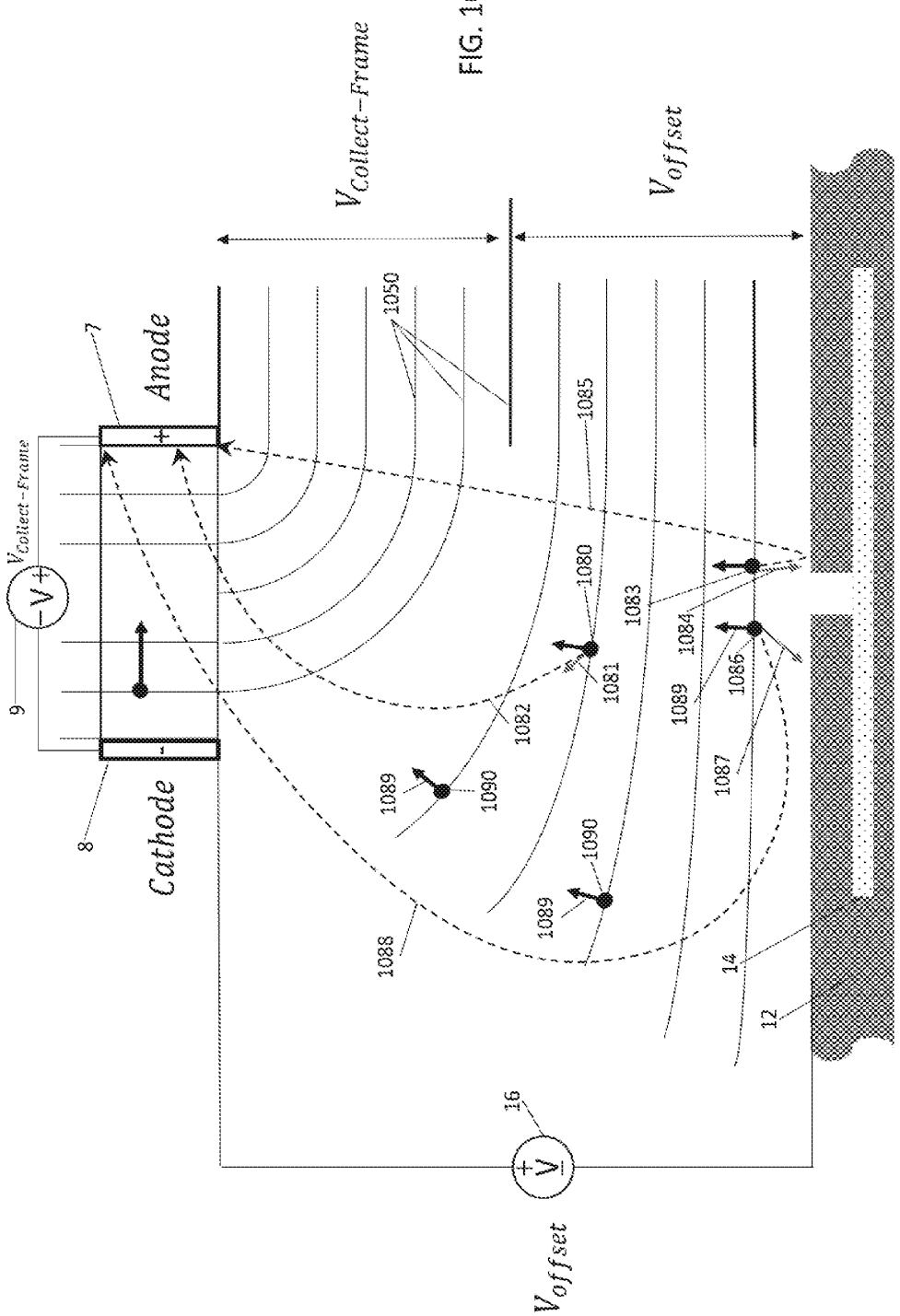

39
< 264 nm Drill & measurement pulse Generator
2
1
3
43
6
38
Control Unit
40
5
44
37
37.1
10.1
200
9
35
11
10
-
+
CP
CP
16
8
7
CP
180
12
18
e
Z
X
Y
13
12.1
e
14
15

FIG. 9

FIG. 10


$V_{Collect-Frame}$
V_{offset}
Anode
Cathode
$V_{Collect-Frame}$
V_{offset}
7
8
9
12
14
16
1050
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090

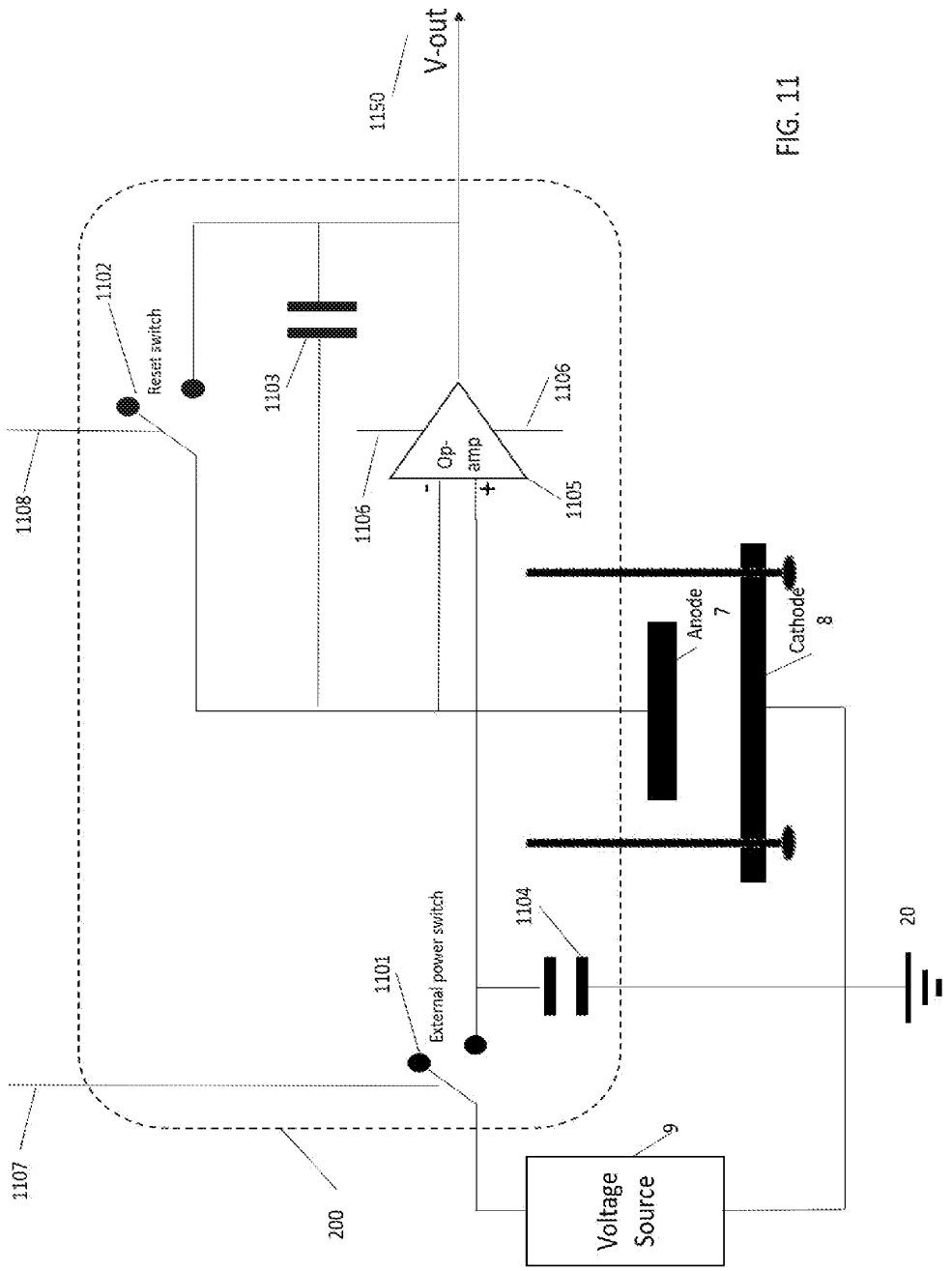

V-out
1150
1102
Reset switch
1103
1106
Op-amp
1106
1105
1108
Anode
7
Cathode
8
1104
20
1101
External power switch
1107
200
9
Voltage Source

FIG. 11

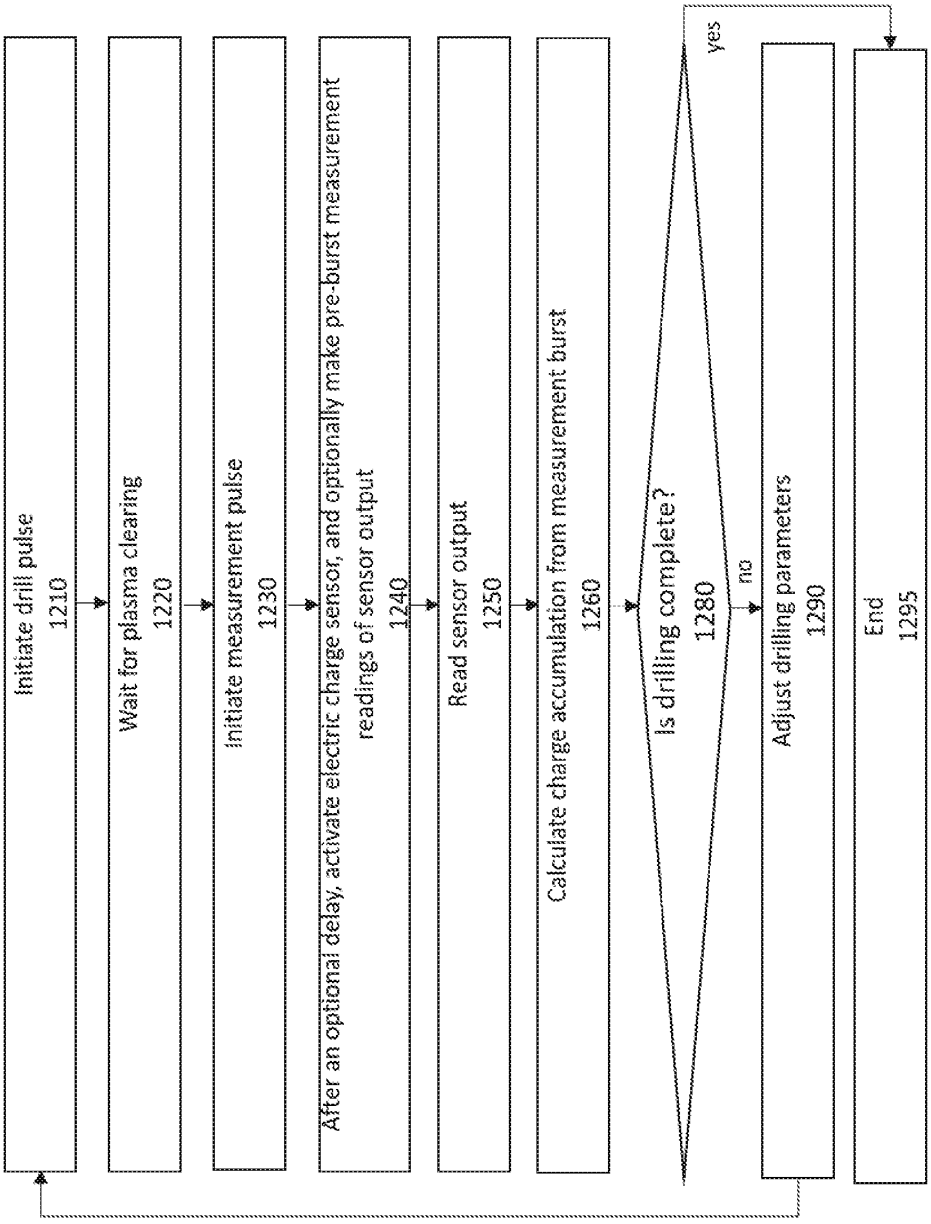

Initiate drill pulse
1210
Wait for plasma clearing
1220
Initiate measurement pulse
1230
After an optional delay, activate electric charge sensor, and optionally make pre-burst measurement readings of sensor output
1240
Read sensor output
1250
Calculate charge accumulation from measurement burst
1260
Is drilling complete?
1280
yes
no
Adjust drilling parameters
1290
End
1295

FIG. 12

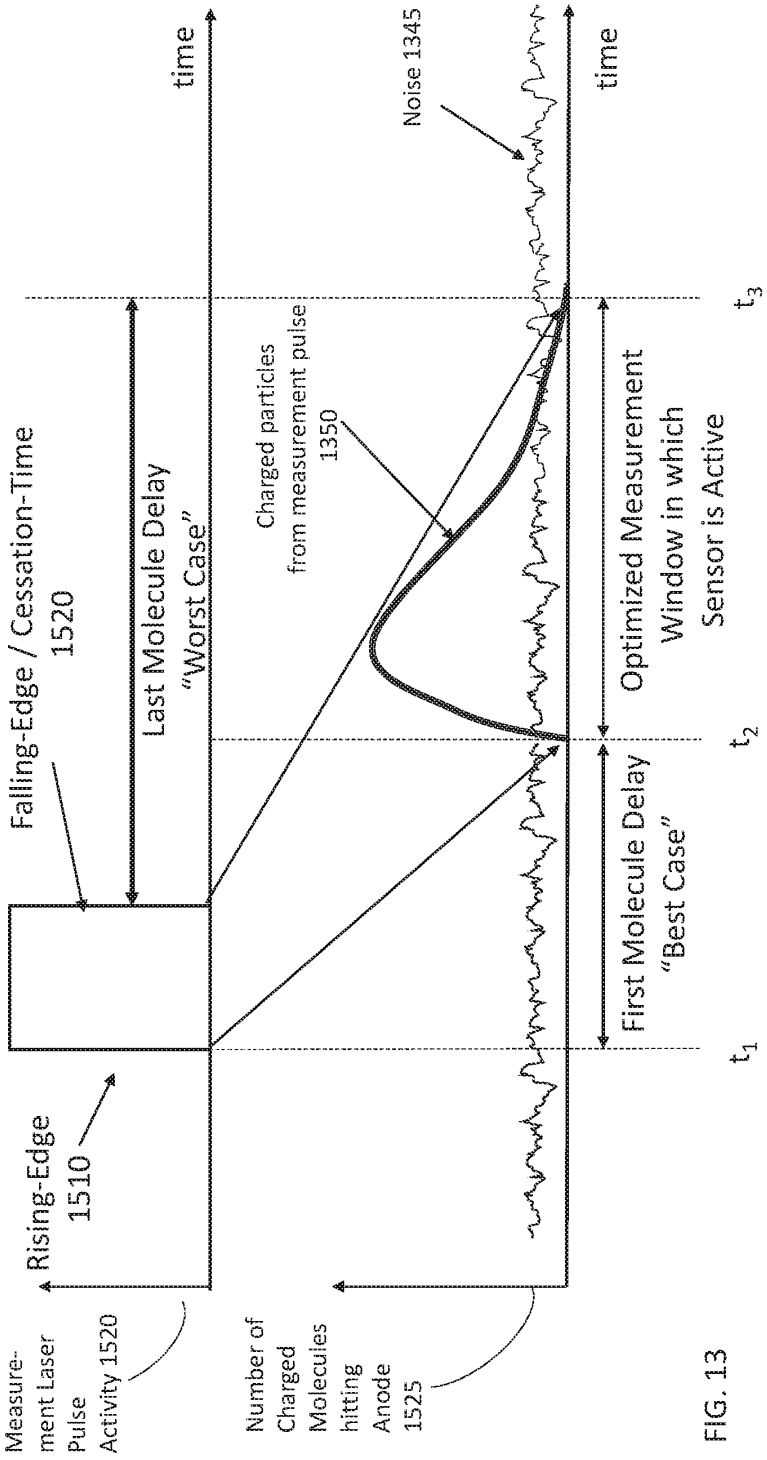

time
Noise 1345
time
Falling-Edge / Cessation-Time
1520
Last Molecule Delay
"Worst Case"
Charged particles
from measurement pulse
1350
Optimized Measurement
Window in which
Sensor is Active
First Molecule Delay
"Best Case"
Rising-Edge
1510
Measure-
ment Laser
Pulse
Activity 1520
Number of
Charged
Molecules
hitting
Anode
1525
t1
t2
t3

FIG. 13