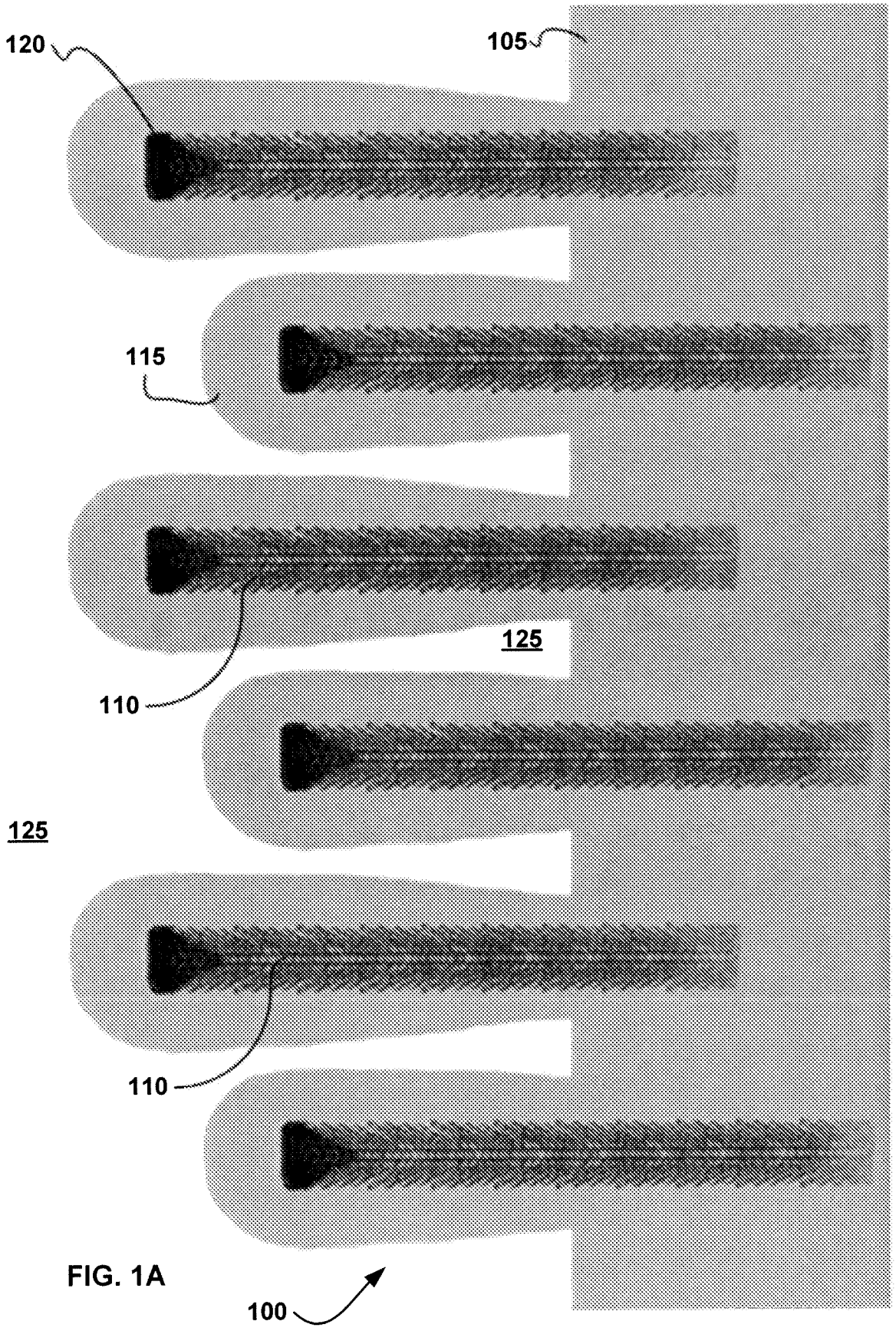


FIG. 1A

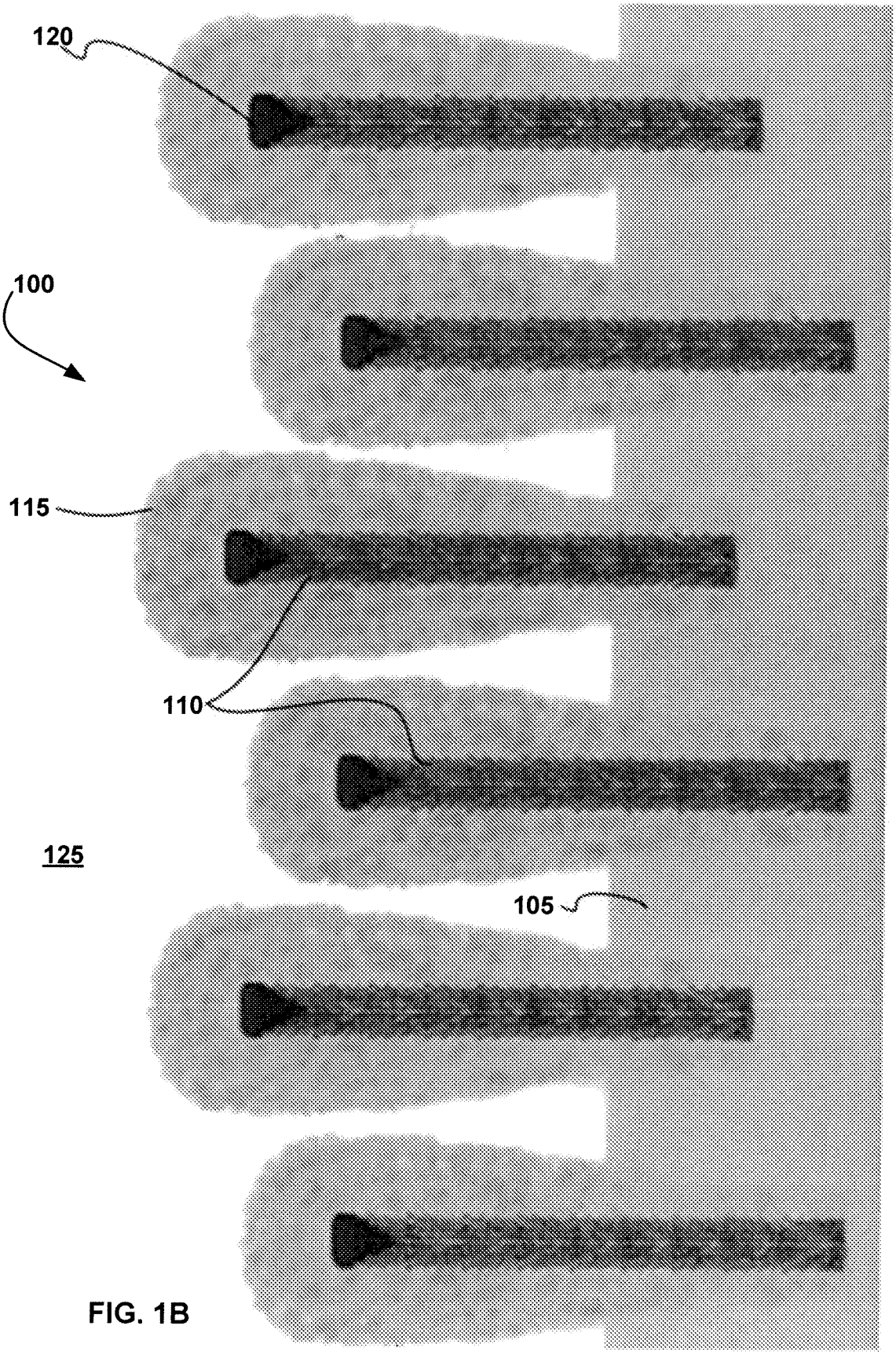


FIG. 1B

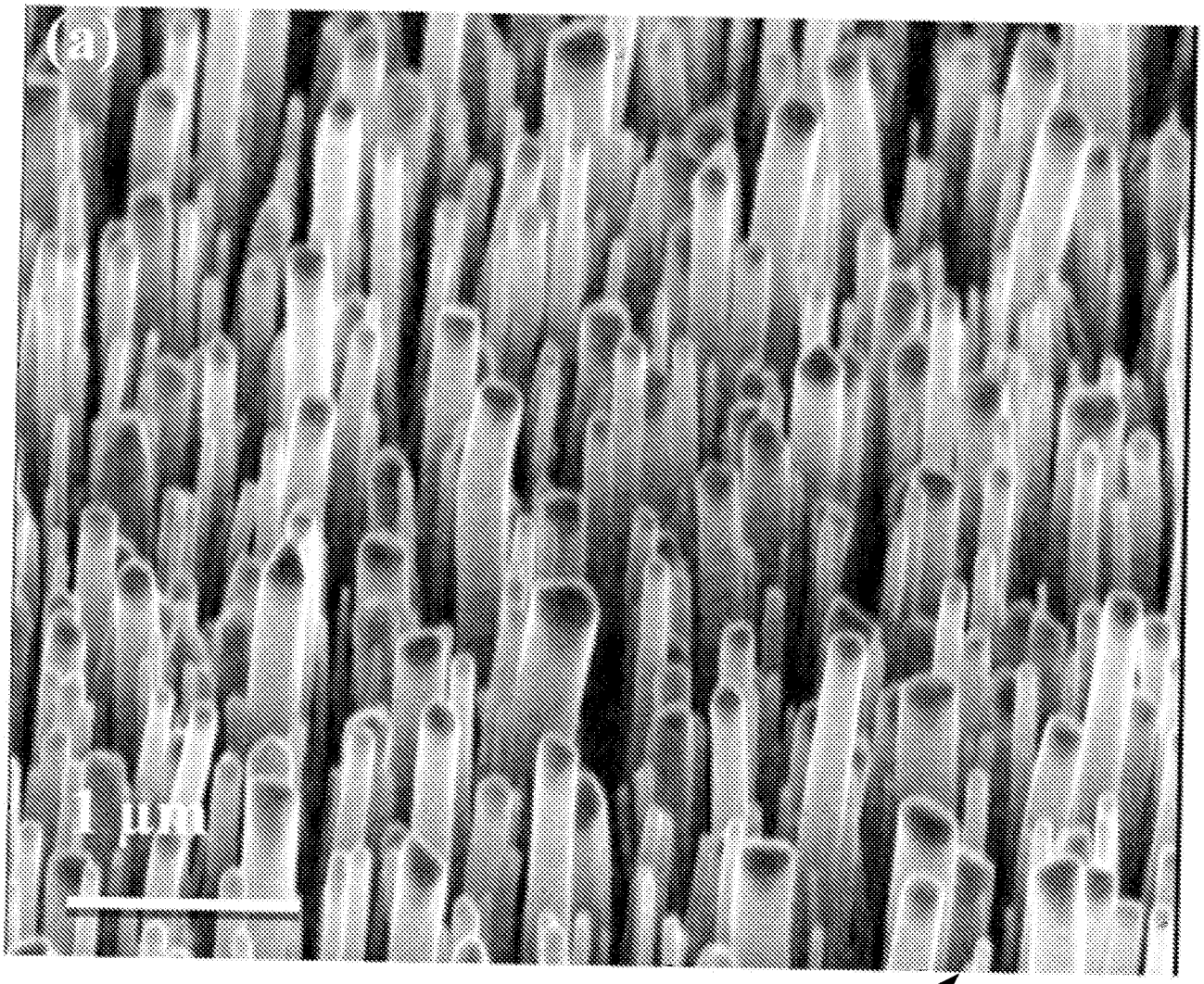


FIG. 2A

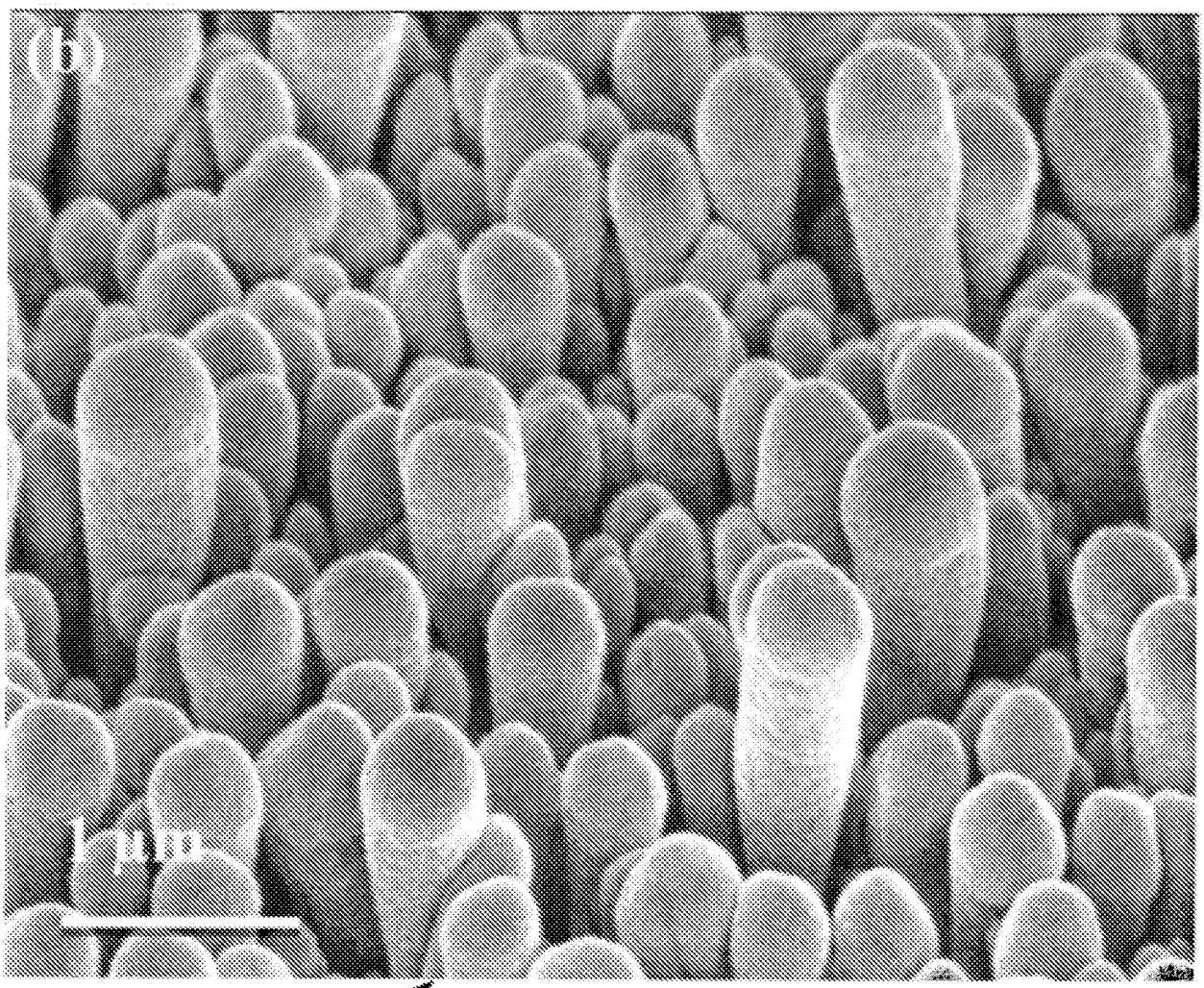


FIG. 2B



FIG. 2C

100

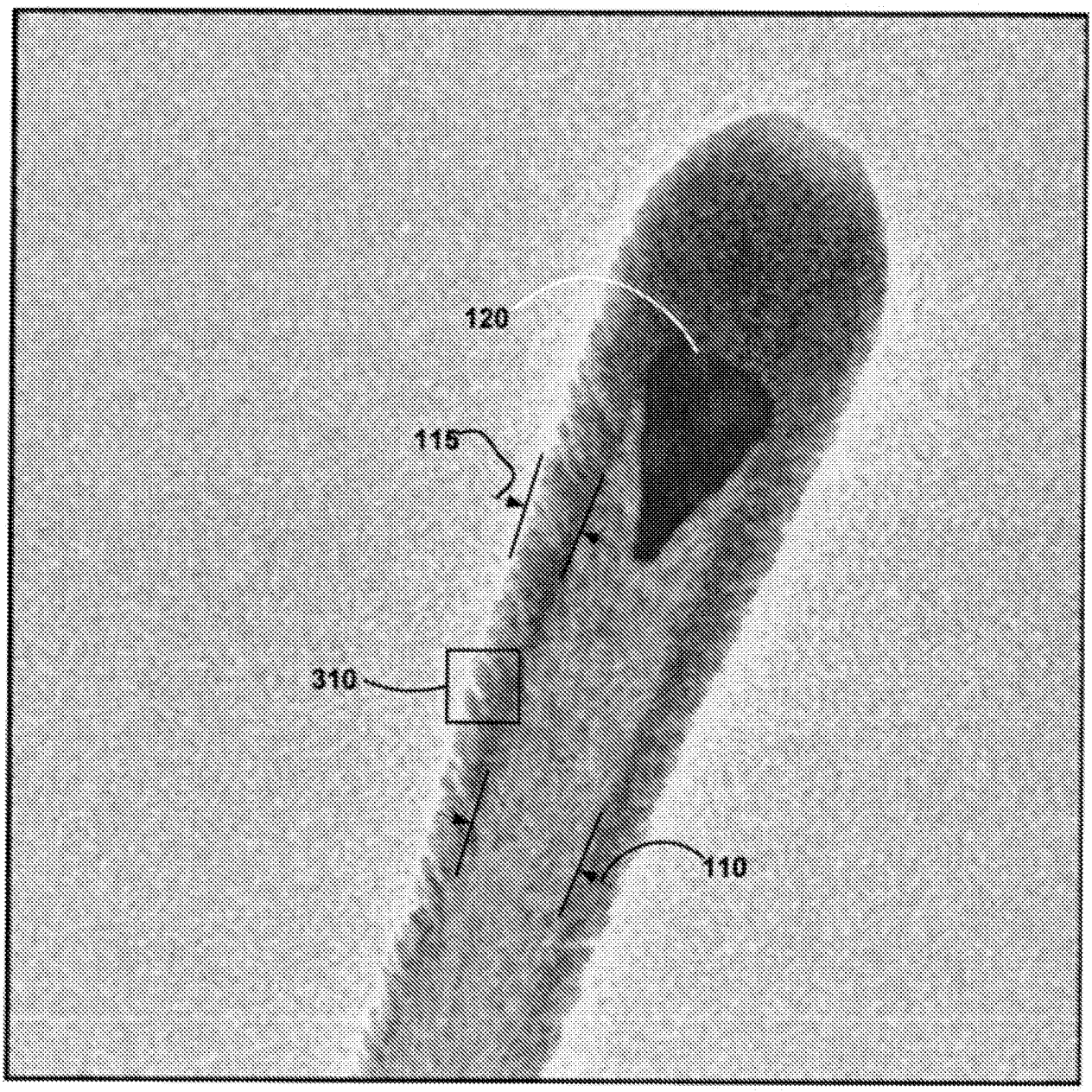


FIG. 3A

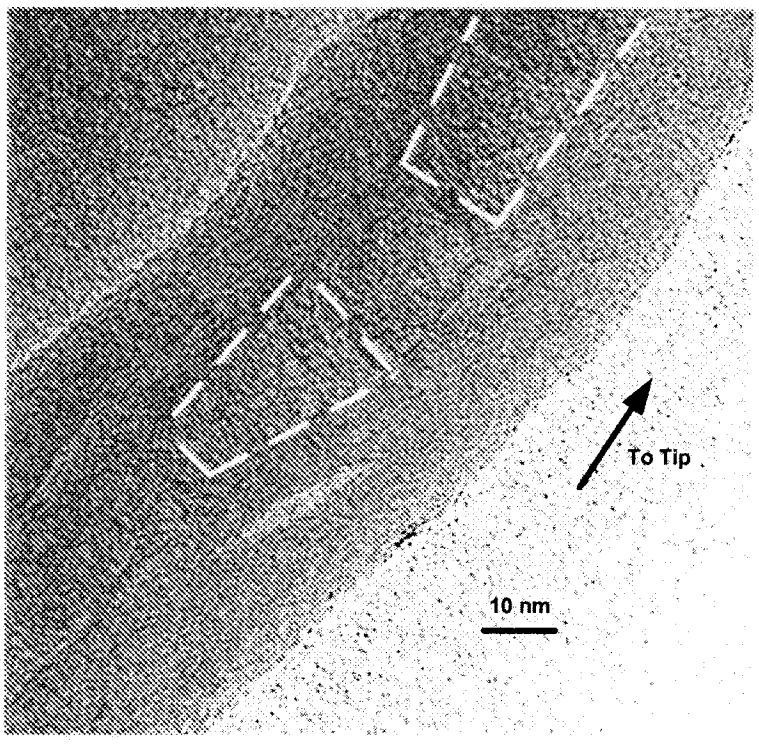


FIG. 3B

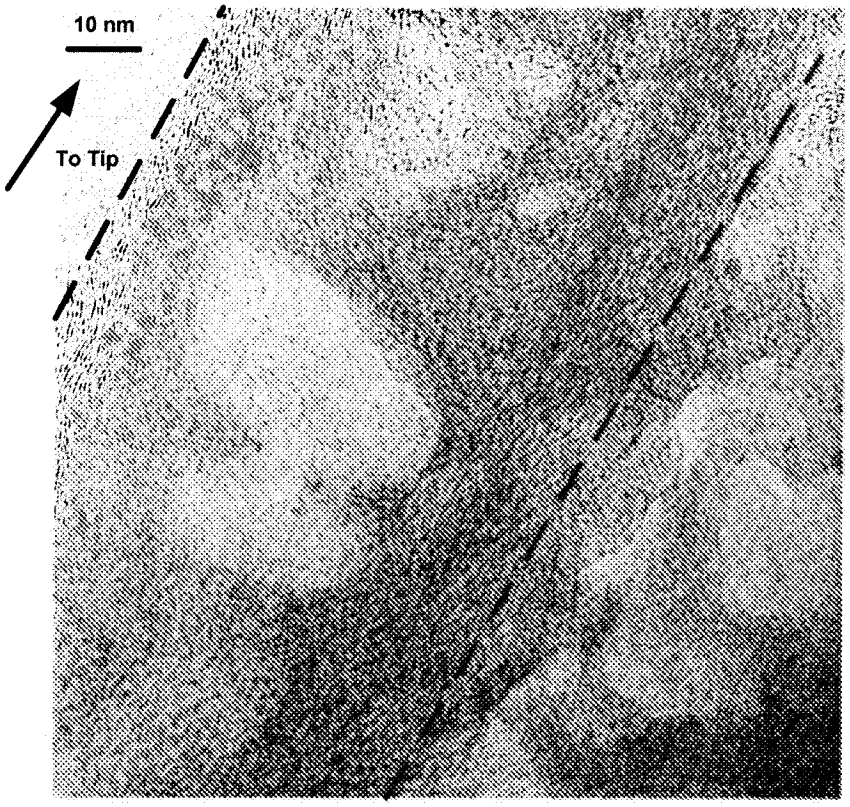


FIG. 3C

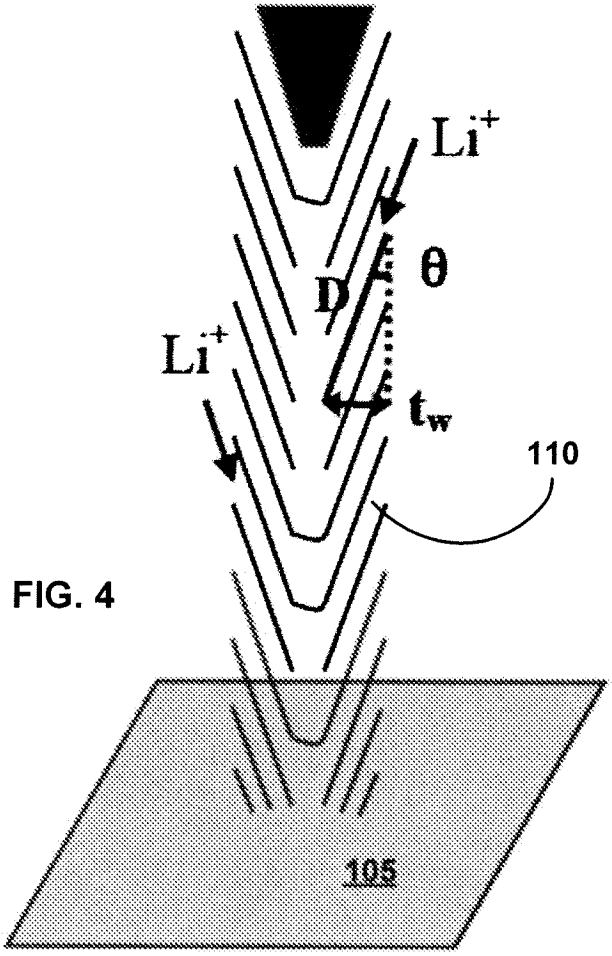


FIG. 4

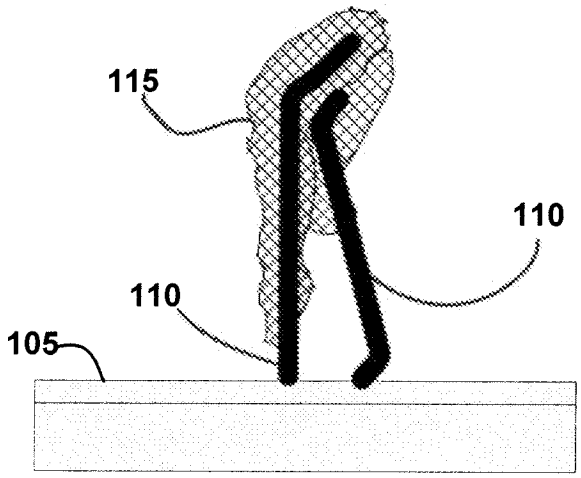


FIG. 11D

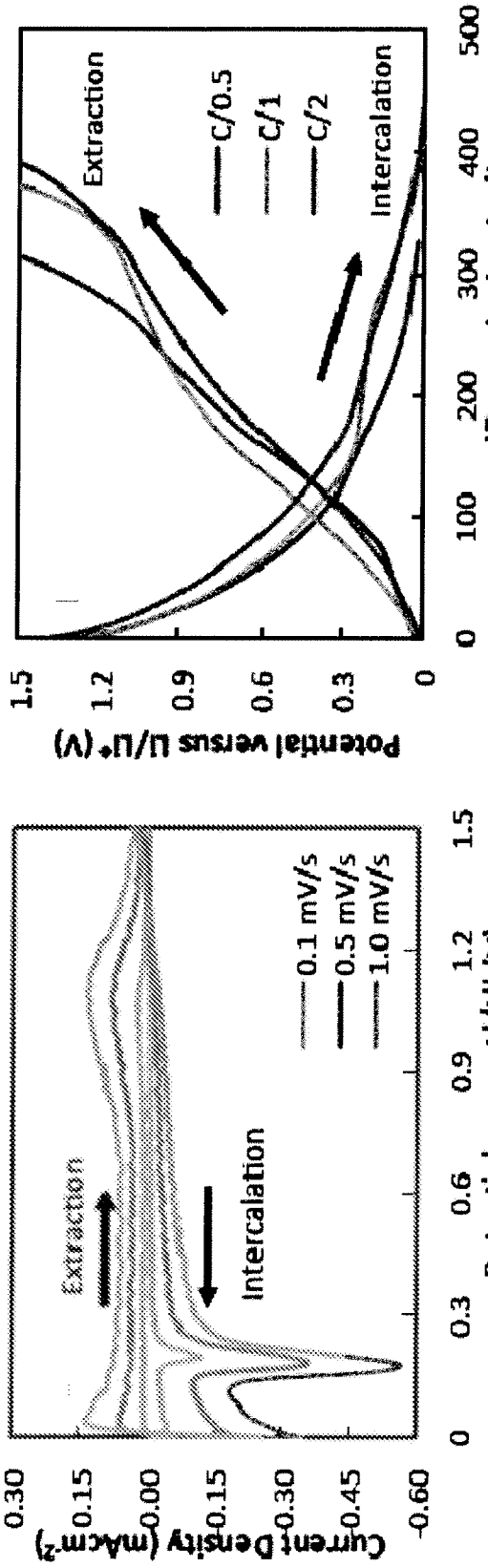


FIG. 5A

FIG. 5B

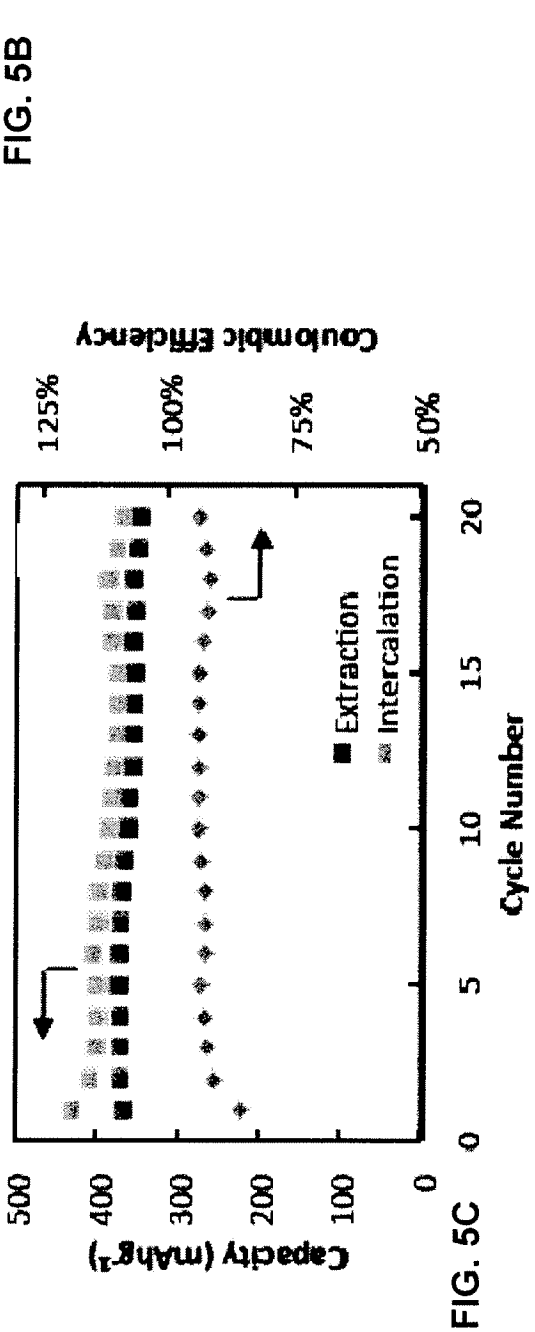


FIG. 5C

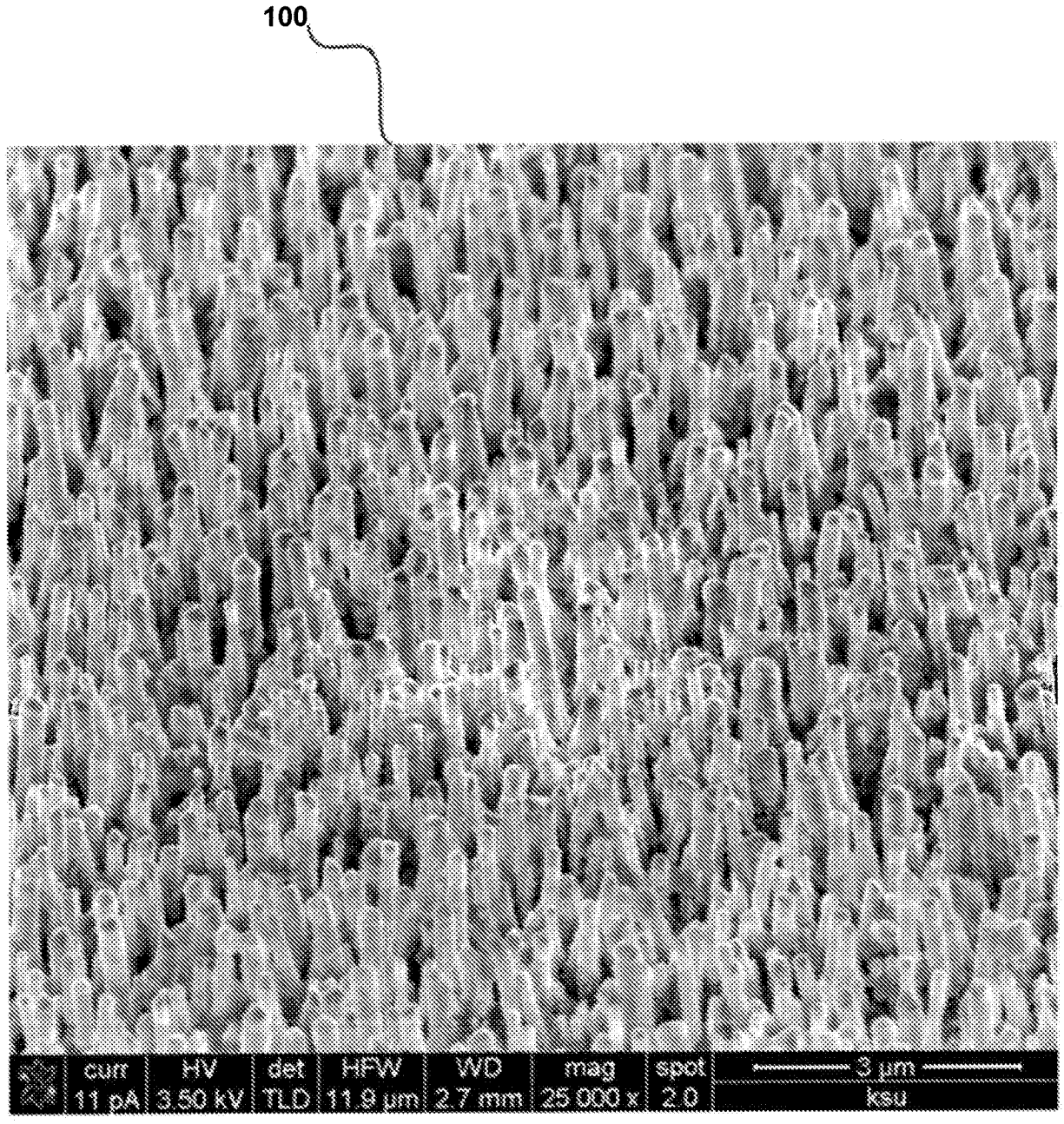

100
curr
11 pA
HV
3.50 kV
det
TLD
HFW
11.9 µm
WD
2.7 mm
mag
25 000 x
spot
2.0
3 µm
ksu

FIG. 6A

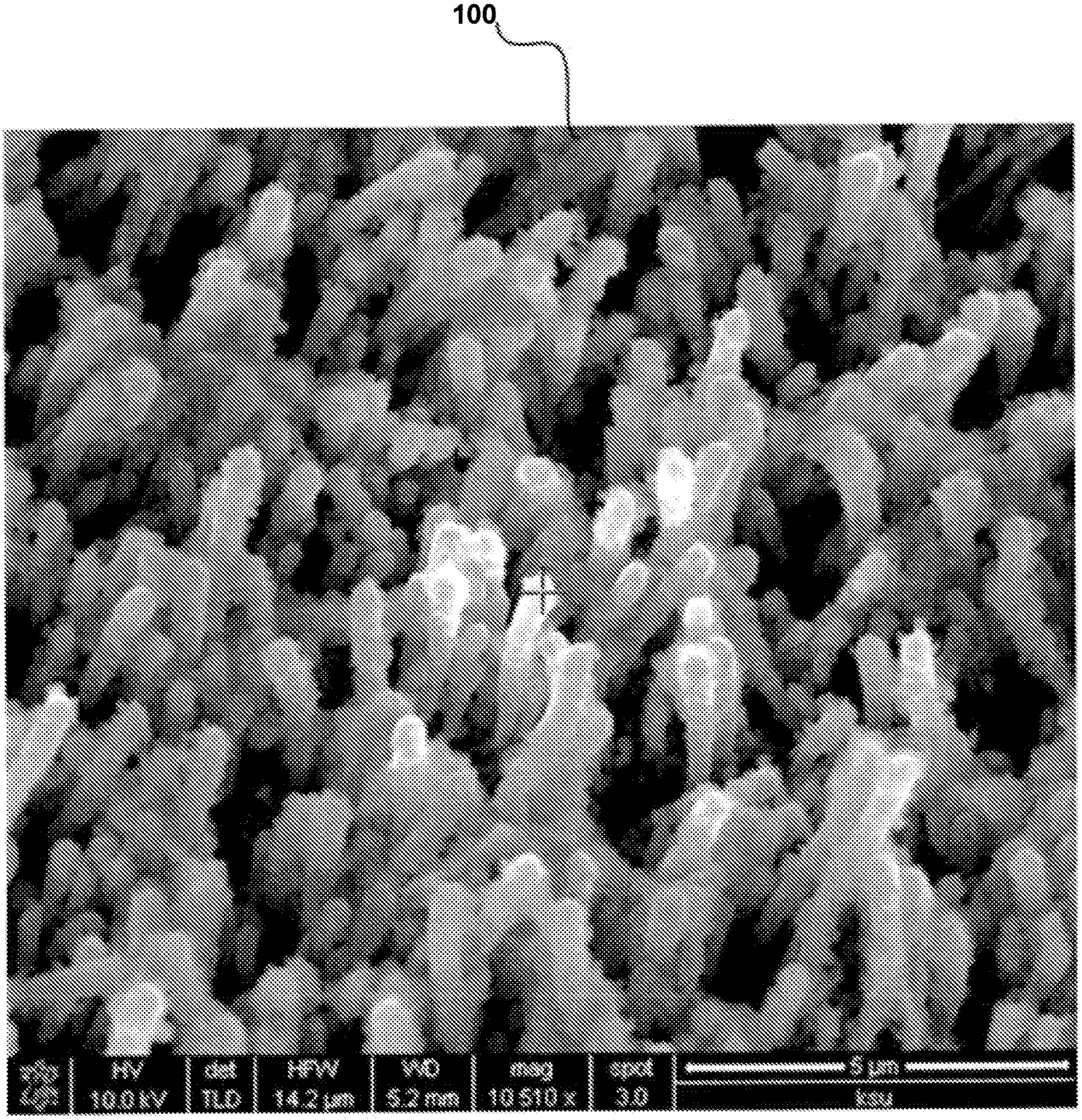

100
HV
10.0 kV
det
TLD
HFW
14.2 µm
WD
5.2 mm
mag
10 510 x
spot
3.0
5 µm
ESM

FIG. 6B

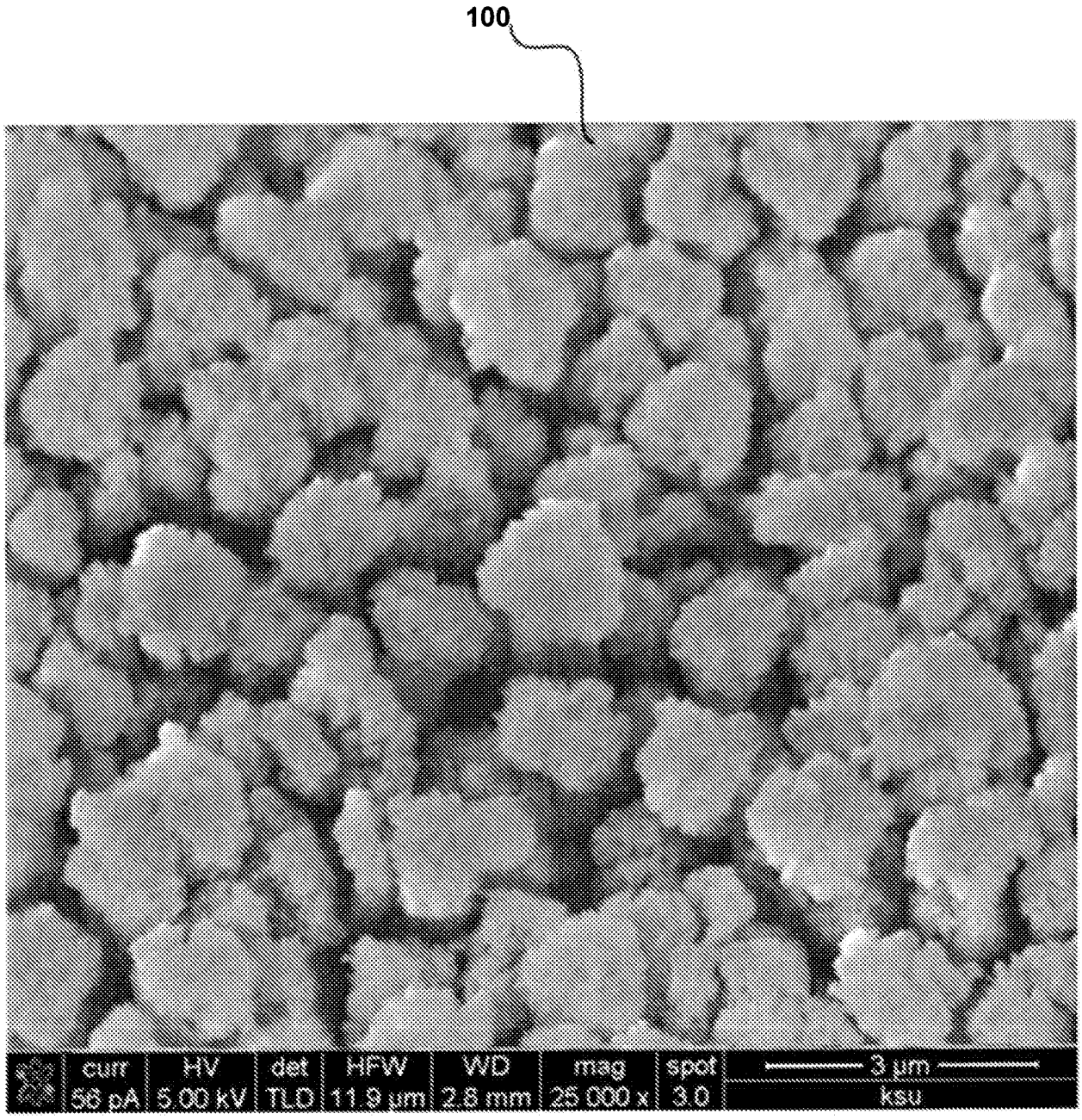
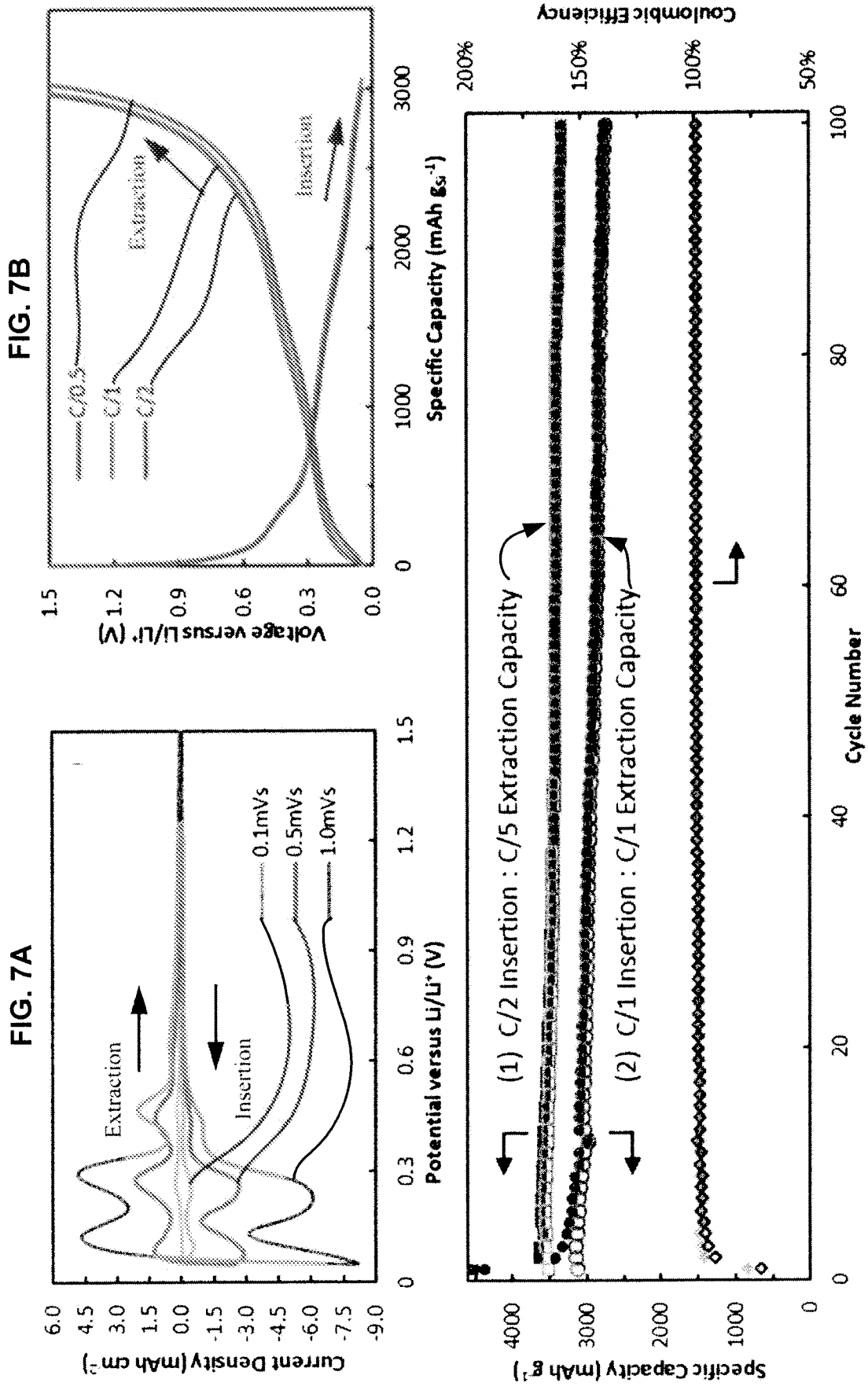

100
curr
56 pA
HV
5.00 kV
det
TLD
HFW
11.9 um
WD
2.8 mm
mag
25 000 x
spot
3.0
3 um
ksu

FIG. 6C


FIG. 7A
Extraction
Insertion
0.1mVs
0.5mVs
1.0mVs
Current Density (mAh cm⁻²)
Potential versus Li/Li⁺ (V)
FIG. 7B
C/0.5
C/1
C/2
Extraction
Insertion
Voltage versus Li/Li⁺ (V)
Specific Capacity (mAh gs⁻¹)
FIG. 7C
(1) C/2 Insertion : C/5 Extraction Capacity
(2) C/1 Insertion : C/1 Extraction Capacity
Specific Capacity (mAh g⁻¹)
Coulombic Efficiency
Cycle Number

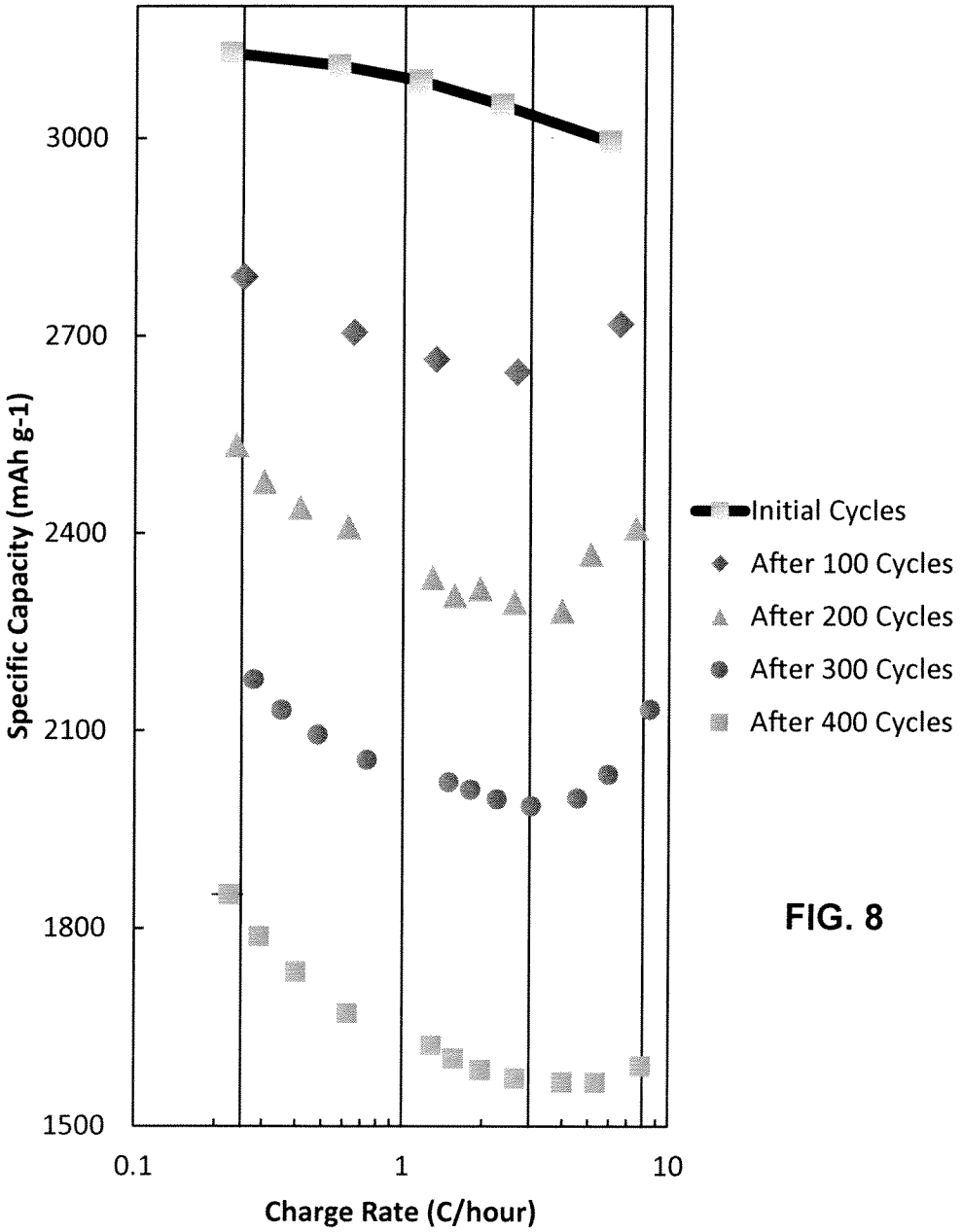

3000
2700
2400
2100
1800
1500
Specific Capacity (mAh g-1)
0.1
1
10
Charge Rate (C/hour)
Initial Cycles
After 100 Cycles
After 200 Cycles
After 300 Cycles
After 400 Cycles

FIG. 8

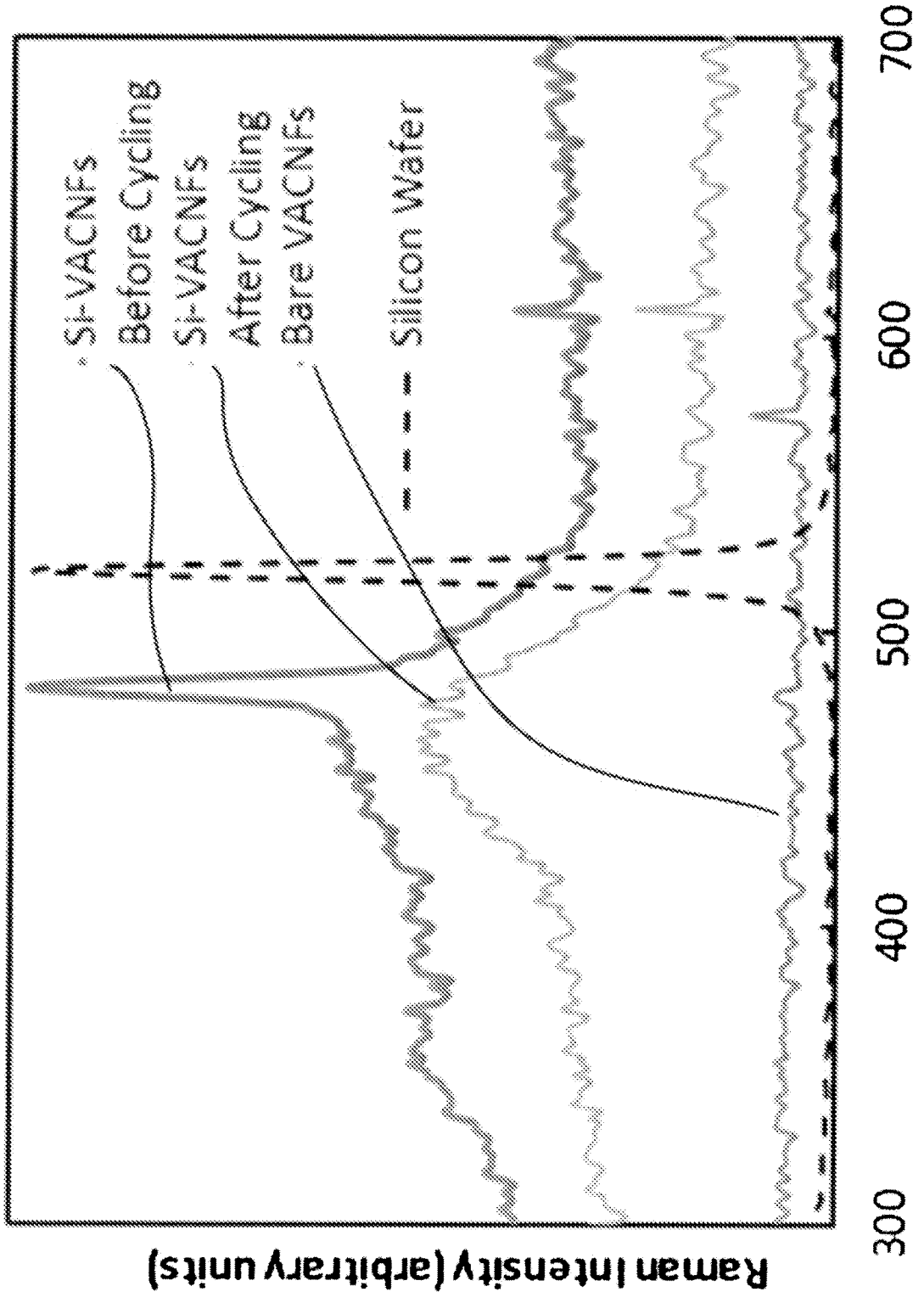

Si-VACNFs
Before Cycling
Si-VACNFs
After Cycling
Bare VACNFs
Silicon Wafer
Raman Intensity (arbitrary units)
300
400
500
600
700
Raman Shift (cm-1)

FIG. 9

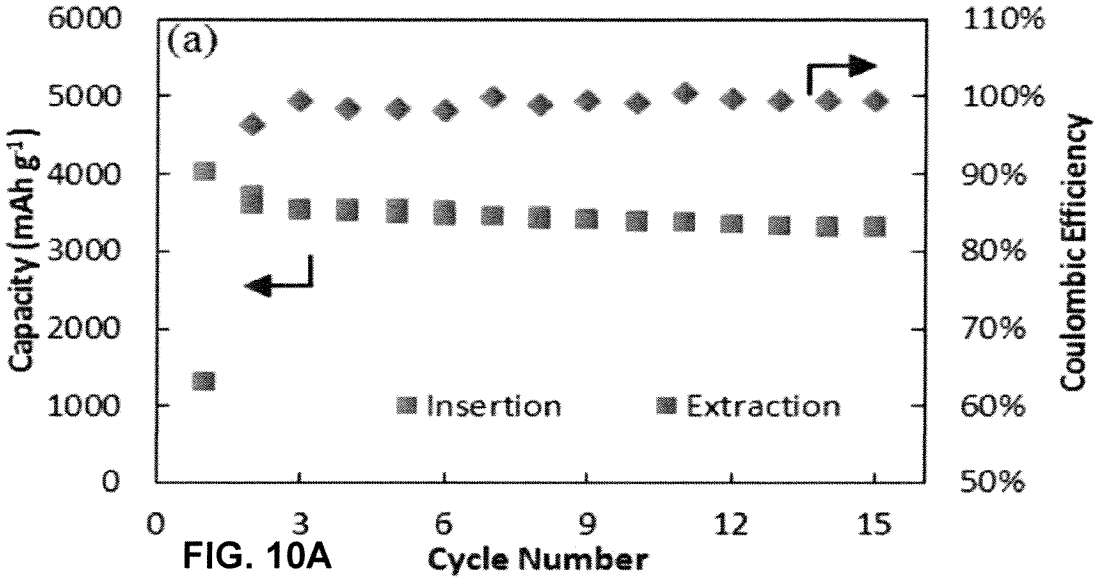


FIG. 10A

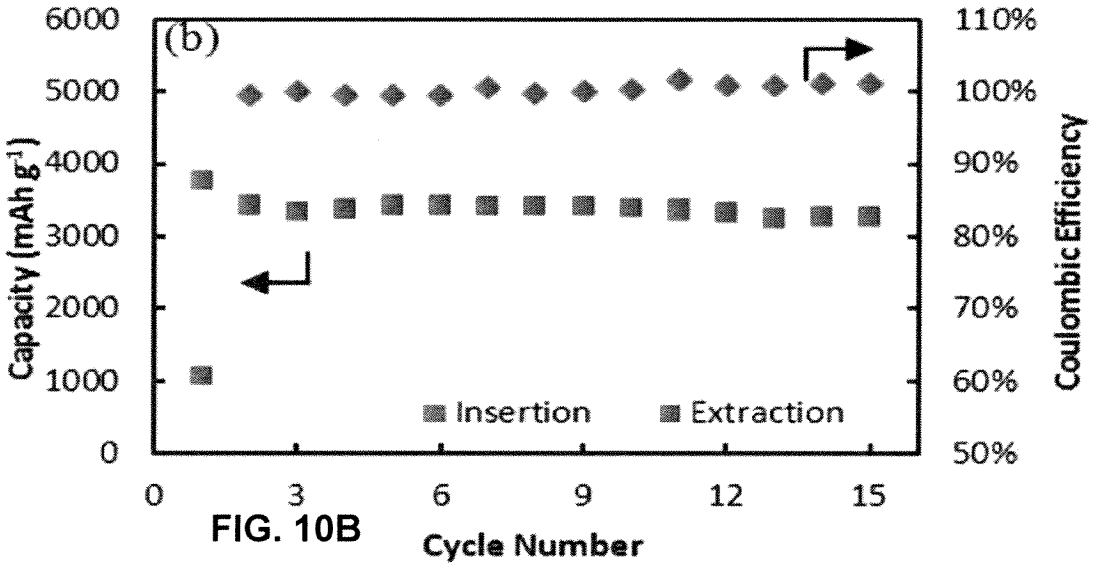


FIG. 10B

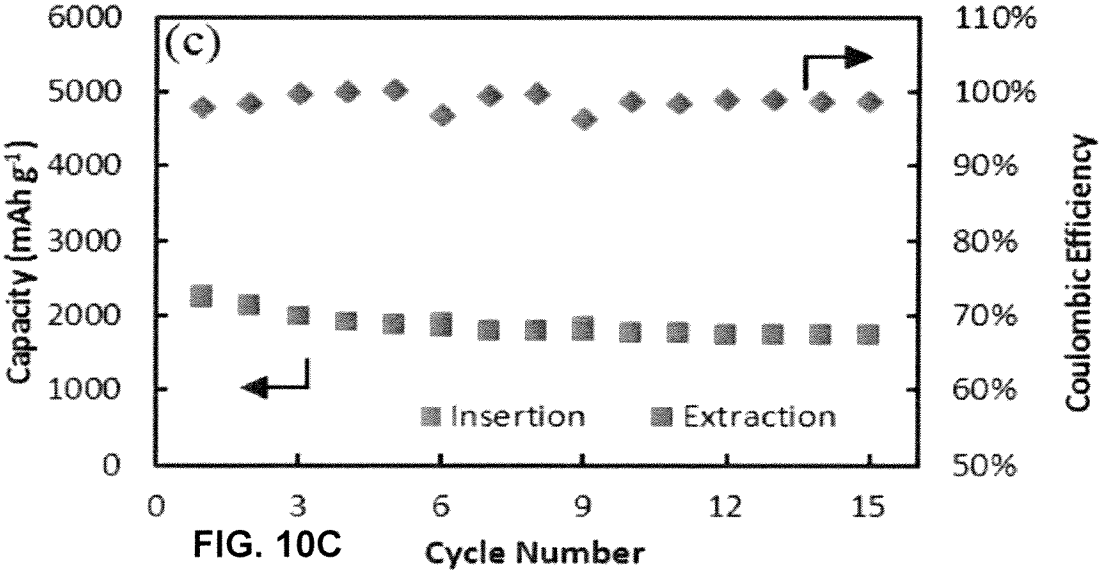


FIG. 10C

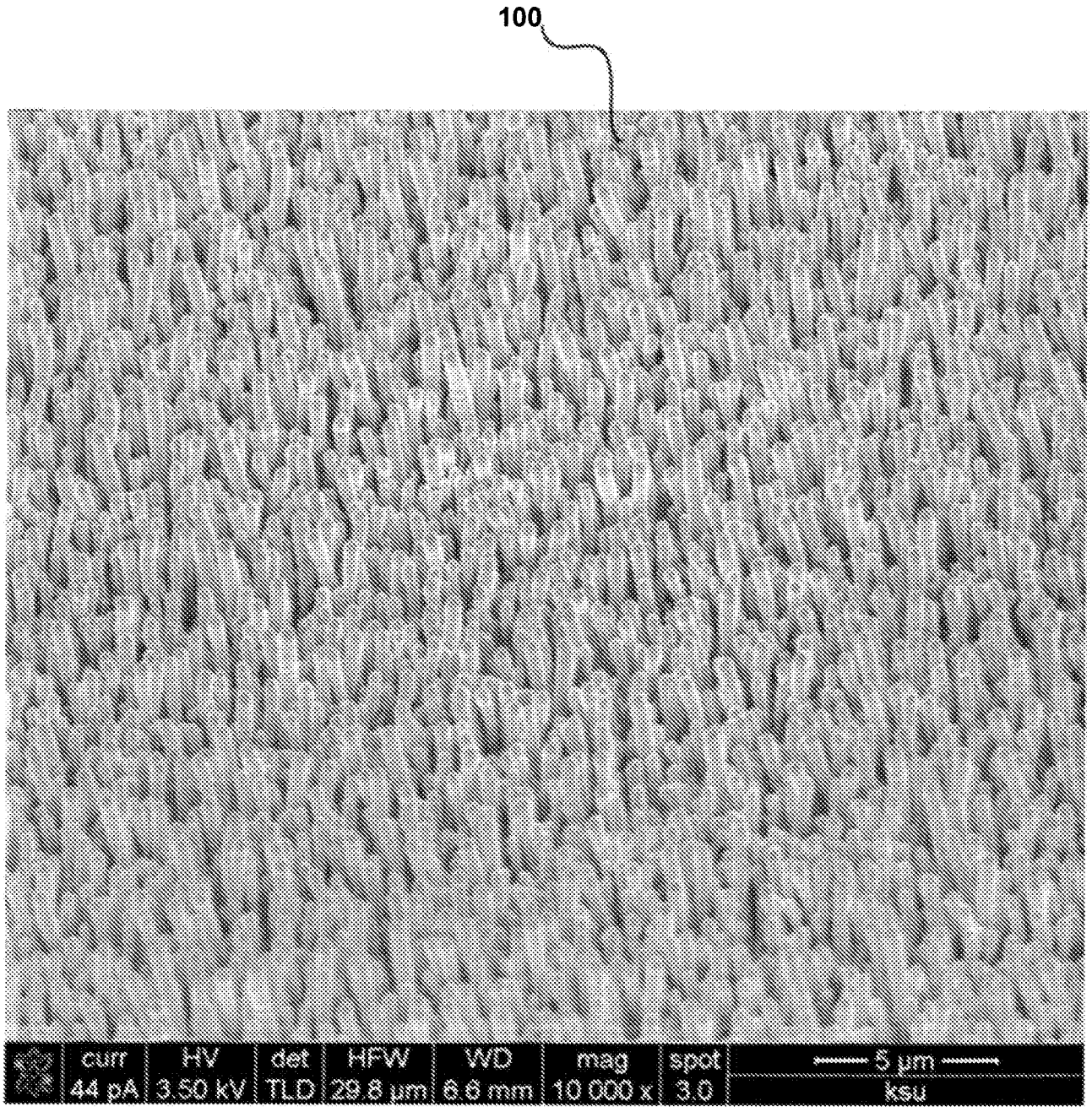

100
curr
44 pA
HV
3.50 kV
det
TLD
HFW
29.8 µm
WD
6.6 mm
mag
10 000 x
spot
3.0
5 µm
ksu

FIG. 11A

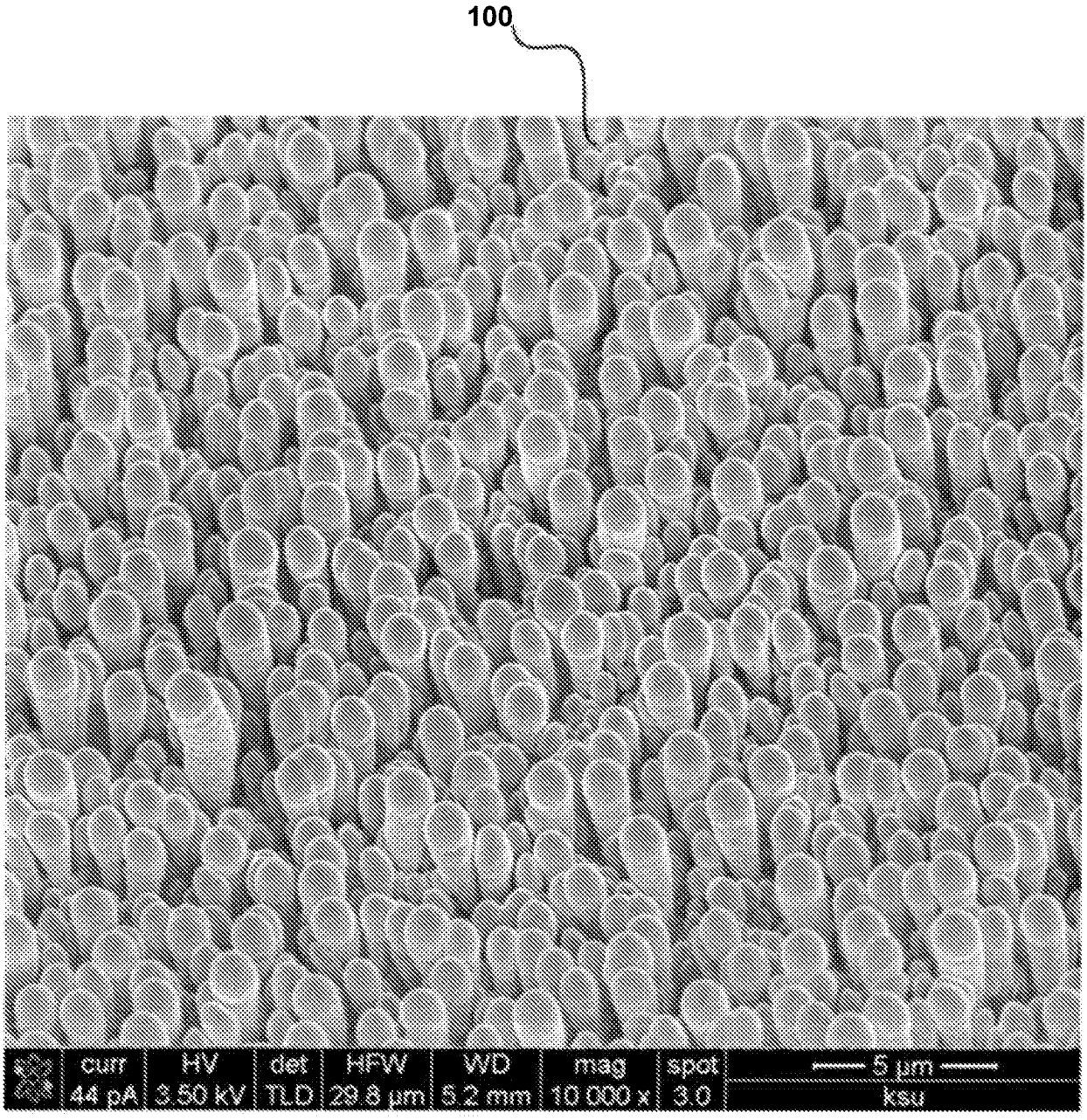

100
curr
44 pA
HV
3.50 kV
det
TLD
HFW
29.8 µm
WD
5.2 mm
mag
10 000 x
spot
3.0
5 µm
ksu

FIG. 11B

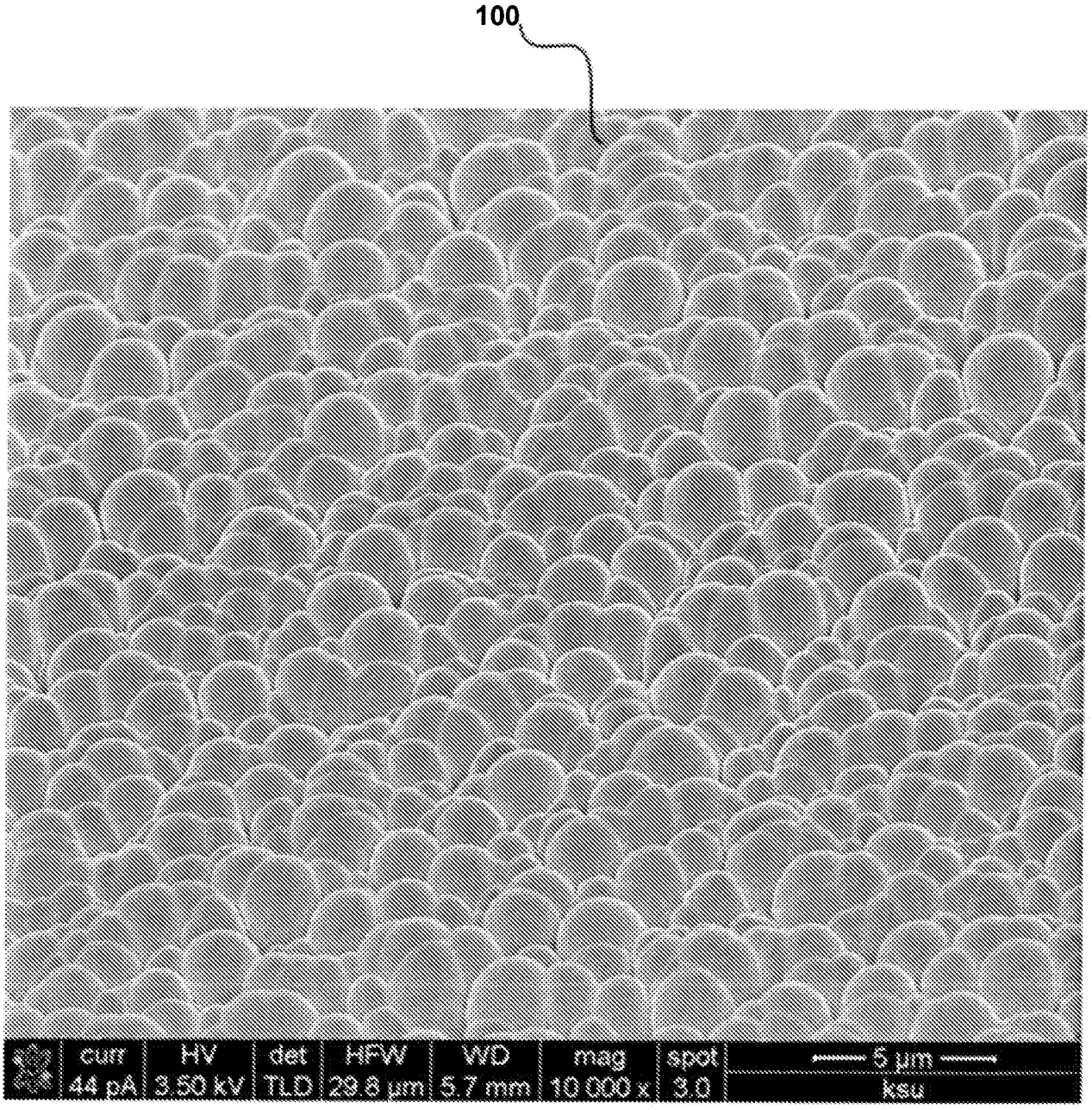

100
curr
44 pA
HV
3.50 kV
det
TLD
HFW
29.8 µm
WD
5.7 mm
mag
10 000 x
spot
3.0
5 µm
ksu

FIG. 11C

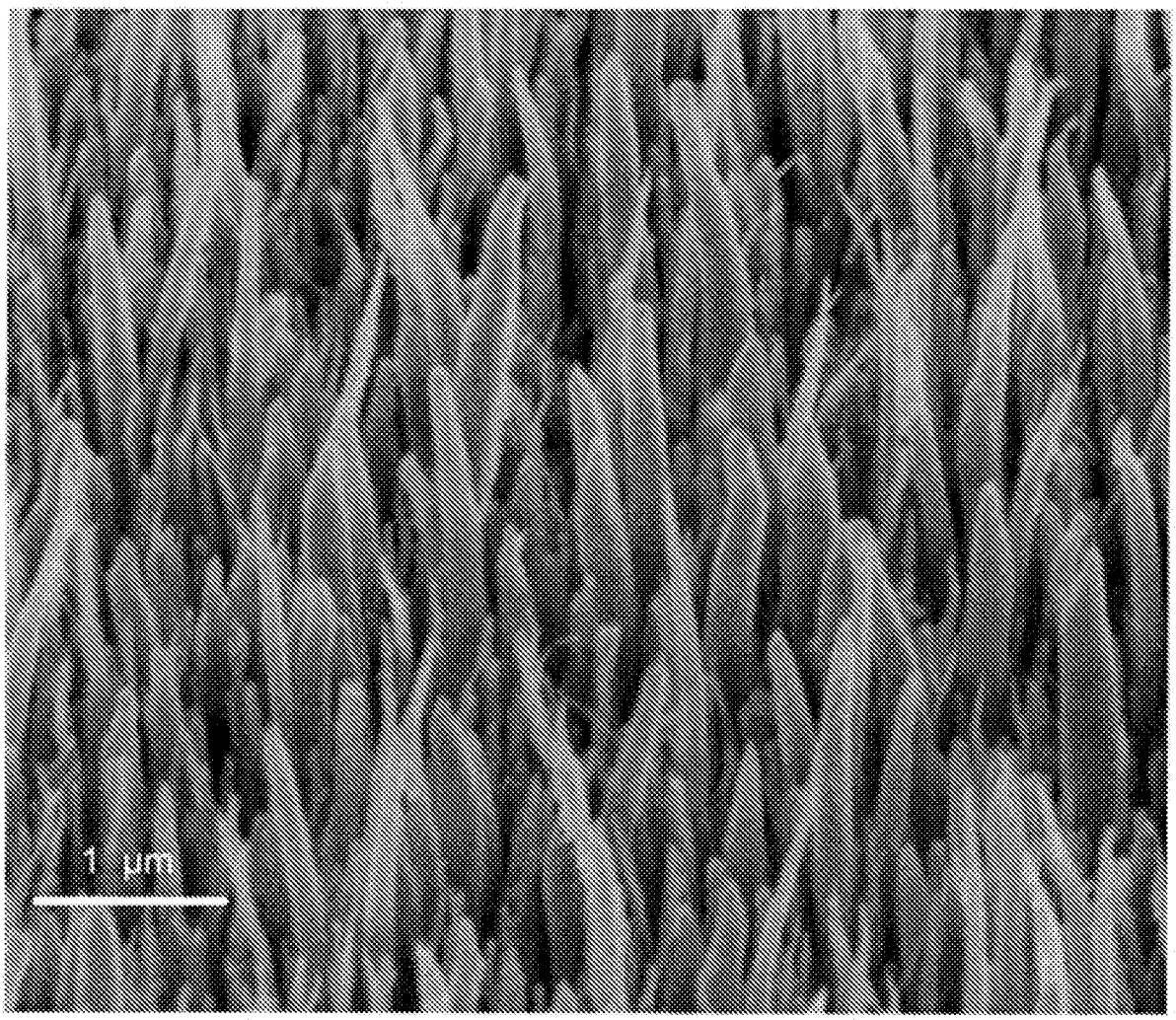

1 μm

FIG. 12

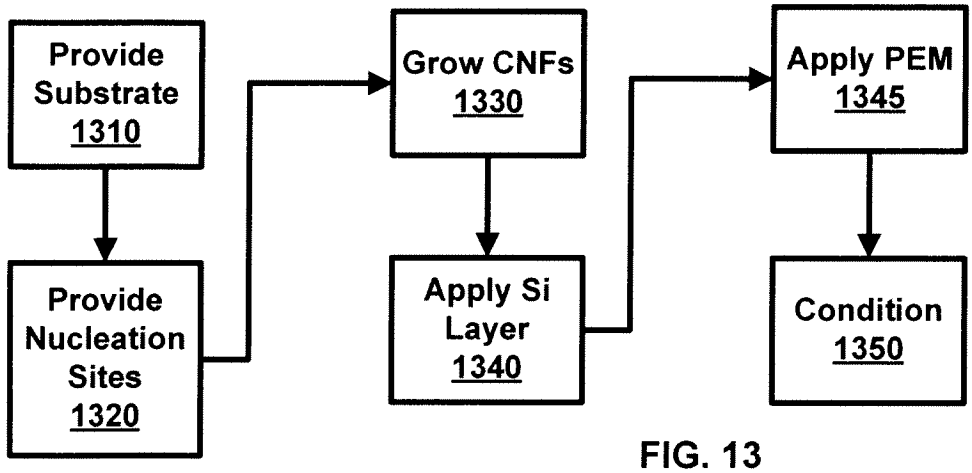

Provide Substrate 1310
Provide Nucleation Sites 1320
Grow CNFs 1330
Apply Si Layer 1340
Apply PEM 1345
Condition 1350

FIG. 13

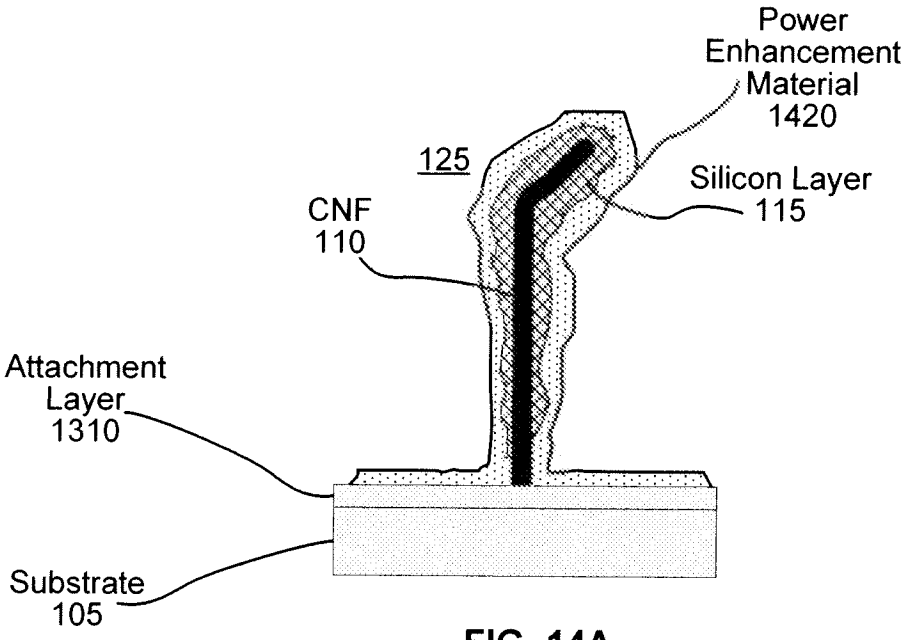


FIG. 14A

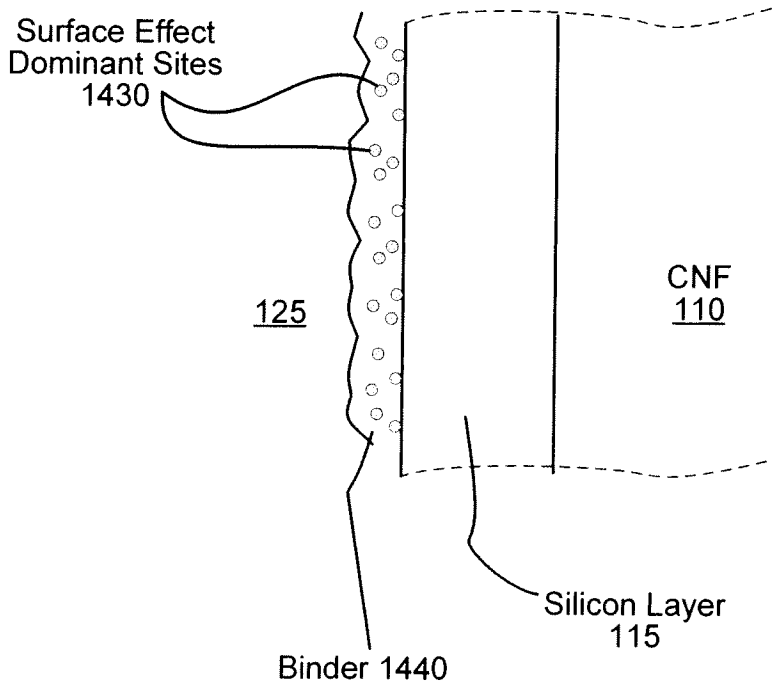


FIG. 14B

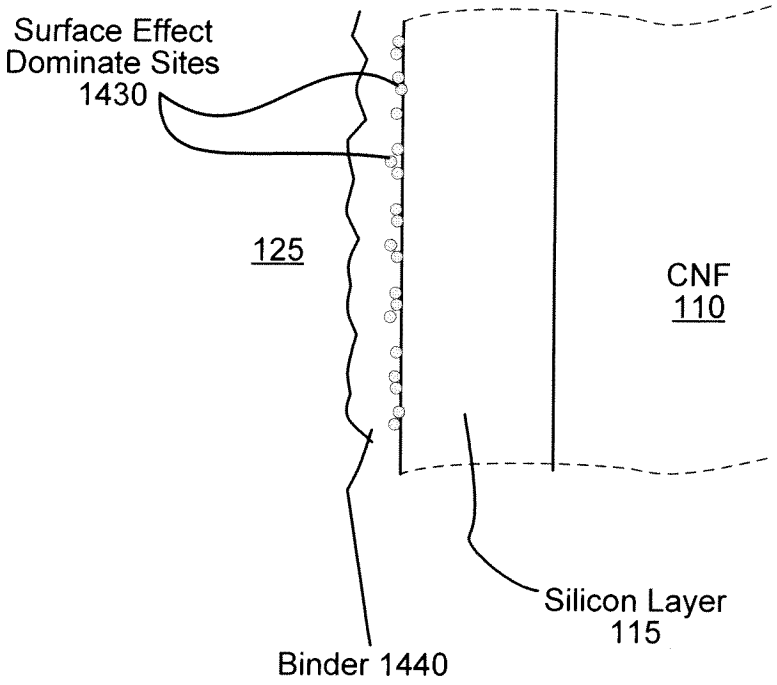

Surface Effect
Dominate Sites
1430
125
CNF
110
Silicon Layer
115
Binder 1440

FIG. 14C

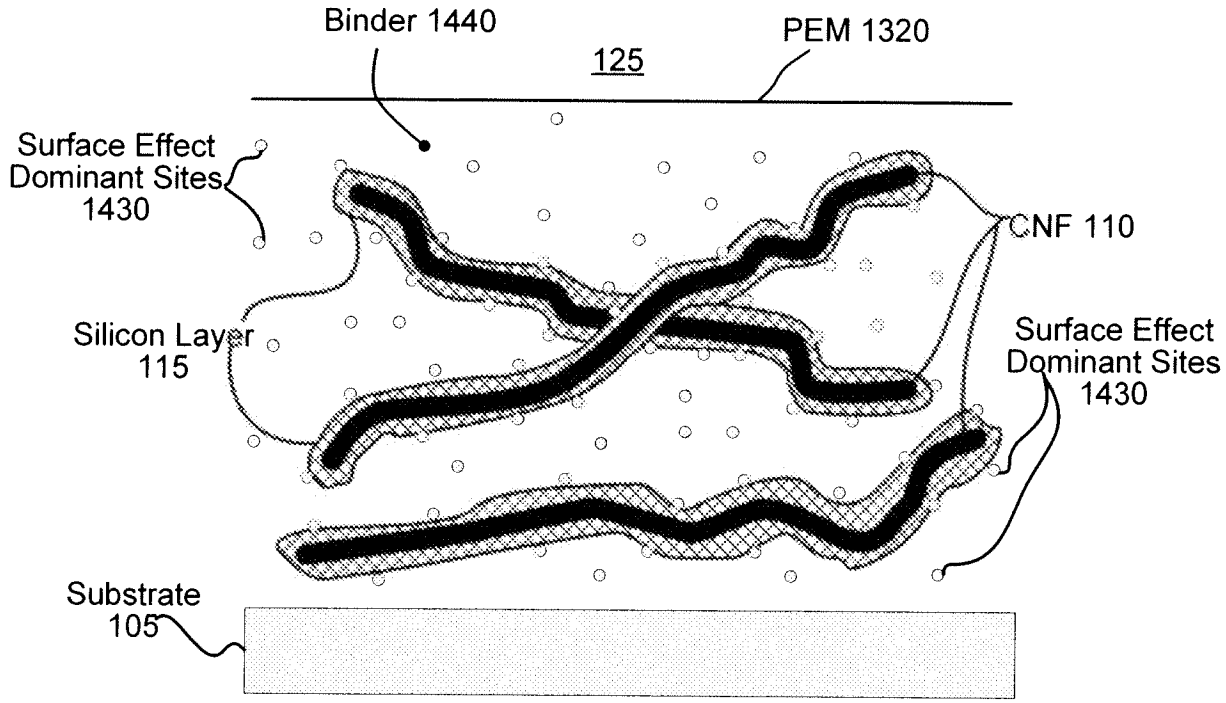

Binder 1440
PEM 1320
125
Surface Effect Dominant Sites 1430
CNF 110
Silicon Layer 115
Surface Effect Dominant Sites 1430
Substrate 105

FIG. 15

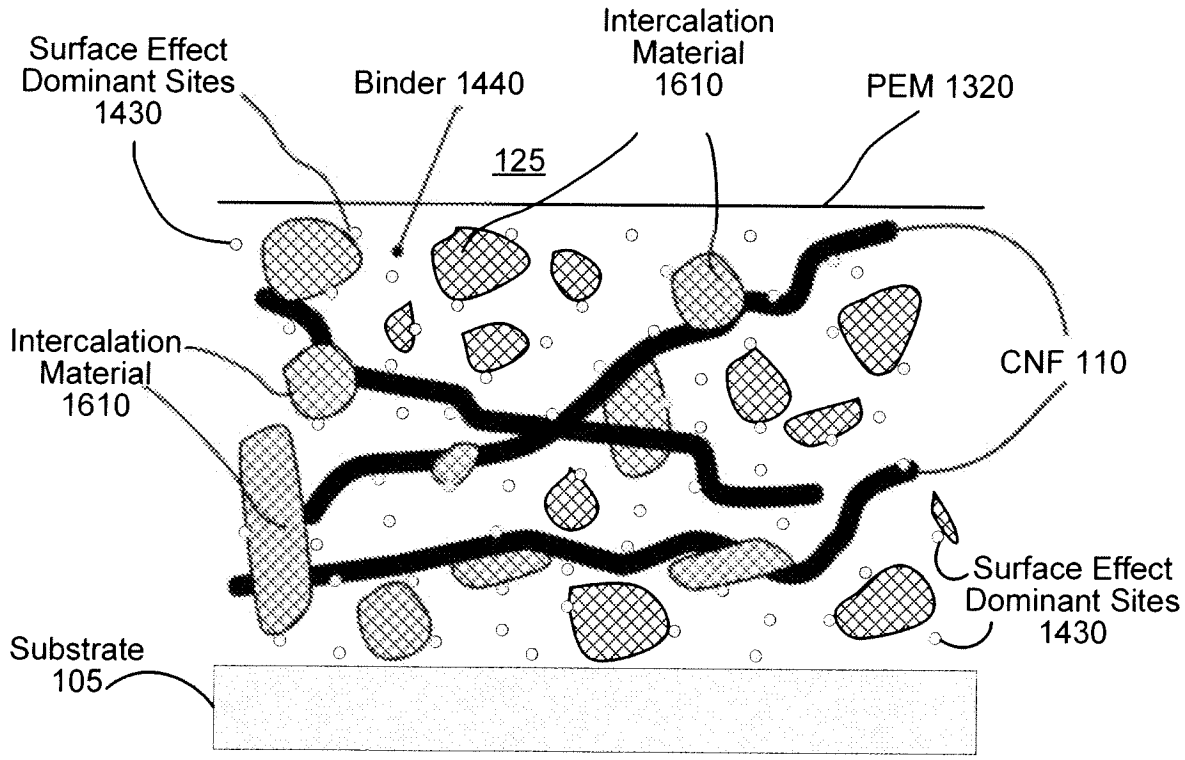

Intercalation Material 1610
Surface Effect Dominant Sites 1430
Binder 1440
PEM 1320
125
Intercalation Material 1610
CNF 110
Surface Effect Dominant Sites 1430
Substrate 105

FIG. 16

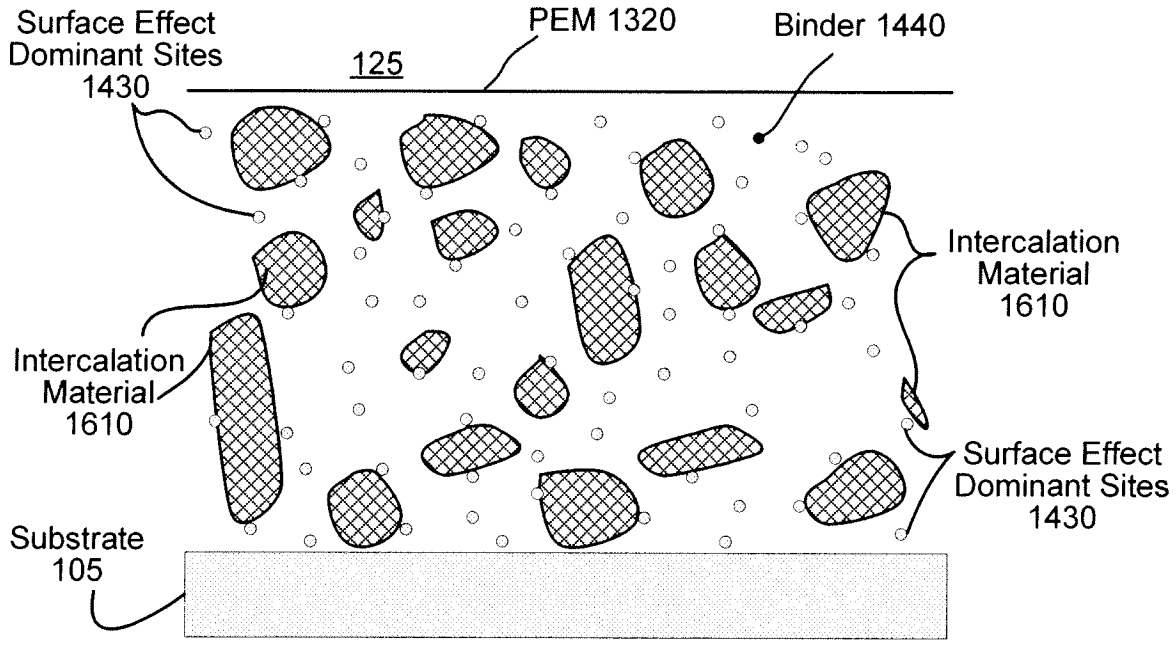

Surface Effect
Dominant Sites
1430
125
PEM 1320
Binder 1440
Intercalation
Material
1610
Intercalation
Material
1610
Surface Effect
Dominant Sites
1430
Substrate
105

FIG. 17

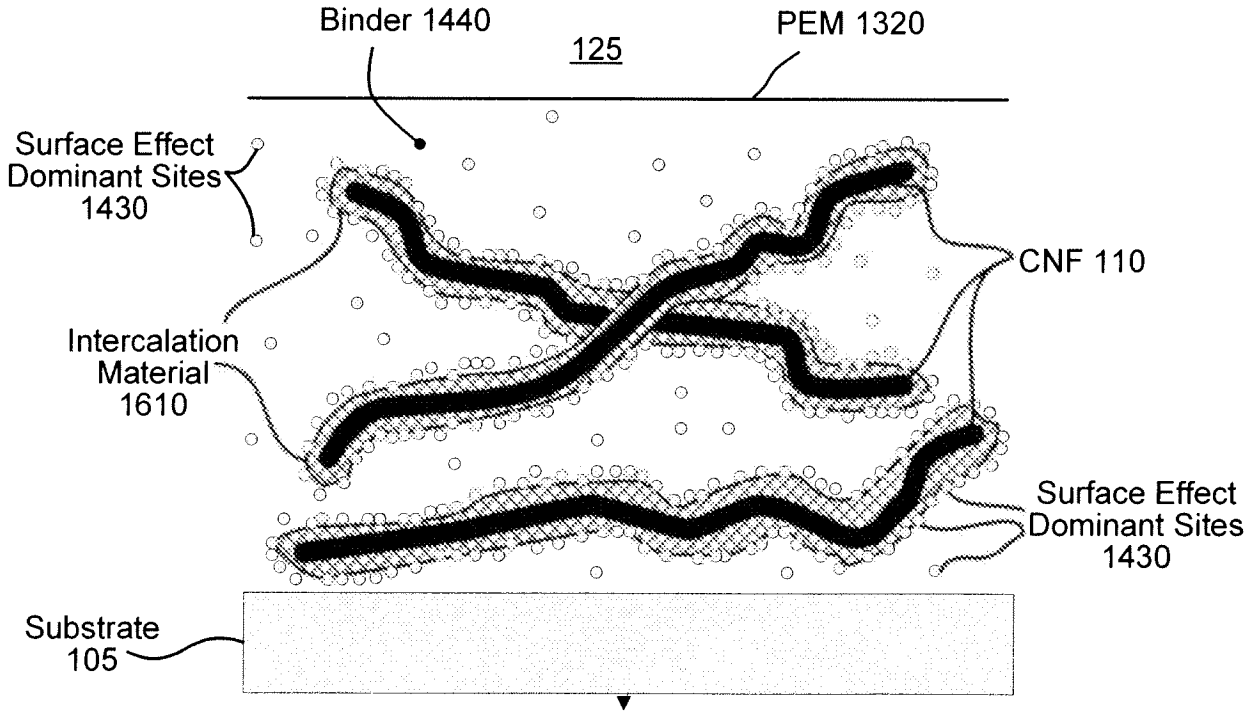

Binder 1440
125
PEM 1320
Surface Effect
Dominant Sites
1430
CNF 110
Intercalation
Material
1610
Surface Effect
Dominant Sites
1430
Substrate
105

FIG. 18

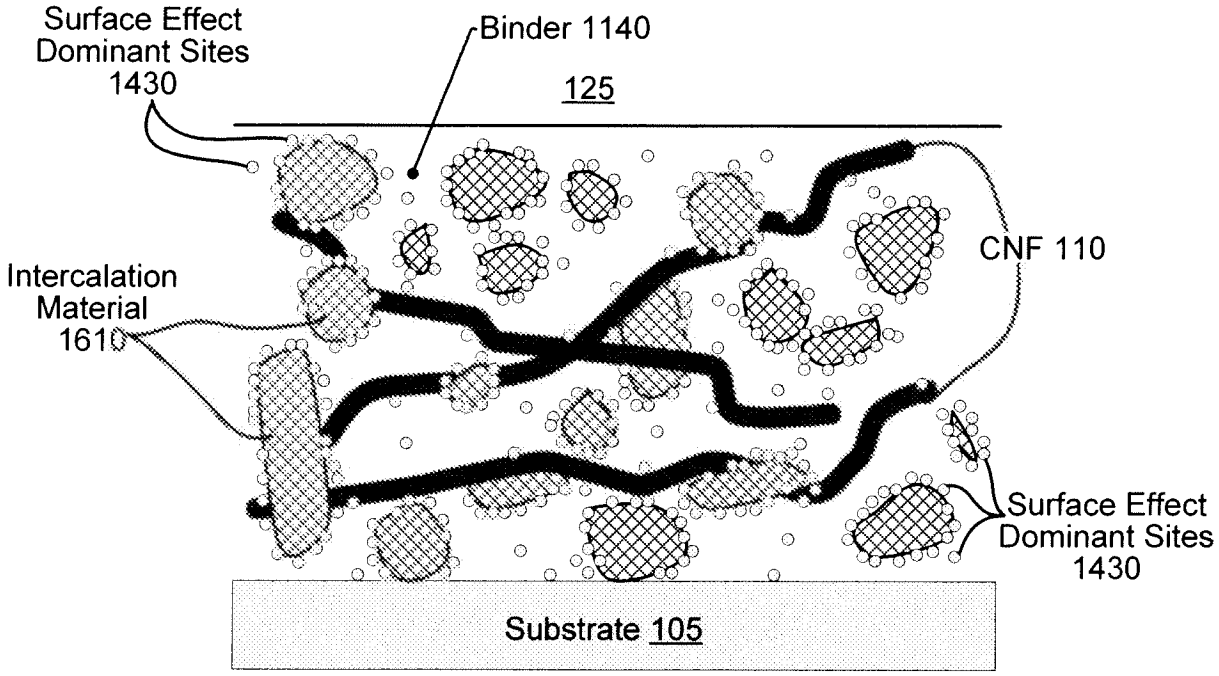

Surface Effect
Dominant Sites
1430
Binder 1140
125
CNF 110
Intercalation
Material
1610
Surface Effect
Dominant Sites
1430
Substrate 105

FIG. 19

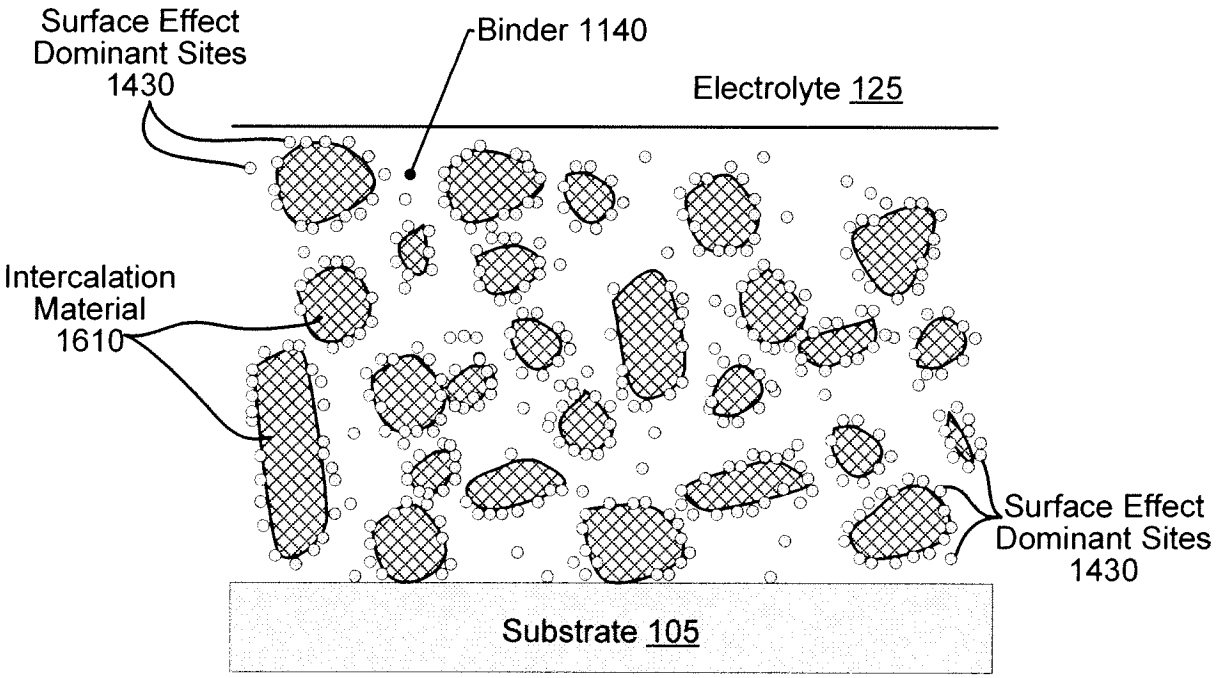

Surface Effect
Dominant Sites
1430
Binder 1140
Electrolyte 125
Intercalation
Material
1610
Surface Effect
Dominant Sites
1430
Substrate 105

FIG. 20

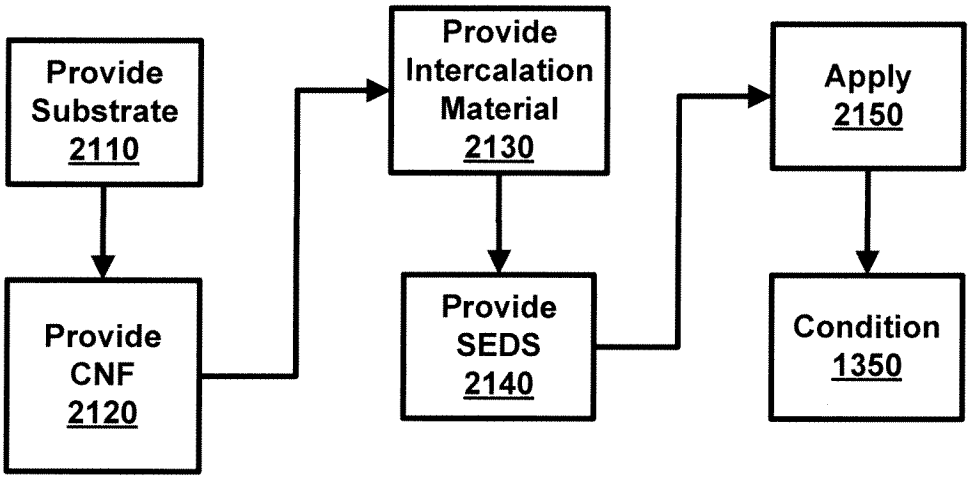

Provide Substrate 2110
Provide CNF 2120
Provide Intercalation Material 2130
Provide SEDS 2140
Apply 2150
Condition 1350

FIG. 21

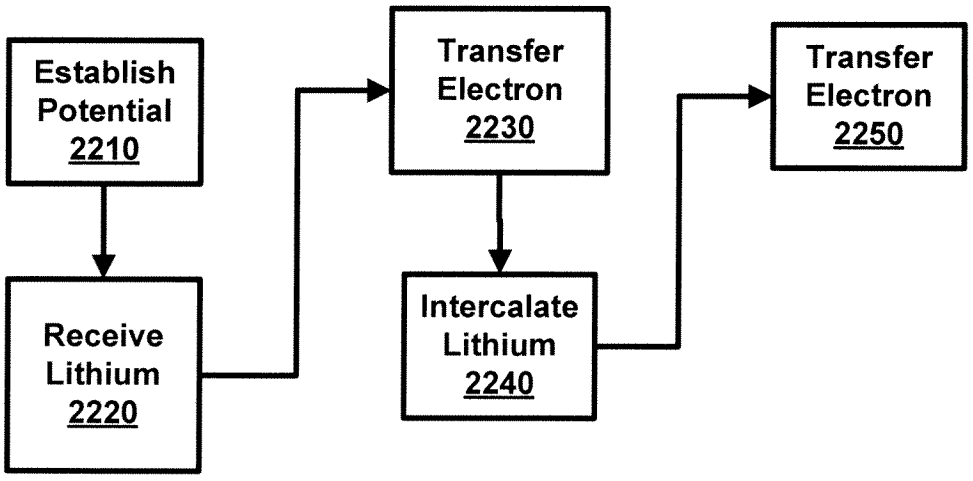

Establish Potential 2210
Receive Lithium 2220
Transfer Electron 2230
Intercalate Lithium 2240
Transfer Electron 2250

FIG. 22