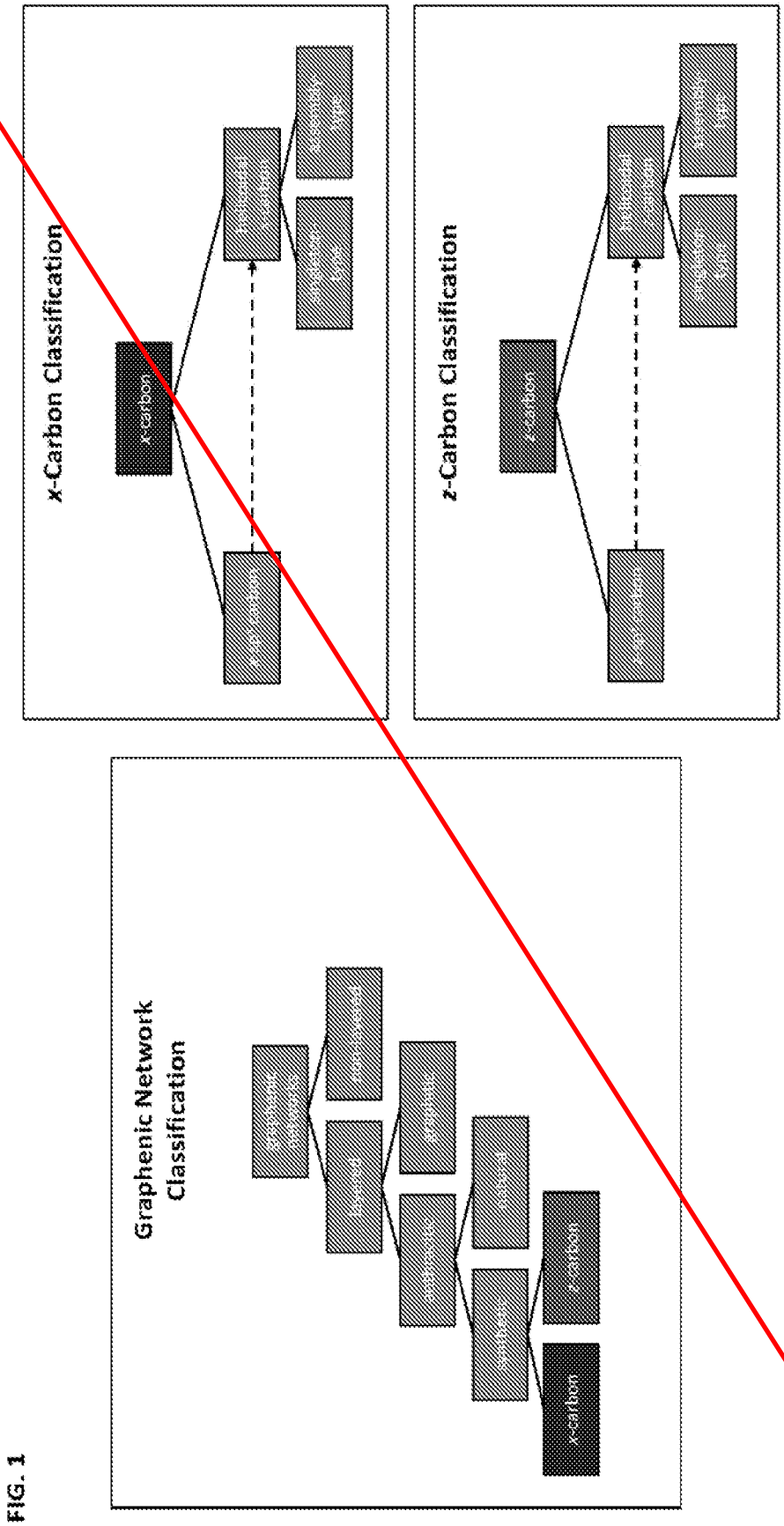

x-Carbon Classification
x-carbon
z-carbon
z-Carbon Classification
z-carbon
Graphenic Network Classification
x-carbon

FIG. 1

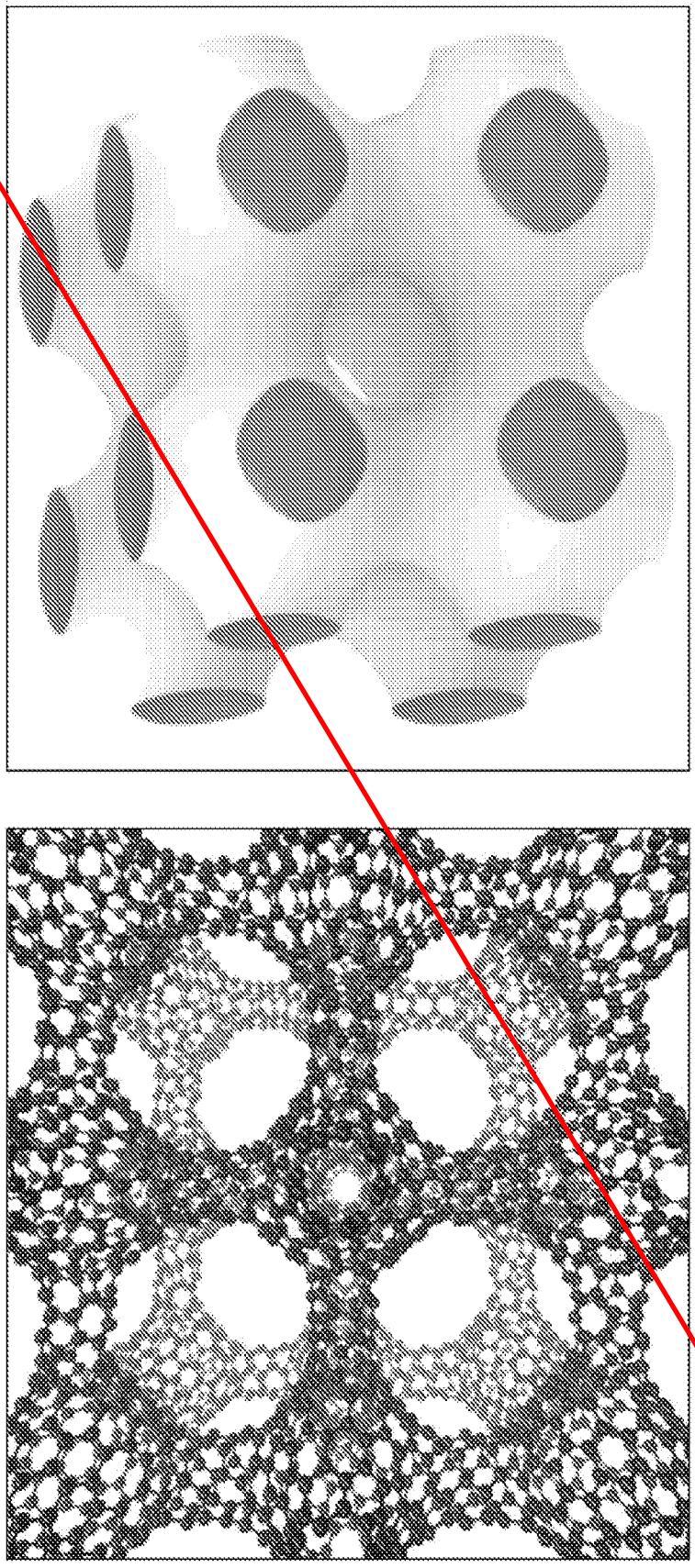


FIG. 4

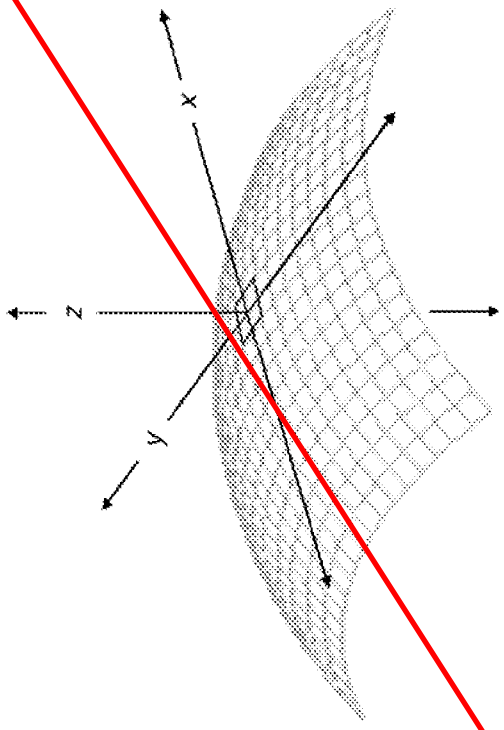


FIG. 3

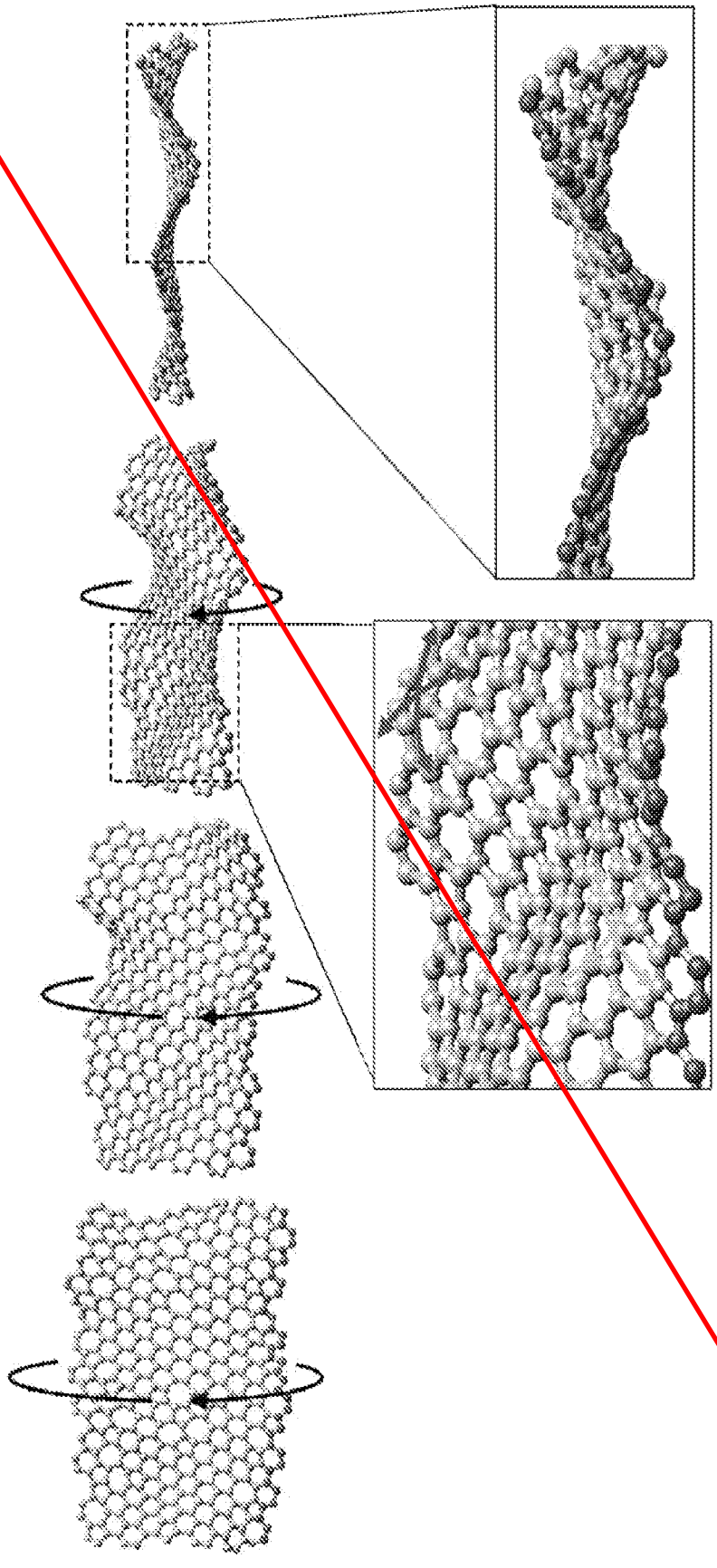


FIG. 4

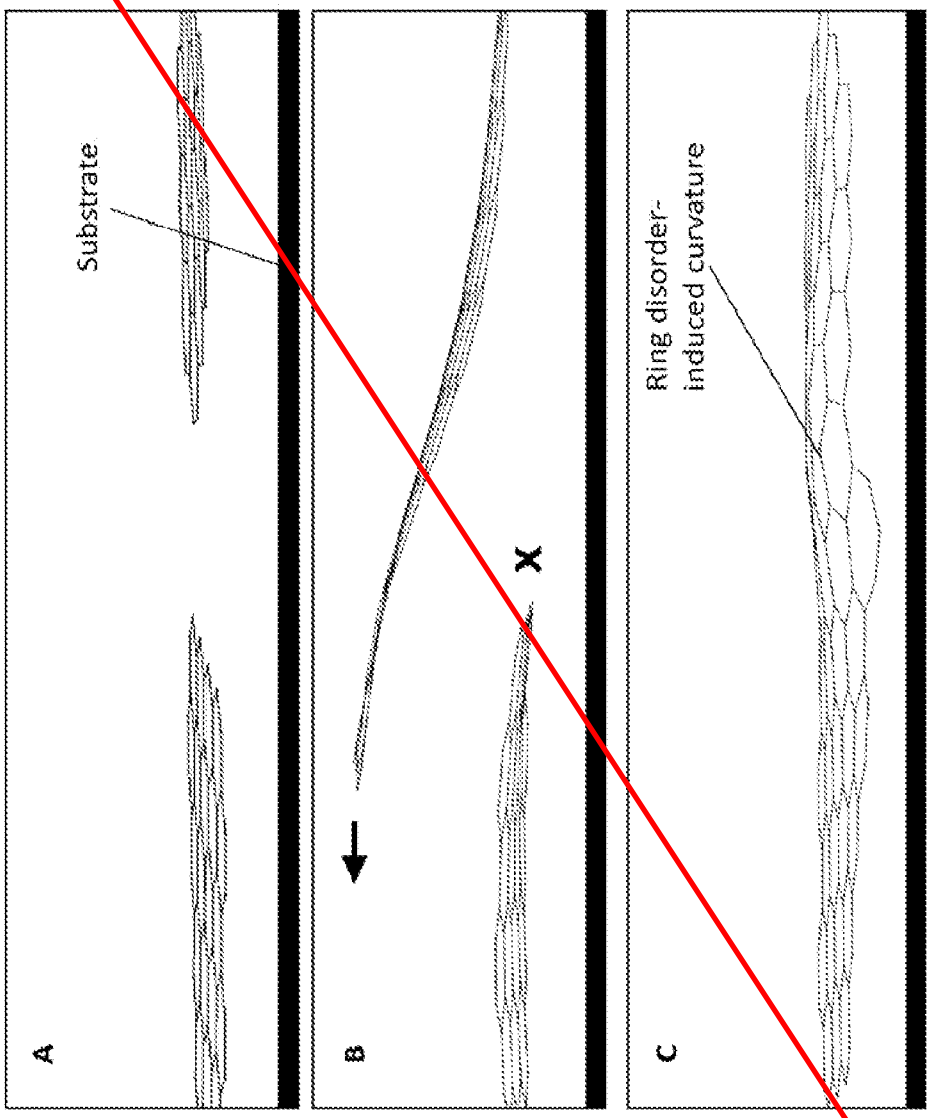


FIG. 5

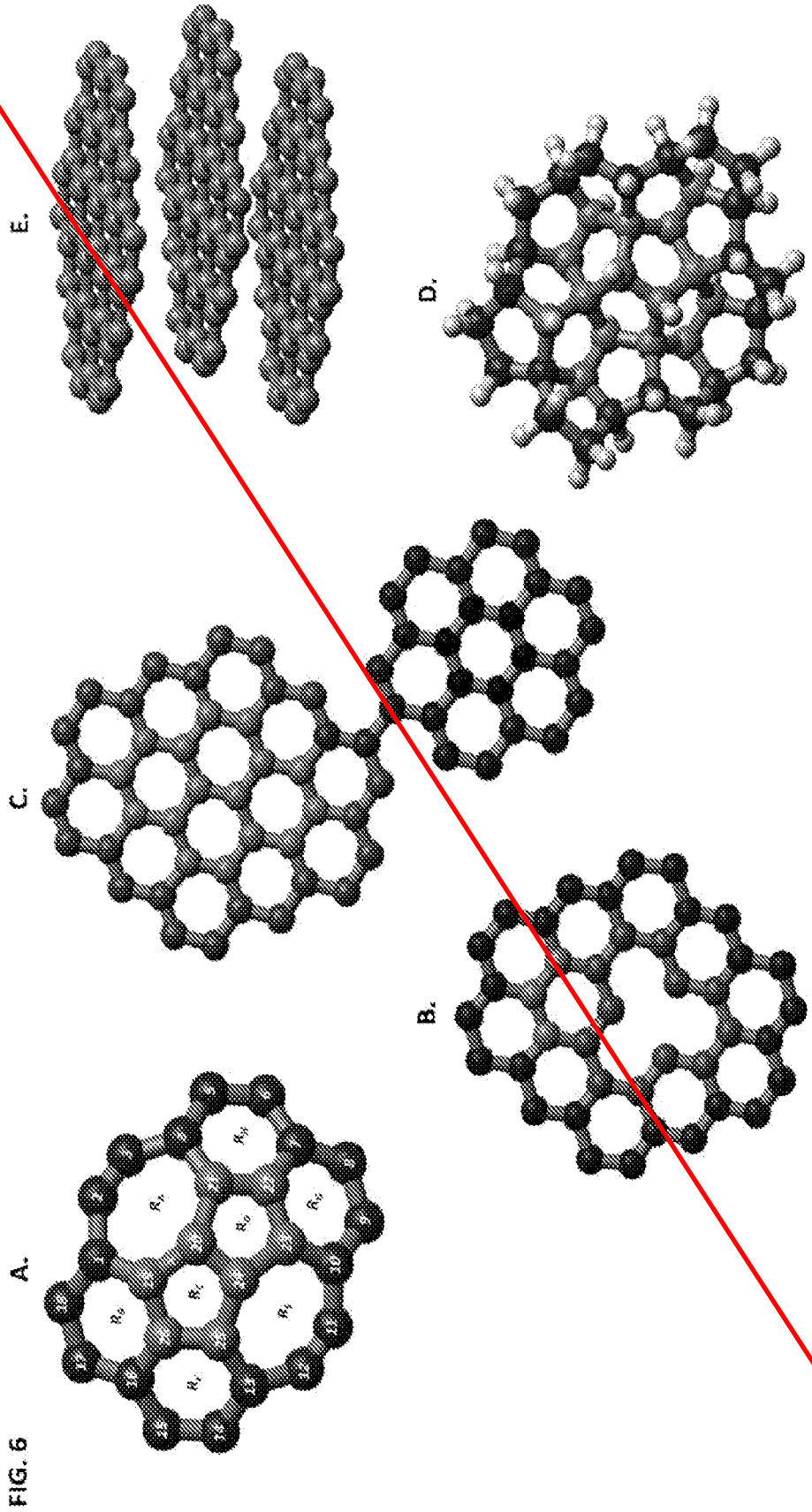


FIG. 6

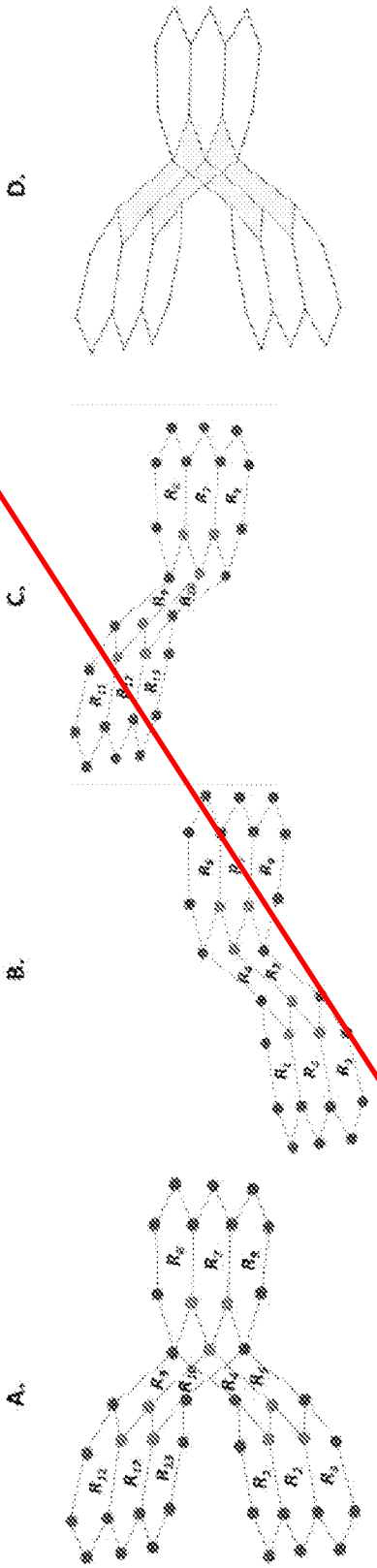


FIG. 7

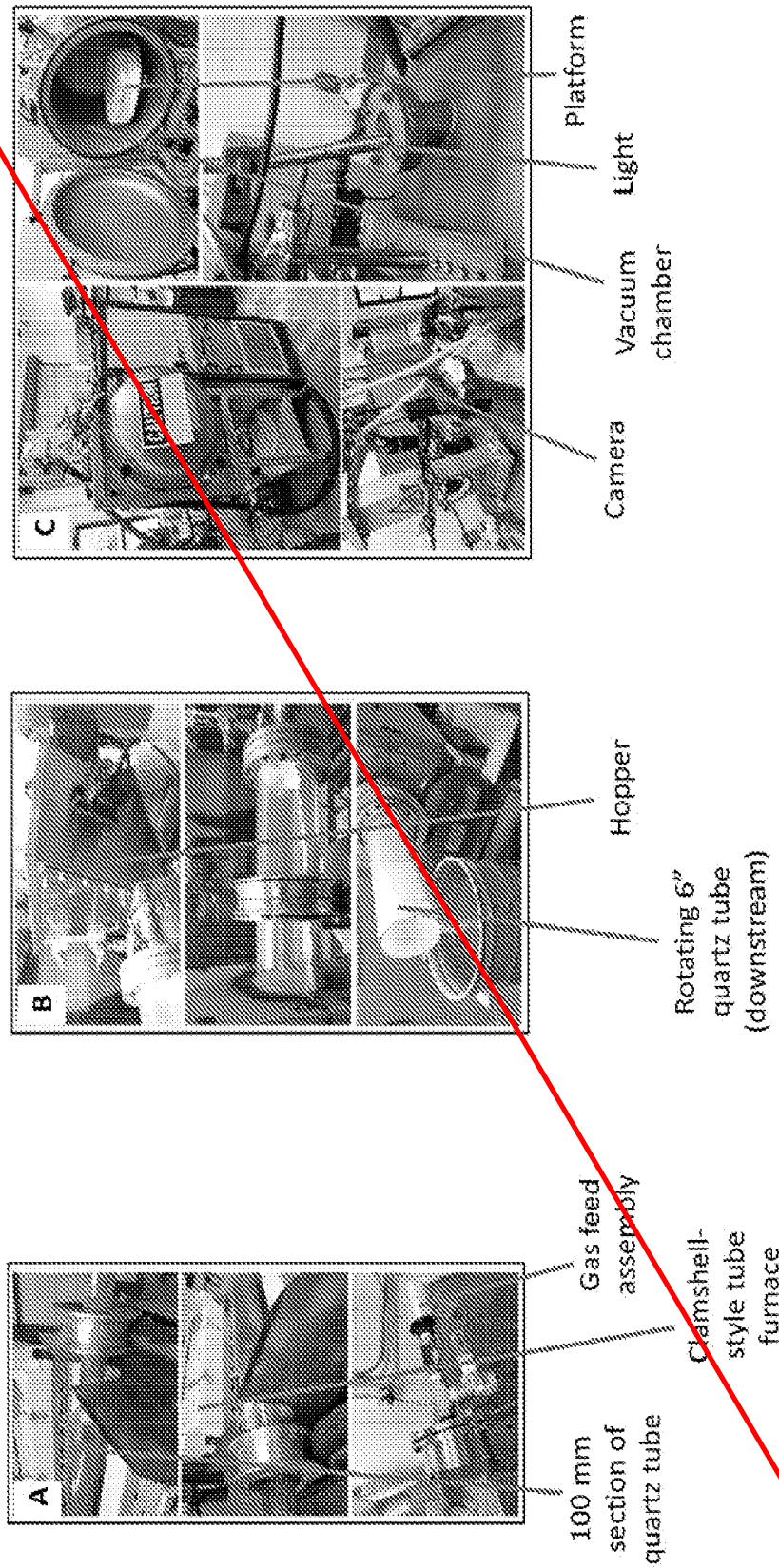

A
B
C
100 mm section of quartz tube
Gas feed assembly
Clamshell-style tube furnace
Hopper
Rotating 6" quartz tube (downstream)
Camera
Vacuum chamber
Light
Platform

FIG. 8

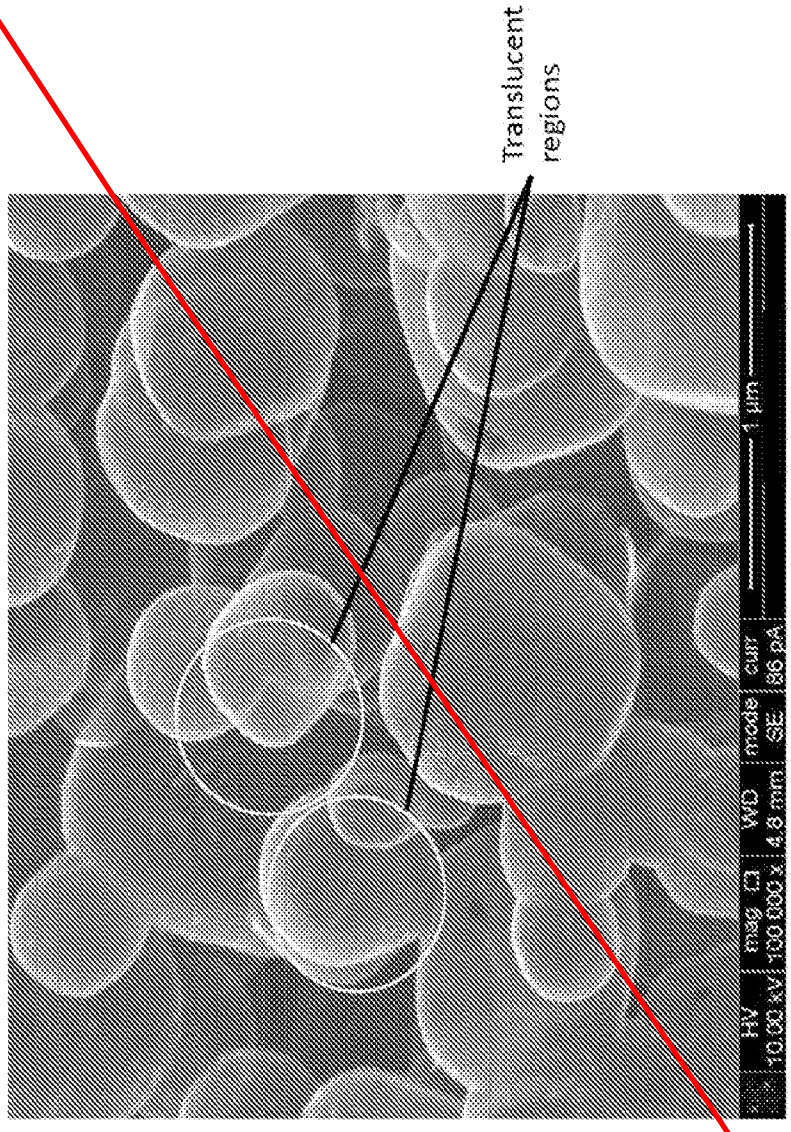

Translucent regions
HV
10.00 kV
mag
100 000 x
WD
4.8 mm
mode
SE
curr
86 pA
1 µm

FIG. 9

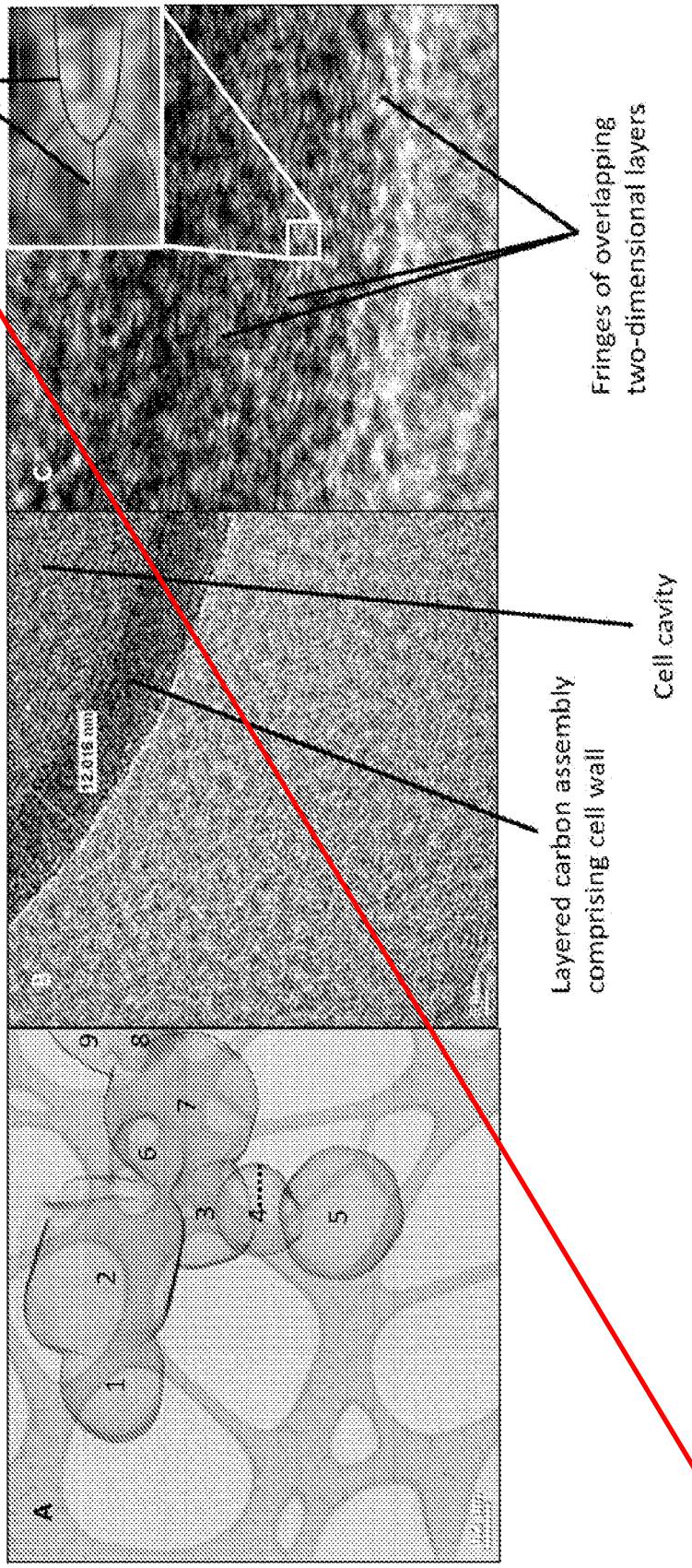

Y
Fringes of overlapping two-dimensional layers
Cell cavity
Layered carbon assembly comprising cell wall
12.0 12 nm
A
1
2
3
4
5
6
7
8
9

FIG. 10

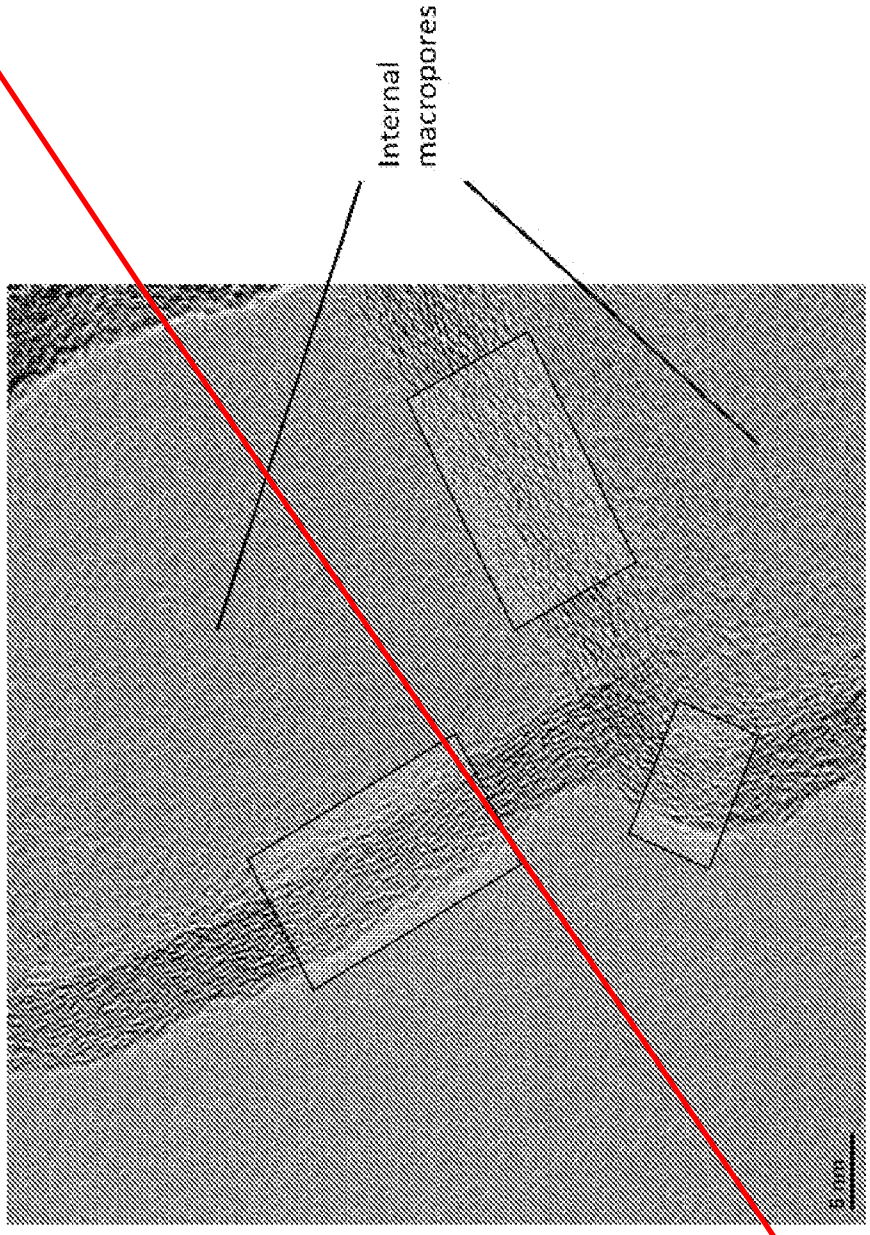


FIG. 11

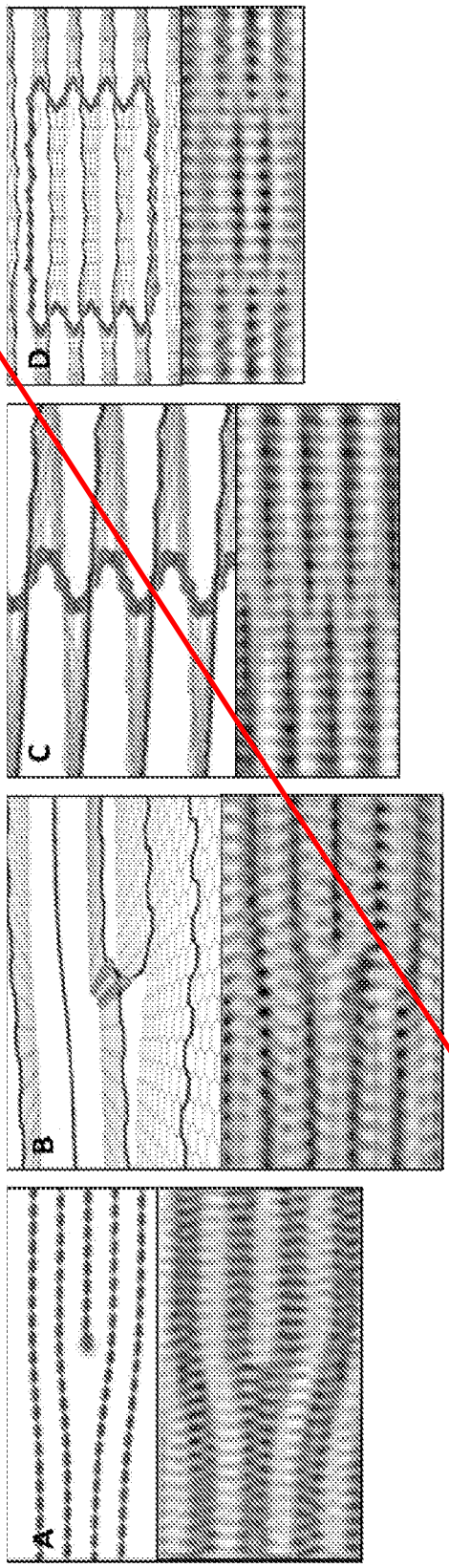


FIG. 12

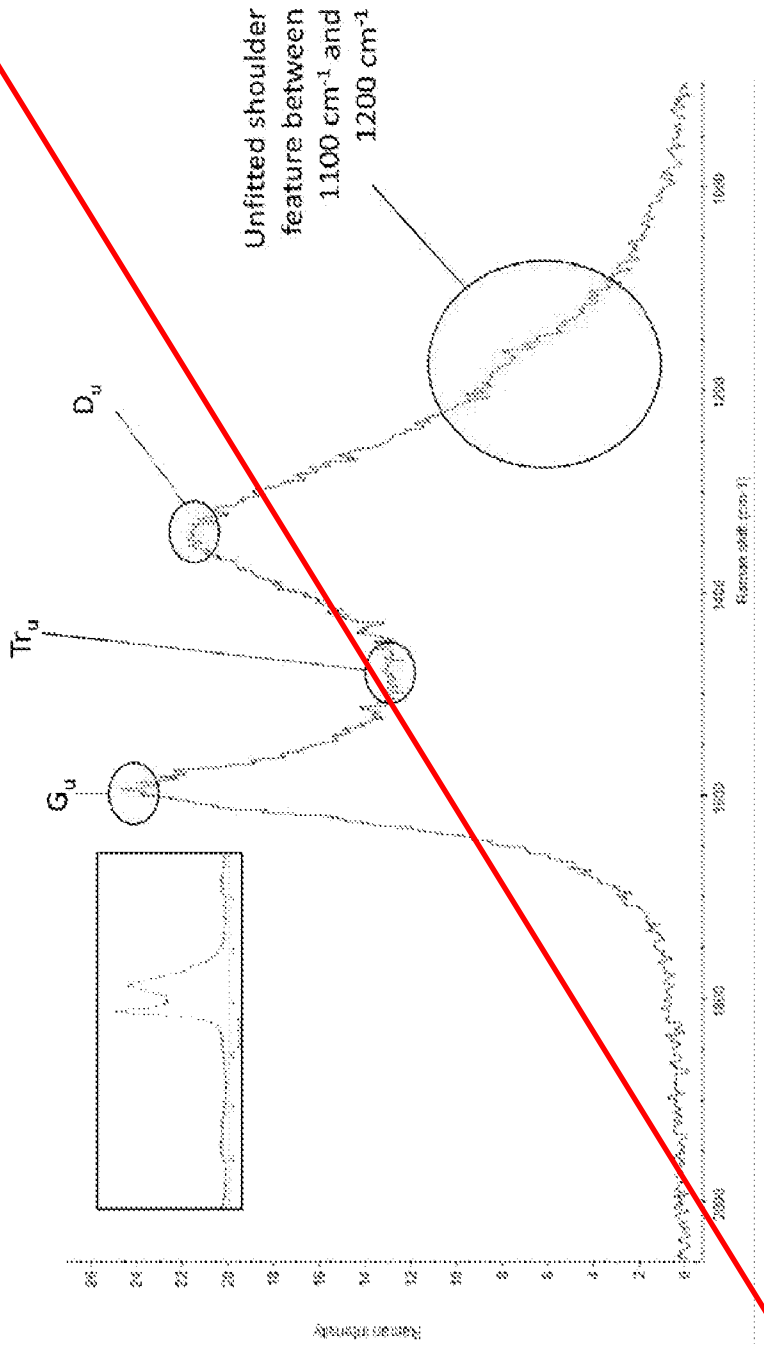

Unfitted shoulder feature between 1100 cm-1 and 1200 cm-1
Du
Tru
Gu

FIG. 13

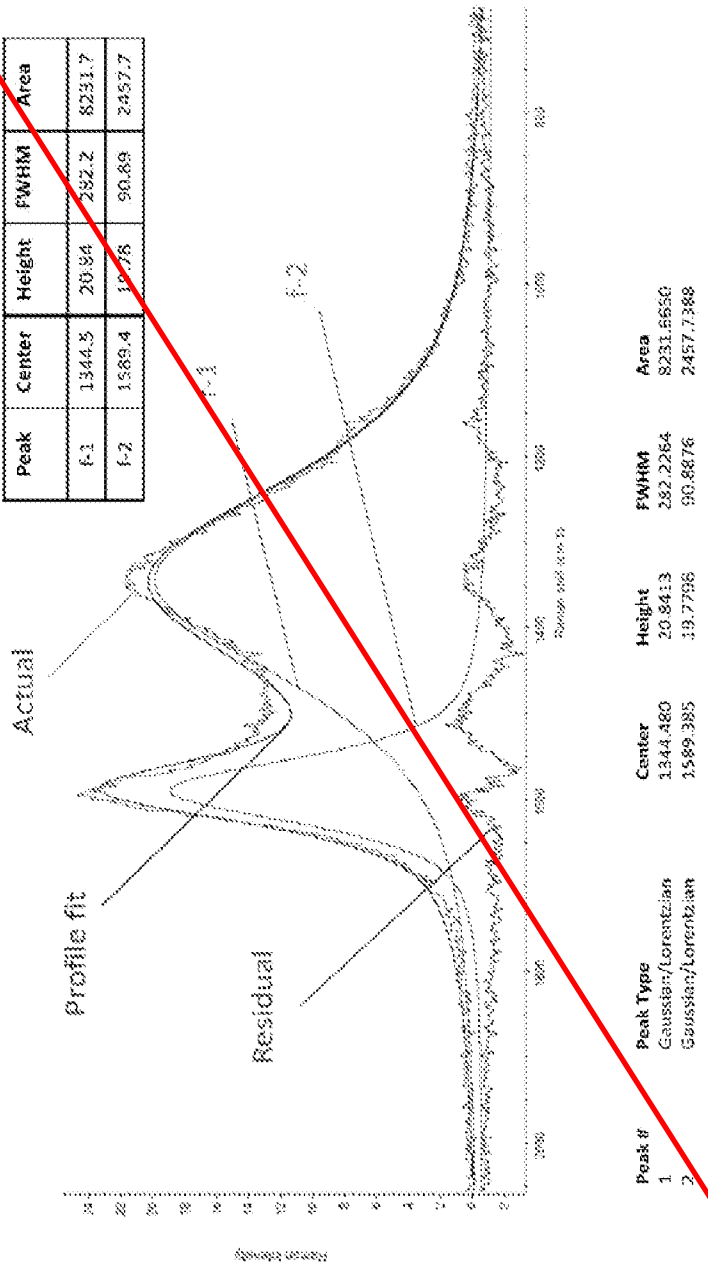
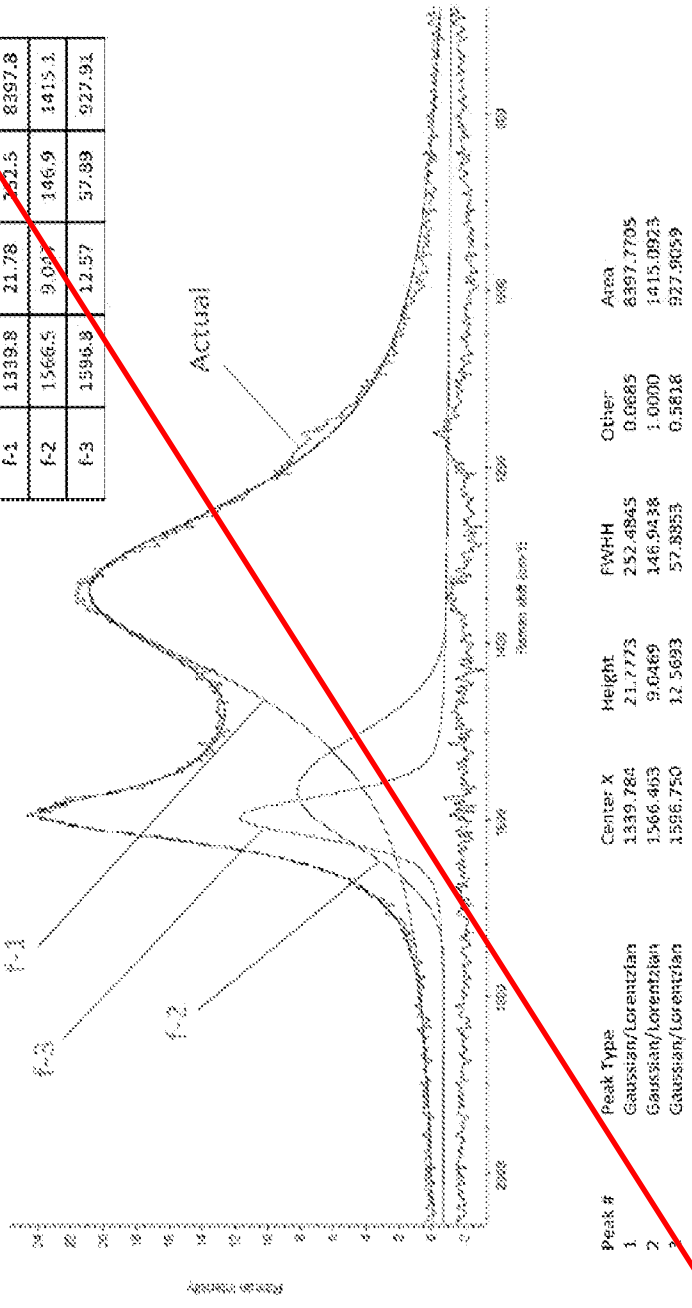

Actual
Profile fit
Residual
f-1
f-2
Peak | Center | Height | FWHM | Area
f-1 | 1344.5 | 20.84 | 282.2 | 8231.7
f-2 | 1589.4 | 19.78 | 90.89 | 2457.7
Peak # | Peak Type | Center | Height | FWHM | Area
1 | Gaussian/Lorentzian | 1344.480 | 20.8413 | 282.2264 | 8231.6656
2 | Gaussian/Lorentzian | 1589.385 | 19.7786 | 90.8876 | 2457.7388

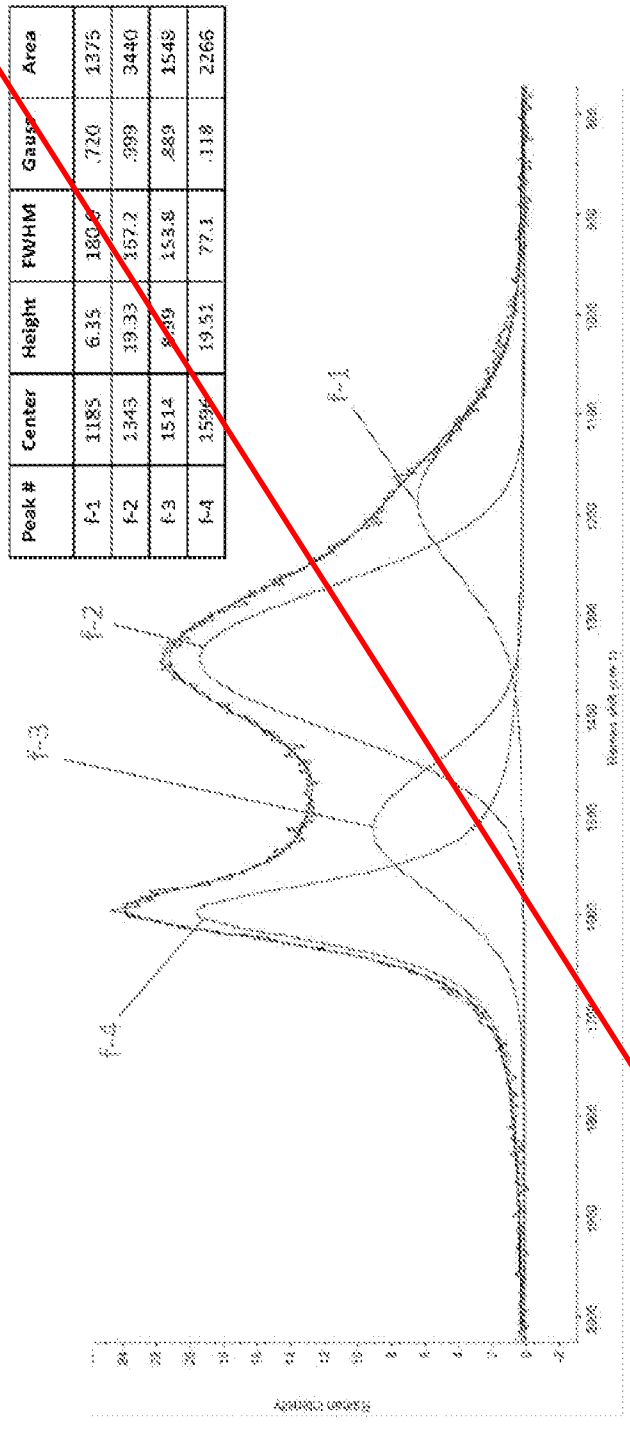
FIG. 14



Peak #	Center	Height	FWHM	Area
f-1	1339.8	21.78	252.5	8397.8
f-2	1566.5	9.04	146.9	1415.1
f-3	1596.8	12.57	57.89	927.91

Peak #	Peak Type	Center X	Height	FWHM	Other	Area
1	Gaussian/Lorentzian	1339.784	21.7773	252.6845	0.0685	8397.7705
2	Gaussian/Lorentzian	1566.463	9.0469	146.9438	1.0000	1415.0923
3	Gaussian/Lorentzian	1596.750	12.5693	57.8853	0.5818	927.9659

FIG. 15



Peak #	Center	Height	FWHM	Gauss	Area
f-1	1185	6.35	180.0	.720	1375
f-2	1343	19.33	167.2	.999	3440
f-3	1514	8.89	153.8	.889	1548
f-4	1596	19.51	77.1	.118	2266

Peak #	Peak Type	Center X	Height	FWHH	Other	Area	
1	Gaussian/Lorentzian		1184.989	6.3476	179.9997	0.7197	1375.3674
2	Gaussian/Lorentzian		1342.546	19.3253	167.1687	0.9992	3440.0989
3	Gaussian/Lorentzian		1513.470	8.9895	153.7798	0.8888	1548.1912
4	Gaussian/Lorentzian		1596.069	19.5124	77.0288	0.1181	2265.7593

FIG. 16

Peak #	Center	Height	FWHM	Gauss	Area
f-1	1180	1.29	167.2	.606	272
f-2	1349	4.76	154.3	.639	914
f-3	1482	2.41	153.4	.552	477
f-4	1596	5.29	99.5	.409	717

Peak #	Peak Type	Center X	Height	FWHH	Other	Area	
1	Gaussian/Lorentzian		1180.483	1.2928	167.1461	0.6061	272.3295
2	Gaussian/Lorentzian		1349.018	4.7645	154.2717	0.6390	914.4910
3	Gaussian/Lorentzian		1482.705	2.4137	153.3638	0.5518	476.6147
4	Gaussian/Lorentzian		1596.475	5.2924	99.5415	0.4090	716.6892

FIG. 17

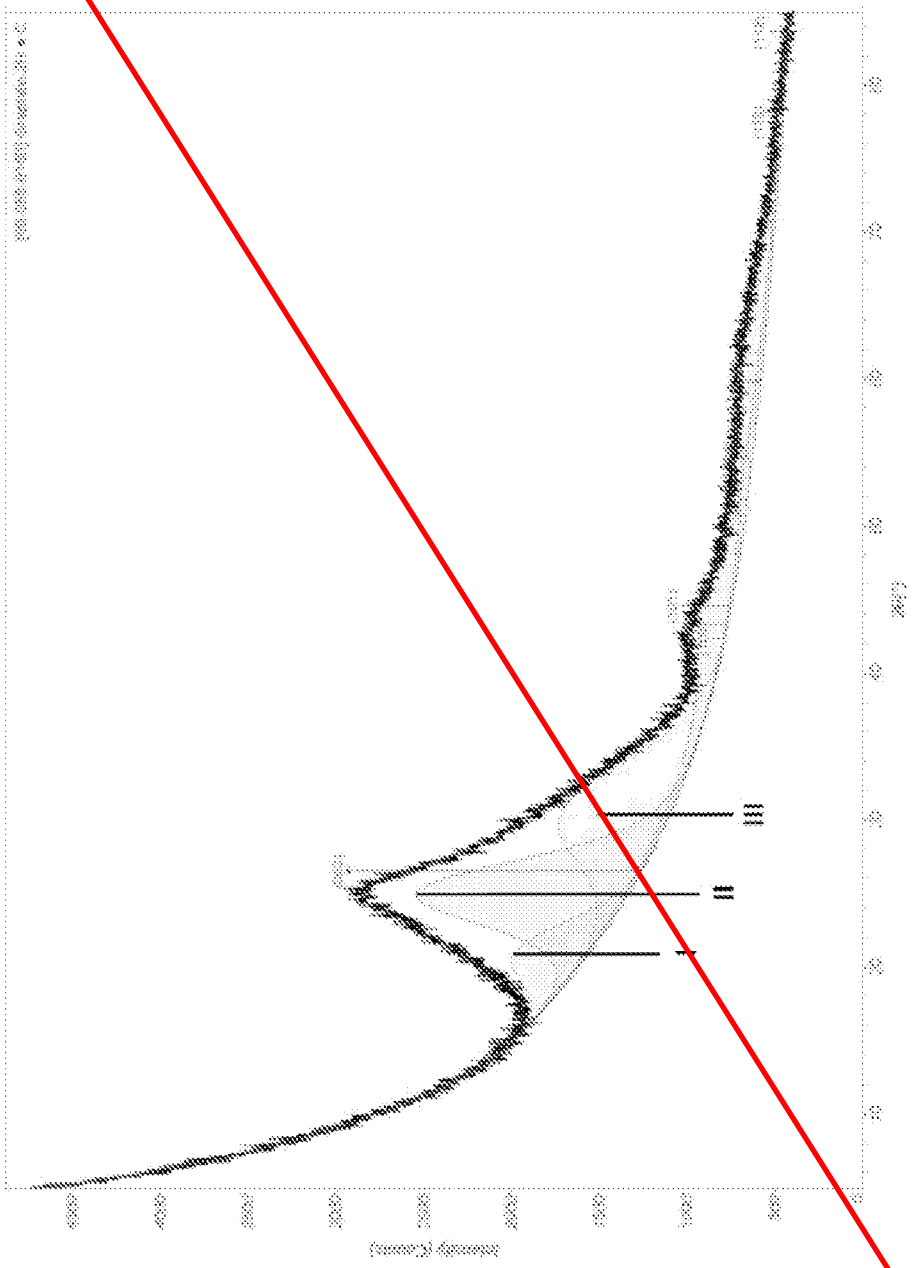


FIG. 18

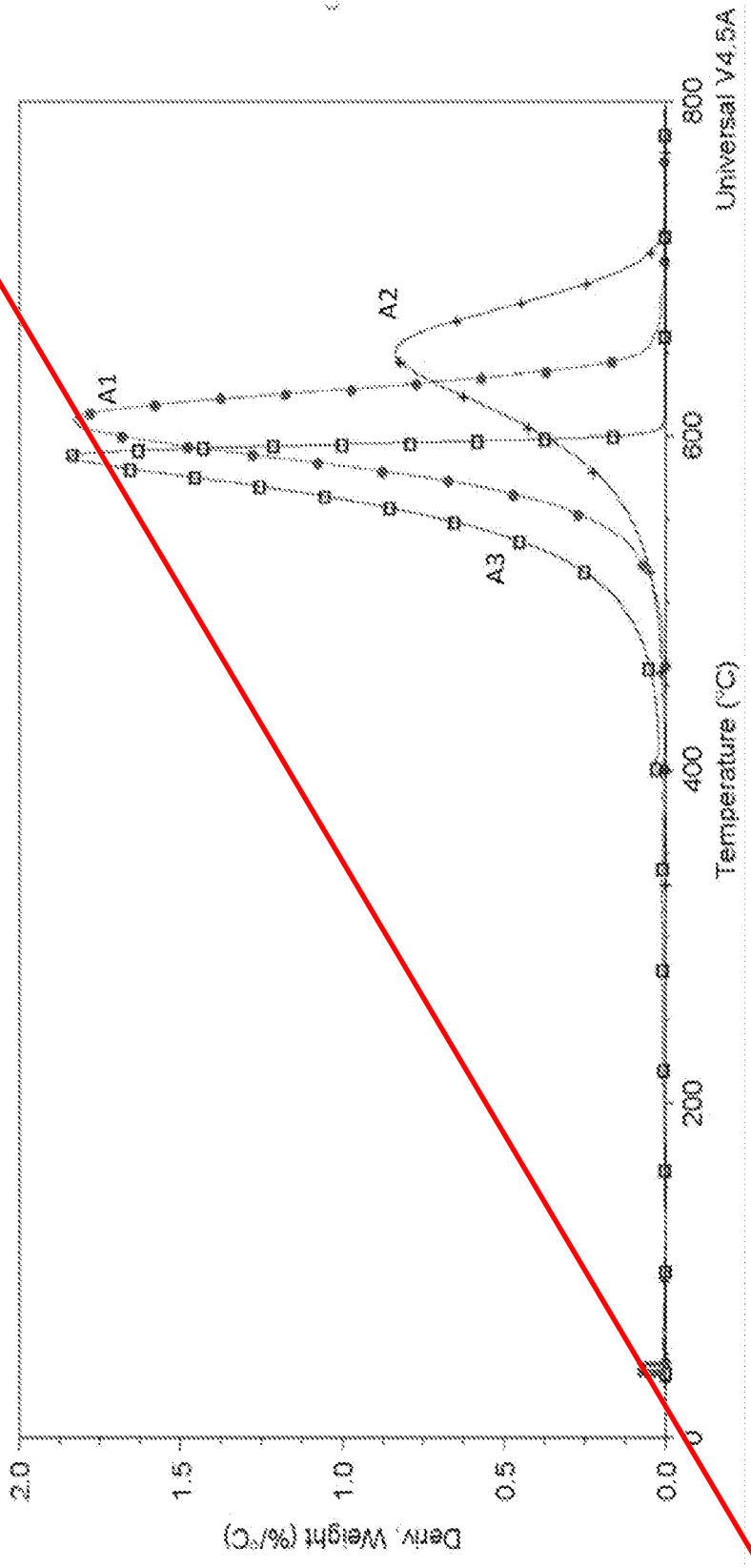

Deriv. Weight (%/°C)
2.0
1.5
1.0
0.5
0.0
0
200
400
600
800
Temperature (°C)
Universal V4.5A
A1
A2
A3

FIG. 19

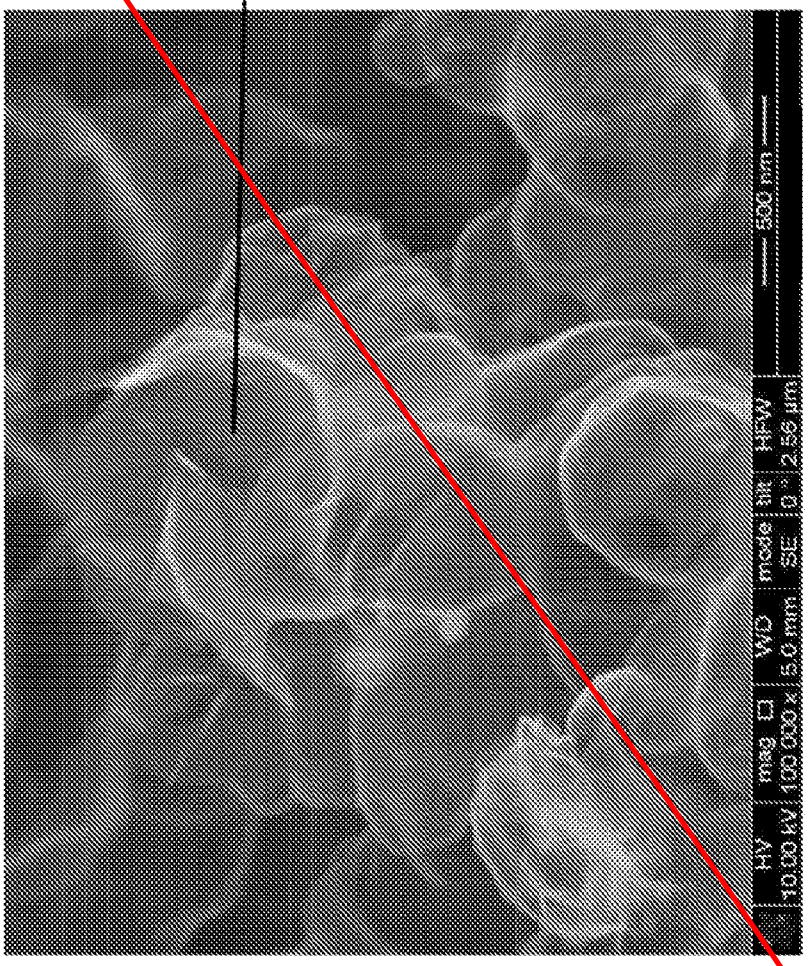

Inner cavity of a fragmented cell
HV
10.00 kV
mag
100 000 x
WD
5.0 mm
mode
SE
tilt
0 °
HFW
2.56 µm
500 nm

FIG. 20

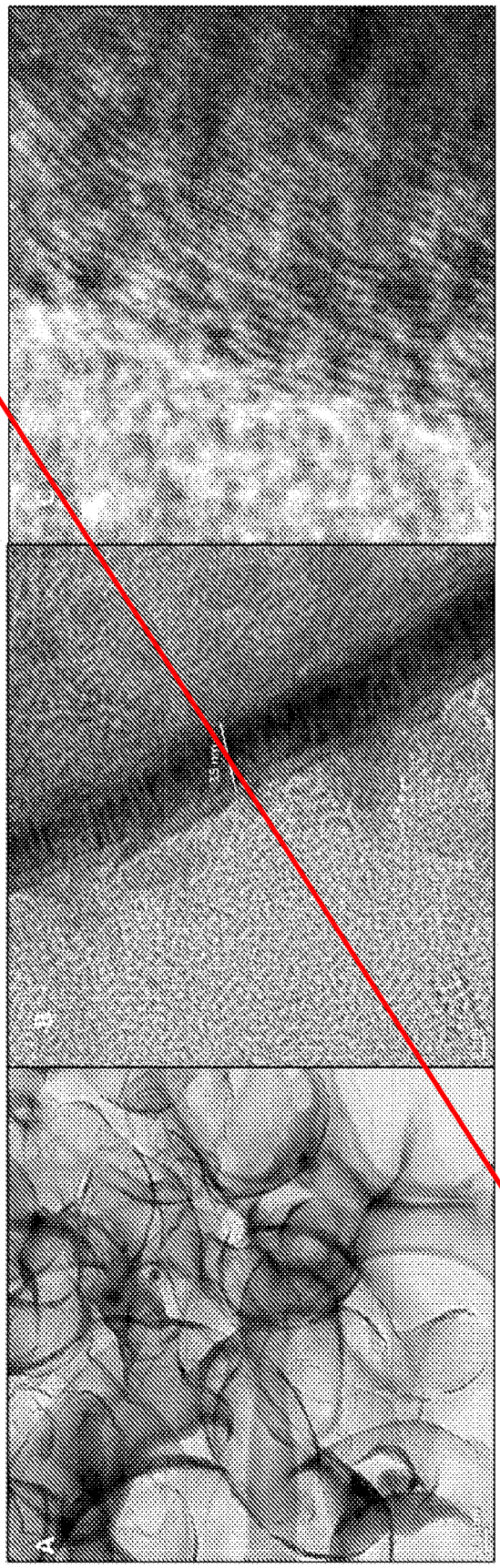


FIG. 21

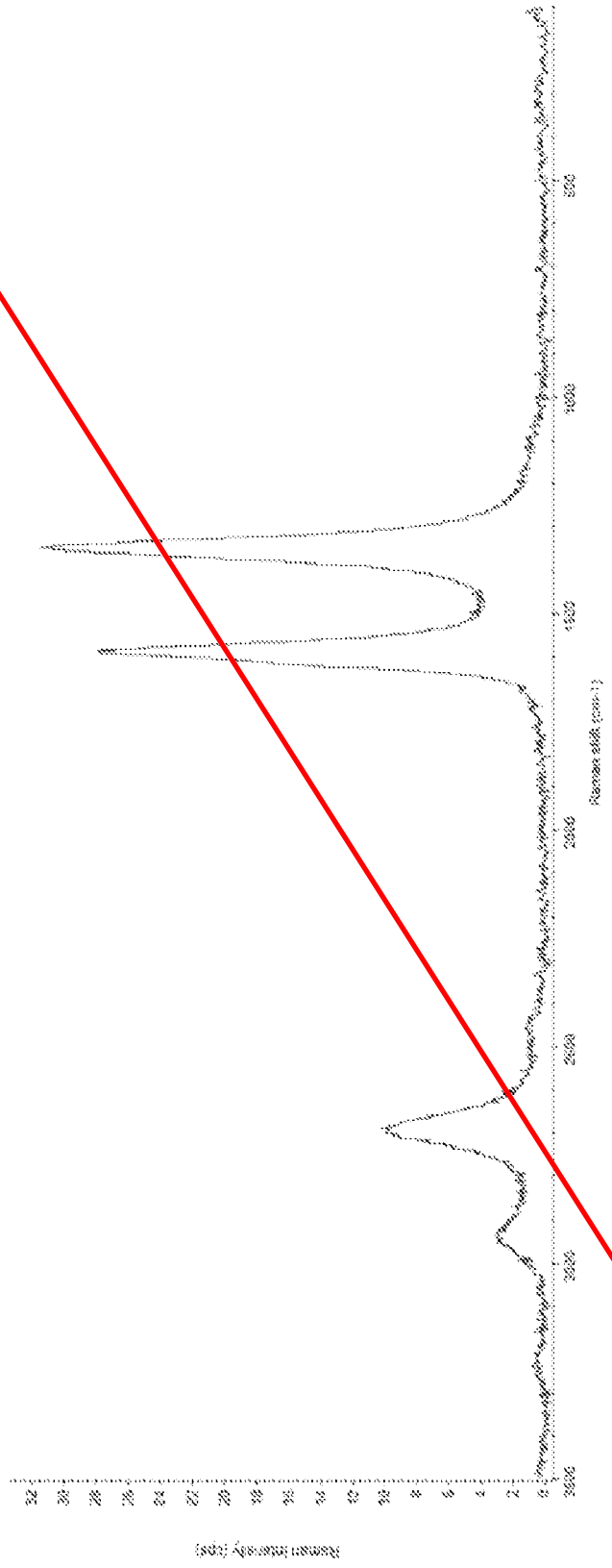


FIG. 22

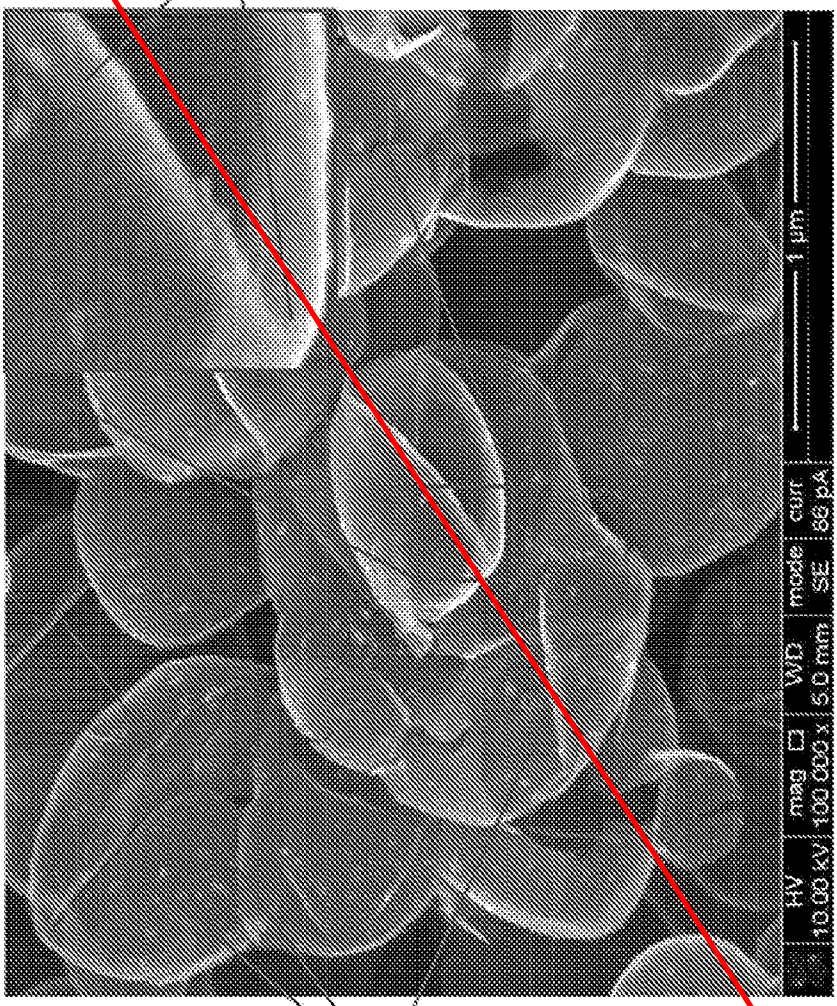

Local bending and buckling of cell walls
Recurring linear features observed post-compression
HV 10.00 kV
mag 100 000 x
WD 5.0 mm
mode SE
curr 86 pA
1 µm

FIG. 23

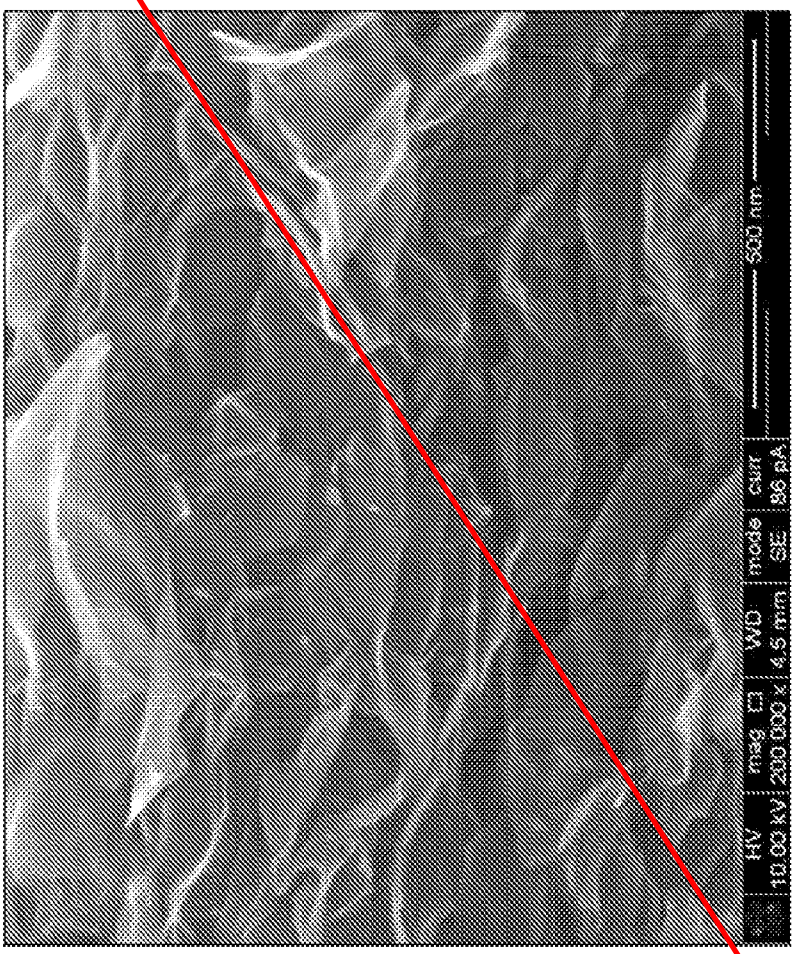


FIG. 24

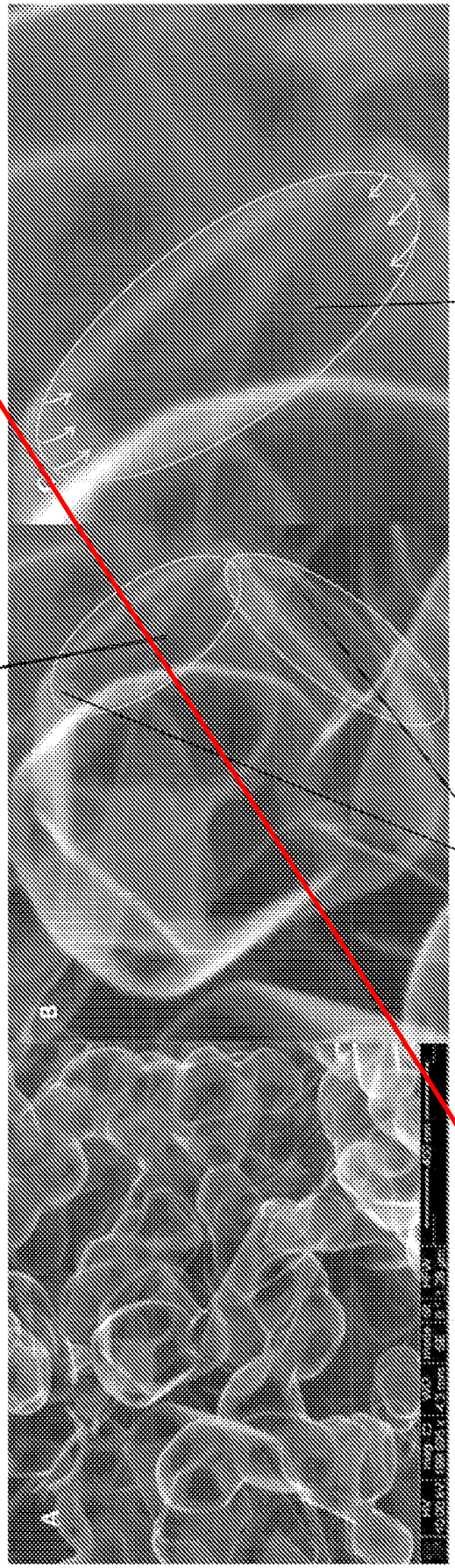

Concave surface extending across facet
Transparent "windows"
More opaque "framing"

FIG. 25

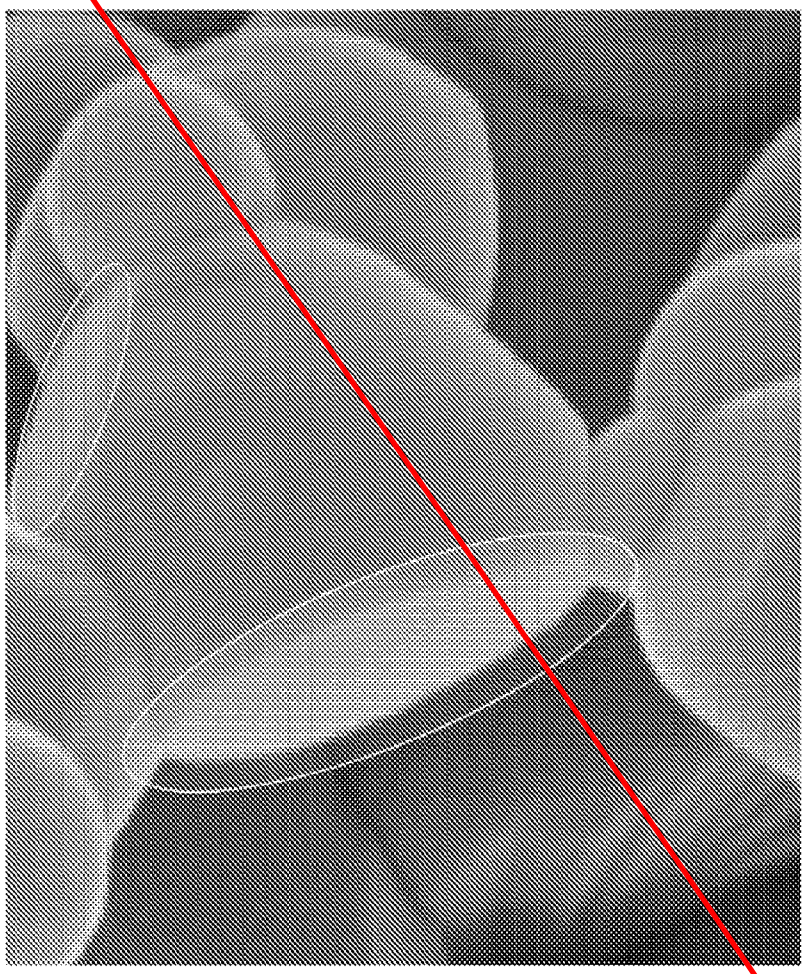


FIG. 26

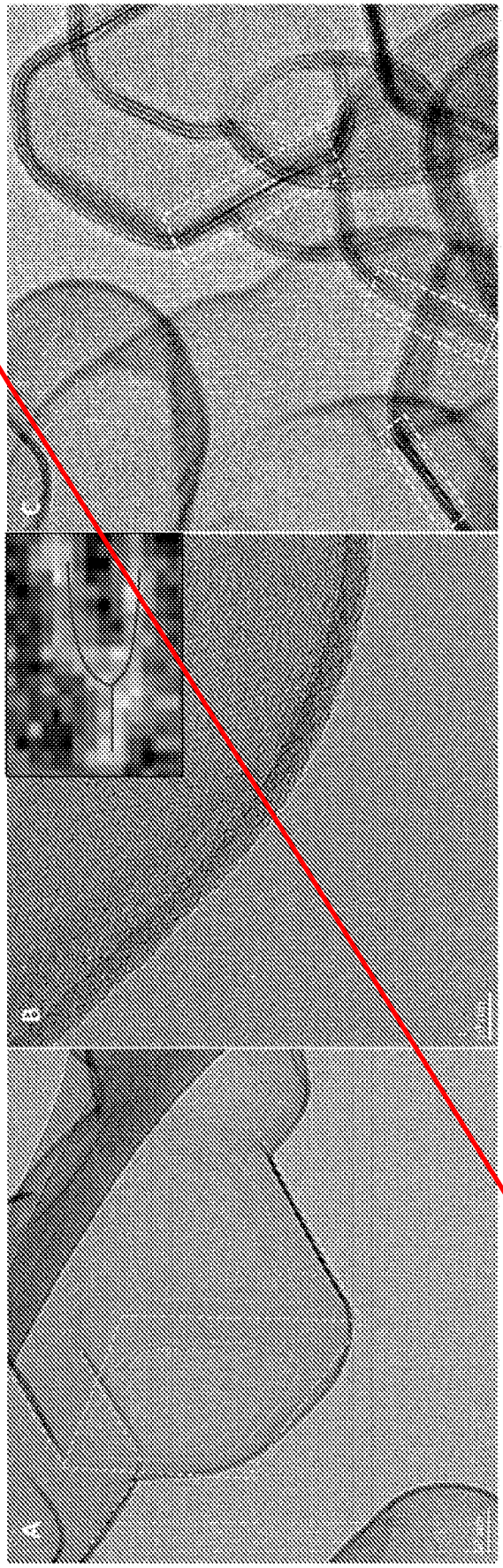


FIG. 27

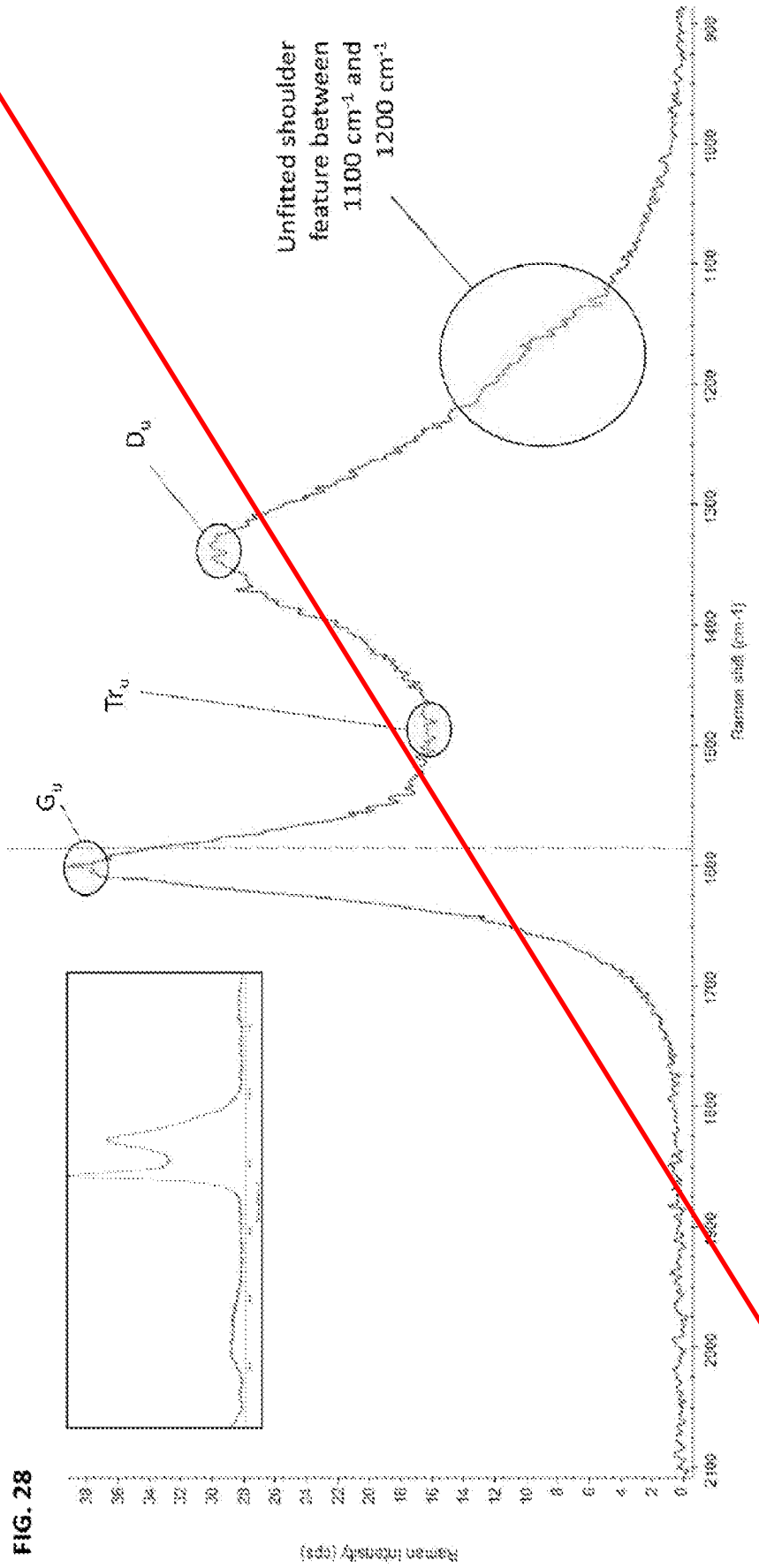

Unfitted shoulder feature between 1100 cm-1 and 1200 cm-1
D
Tr
G
Raman shift (cm-1)
Raman intensity (cps)

FIG. 28

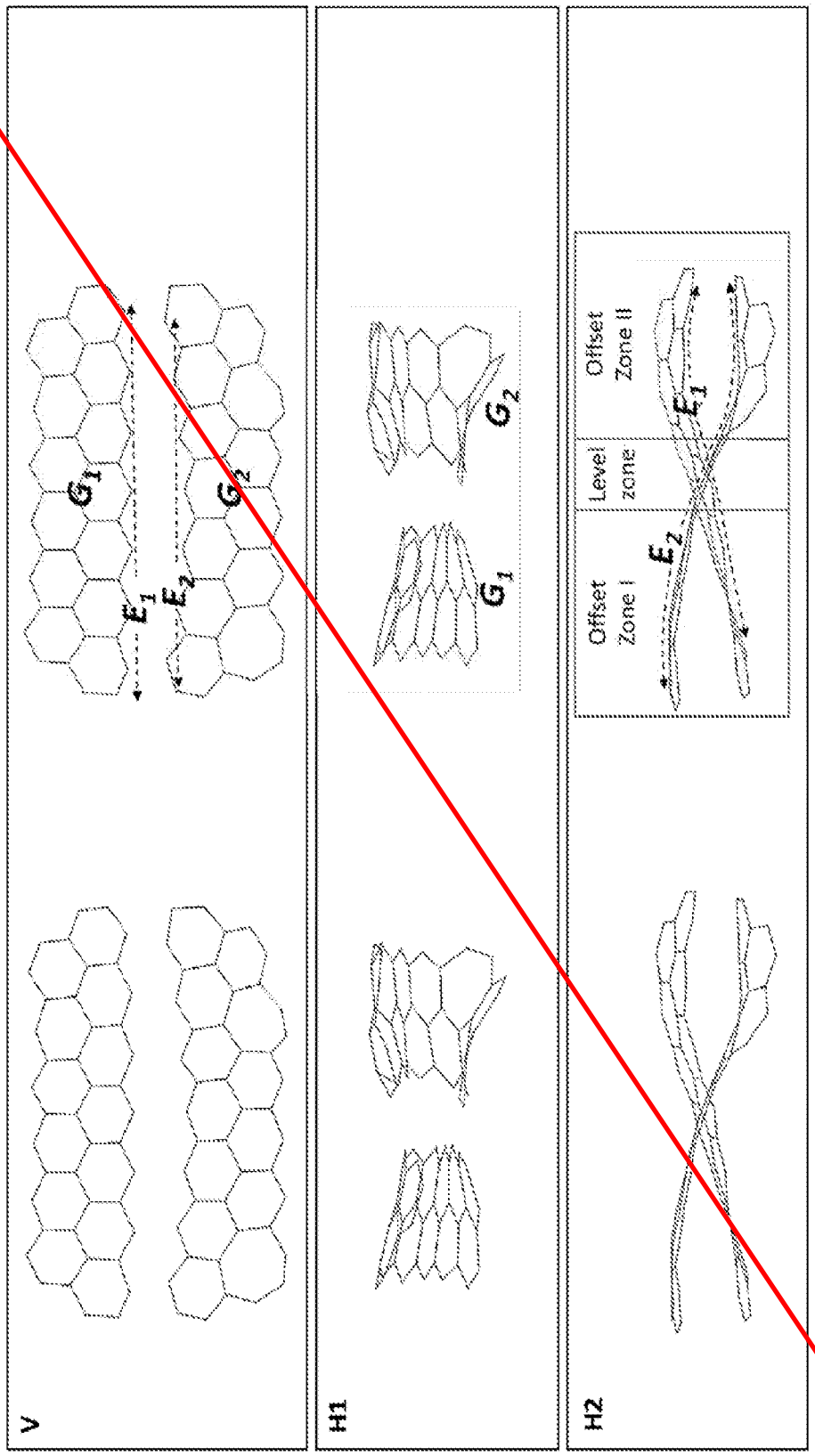


FIG. 29

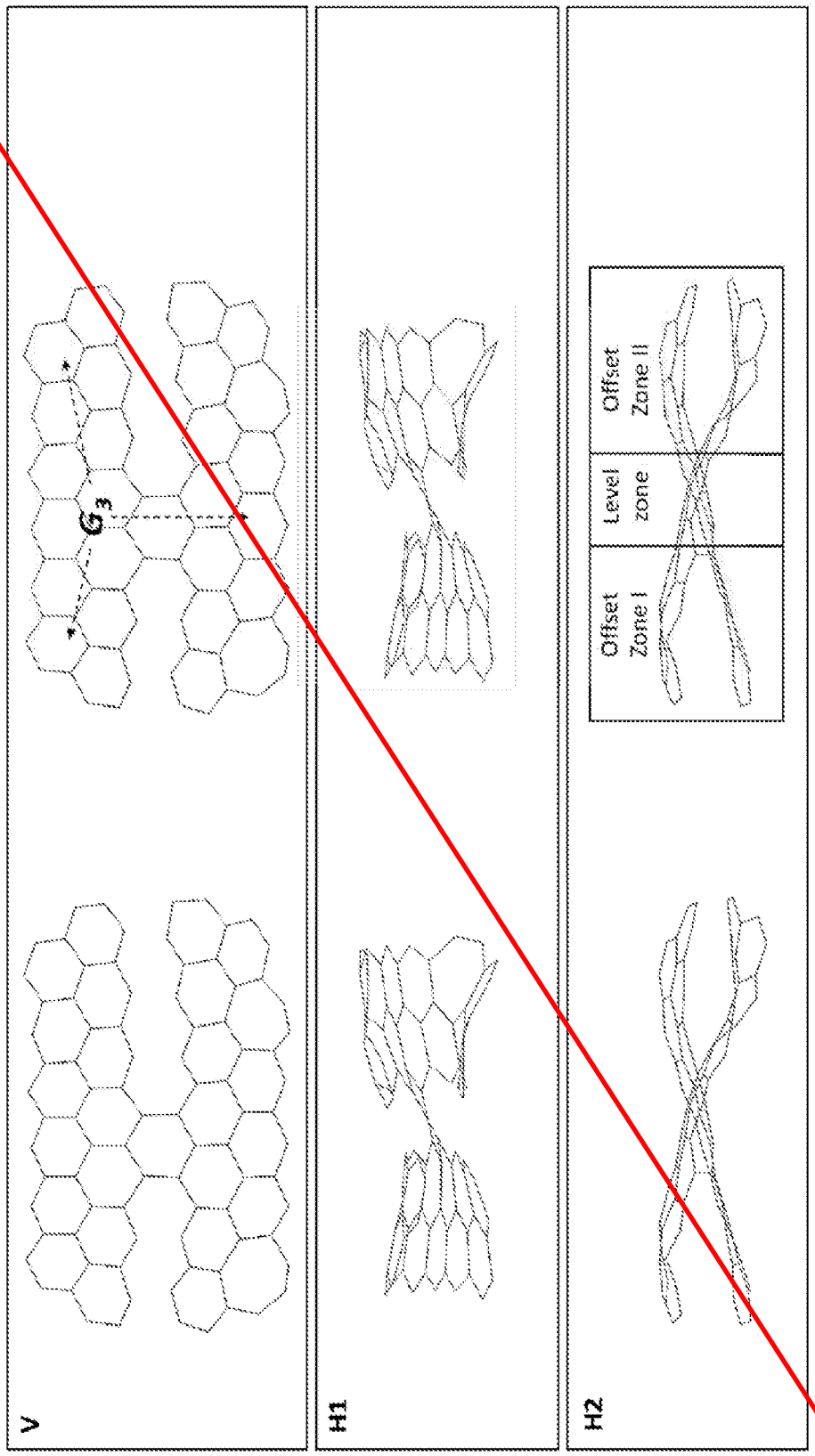


FIG. 30

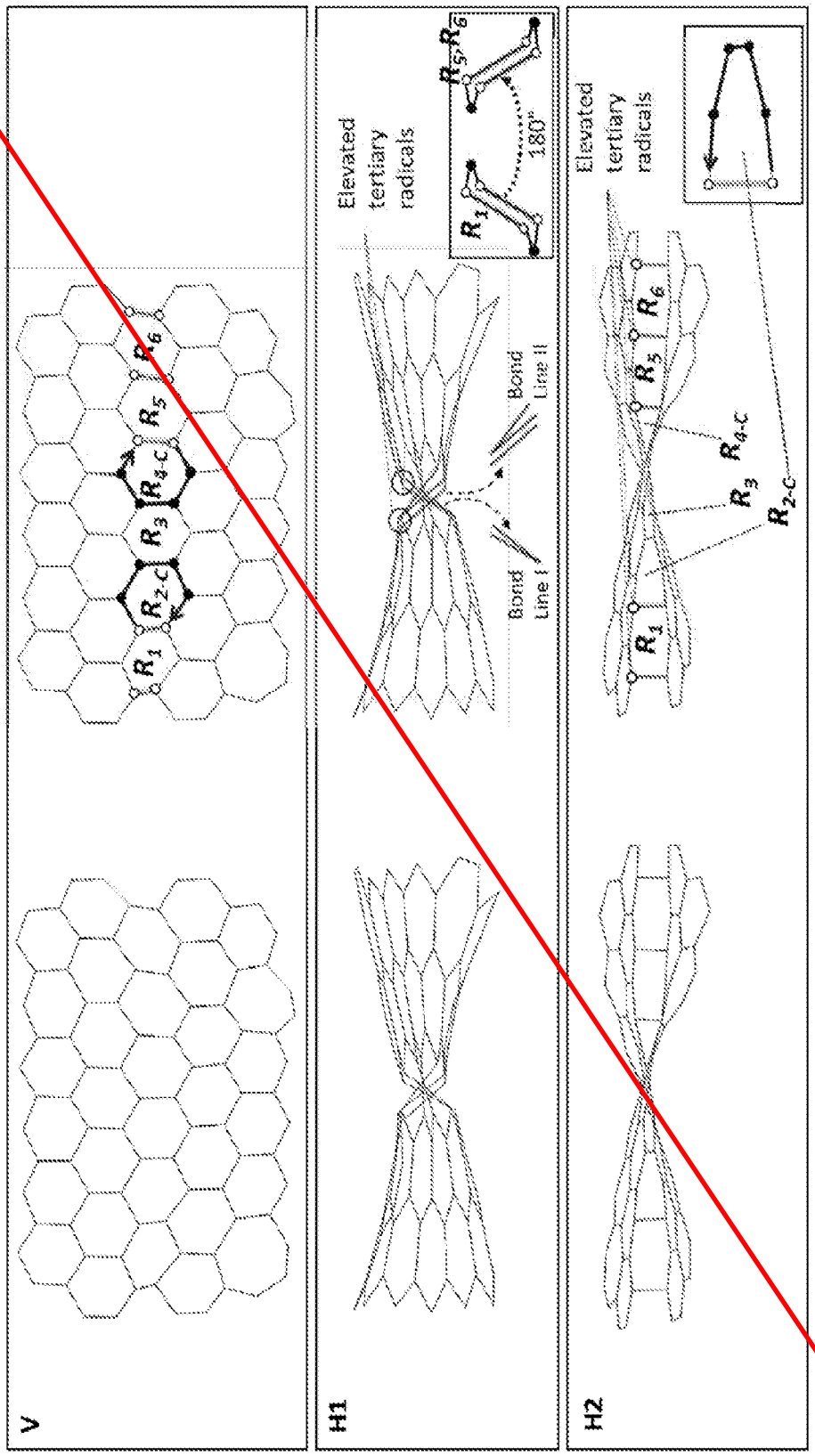

V
H1
H2
Elevated tertiary radicals
Bond Line I
Bond Line II
180°
R_1
R_2-C
R_3
R_4-C
R_5
R_6

FIG. 31

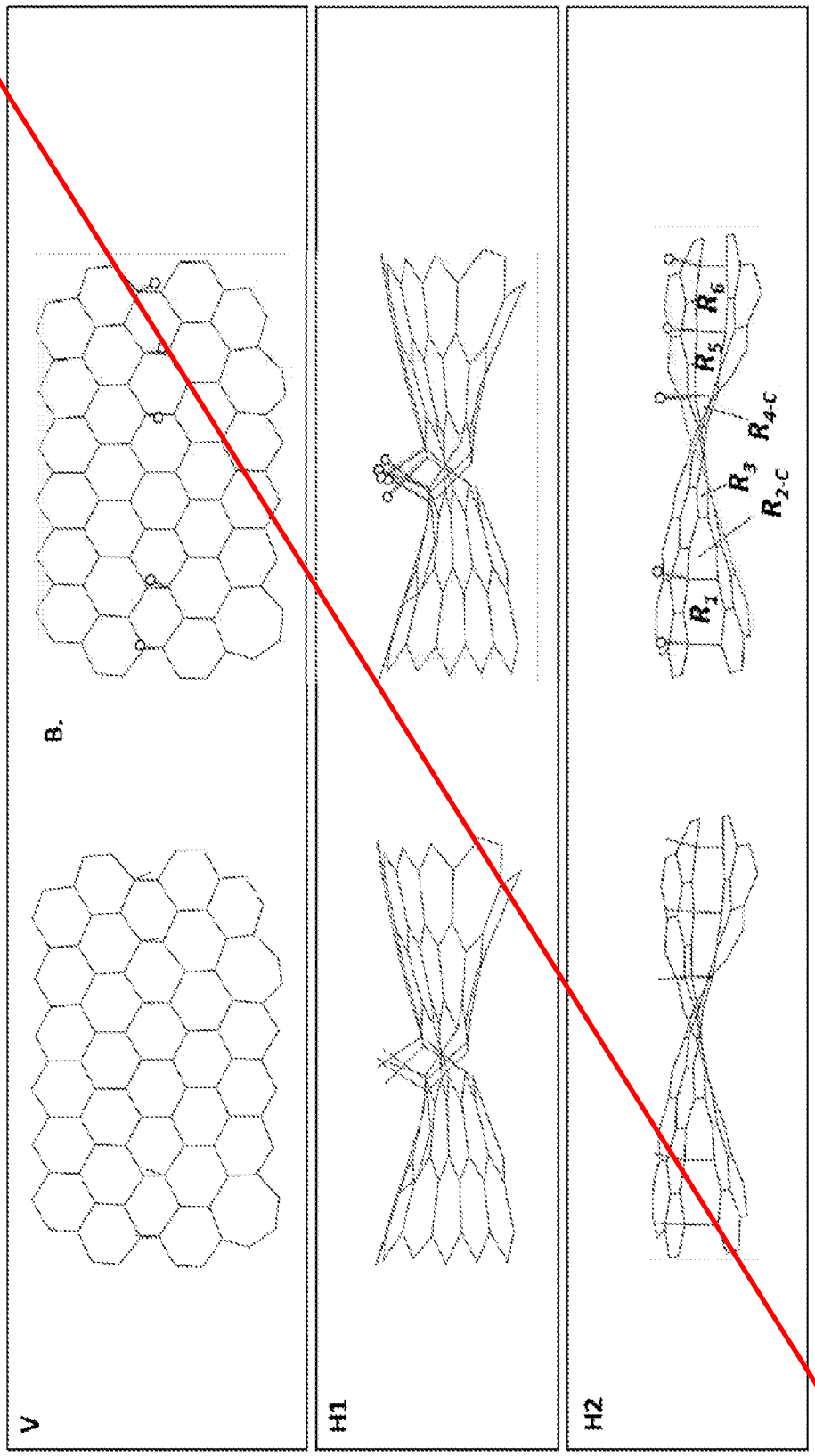


FIG. 32

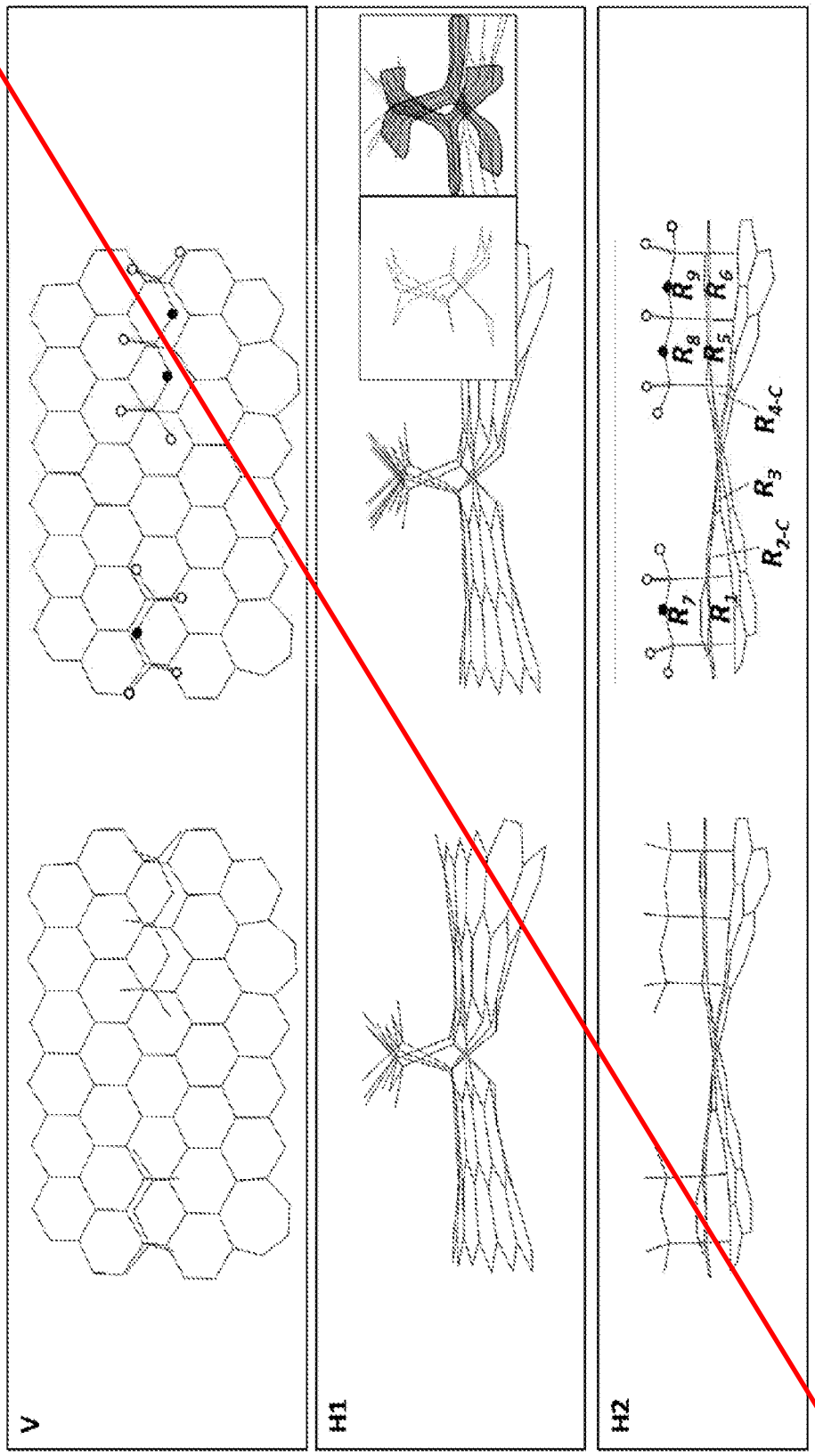


FIG. 33

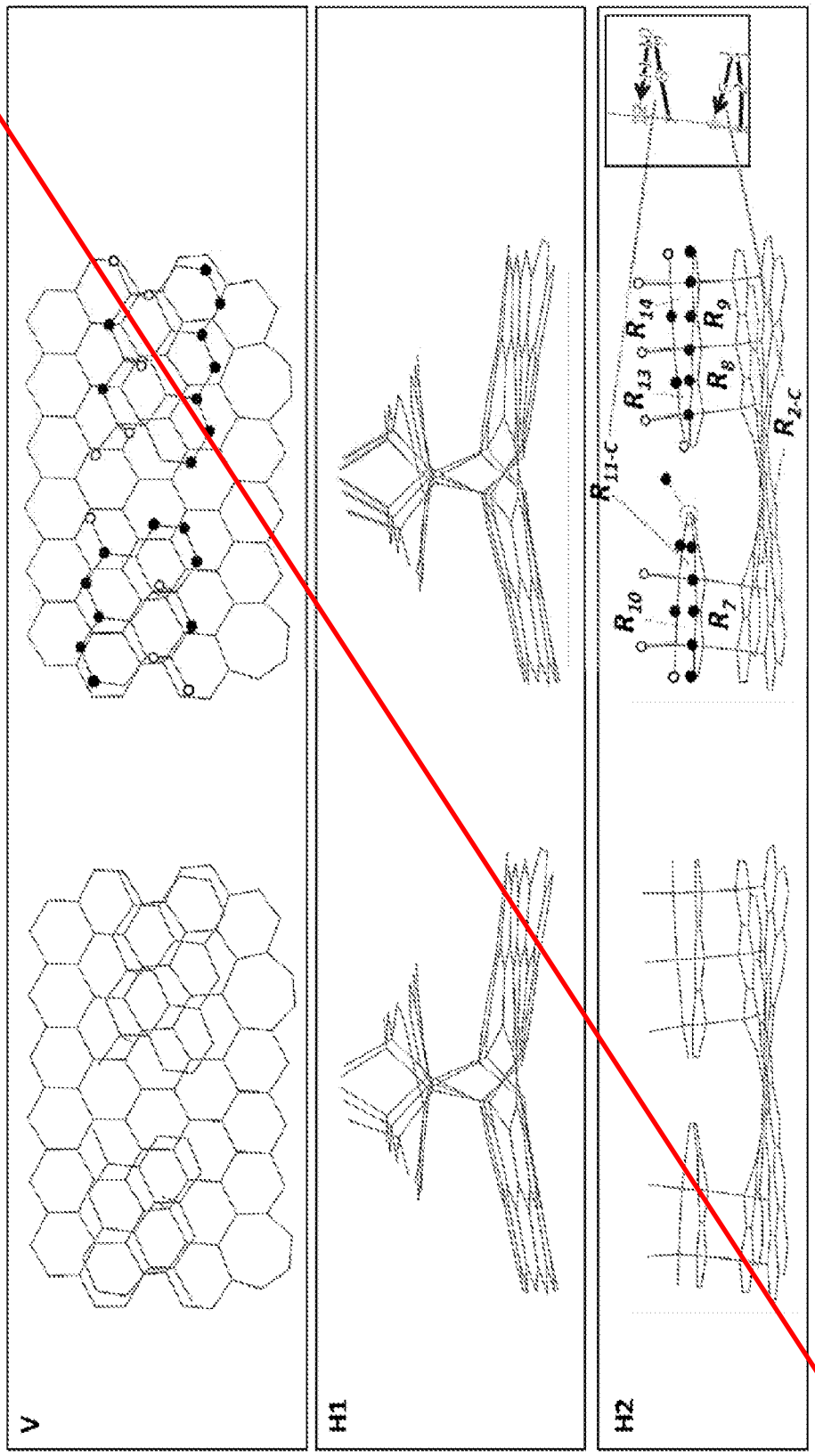


FIG. 34

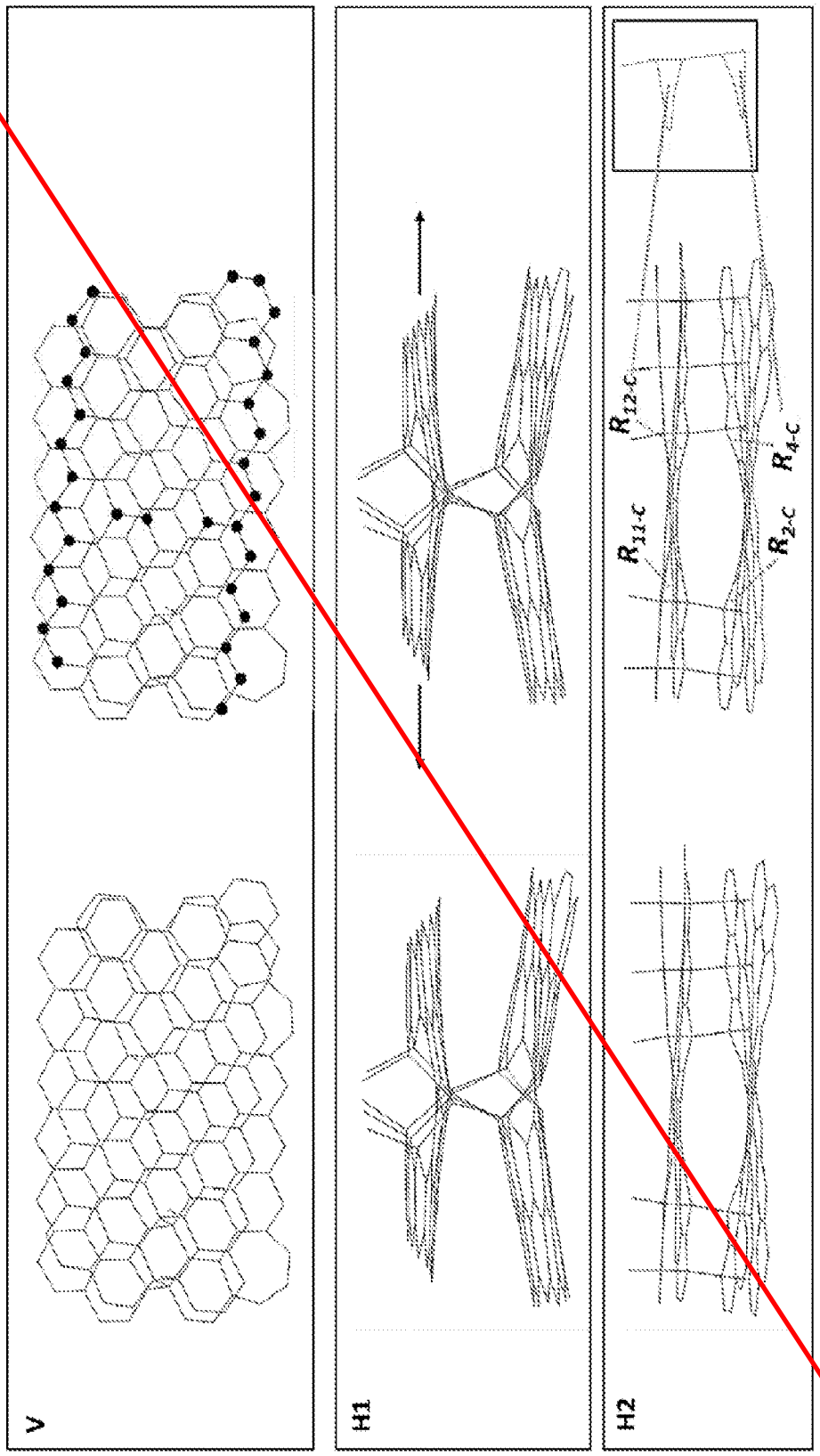


FIG. 35

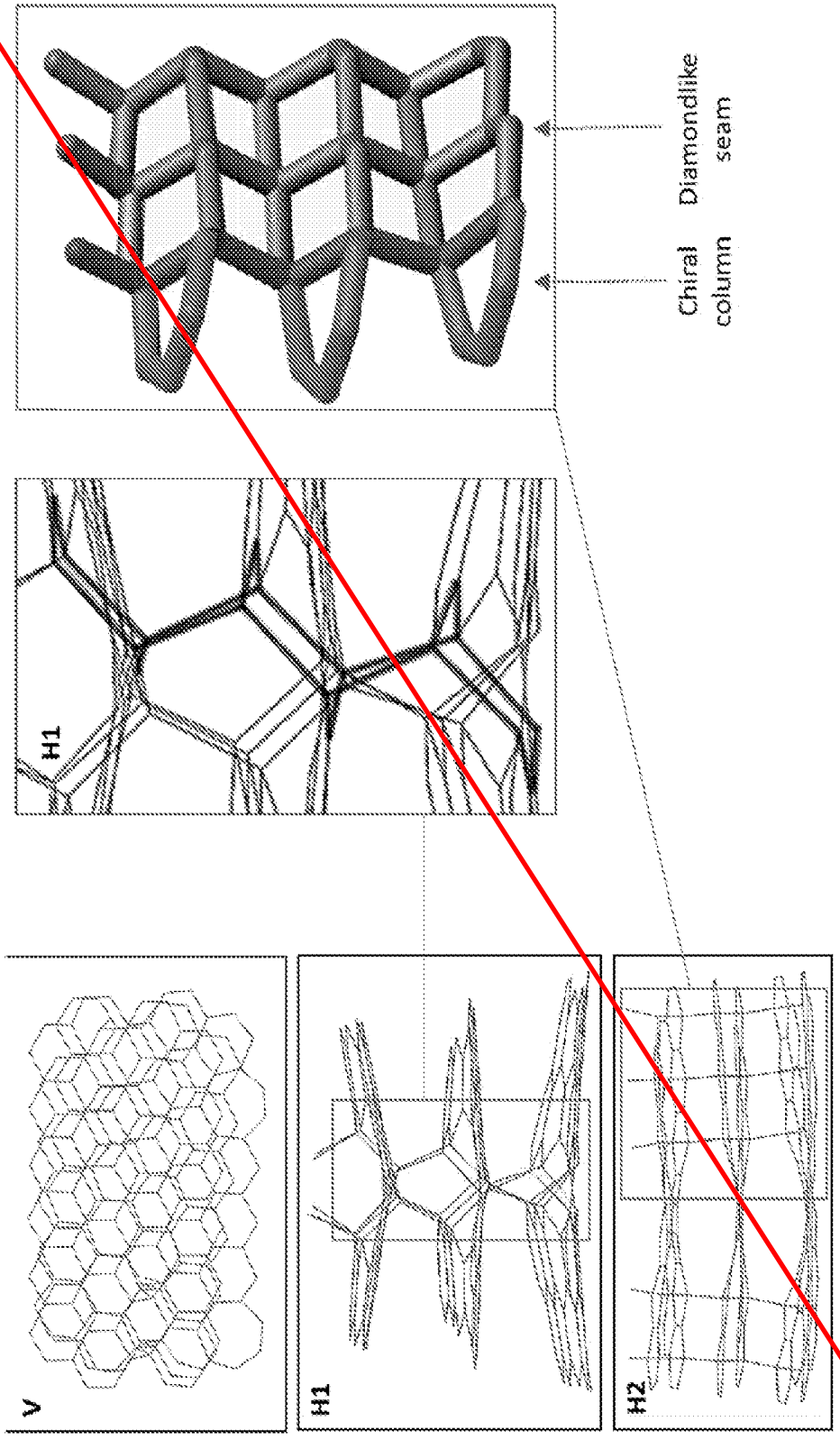


FIG. 36

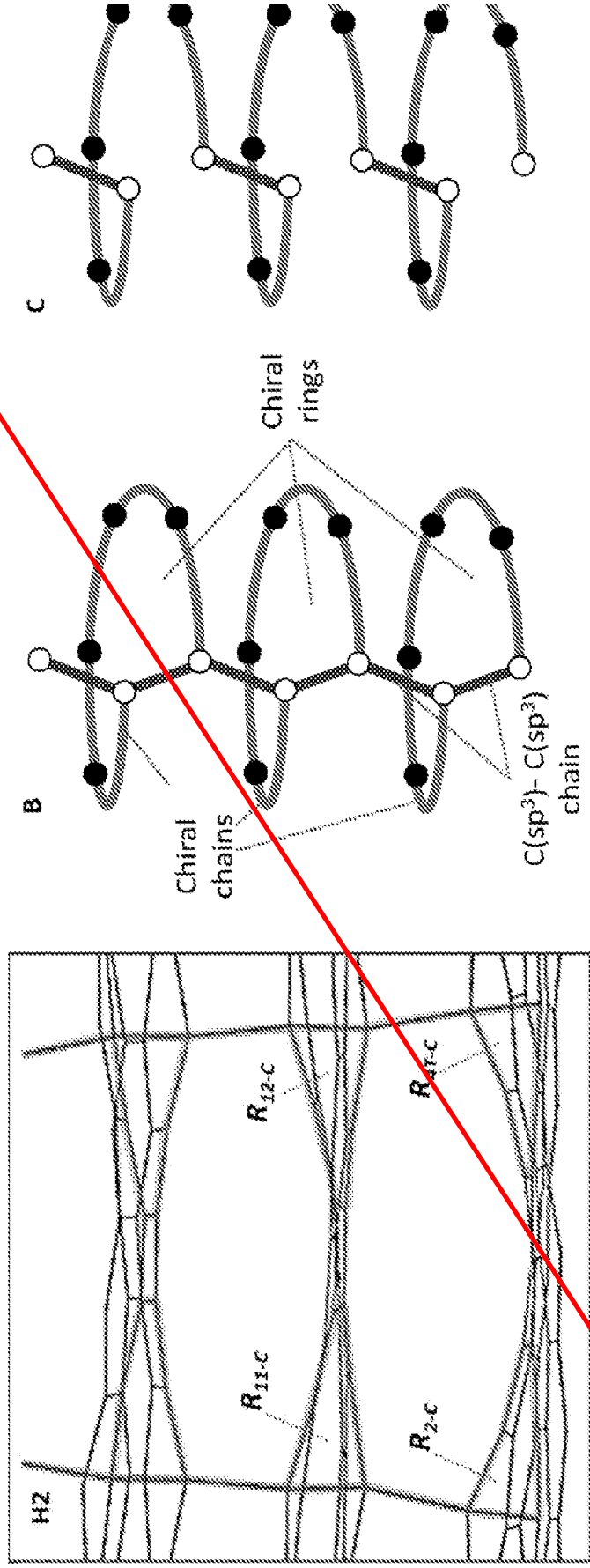

A
H2
R_{12-C}
R_{11-C}
R_{11-C}
R_{2-C}
B
Chiral chains
Chiral rings
$C(sp^3)$- $C(sp^3)$ chain
C

FIG. 37



FIG. 38

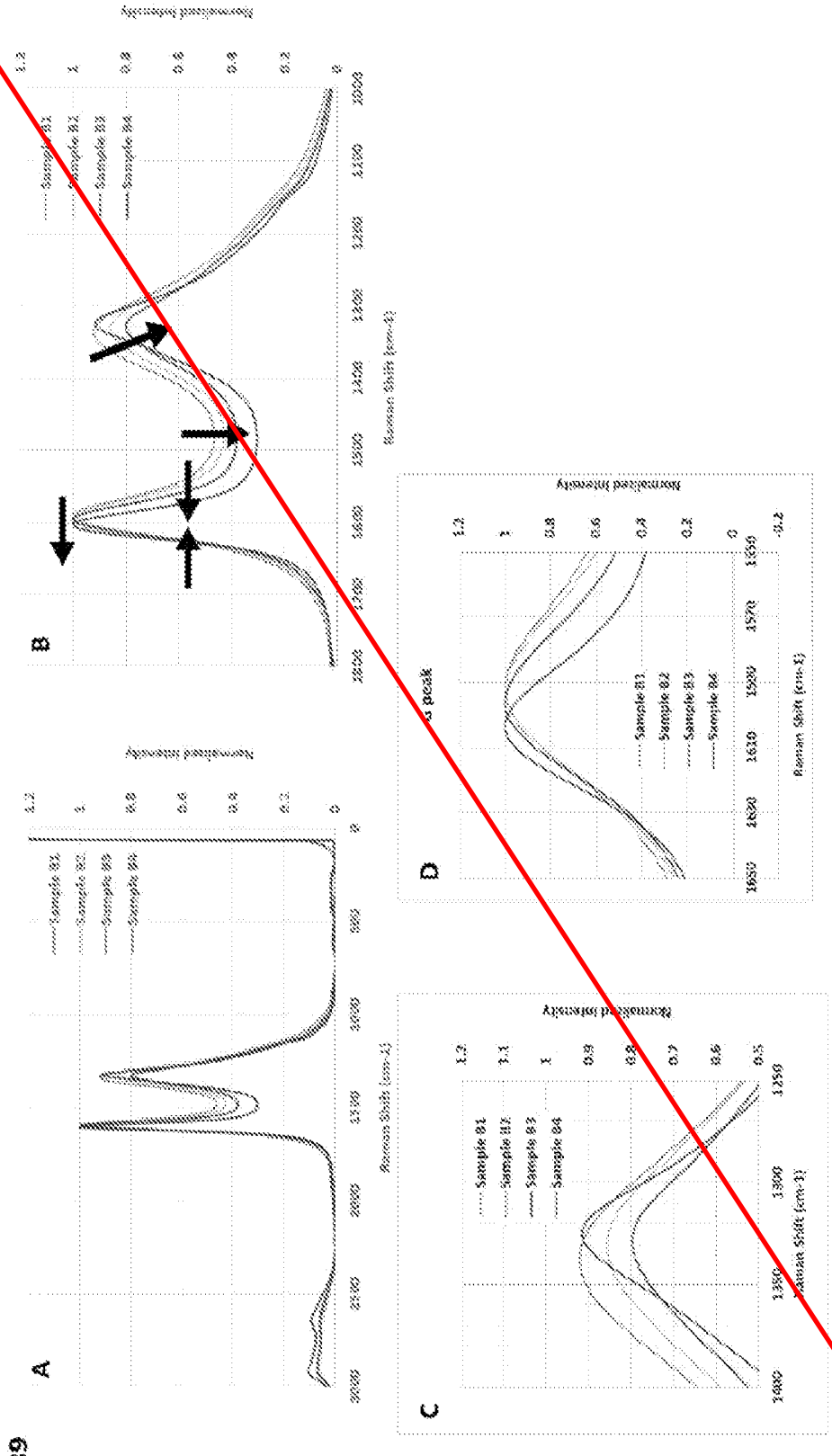

A
B
C
D
Sample B1
Sample B2
Sample B3
Sample B4
Raman Shift (cm-1)
Normalized Intensity

FIG. 39

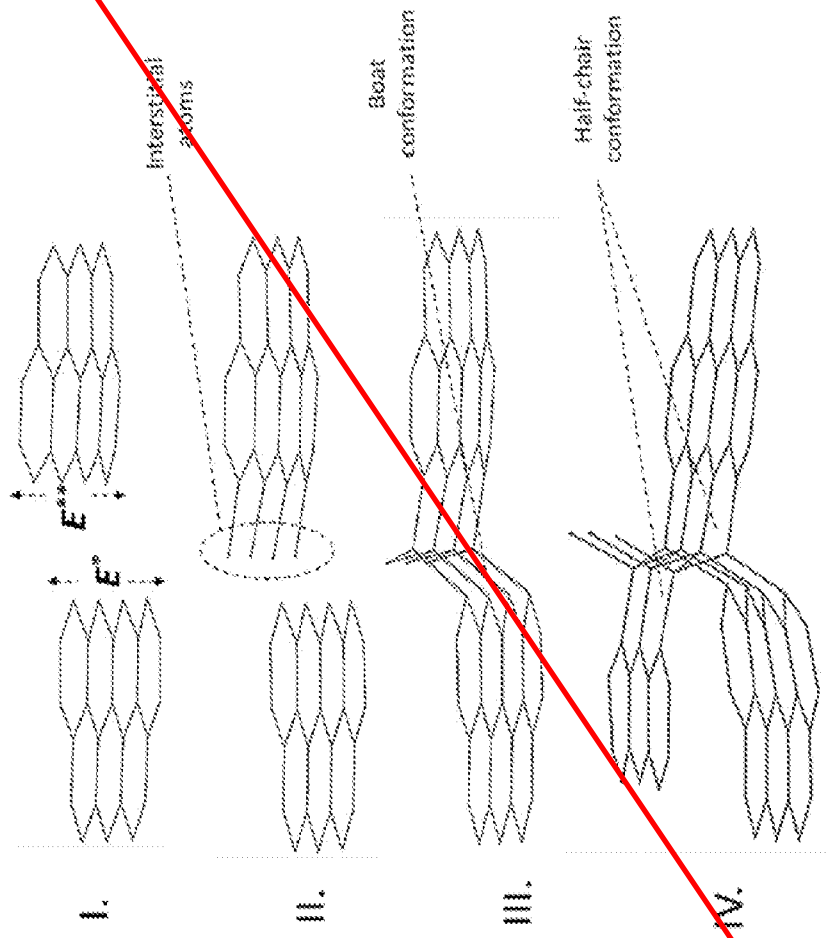

Interstitial atoms
Boat conformation
Half-chair conformation
E''
E'
I.
II.
III.
IV.

FIG. 40

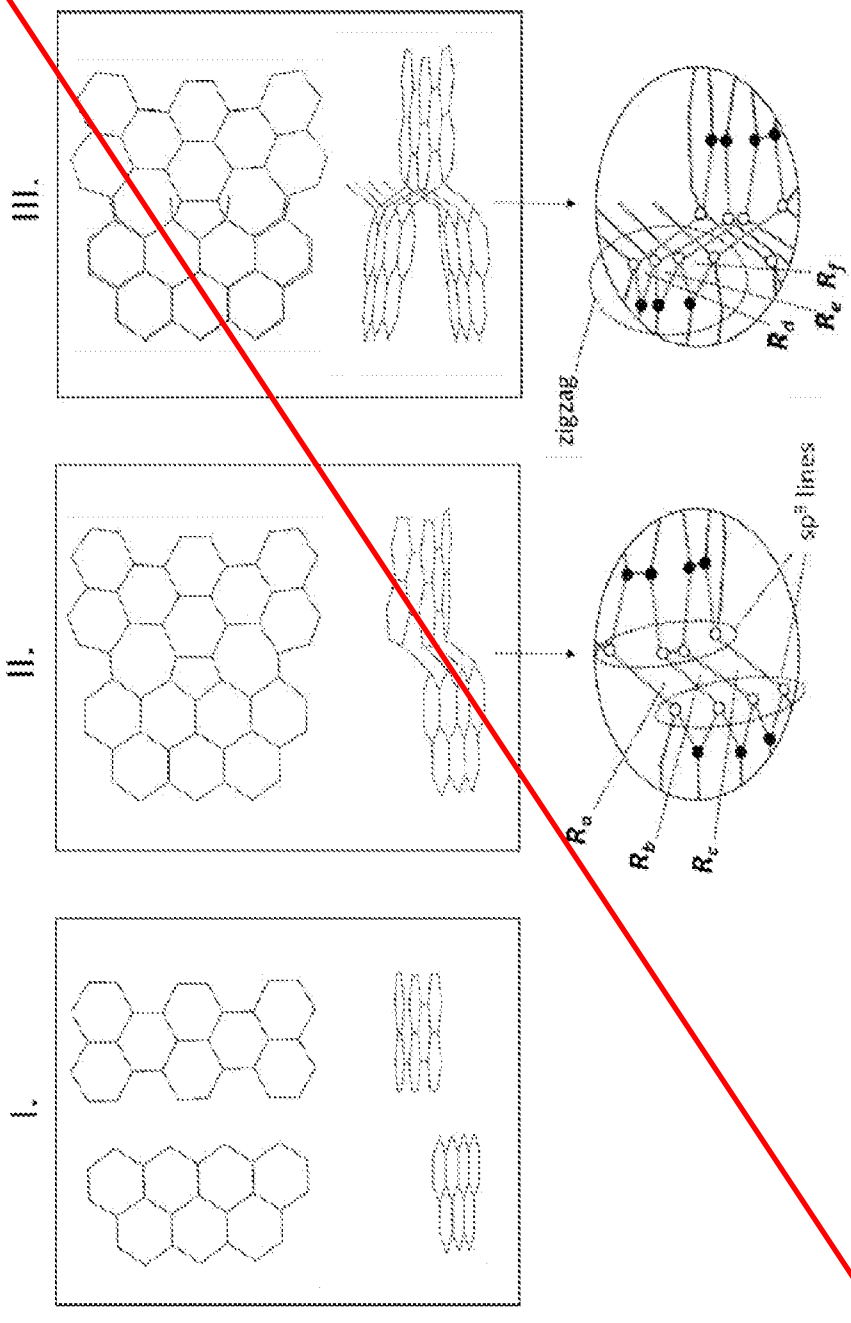


FIG. 41

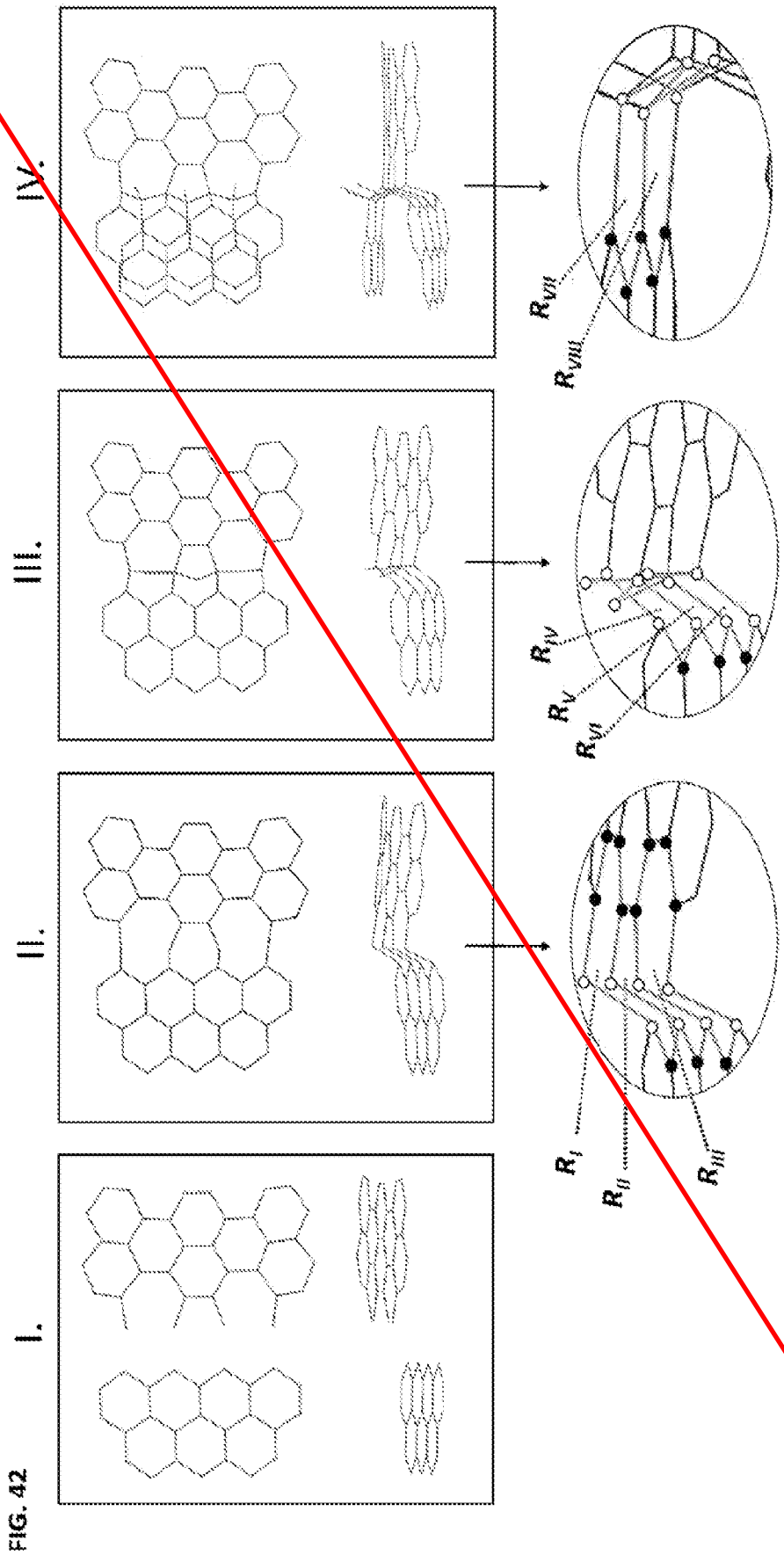


FIG. 42

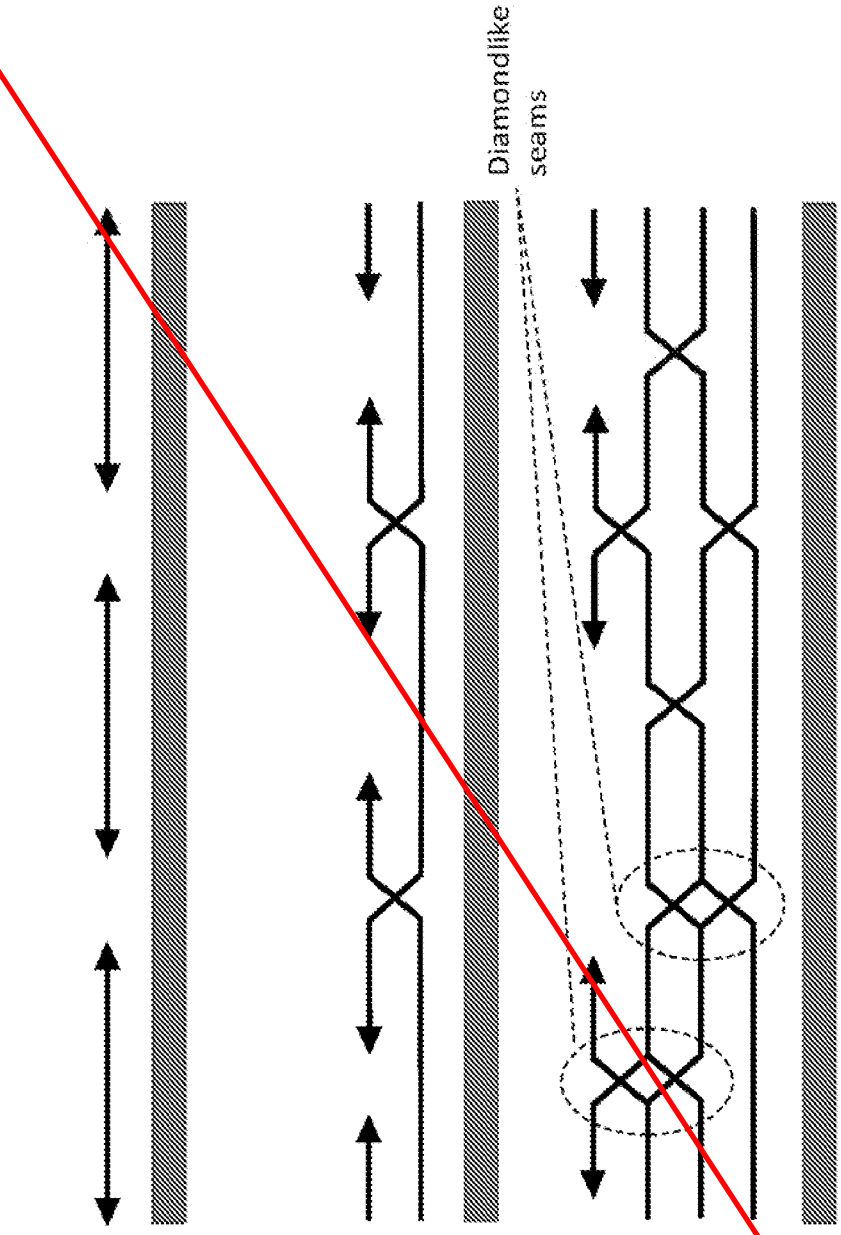


FIG. 43

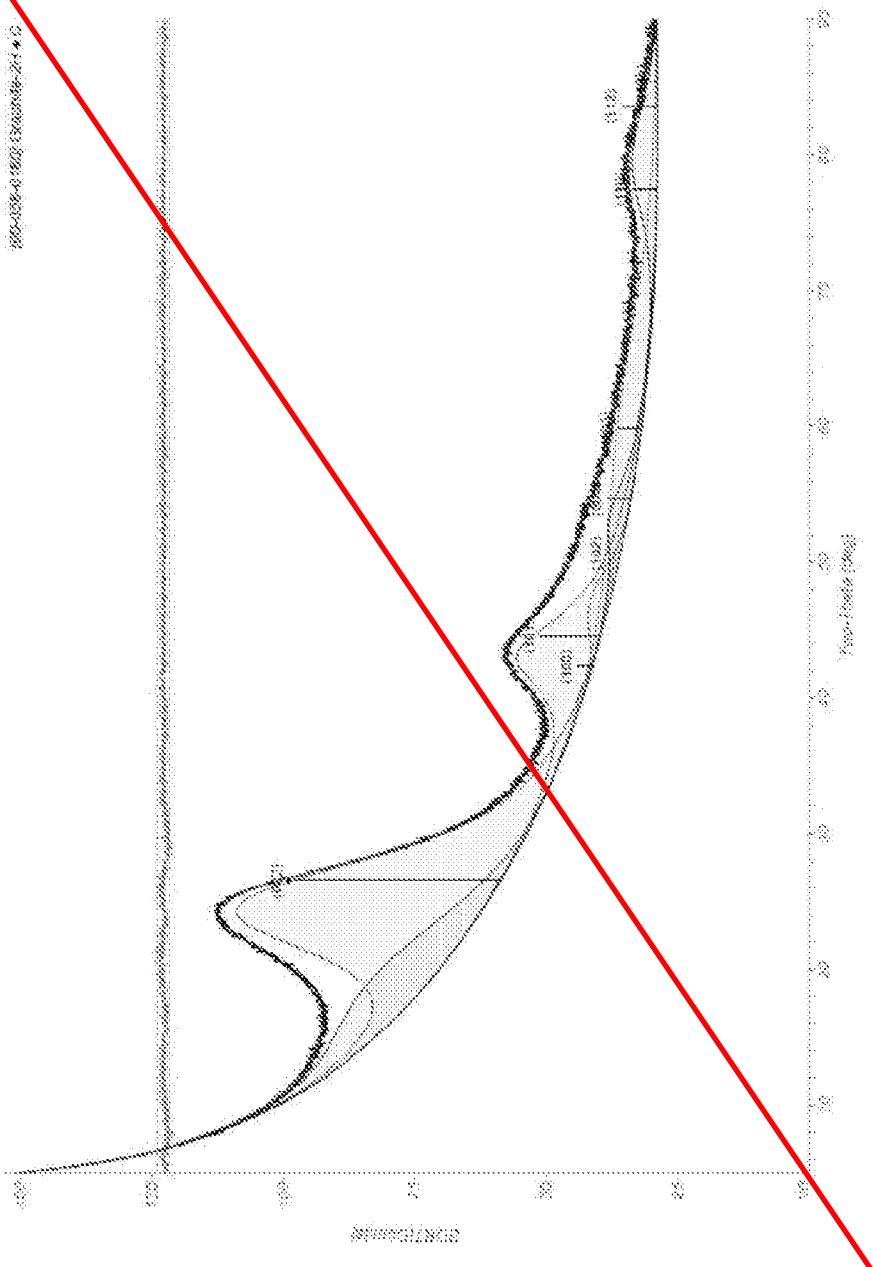


FIG. 44

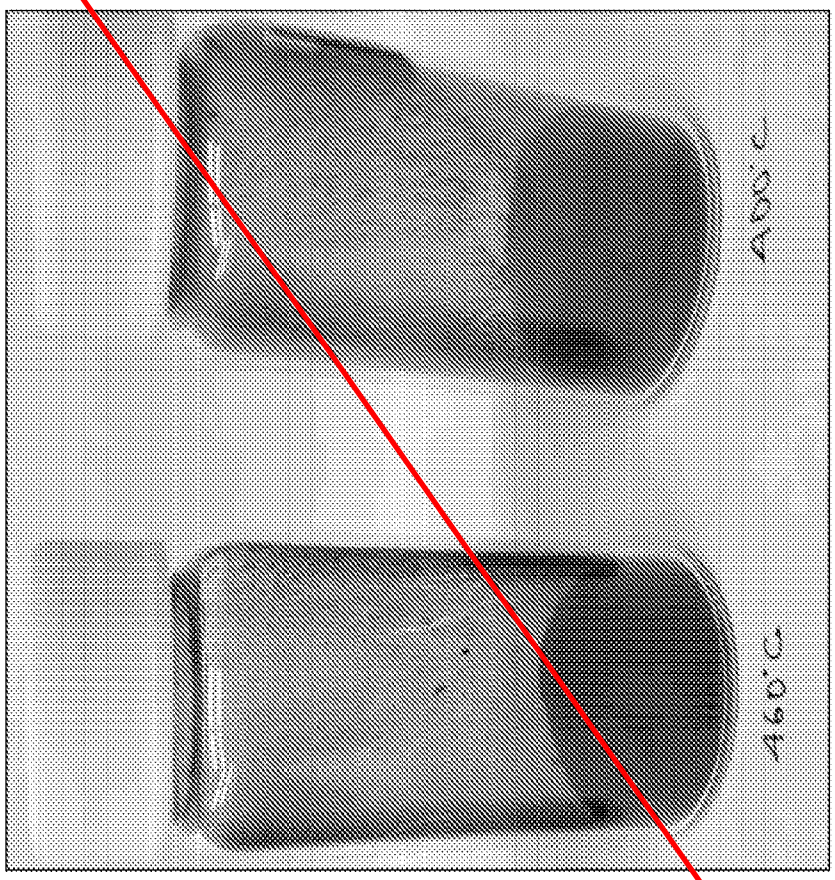


FIG. 45

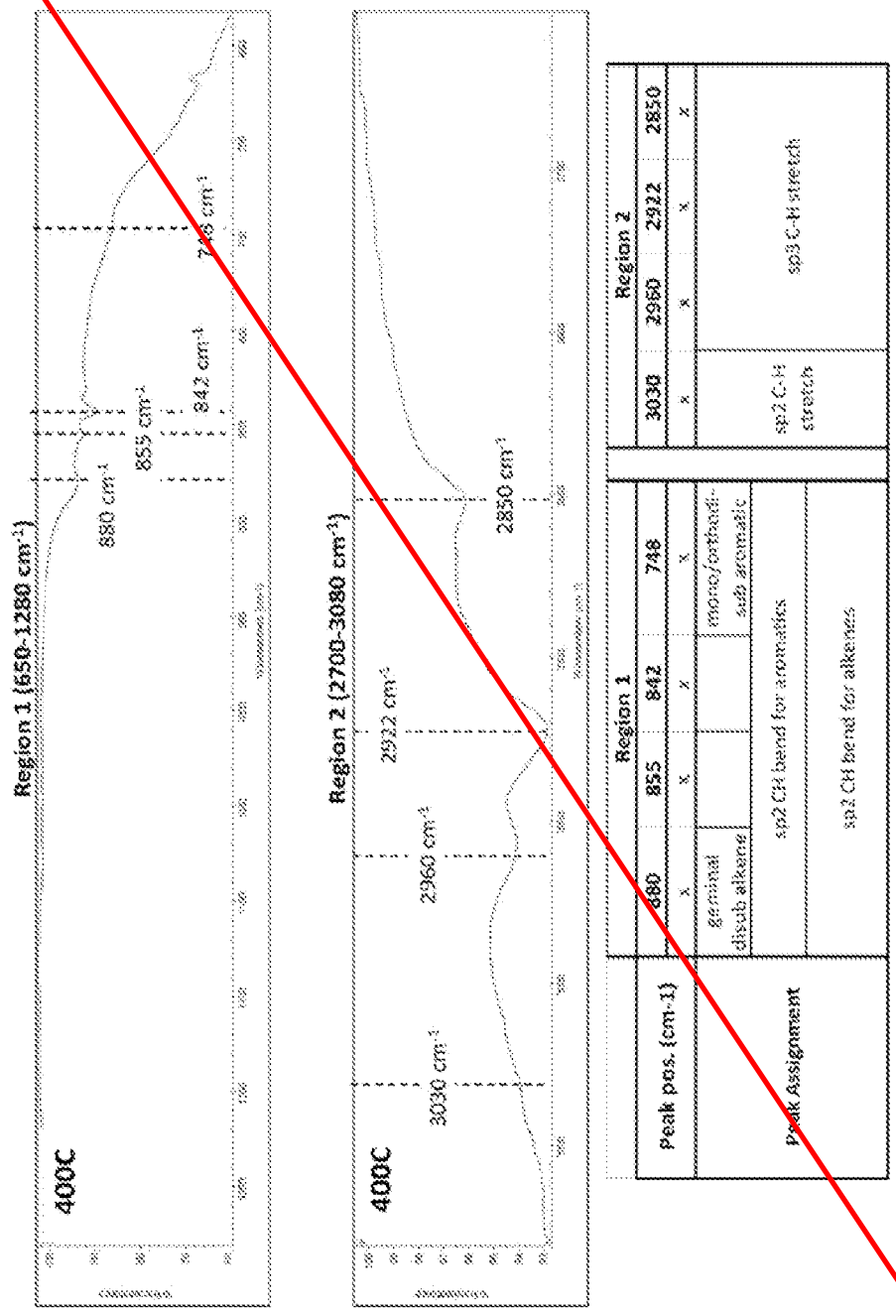

Region 1 (650-1280 cm-1)
400C
880 cm-1
855 cm-1
842 cm-1
748 cm-1
Region 2 (2700-3080 cm-1)
400C
3030 cm-1
2960 cm-1
2922 cm-1
2850 cm-1
Region 1
Peak pos. (cm-1)
880
855
842
748
Peak Assignment
x
x
x
x
germinal disub alkene
sp2 CH bend for aromatics
mono/ortho/di-sub aromatic
sp2 CH bend for alkenes
Region 2
3030
2960
2922
2850
x
x
x
x
sp2 C-H stretch
sp3 C-H stretch

FIG. 46

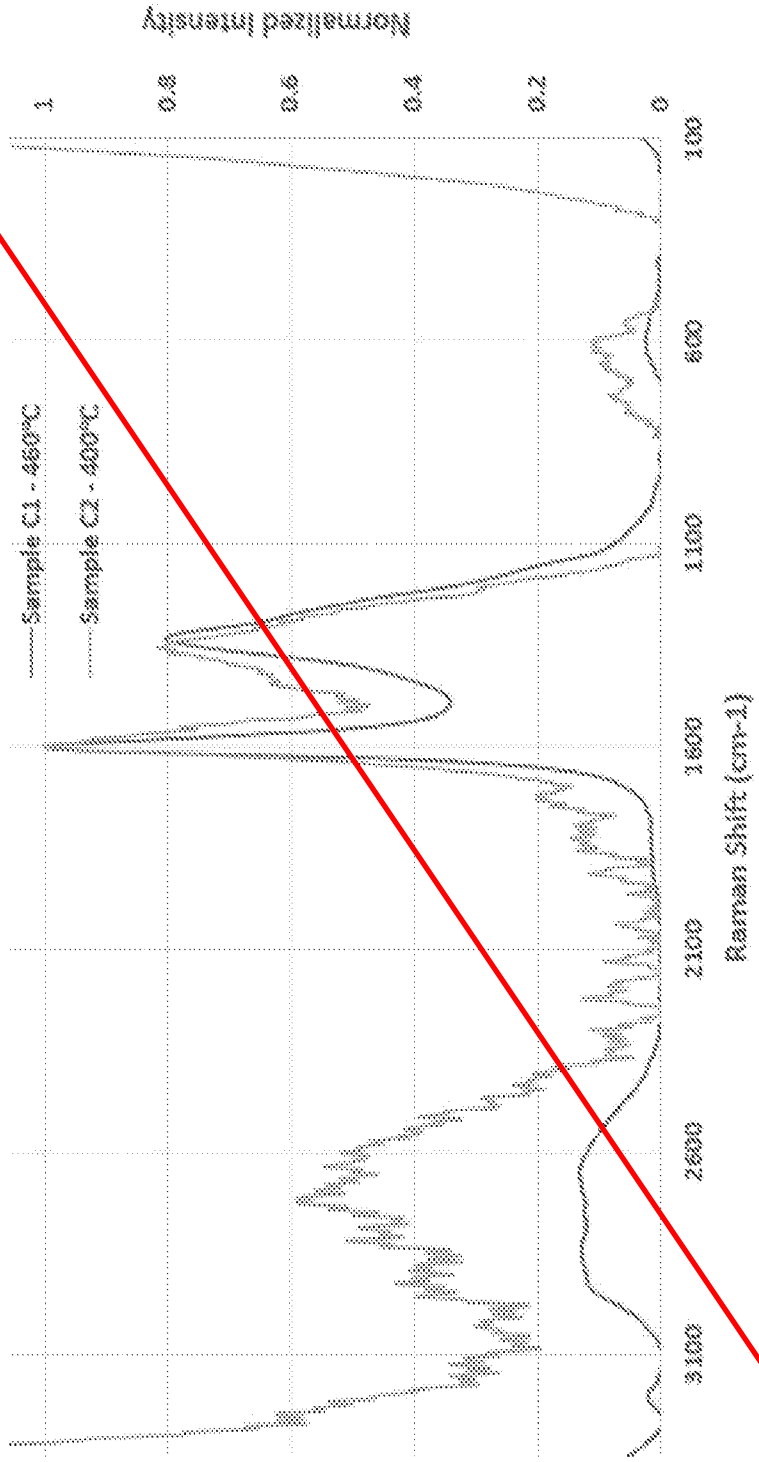

Normalized Intensity
1
0.8
0.6
0.4
0.2
0
100
600
1100
1600
2100
2600
3100
Raman Shift (cm-1)
Sample C1 - 460°C
Sample C1 - 400°C

FIG. 47

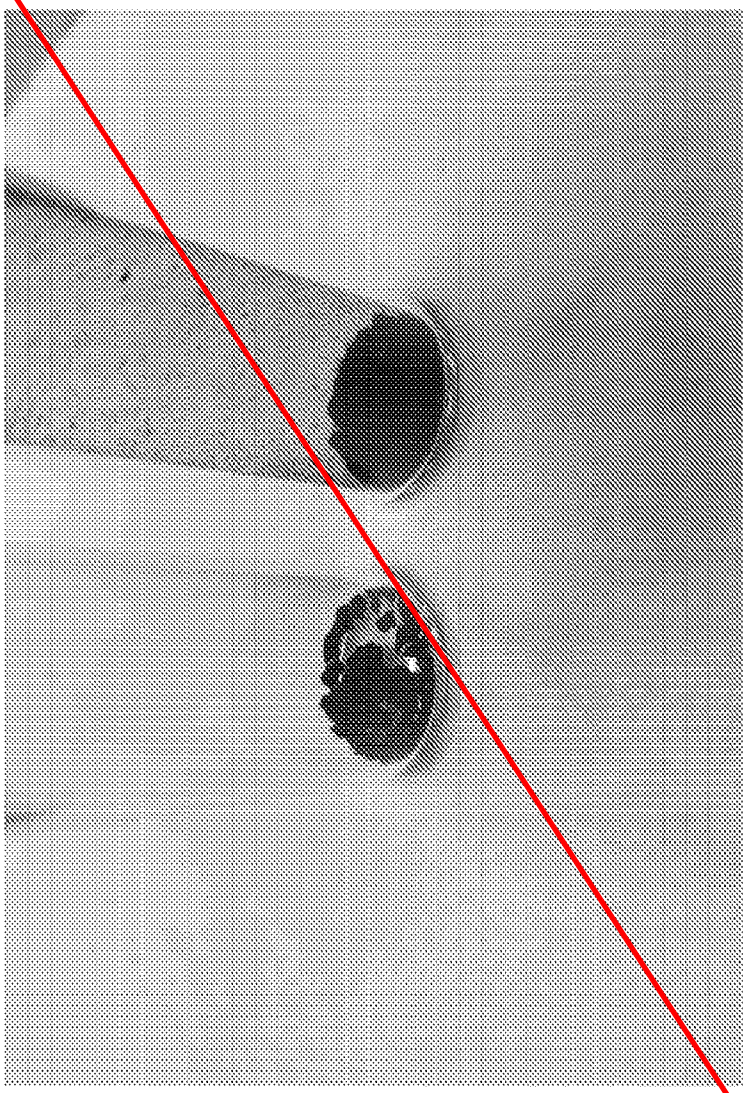


FIG. 48

Curved, tissue-like sheets-of-cells
Dense, macroscopic granules
Smaller agglomerates

FIG. 49

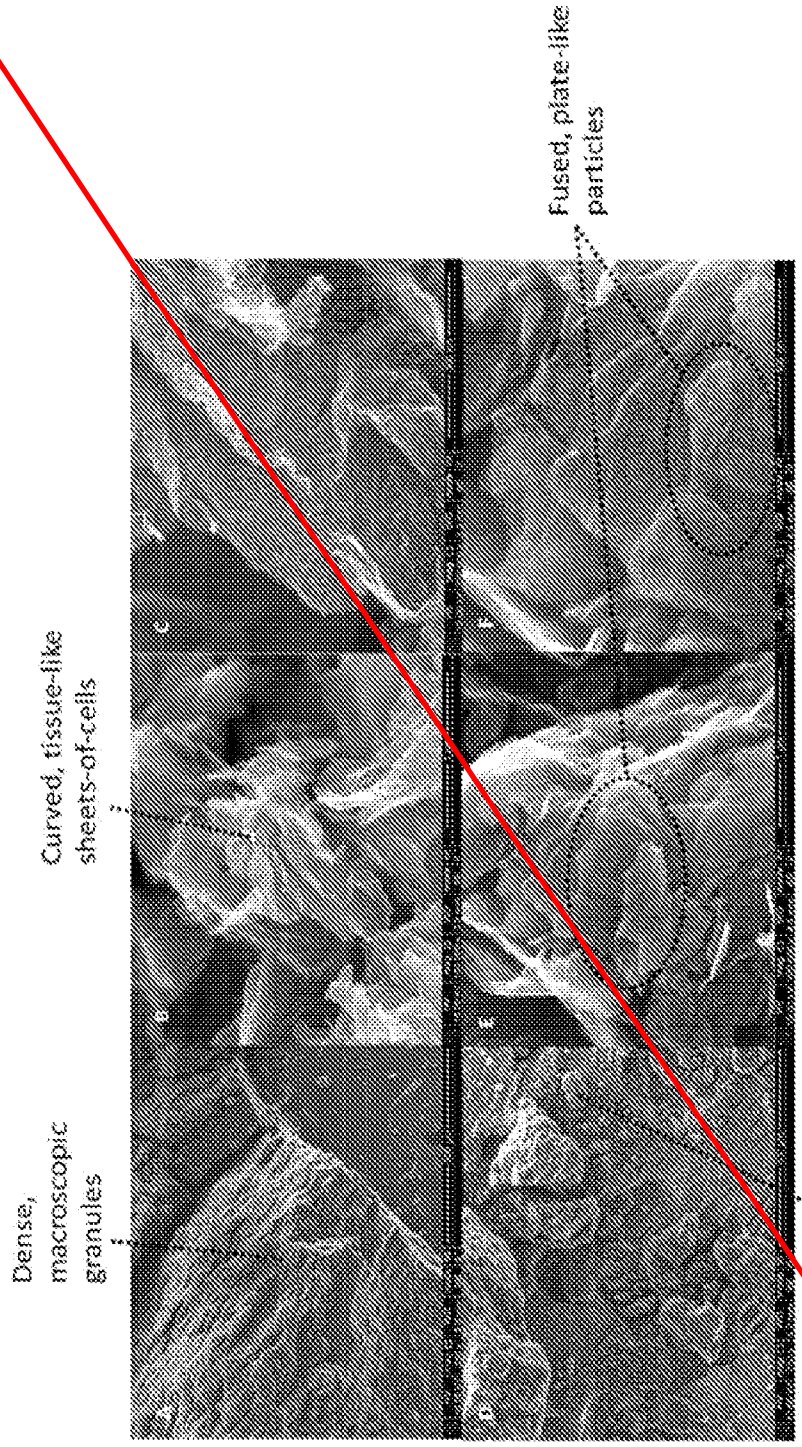

Dense, macroscopic granules
Curved, tissue-like sheets-of-cells
Fused, plate-like particles
Soft, microscopic agglomerates

FIG. 50

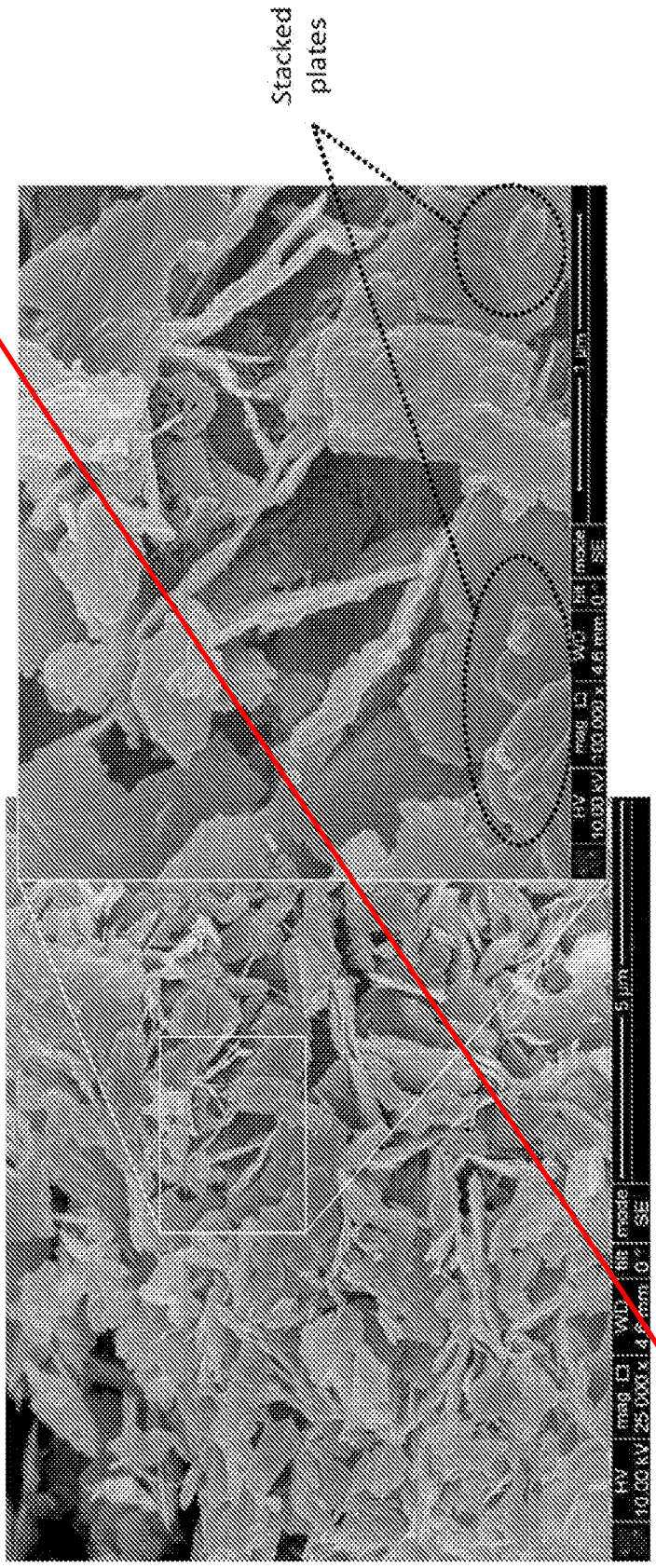


FIG. 55

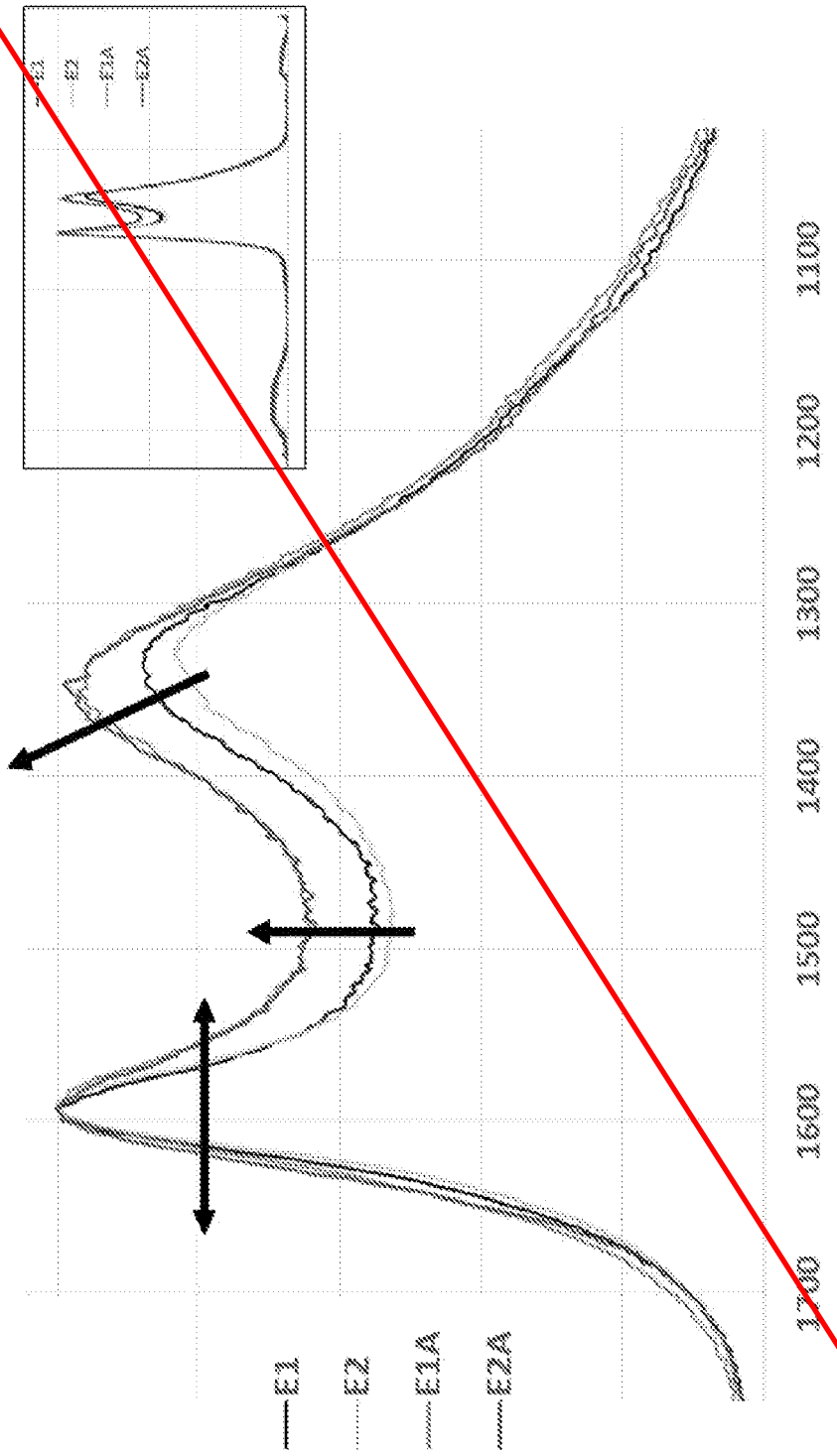


FIG. 52

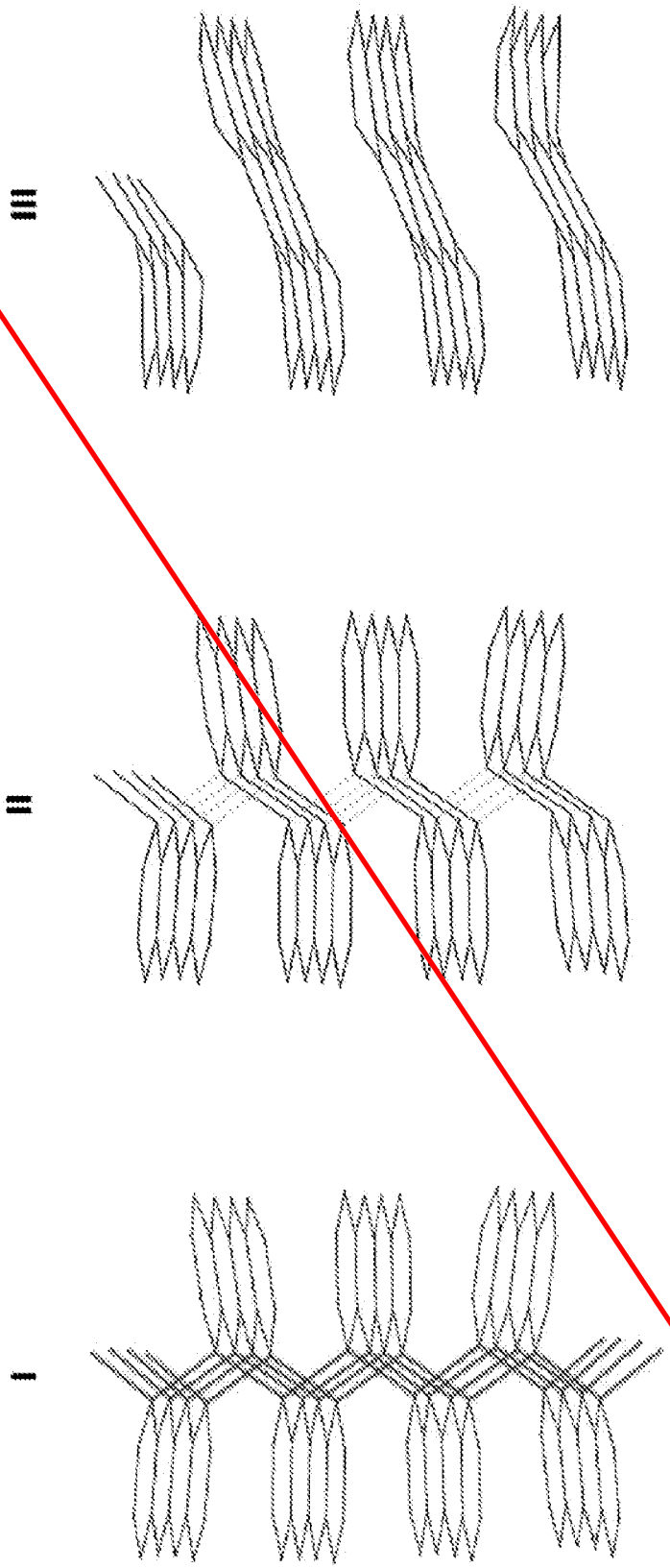


FIG. 53

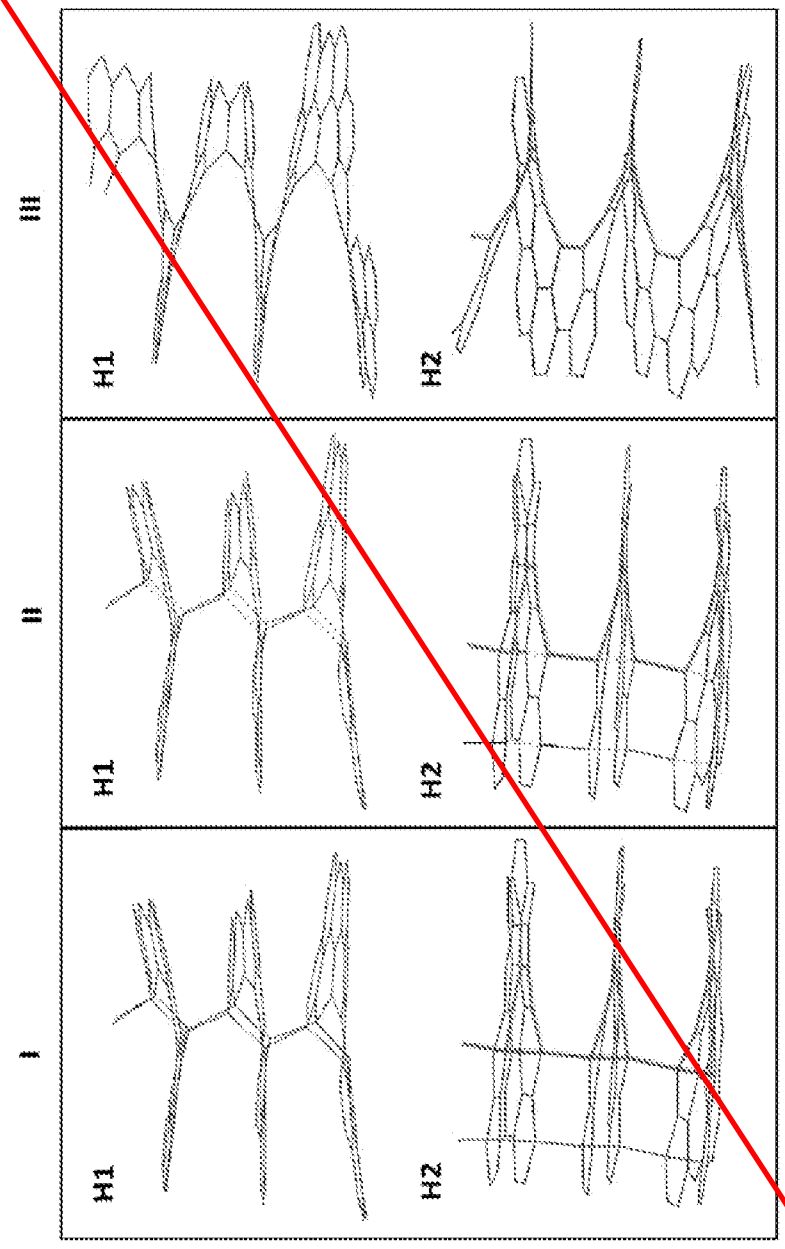


FIG. 54

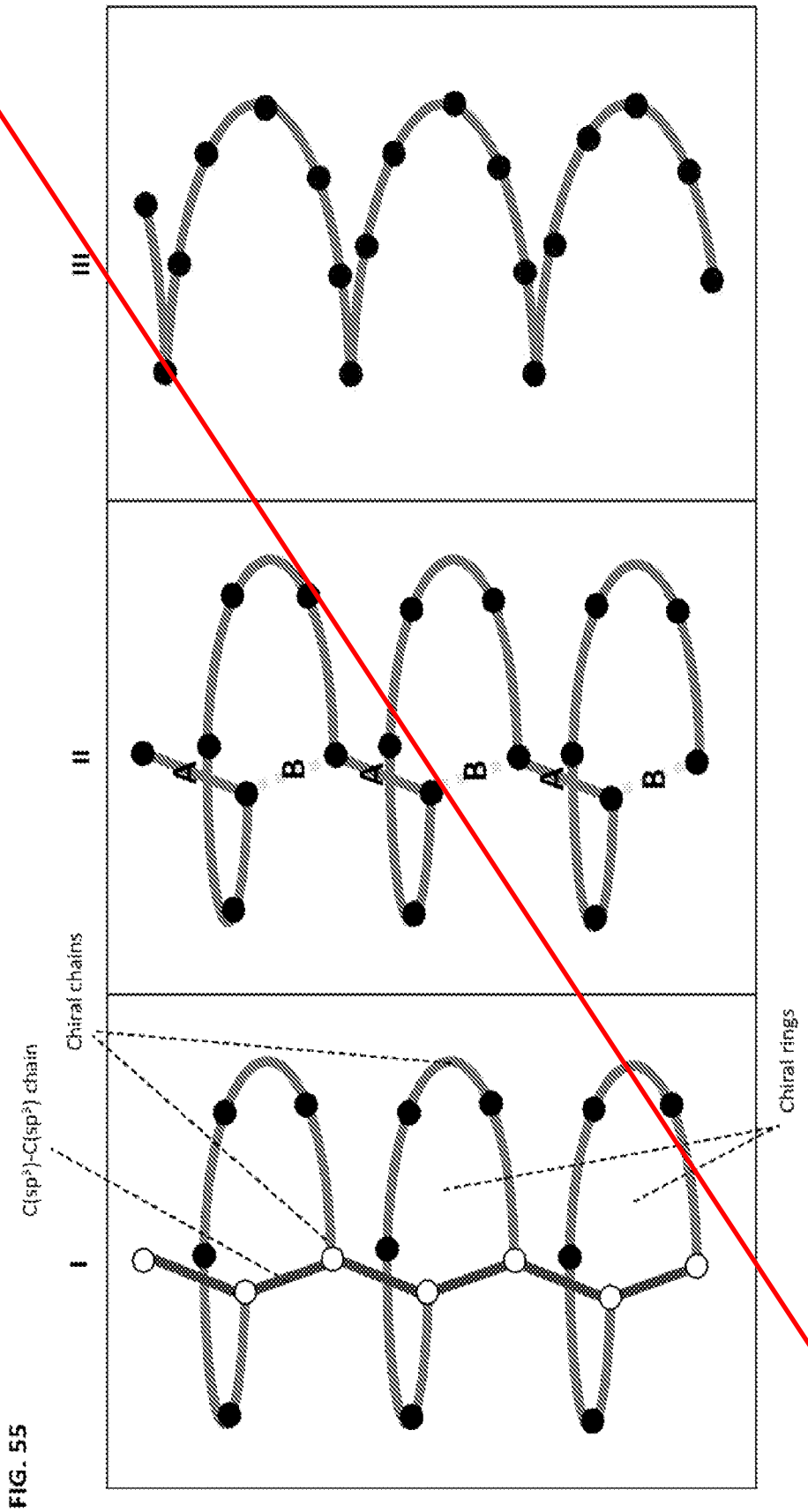


FIG. 55

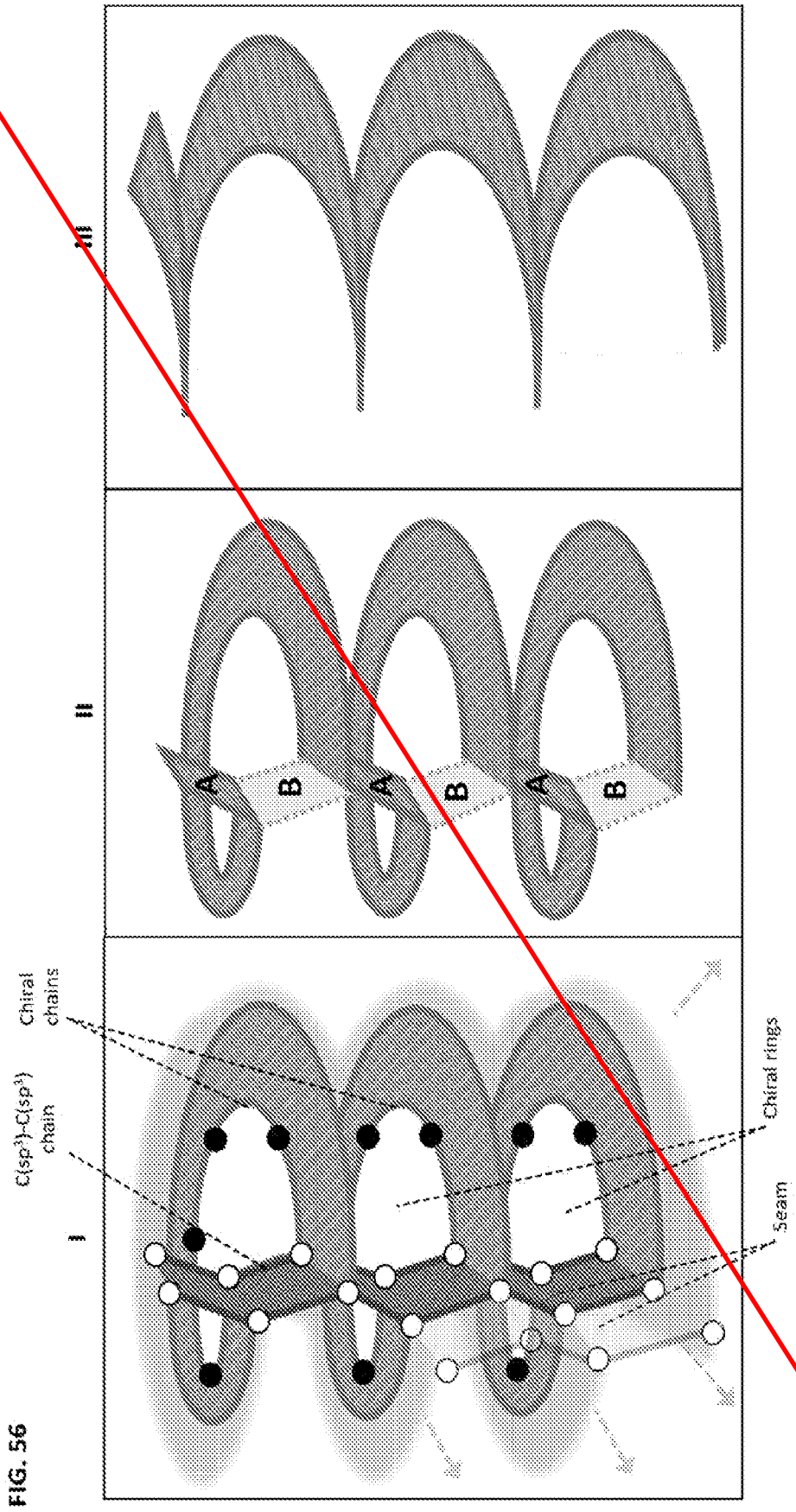

III
II
A
B
A
B
A
B
I
Chiral chains
C(sp³)-C(sp³) chain
Chiral rings
Seam

FIG. 56

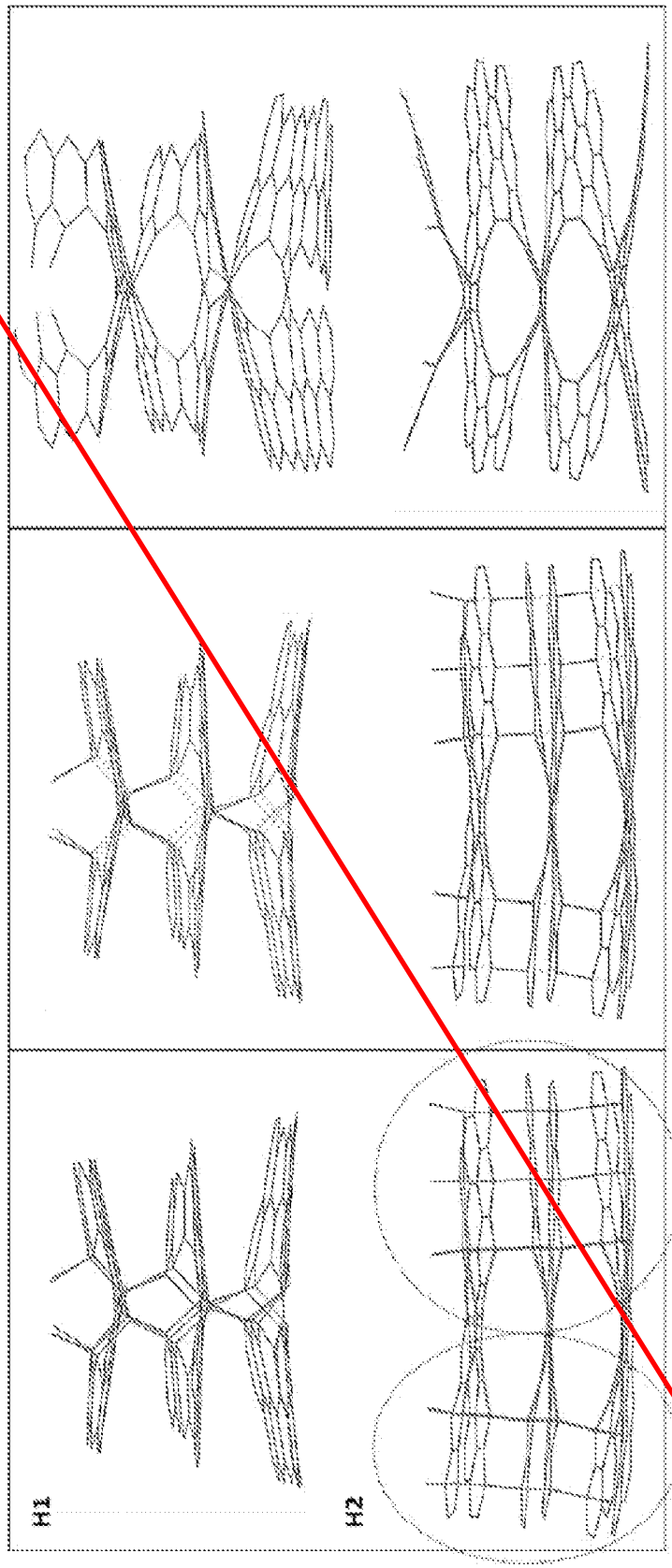


FIG. 57

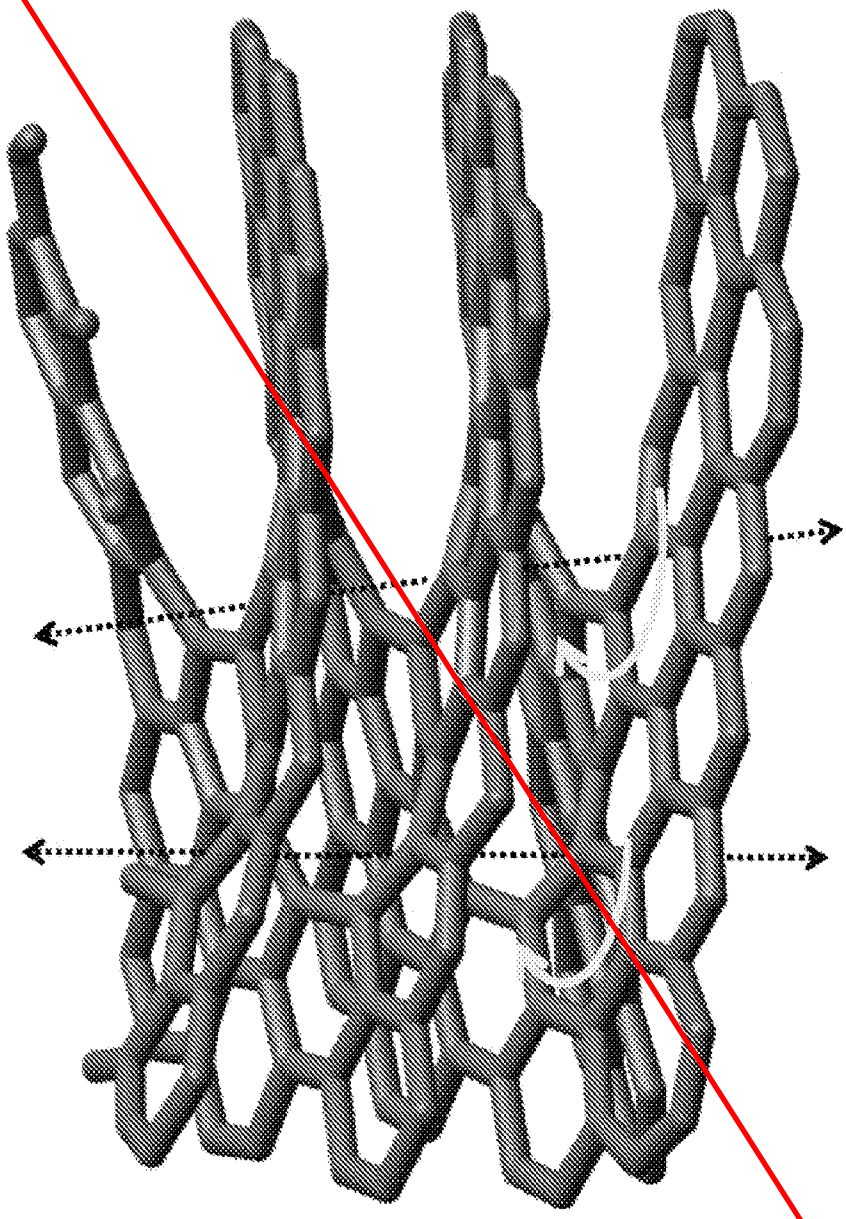


FIG. 58

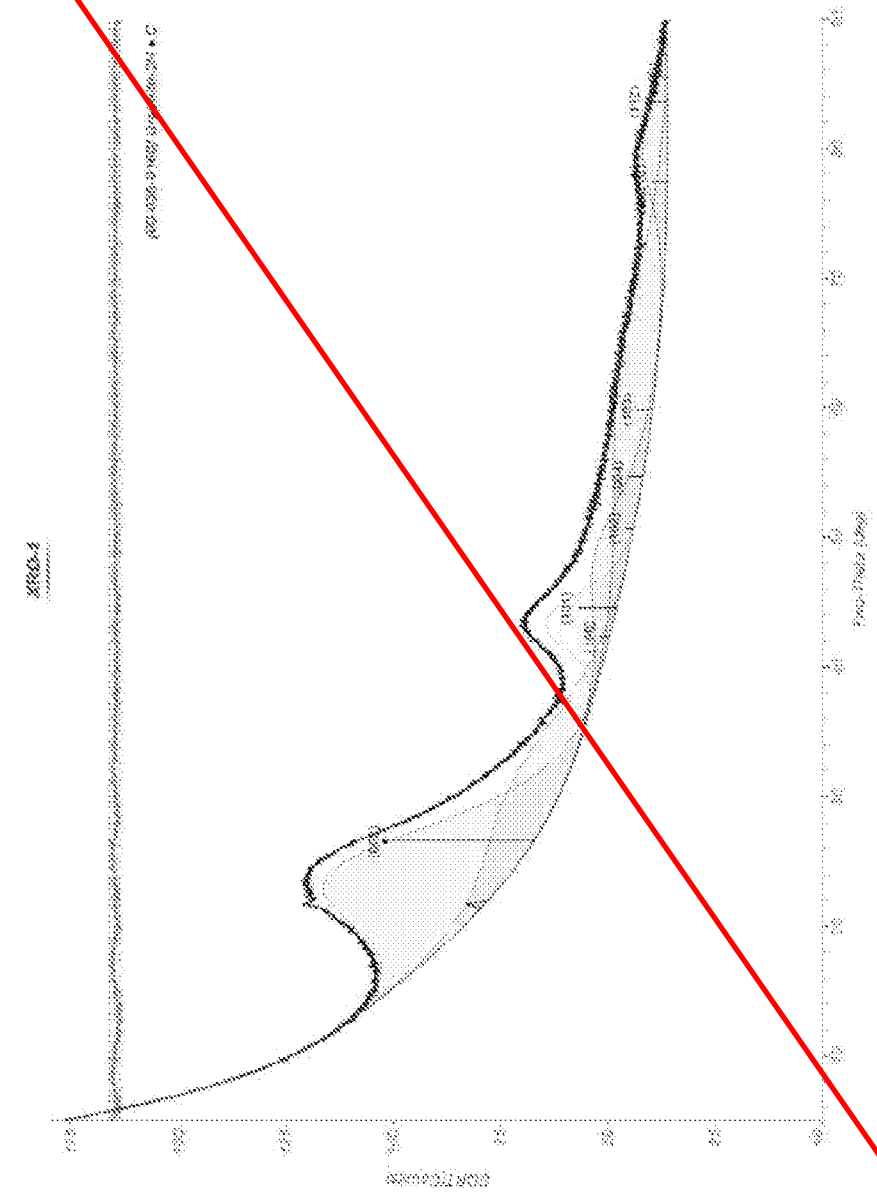


FIG. 59

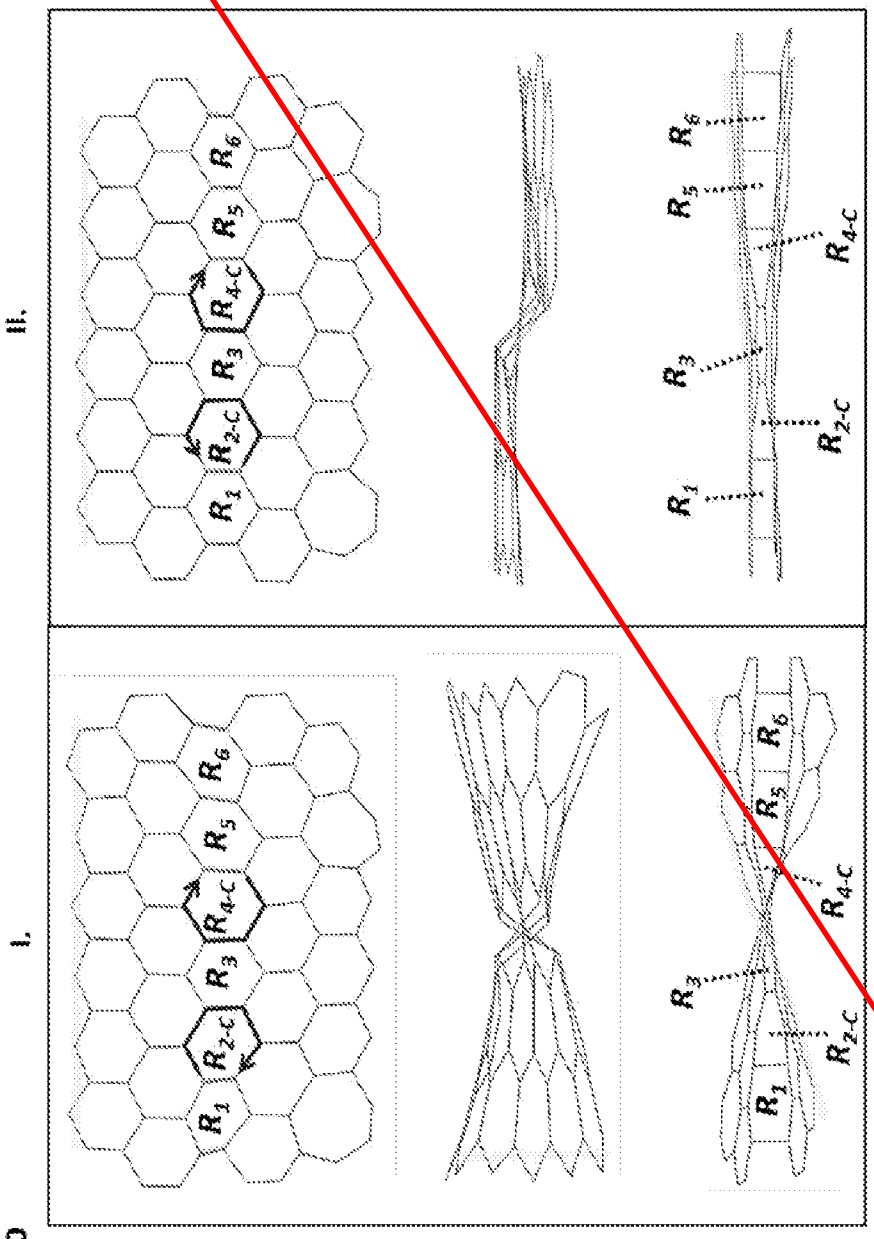


FIG. 60

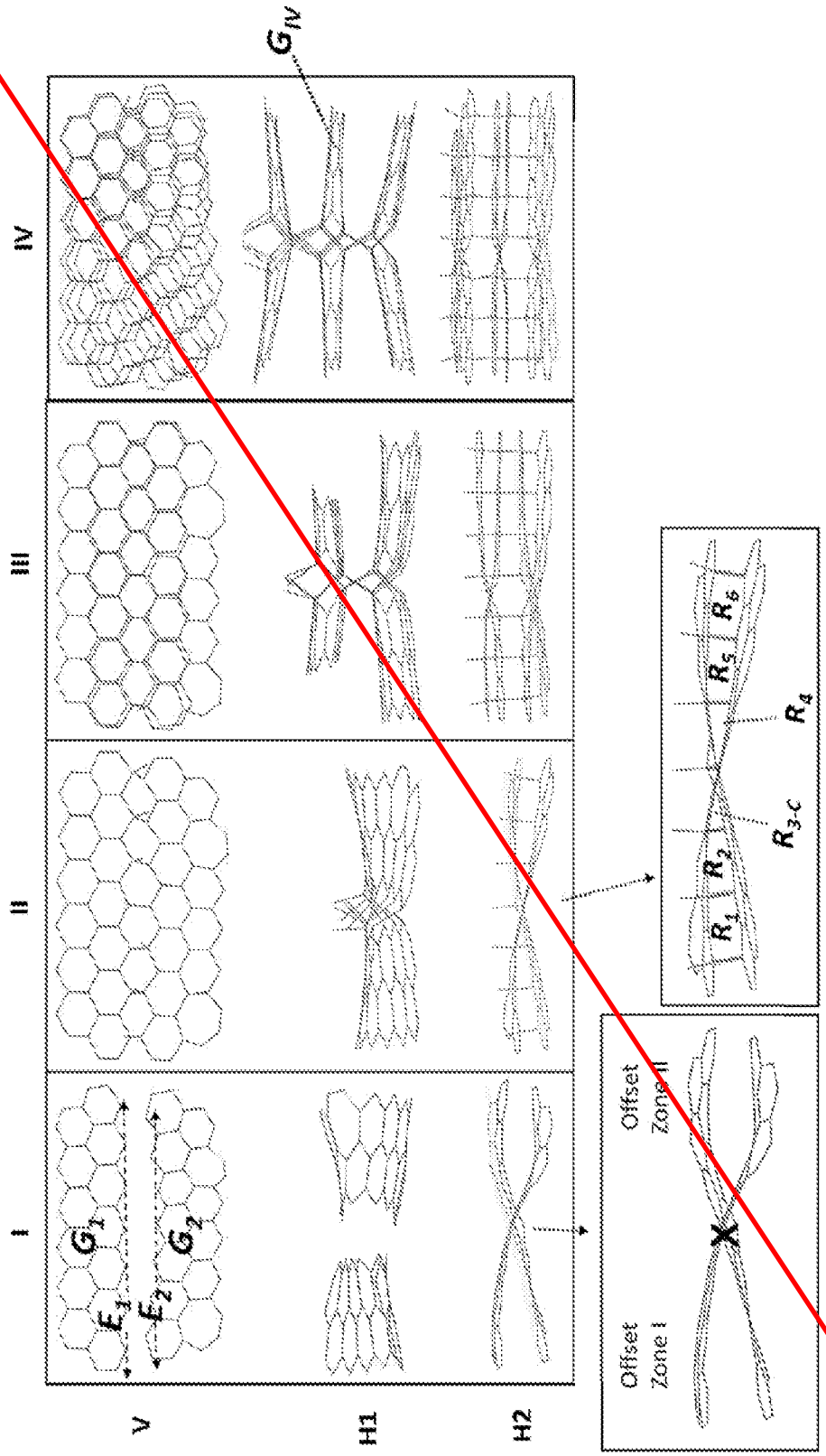

IV
III
II
I
V
H1
H2
G_{IV}
G_1
G_2
E_1
E_2
R_1
R_2
R_{3-C}
R_4
R_5
R_6
Offset
Zone II
Offset
Zone I
X

FIG. 61

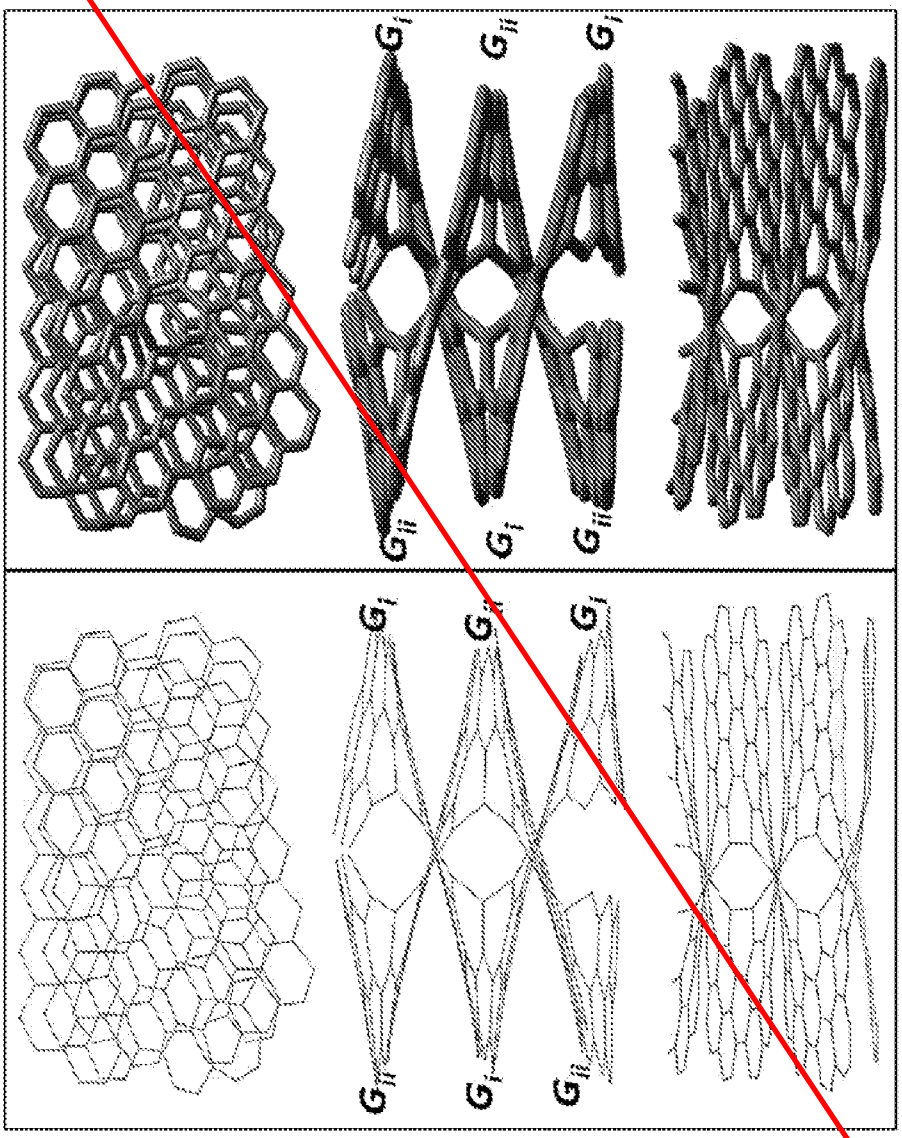
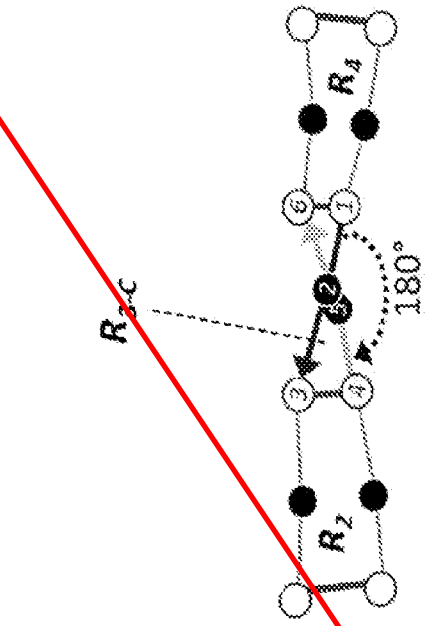


FIG. 62



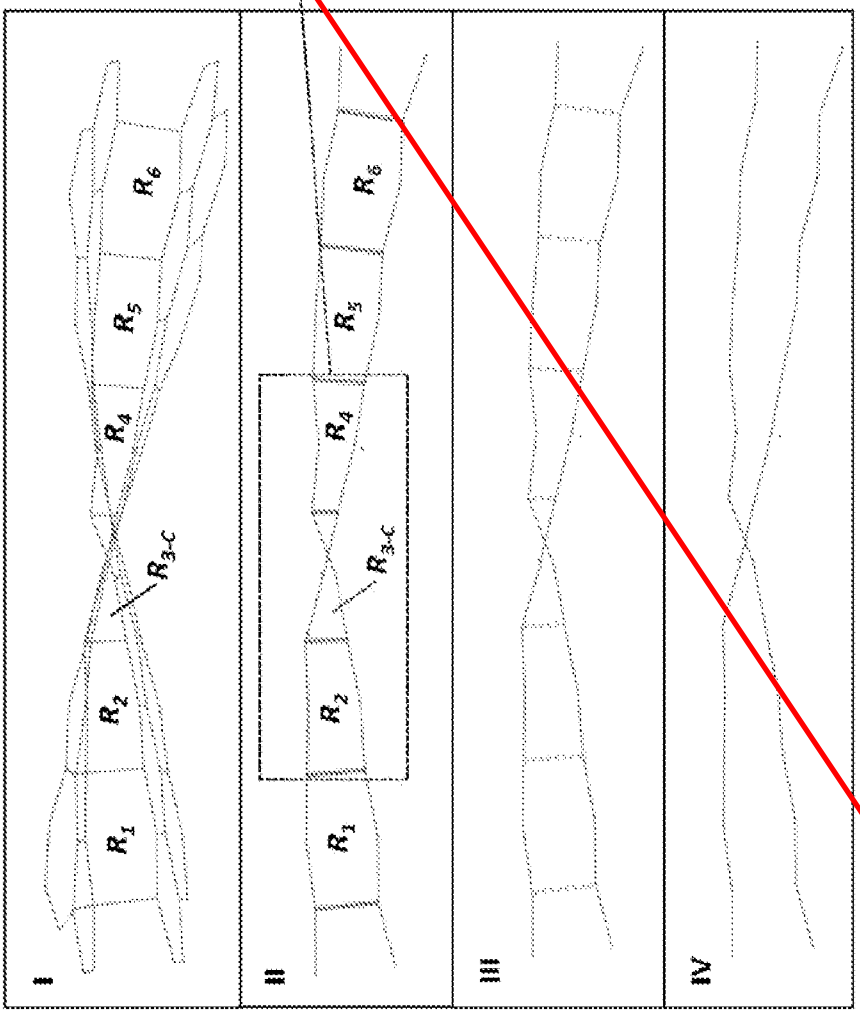


FIG. 63

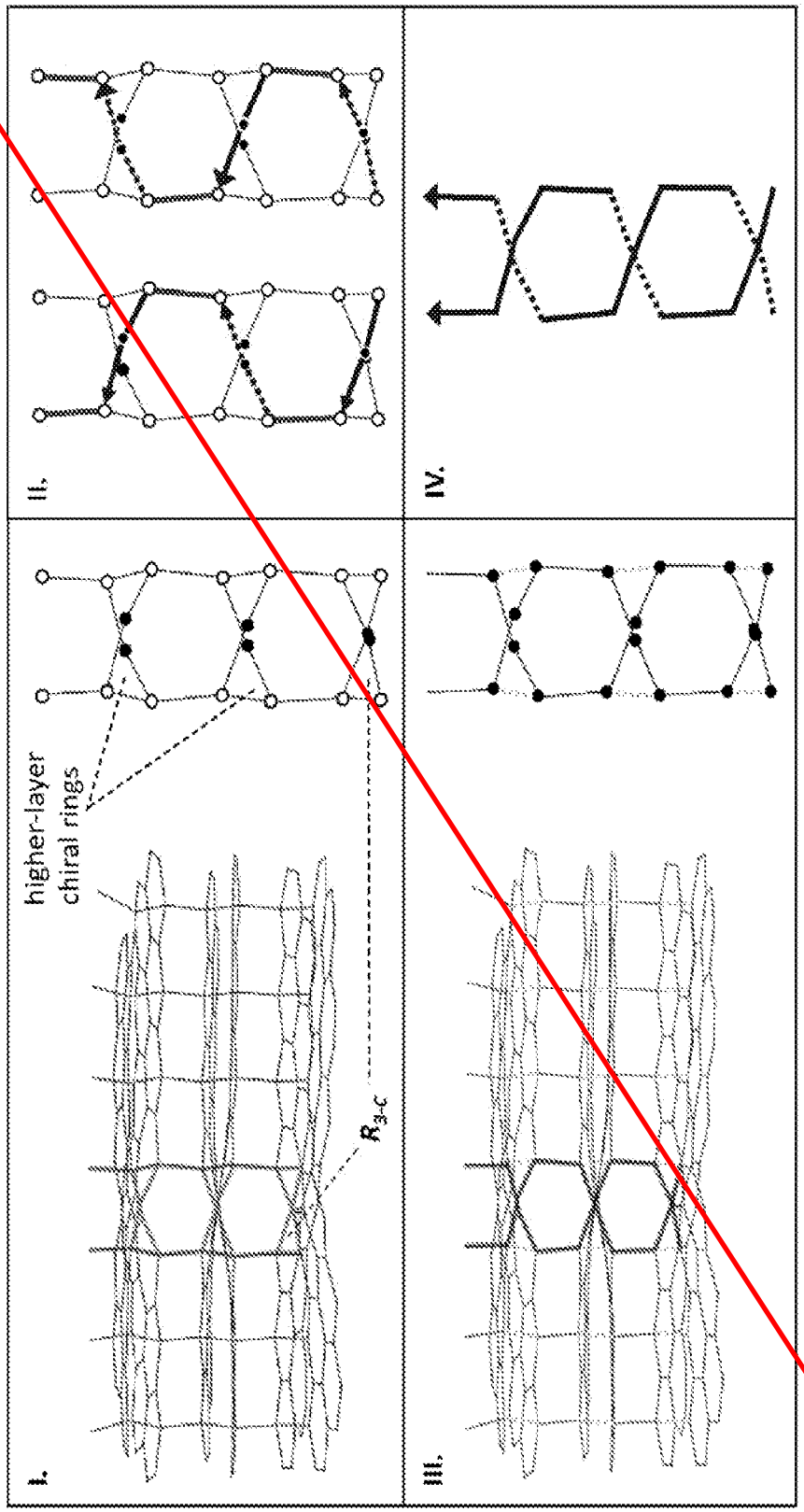


FIG. 64

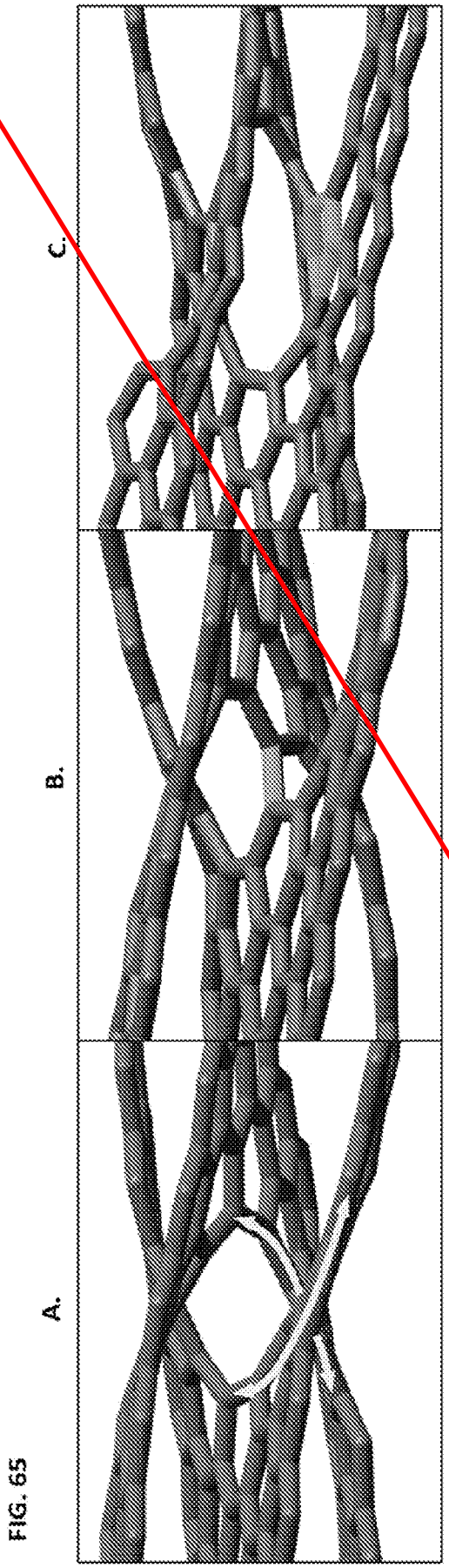


FIG. 65

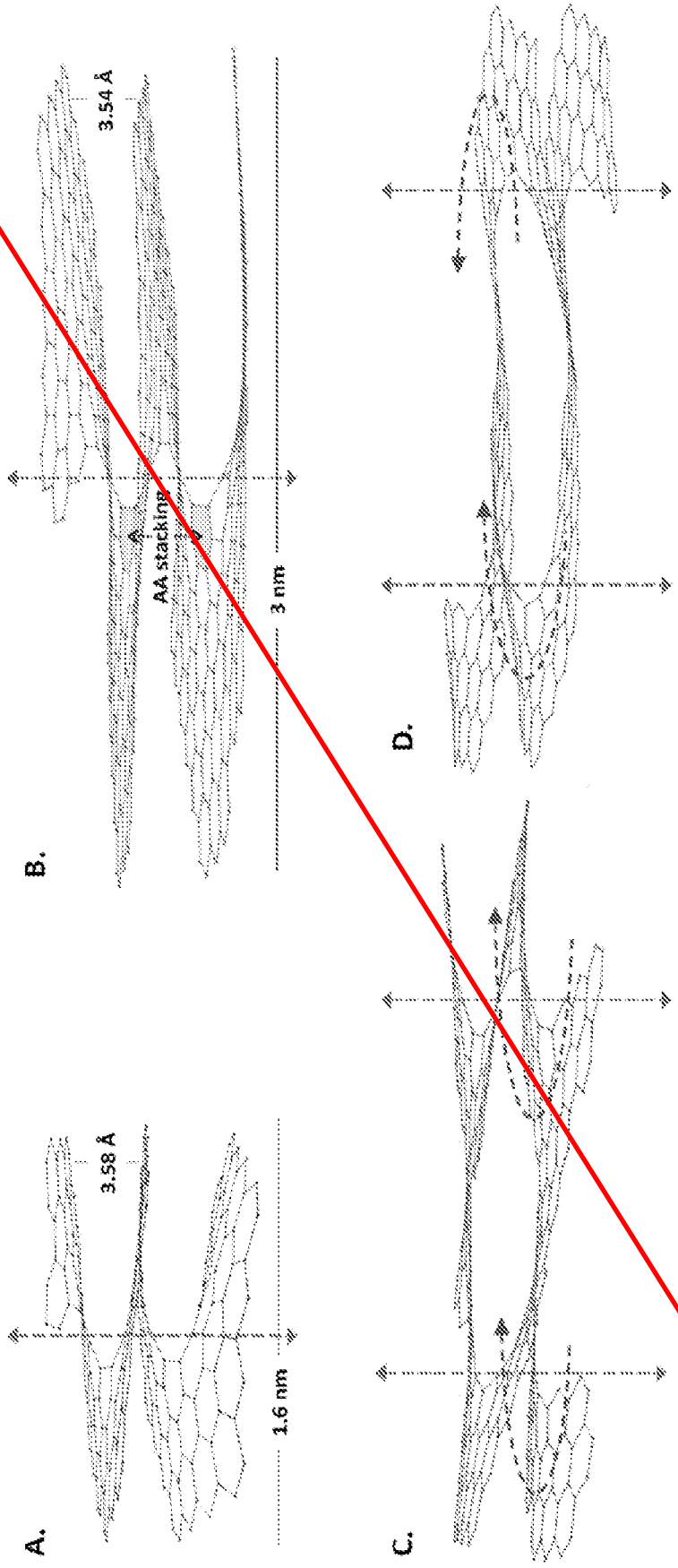


FIG. 66

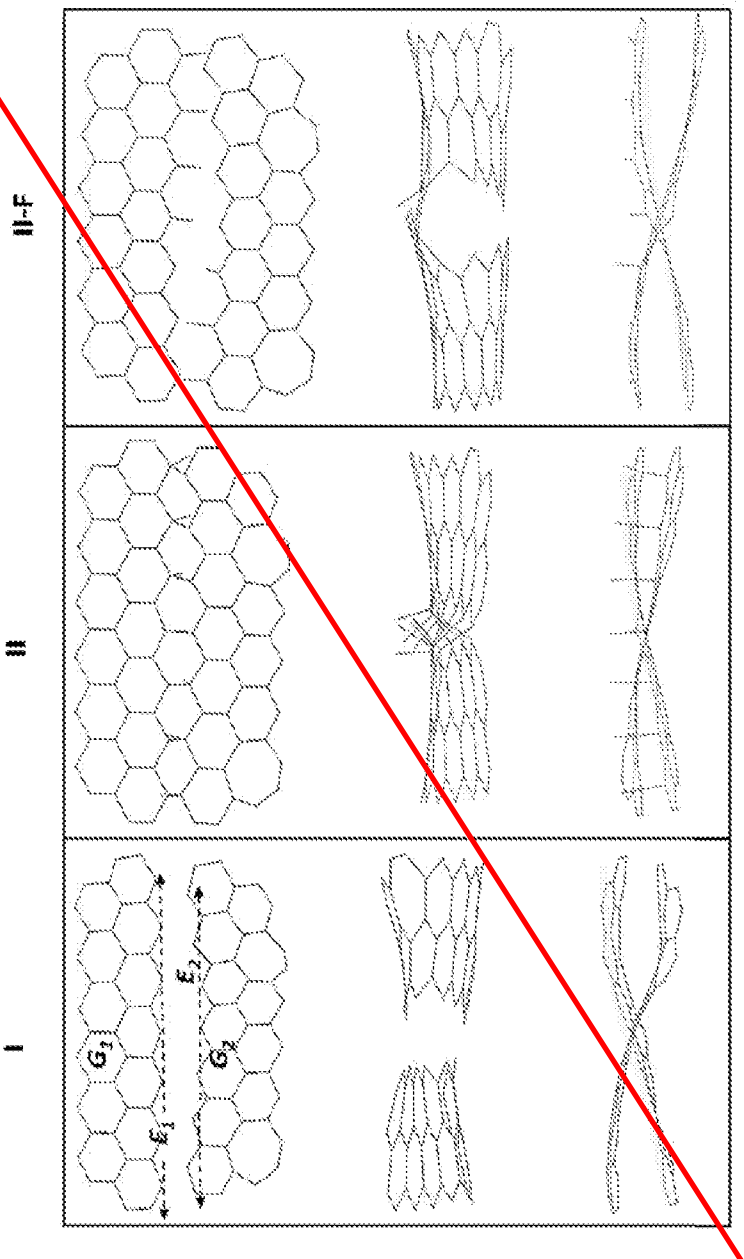


FIG. 67

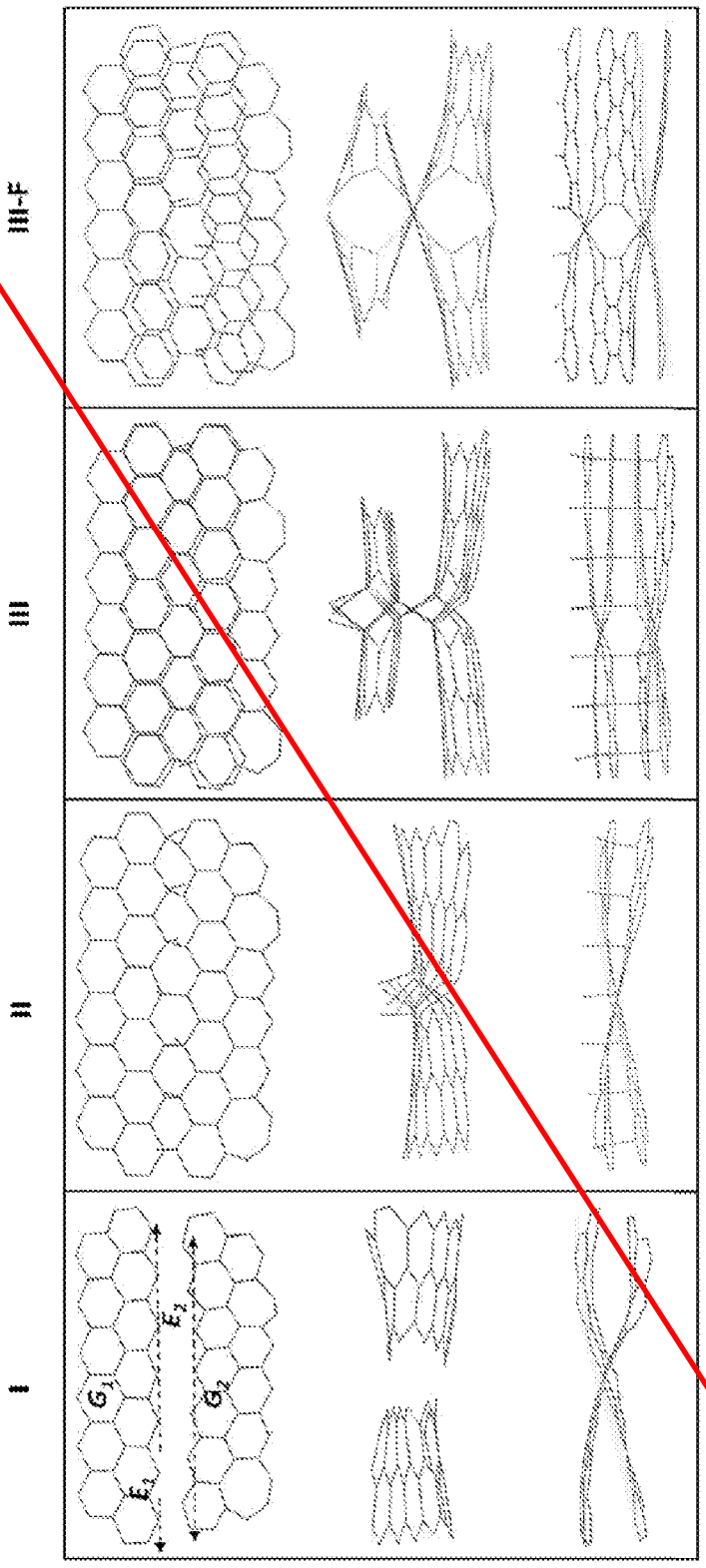


FIG. 68

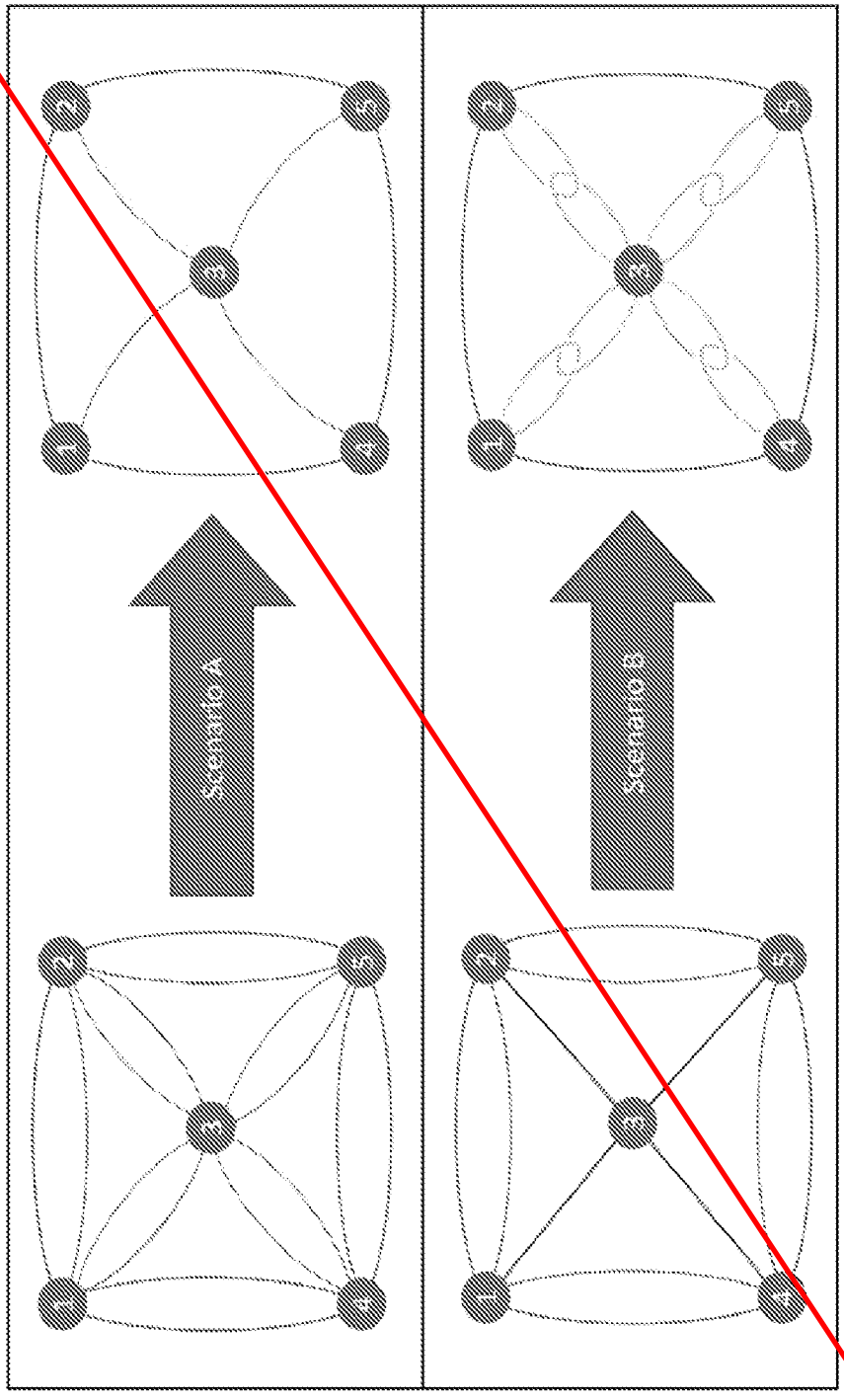


FIG. 69

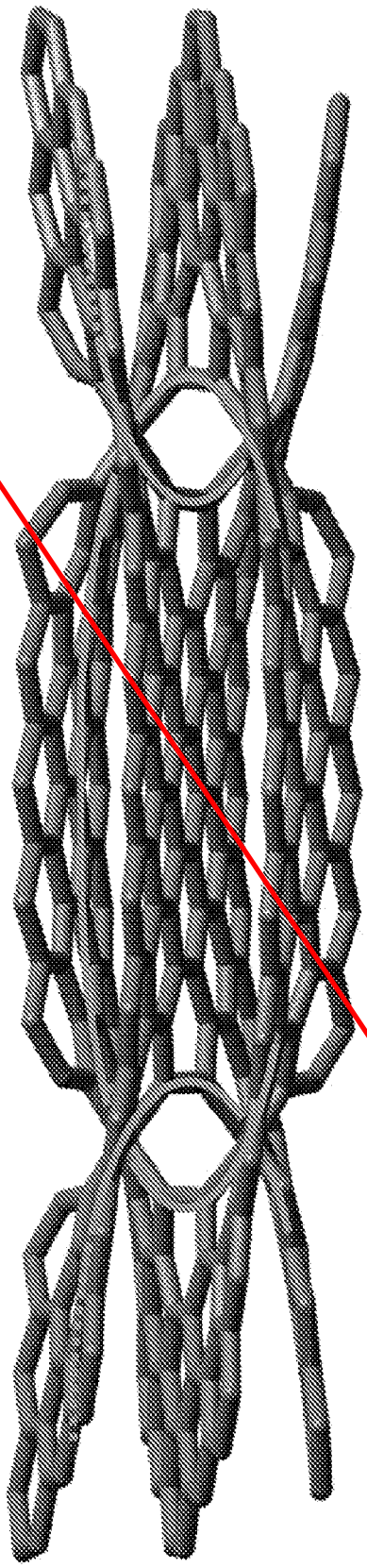


FIG. 70

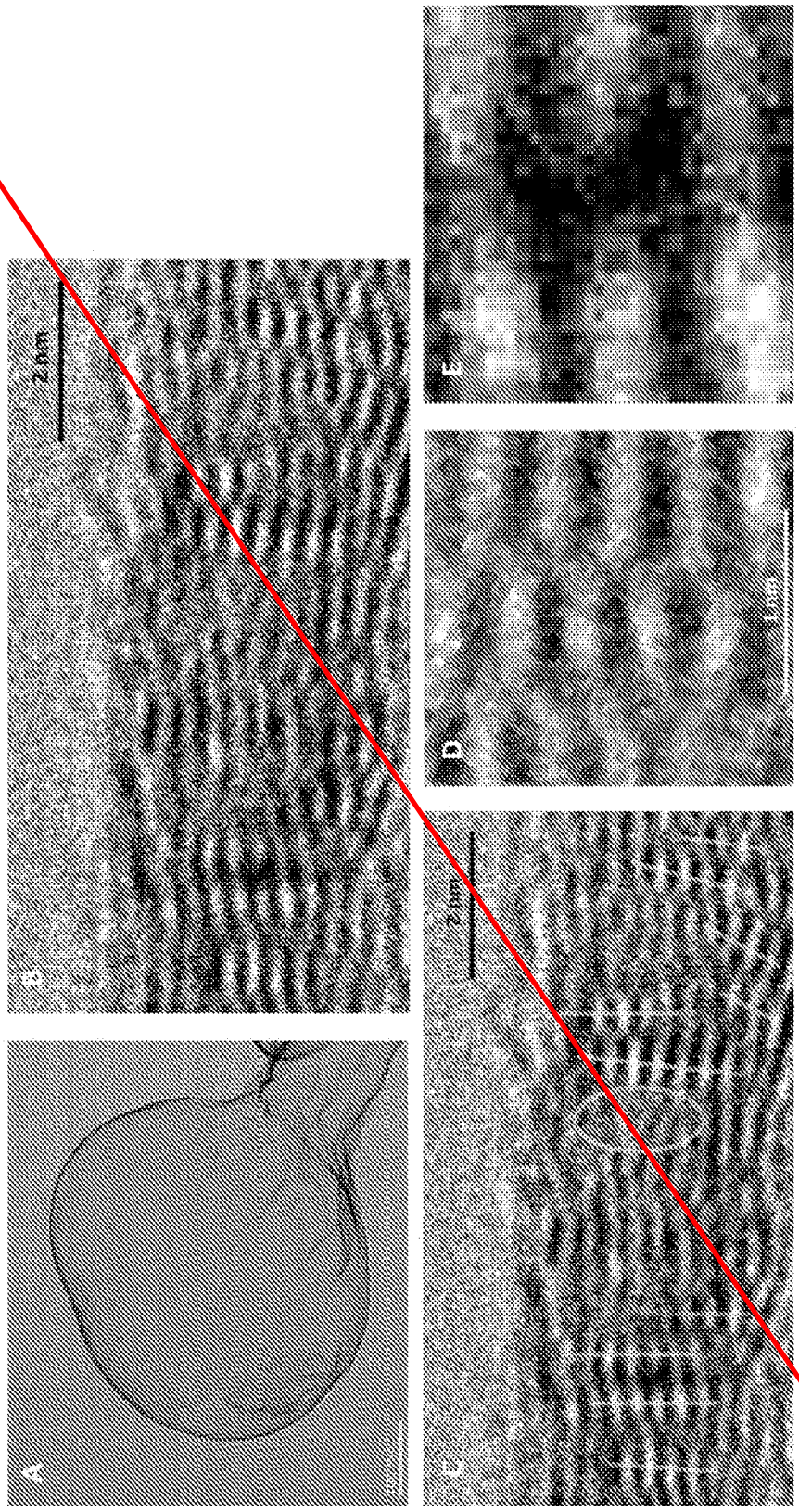


FIG. 71

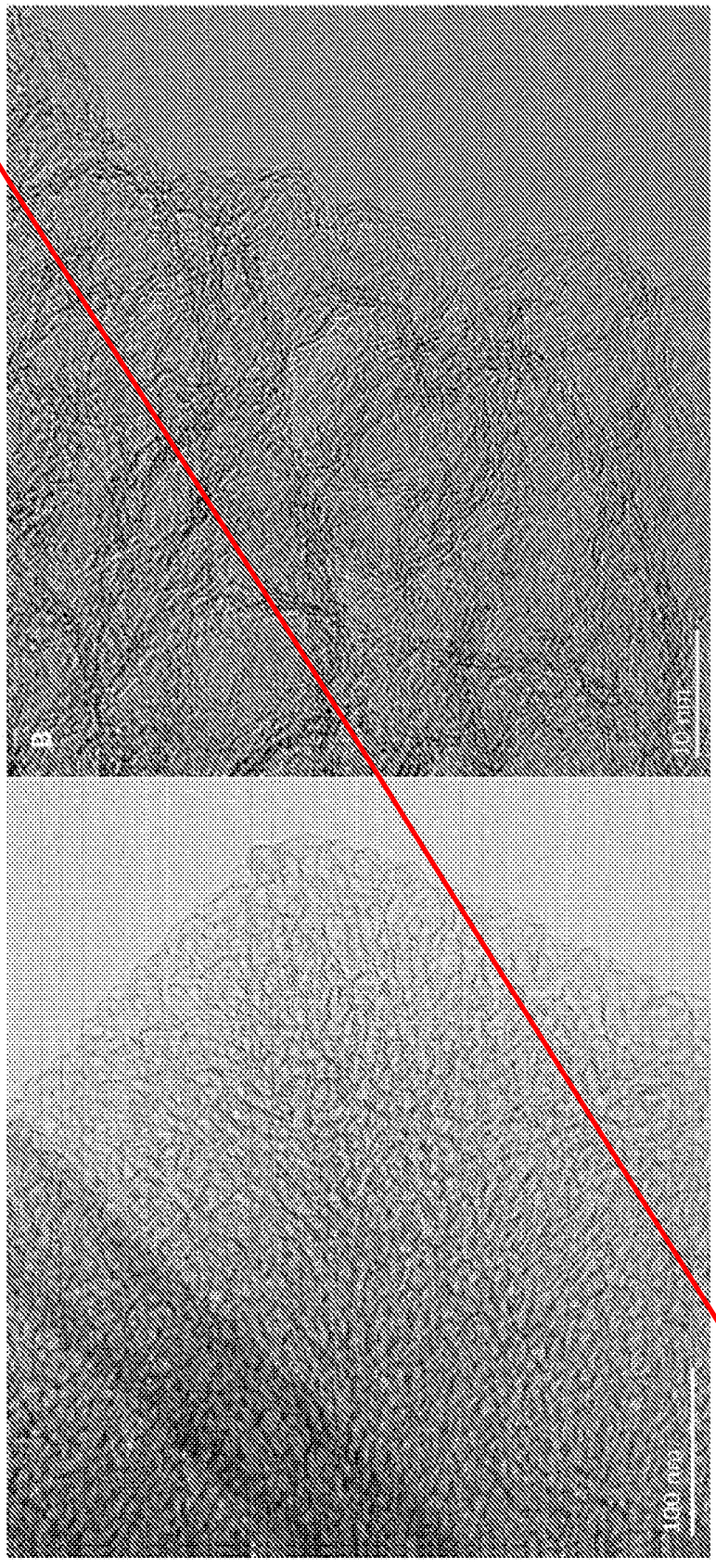
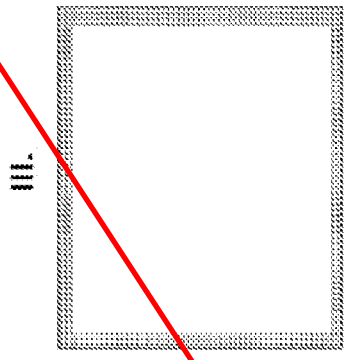
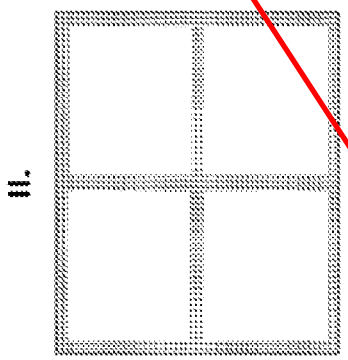


FIG. 72





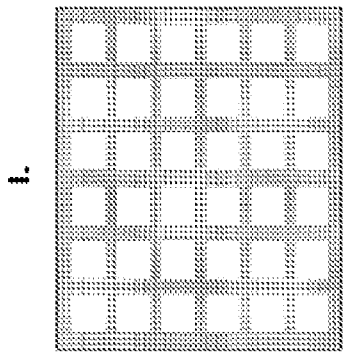


FIG. 73

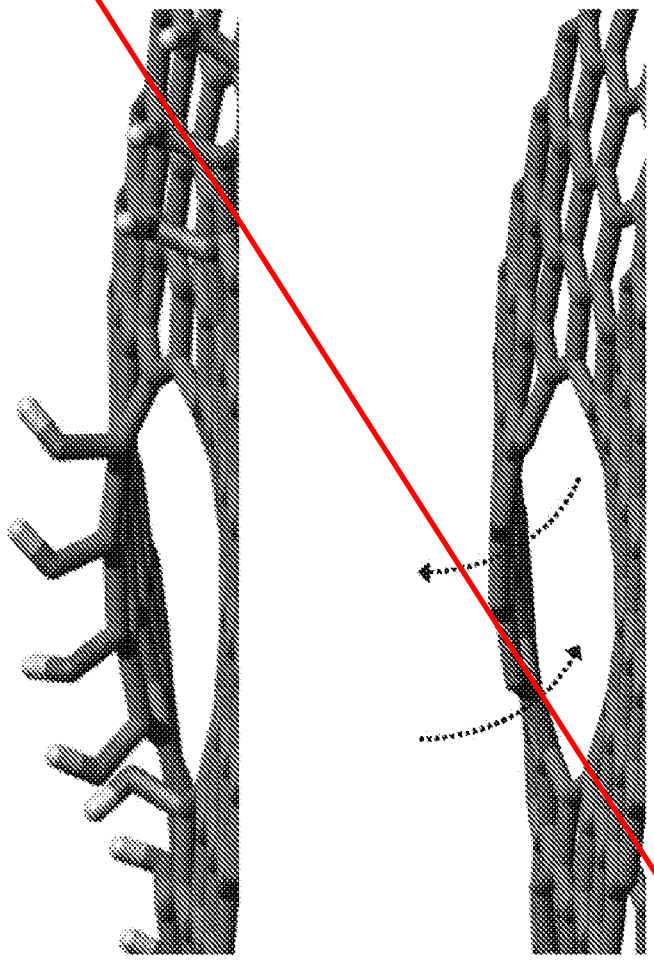


FIG. 74

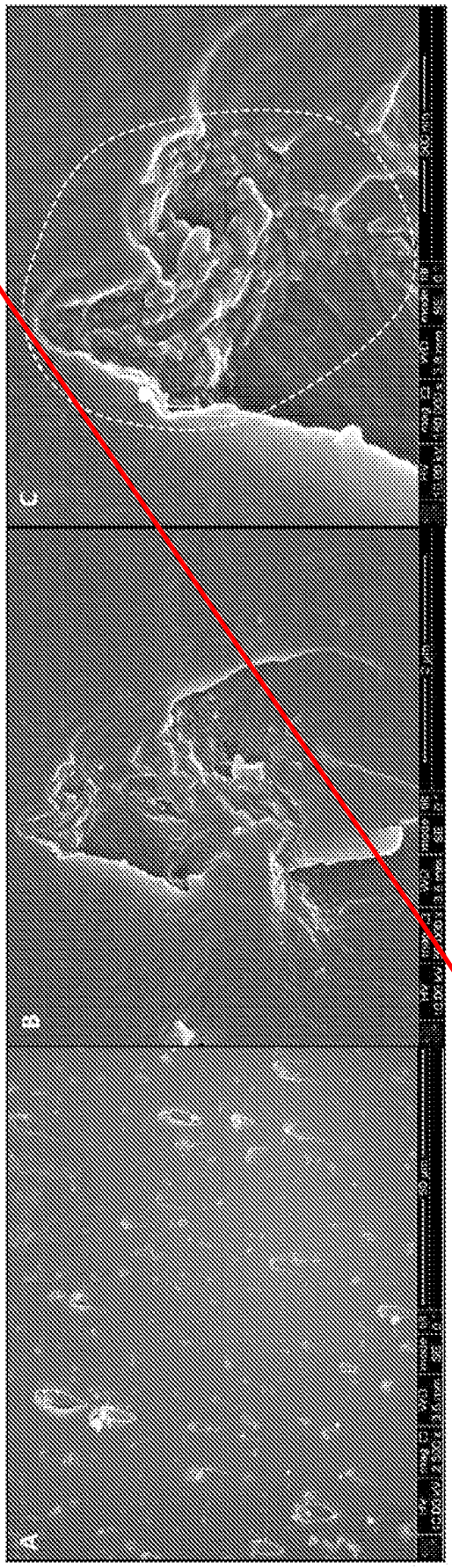


FIG. 75

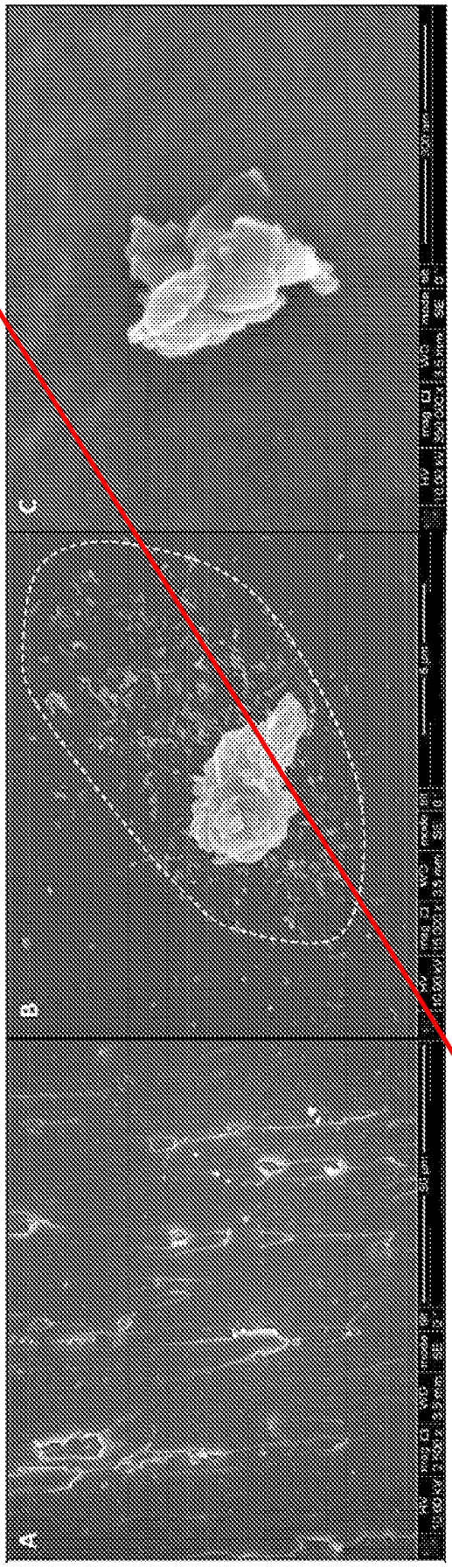


FIG. 76

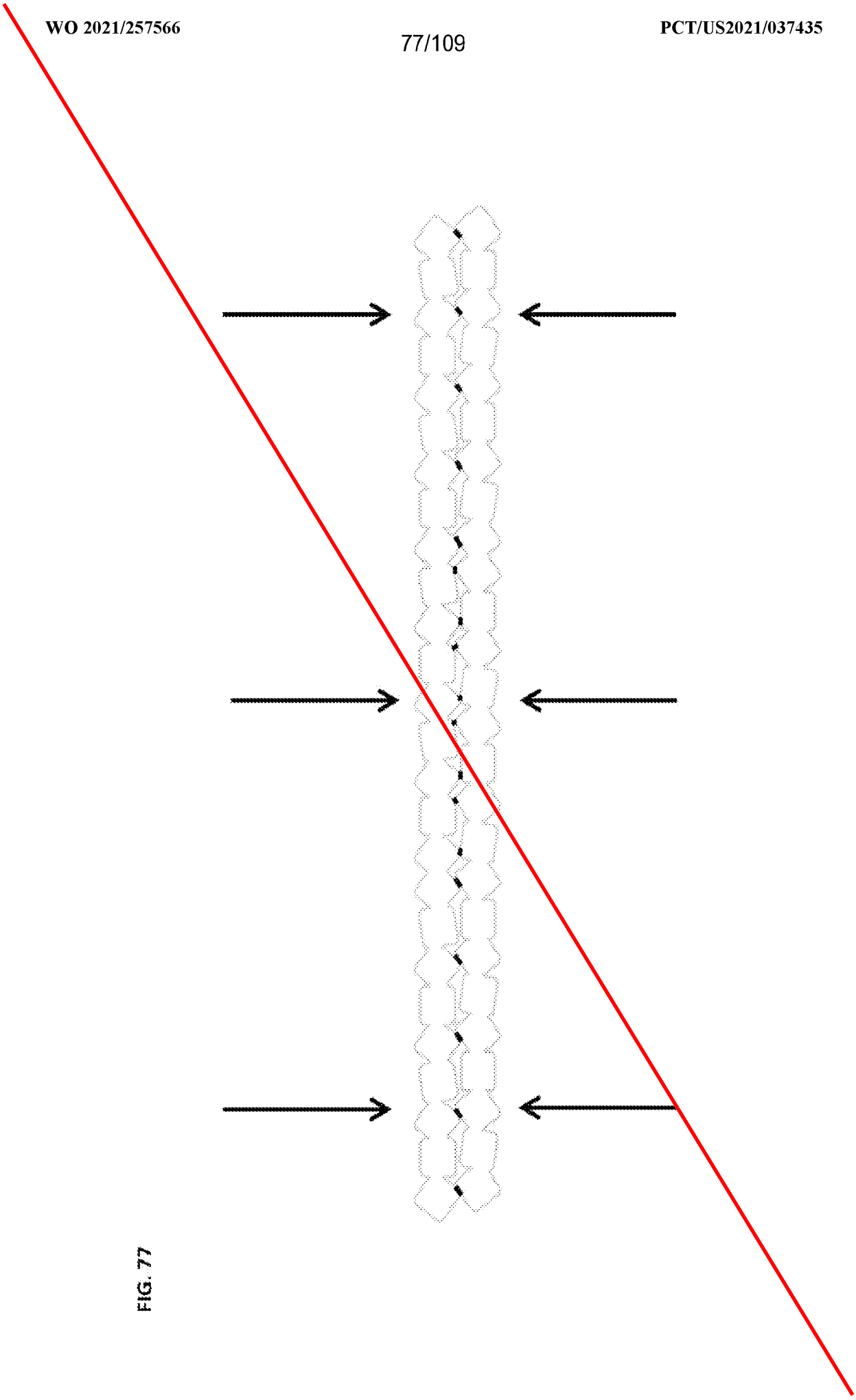


FIG. 77

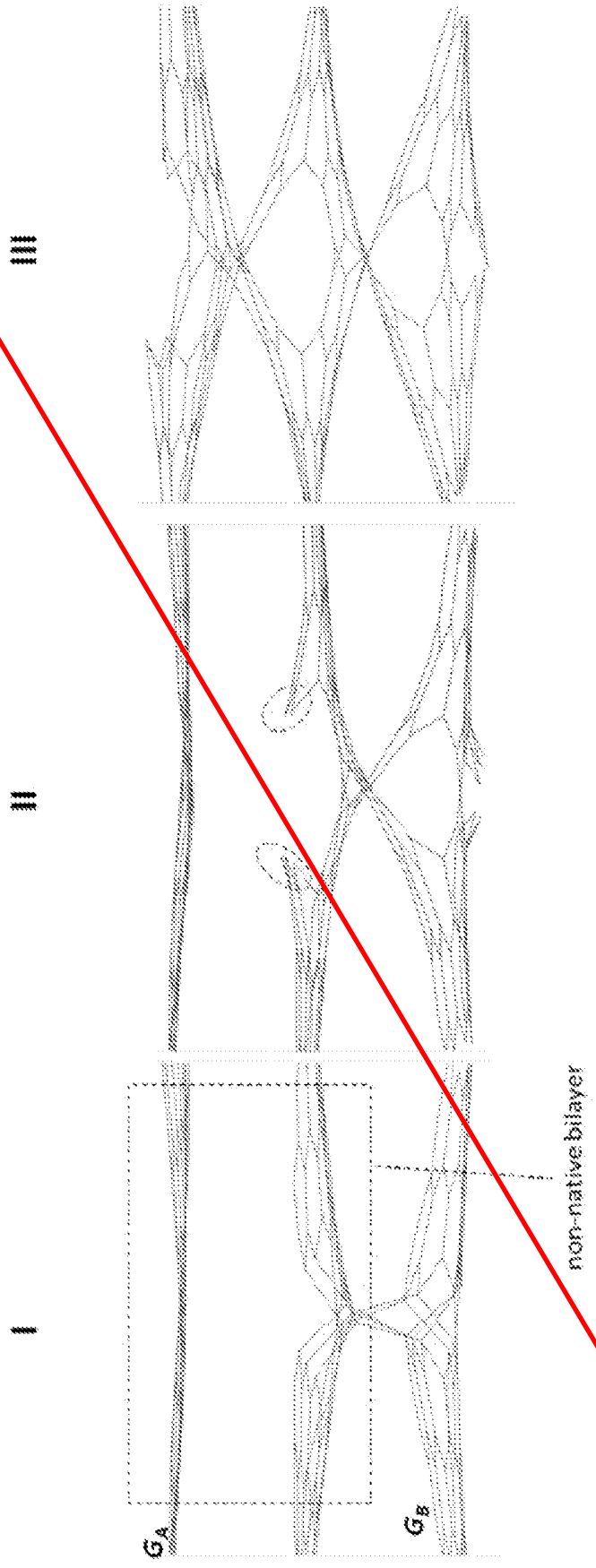


FIG. 78

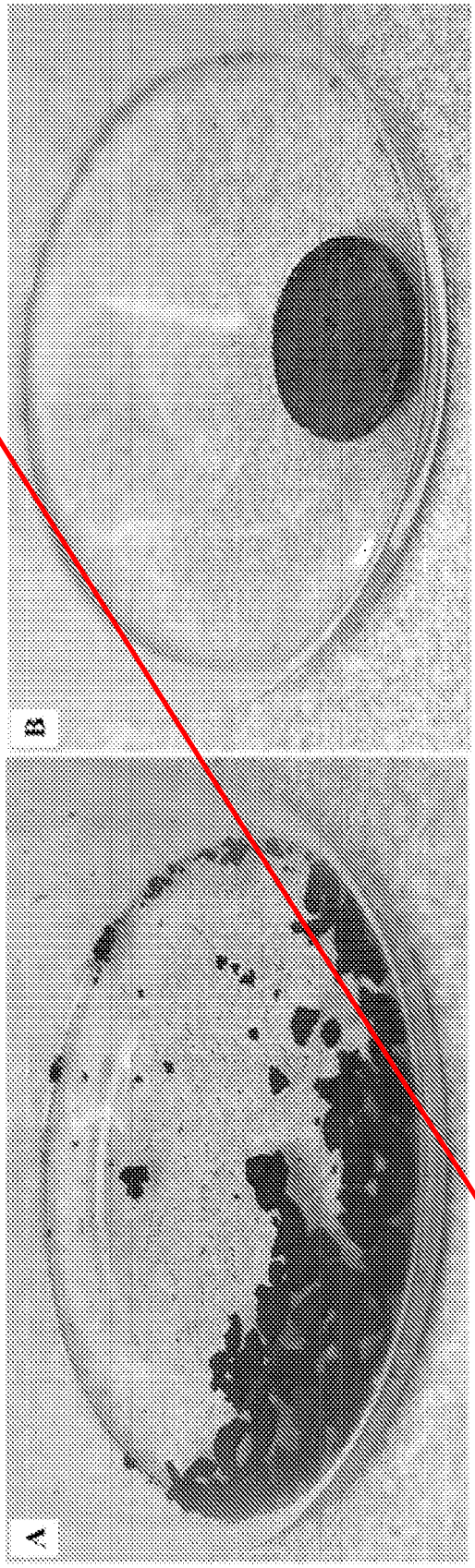
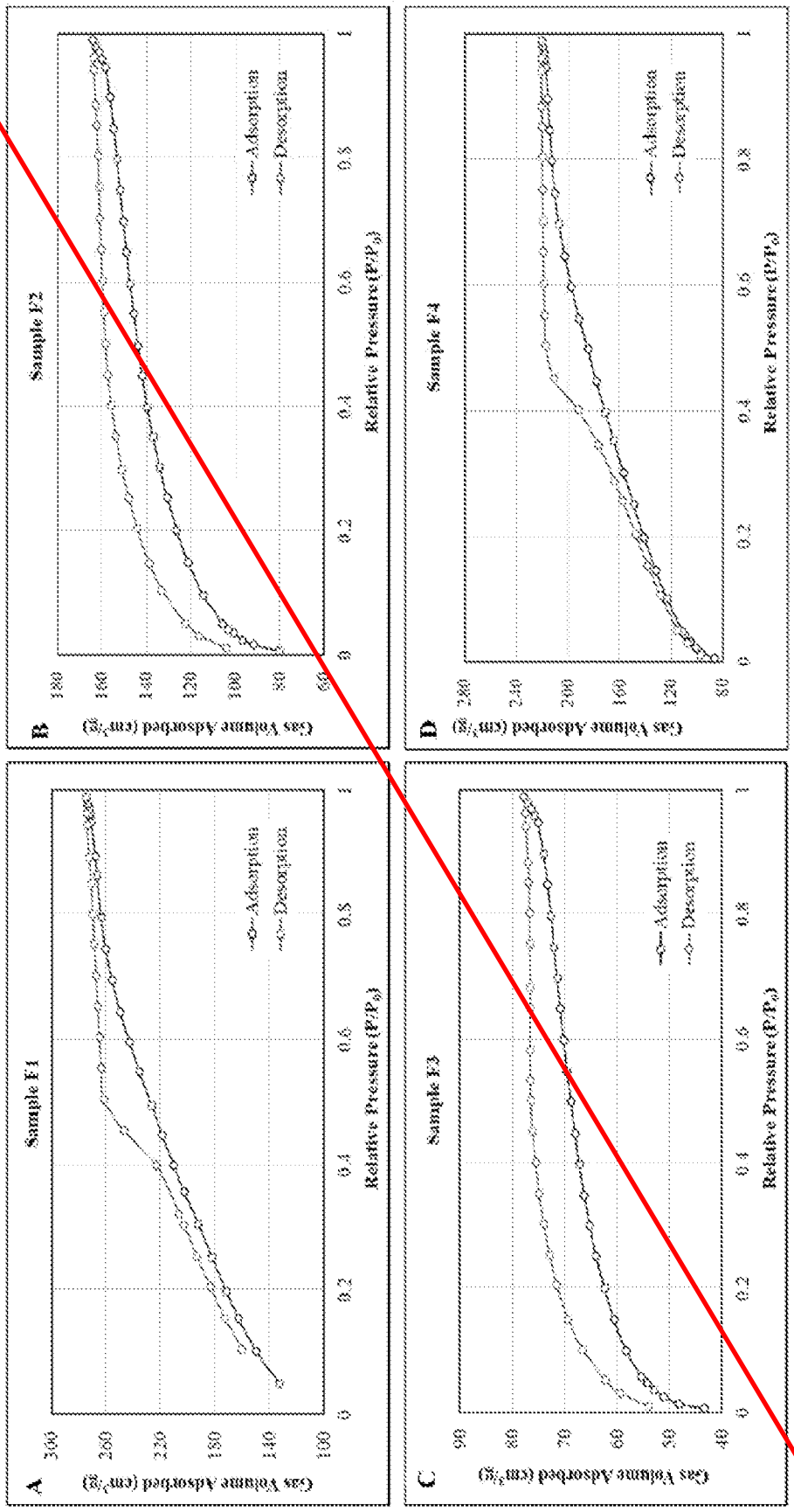


FIG. 79


A
Sample F1
Gas Volume Adsorbed (cm³/g)
Relative Pressure (P/P₀)
Adsorption
Desorption
B
Sample F2
C
Sample F3
D
Sample F4

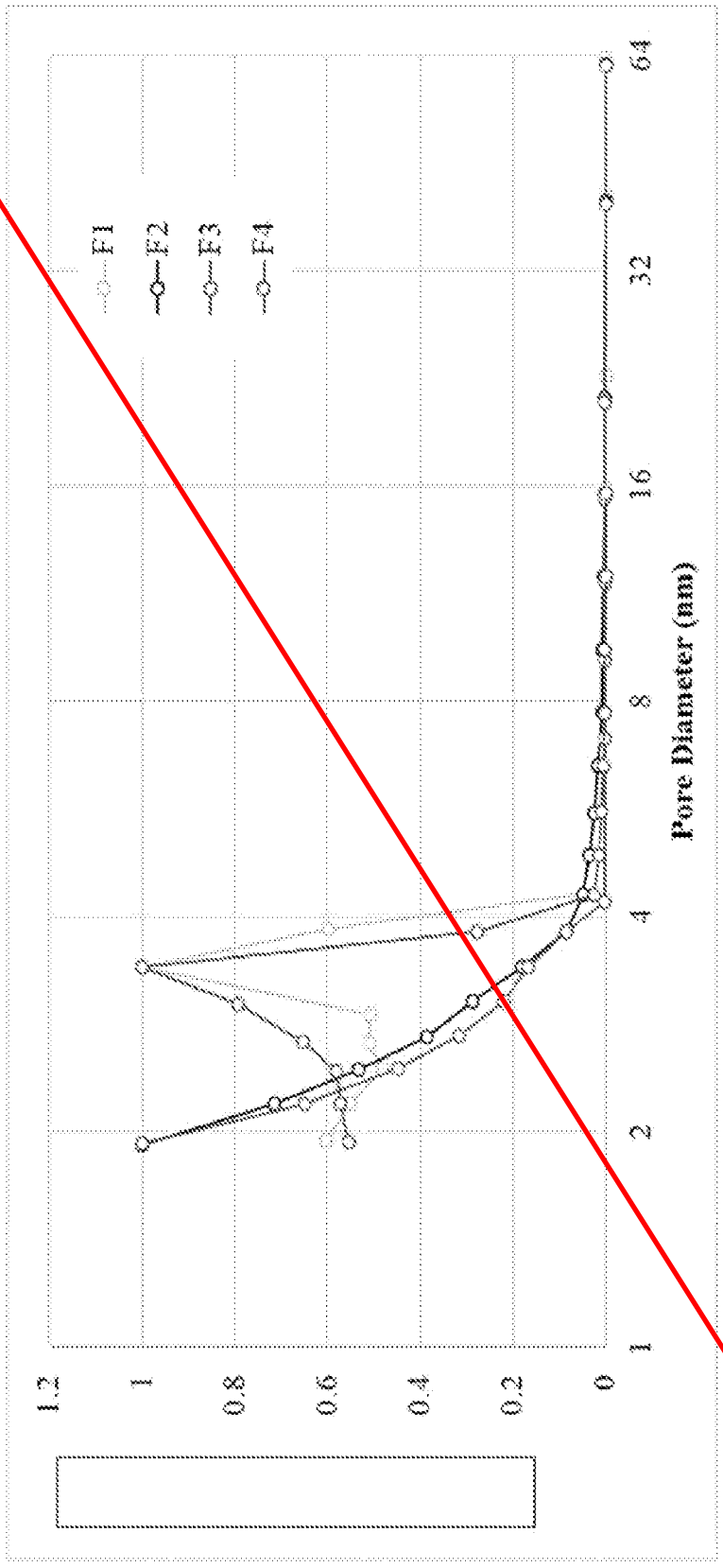


FIG. 81

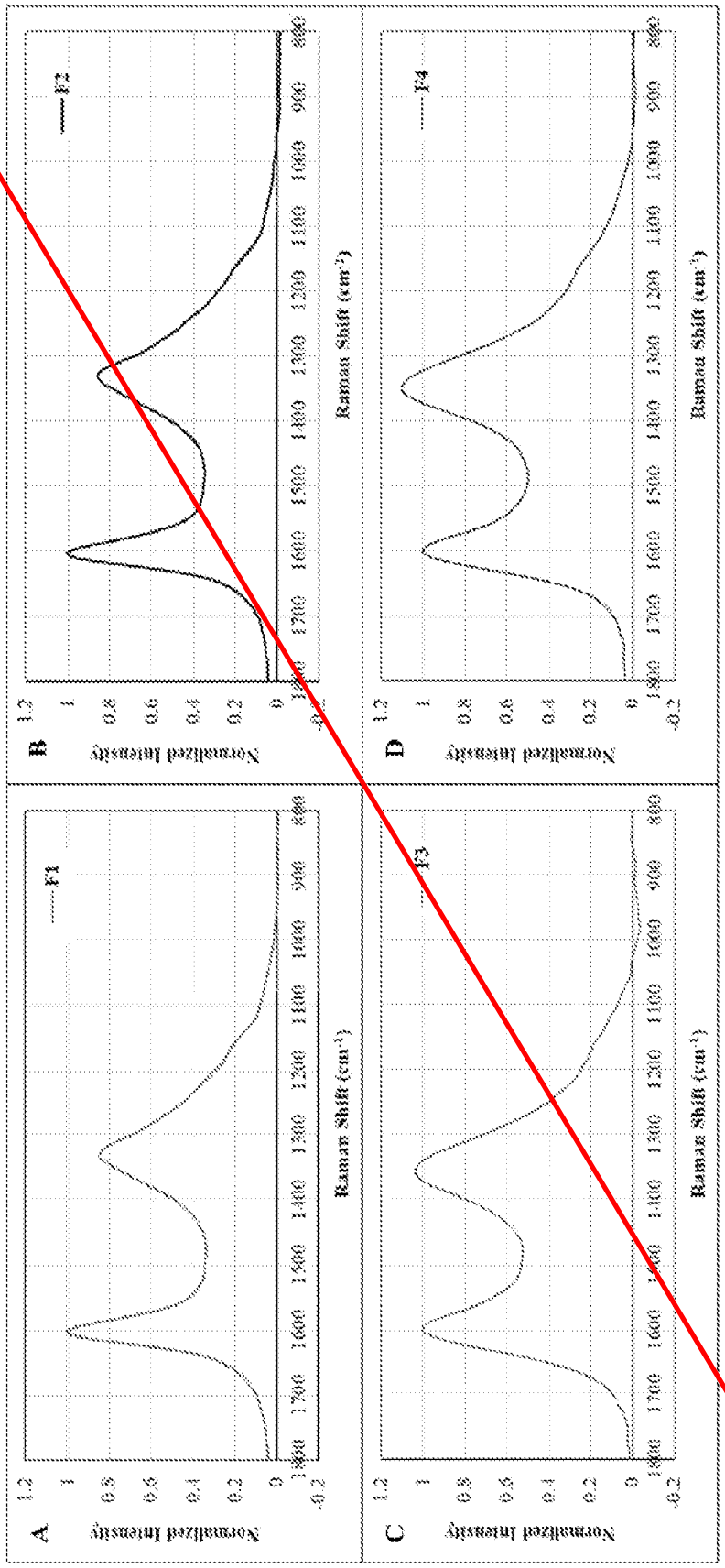


FIG. 82

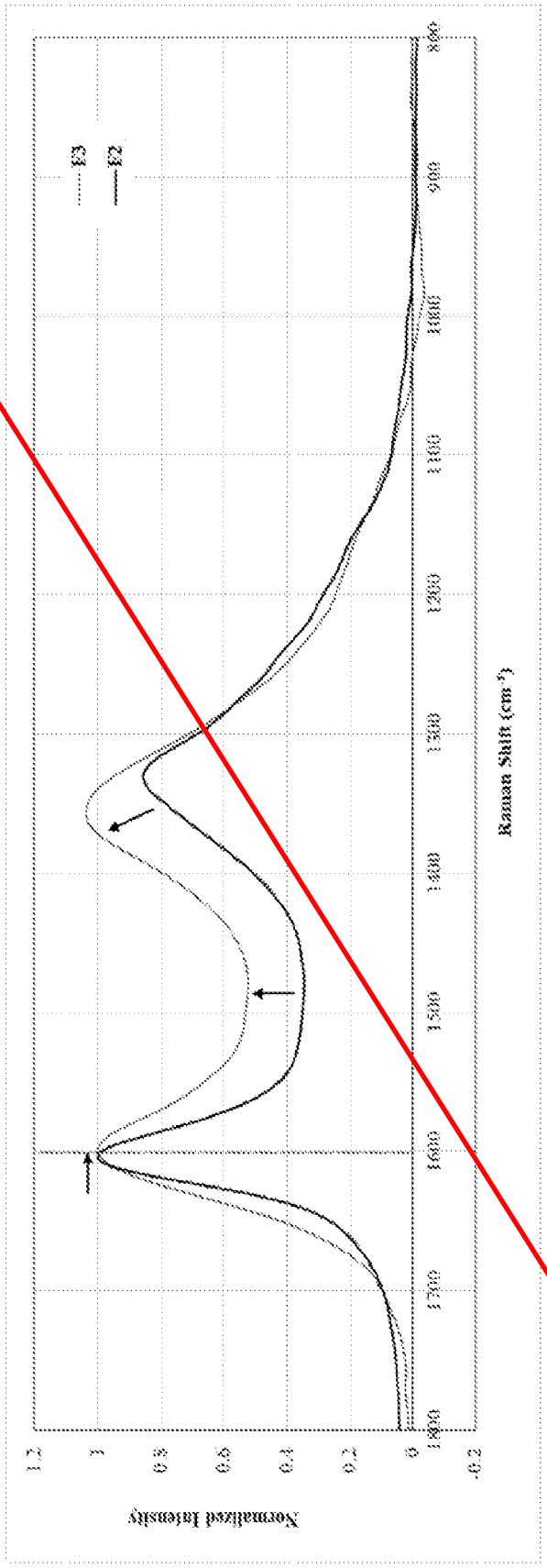

E3
E3
Normalized Intensity
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
Raman Shift (cm⁻¹)

FIG. 83

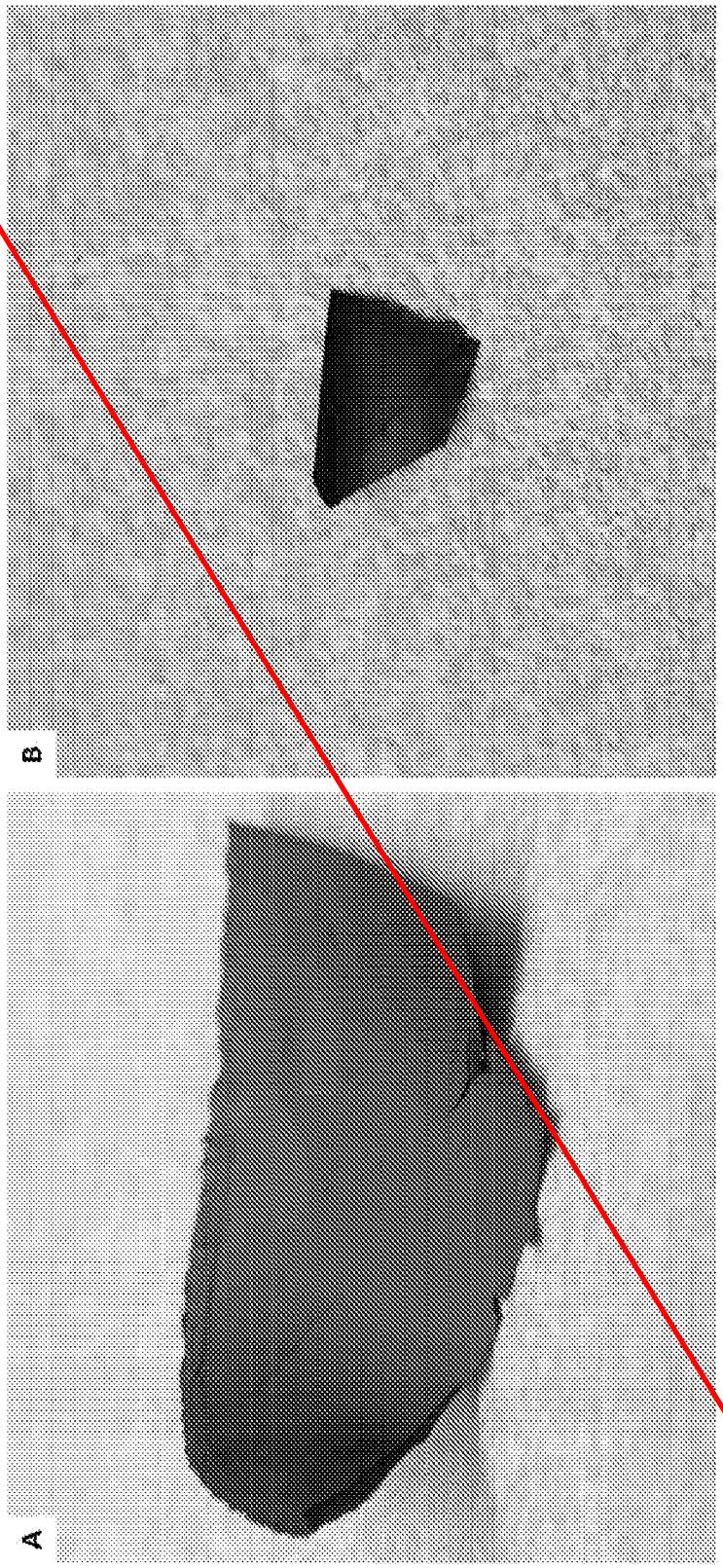


FIG. 84

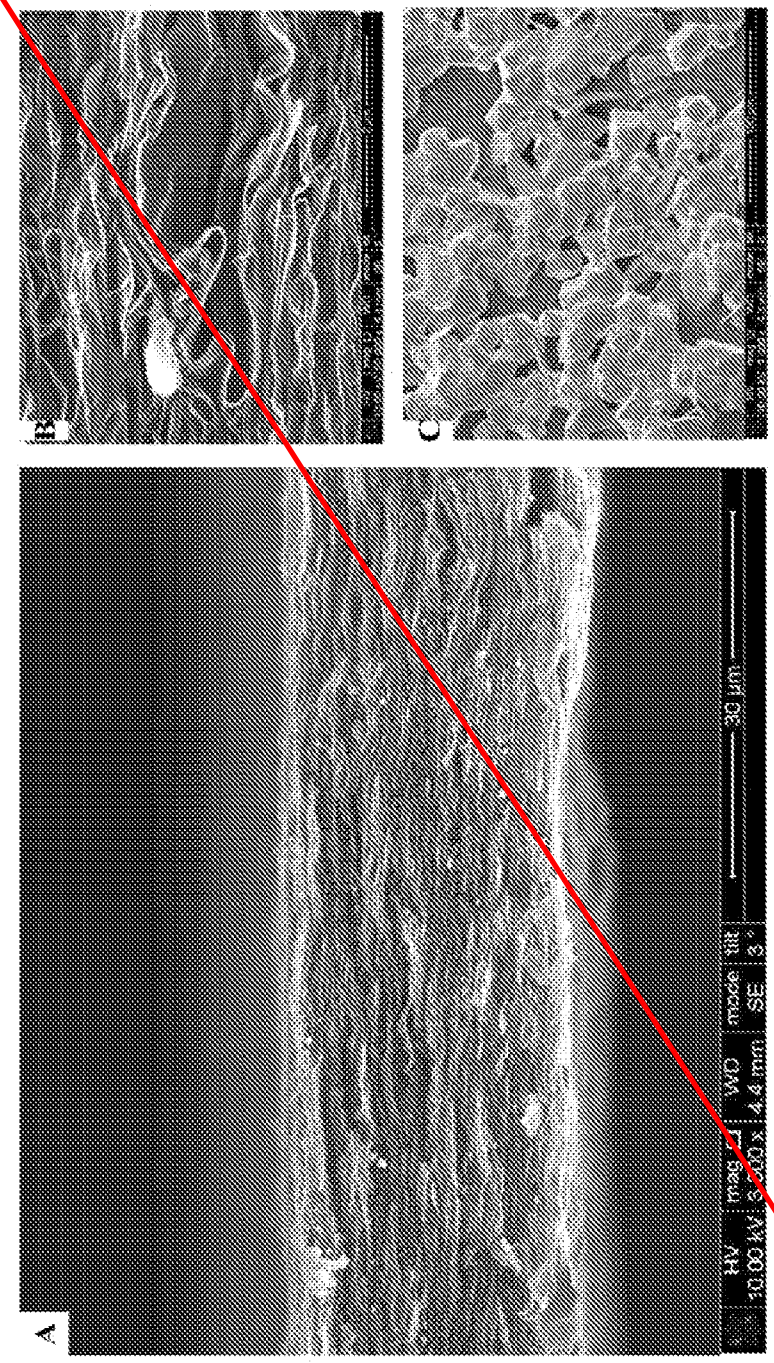


FIG. 85

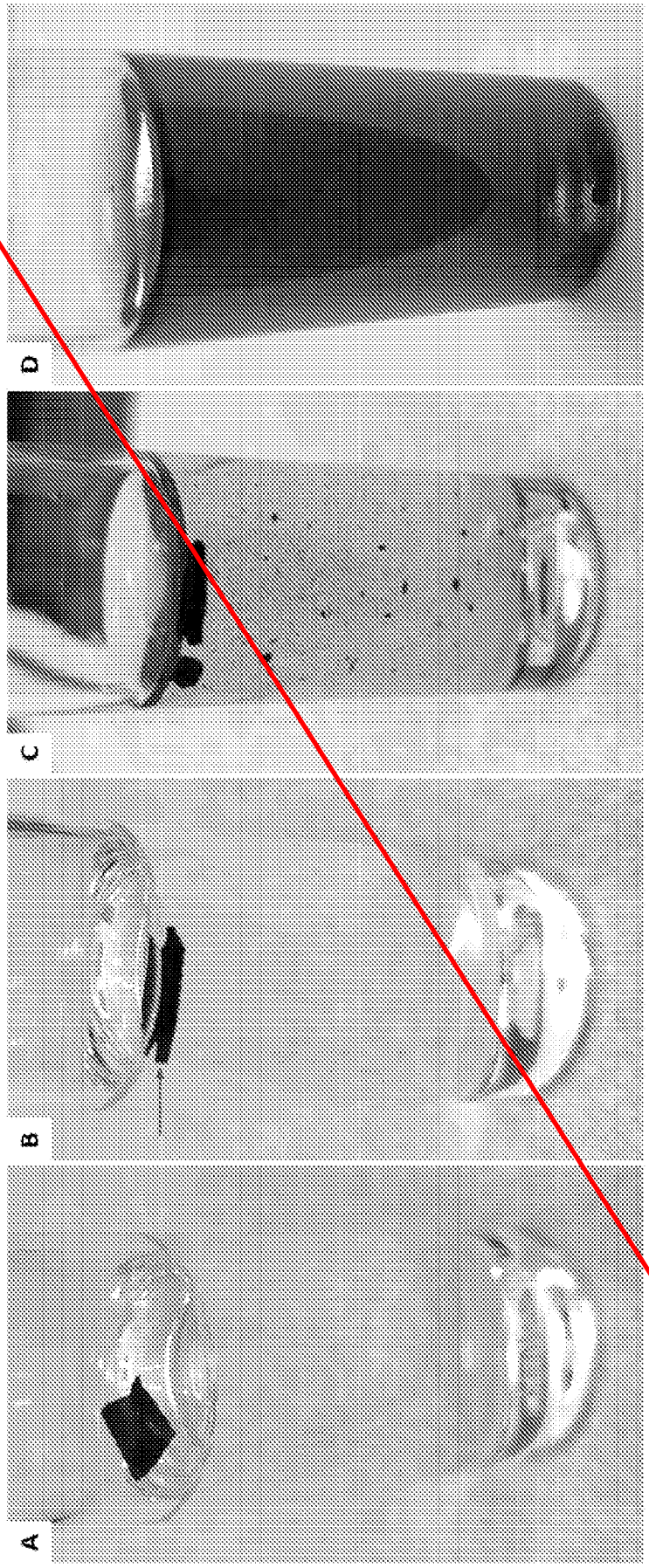


FIG. 86

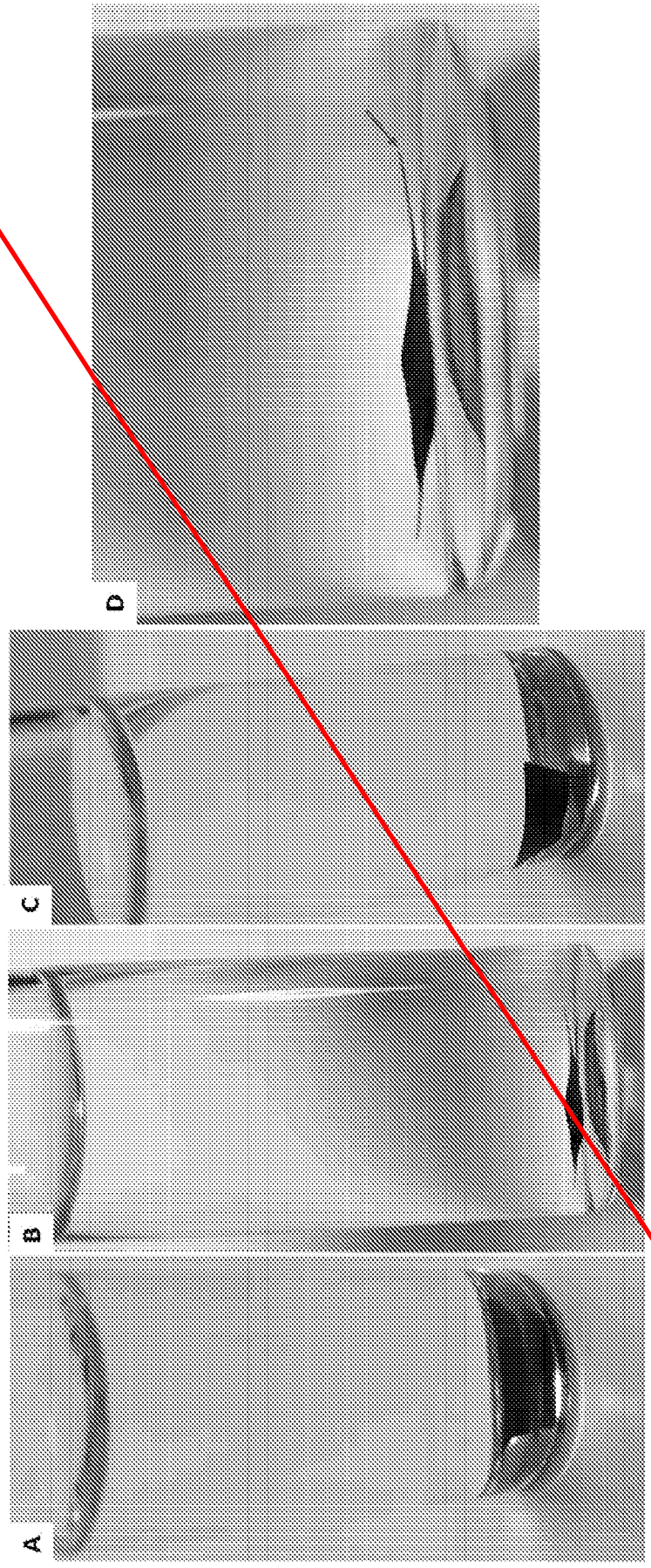


FIG. 87

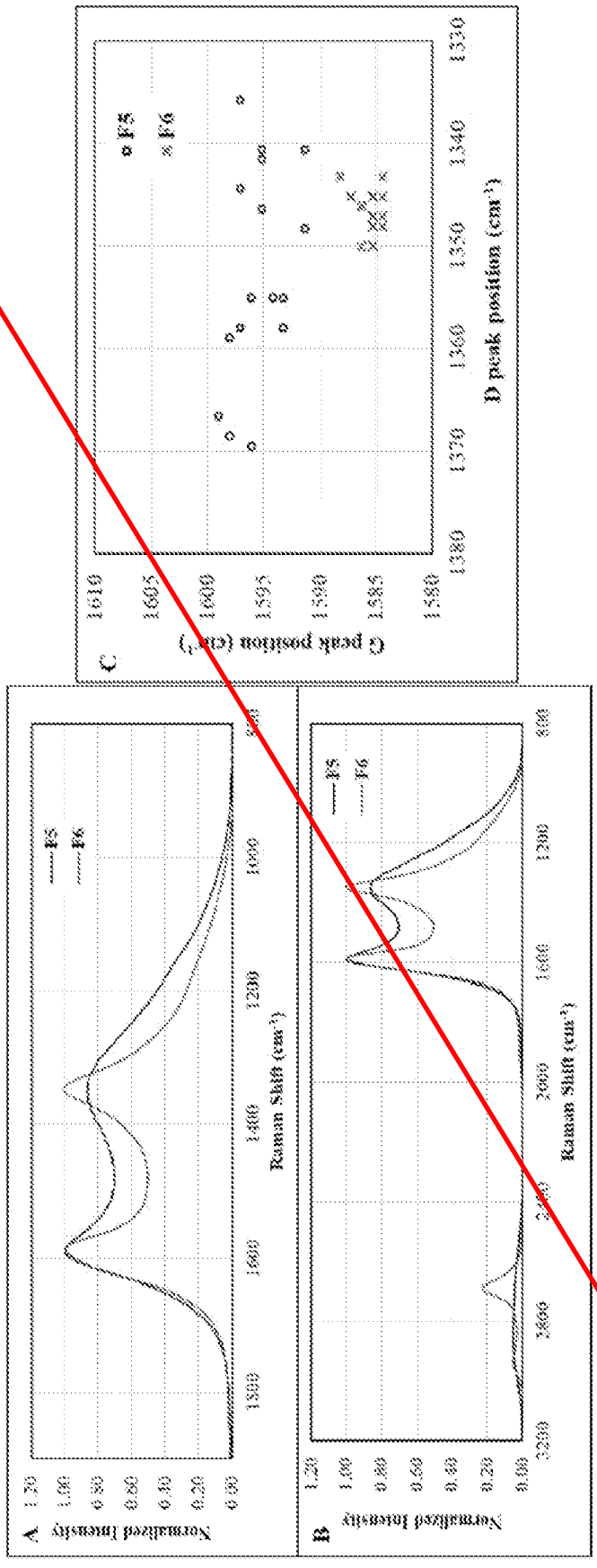
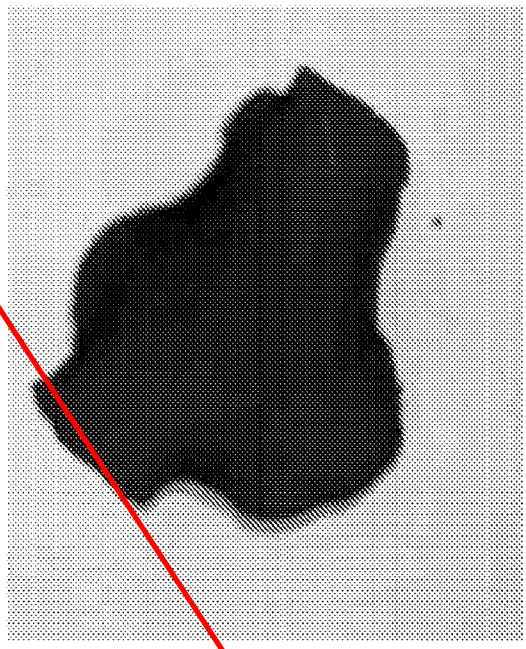

A
Normalized Intensity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1800
1600
1400
1200
1000
800
Raman Shift (cm-1)
F5
F6
B
Normalized Intensity
3200
2800
2400
2000
1600
1200
800
Raman Shift (cm-1)
F5
F6
C
G peak position (cm-1)
1610
1605
1600
1595
1590
1585
1580
D peak position (cm-1)
1380
1370
1360
1350
1340
1330
F5
F6

FIG. 88



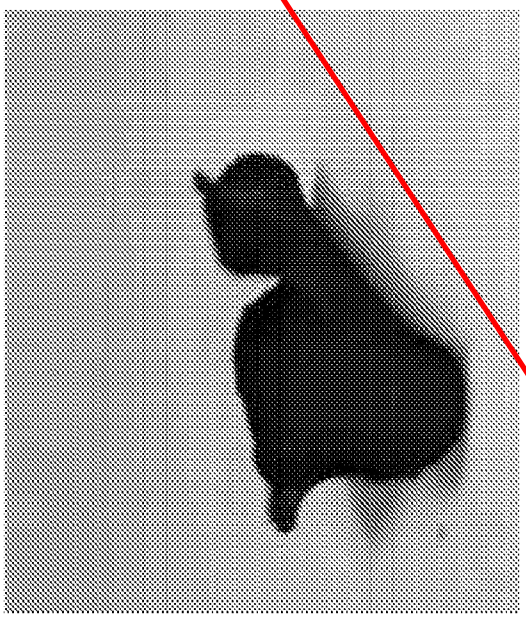


FIG. 89

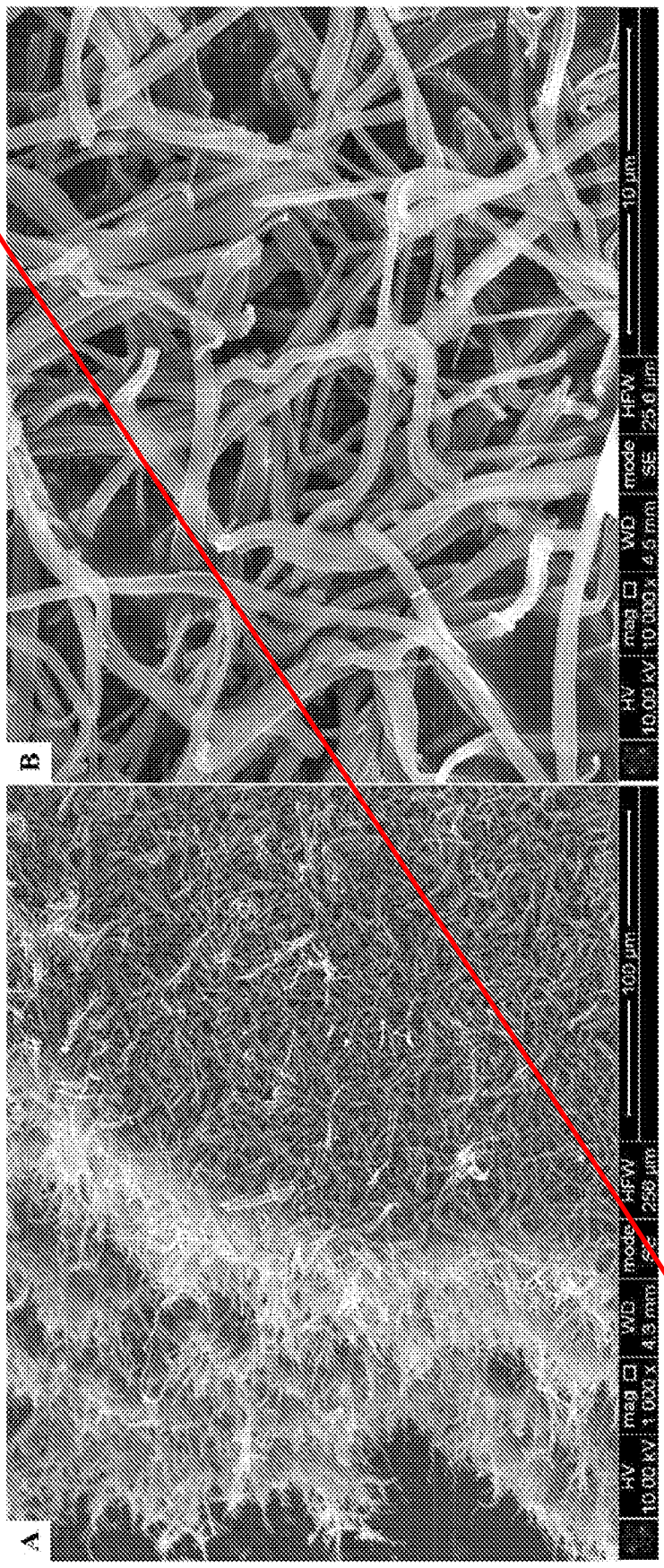

A
B
HV
10.00 kV
mag
1 000 x
WD
4.3 mm
mode
SE
HFW
256 µm
100 µm
HV
10.00 kV
mag
10 000 x
WD
4.6 mm
mode
SE
HFW
25.6 µm
10 µm

FIG. 90

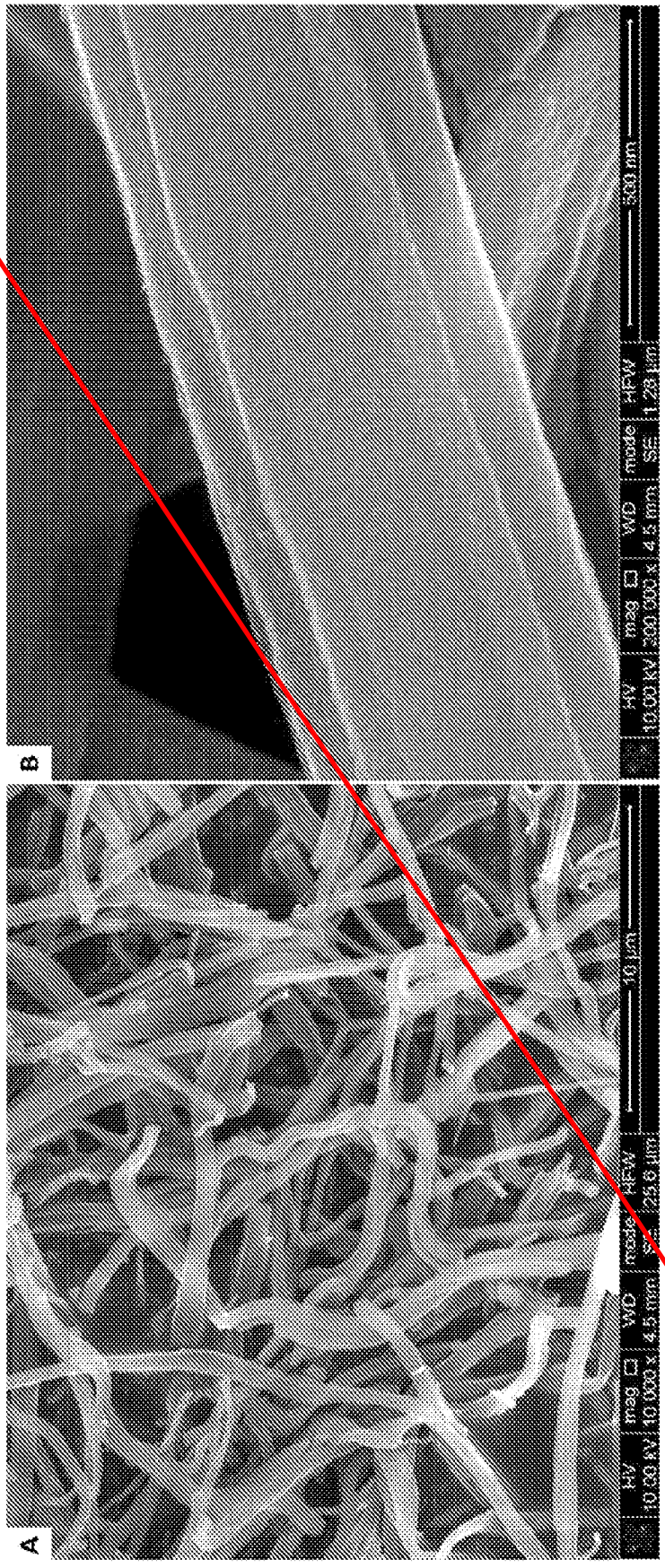

A
B
HV
10.00 kV
mag
10,000 x
WD
4.5 mm
mode
SE
HFW
25.6 µm
10 µm
HV
10.00 kV
mag
300,000 x
WD
4.5 mm
mode
SE
HFW
1.28 µm
500 nm

FIG. 91

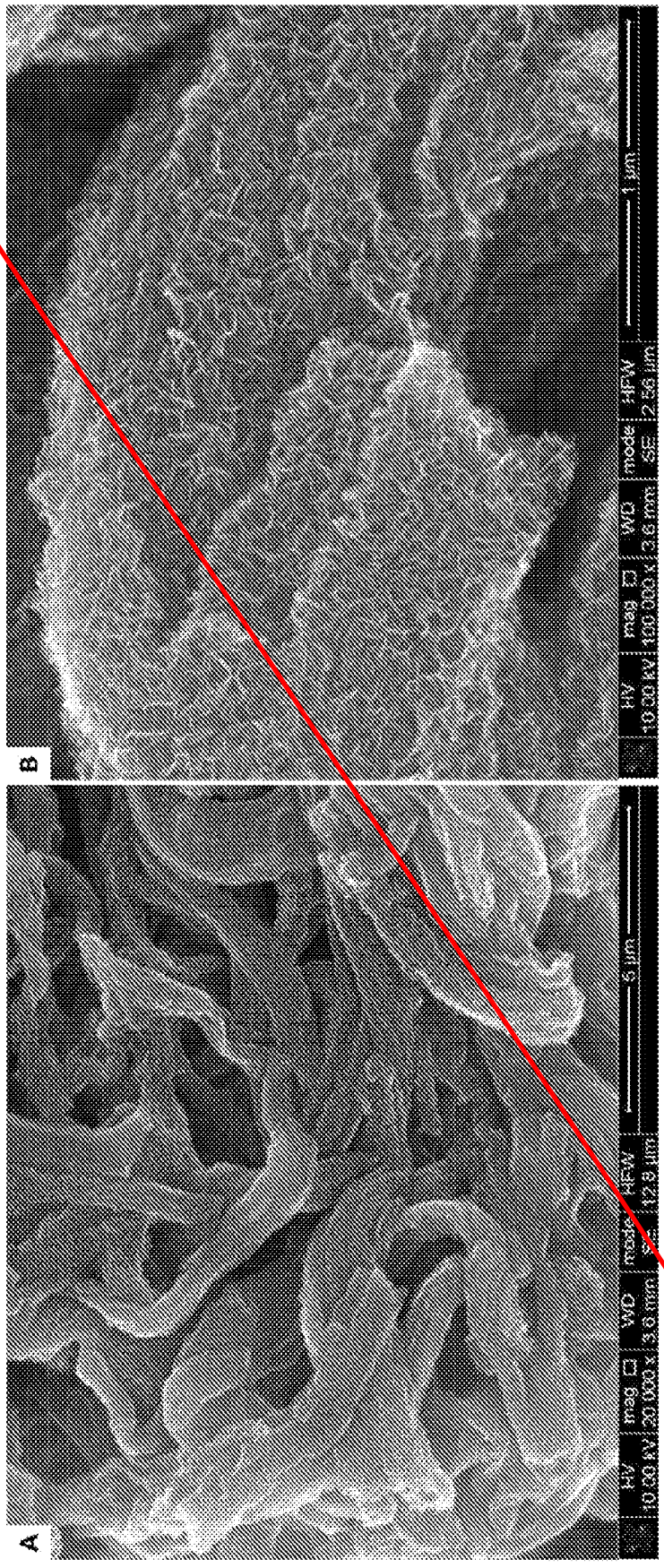

A
HV 10.00 kV
mag 20 000 x
WD 3.6 mm
mode SE
HFW 12.8 µm
5 µm
B
HV 10.00 kV
mag 100 000 x
WD 3.6 mm
mode SE
HFW 2.56 µm
1 µm

FIG. 92

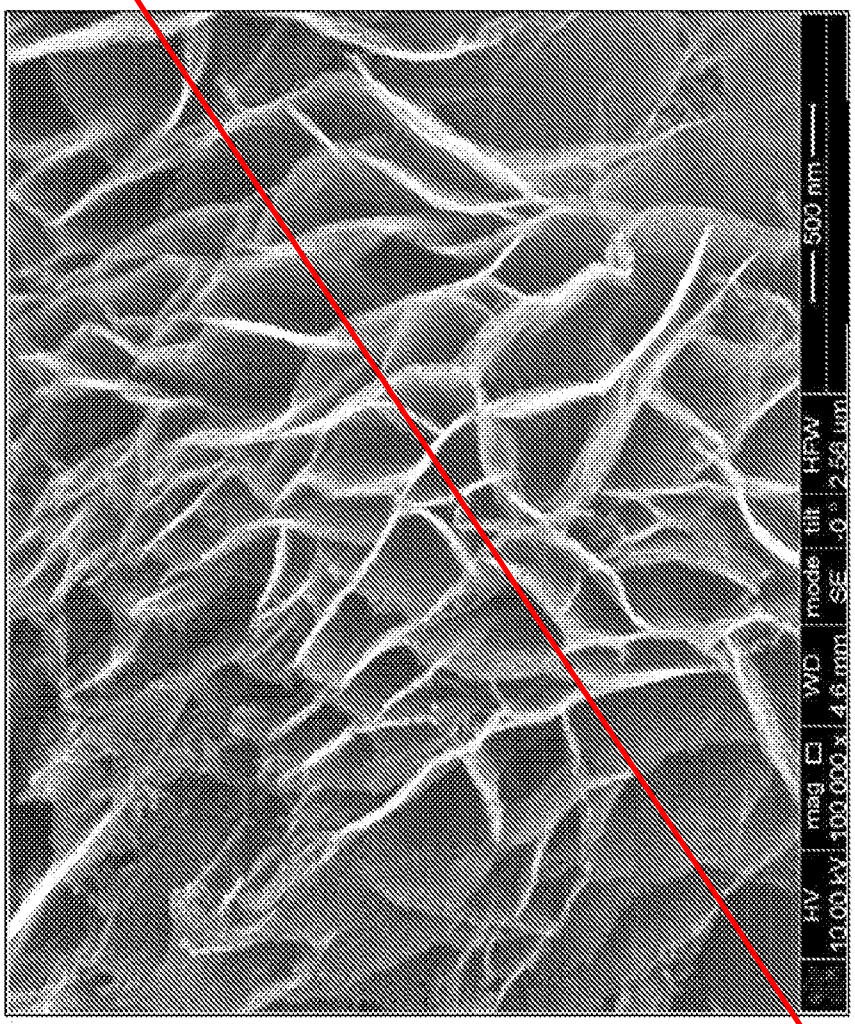


FIG. 93

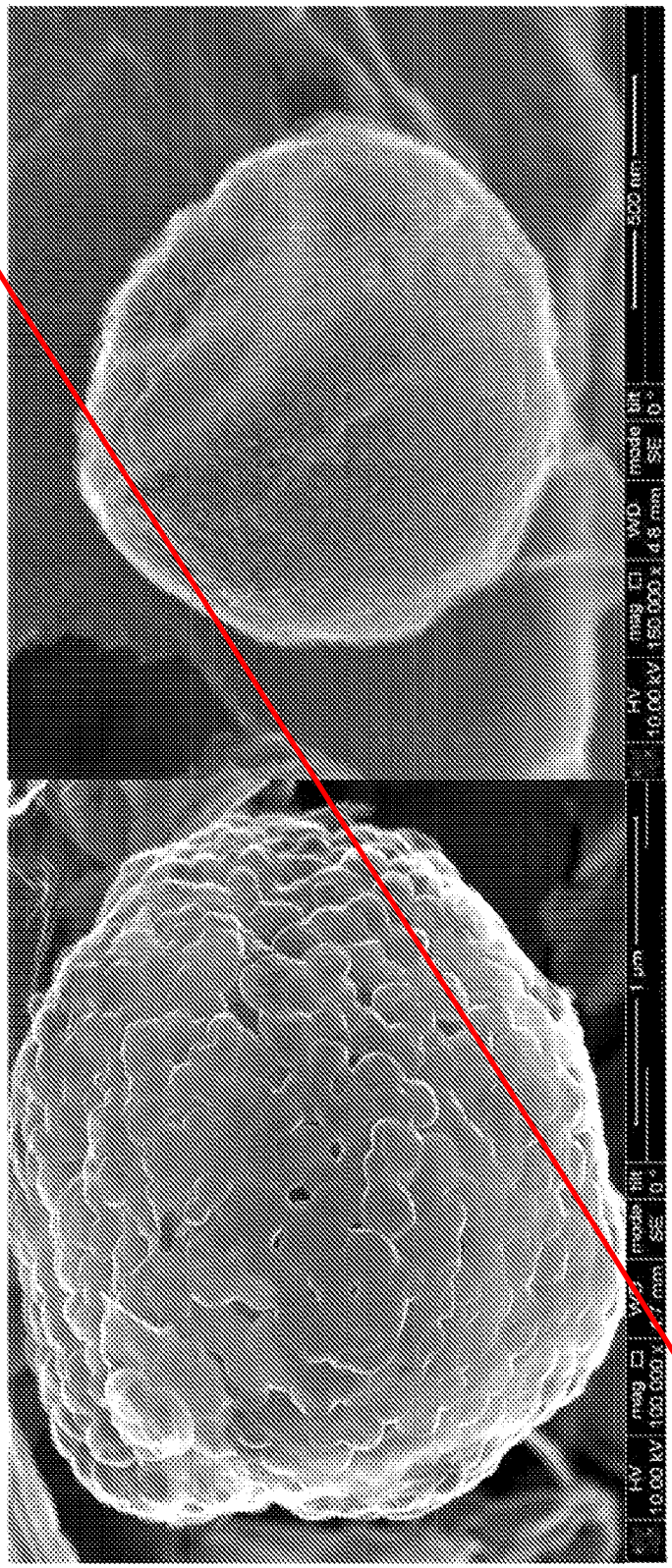


FIG. 94

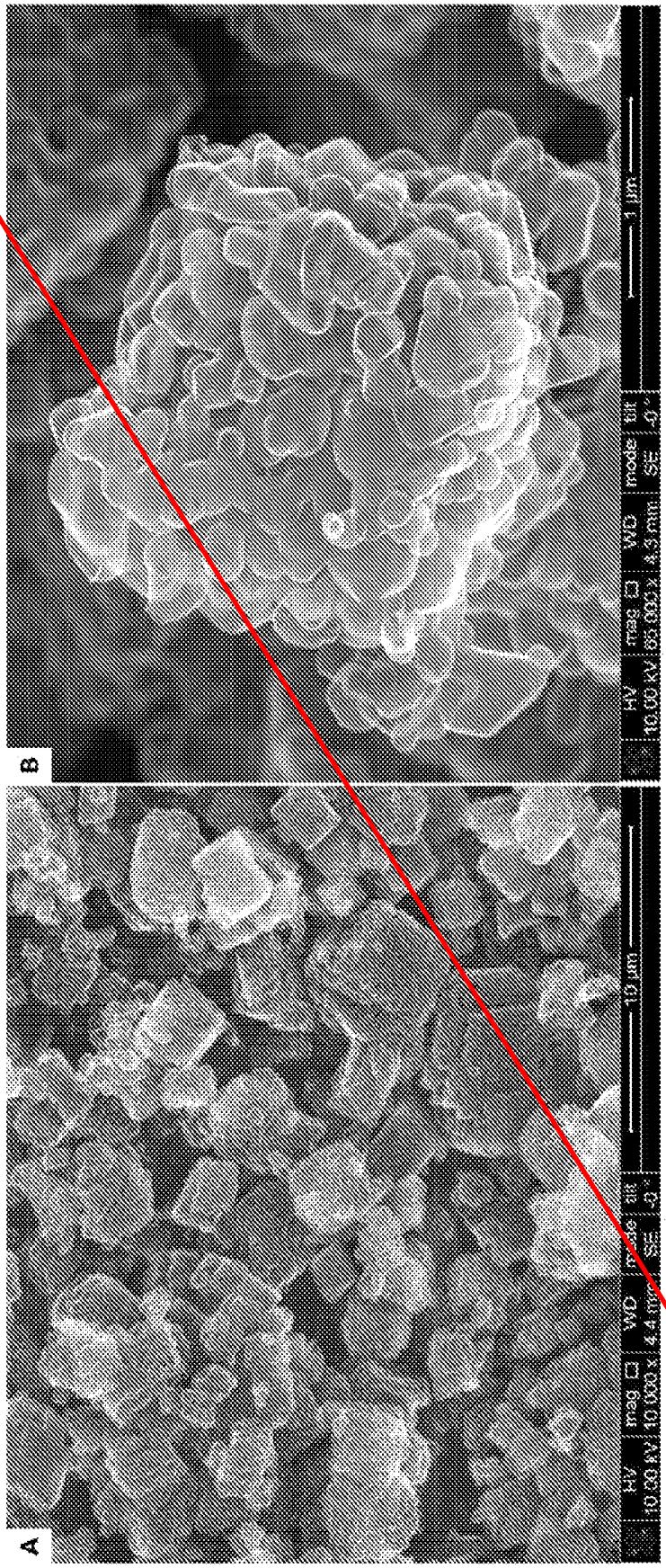


FIG. 95

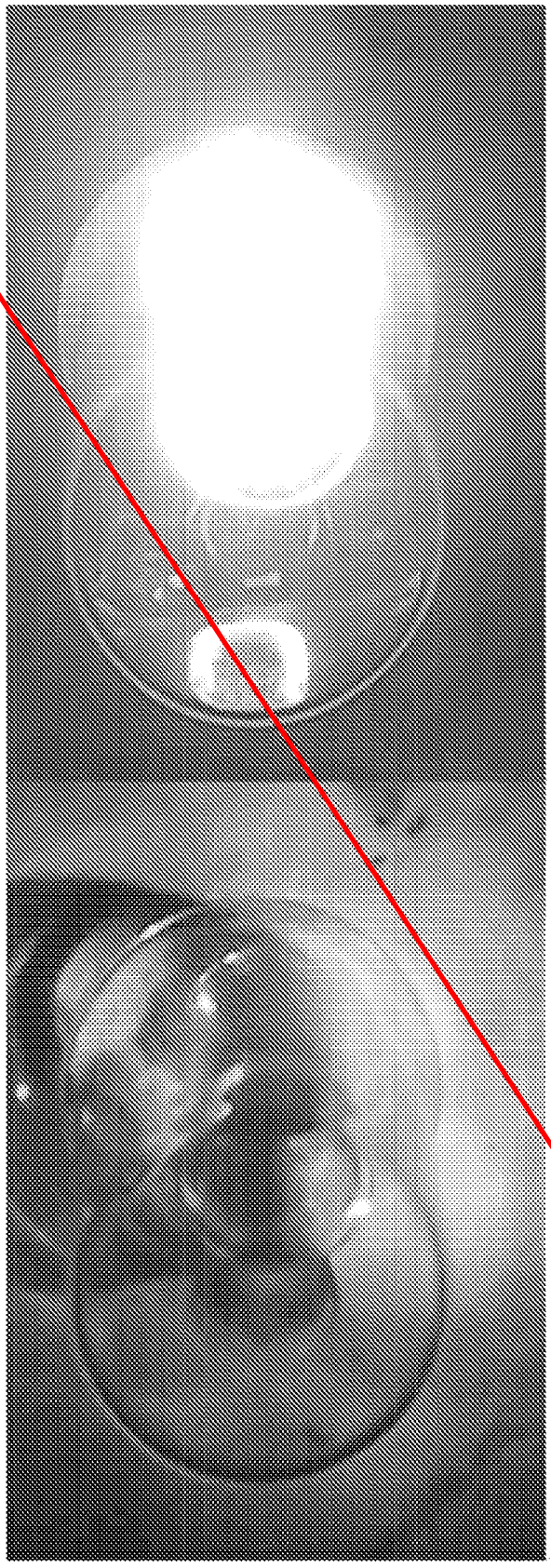

During microwave irradiation
Before microwave irradiation

FIG. 96

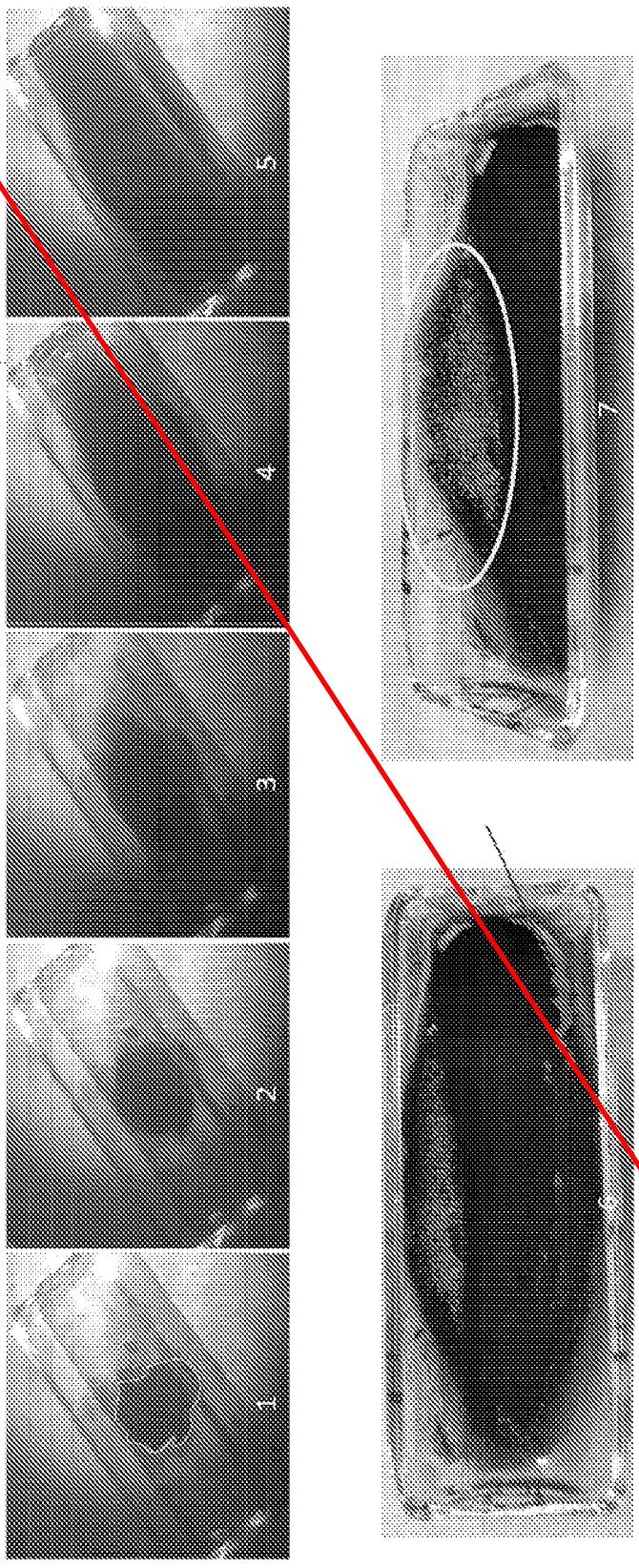


FIG. 97

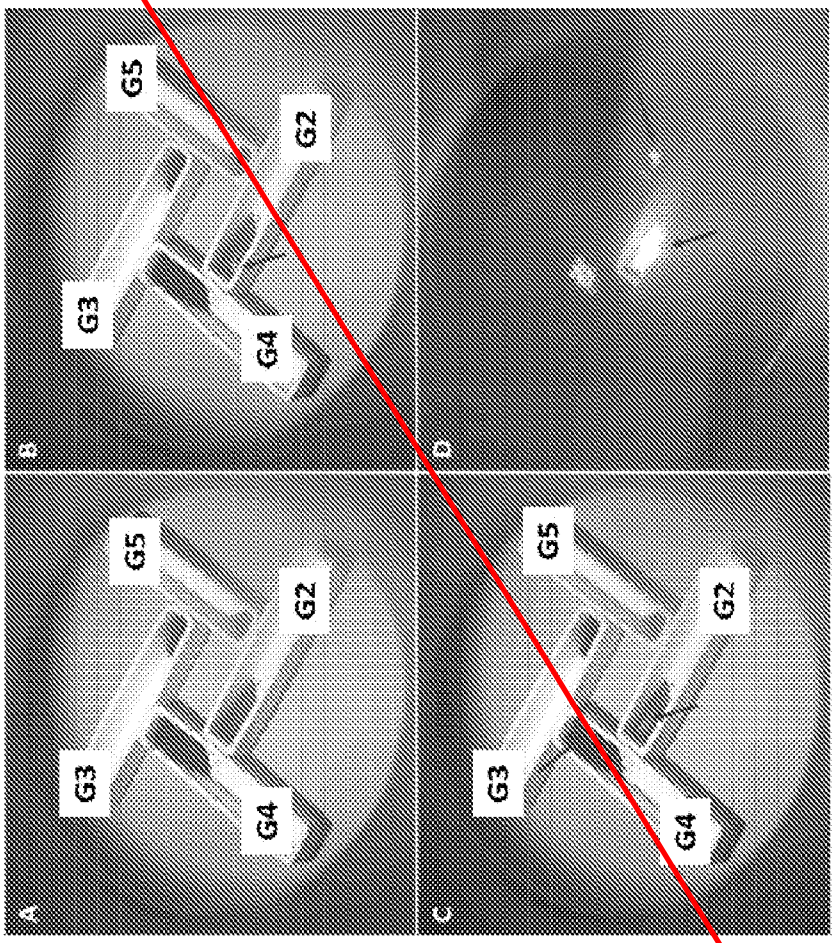


FIG. 98

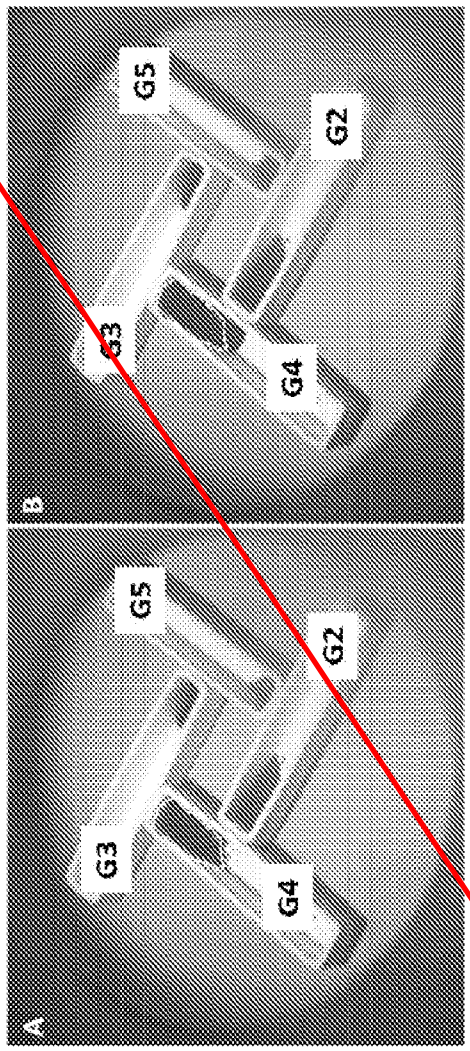


FIG. 99

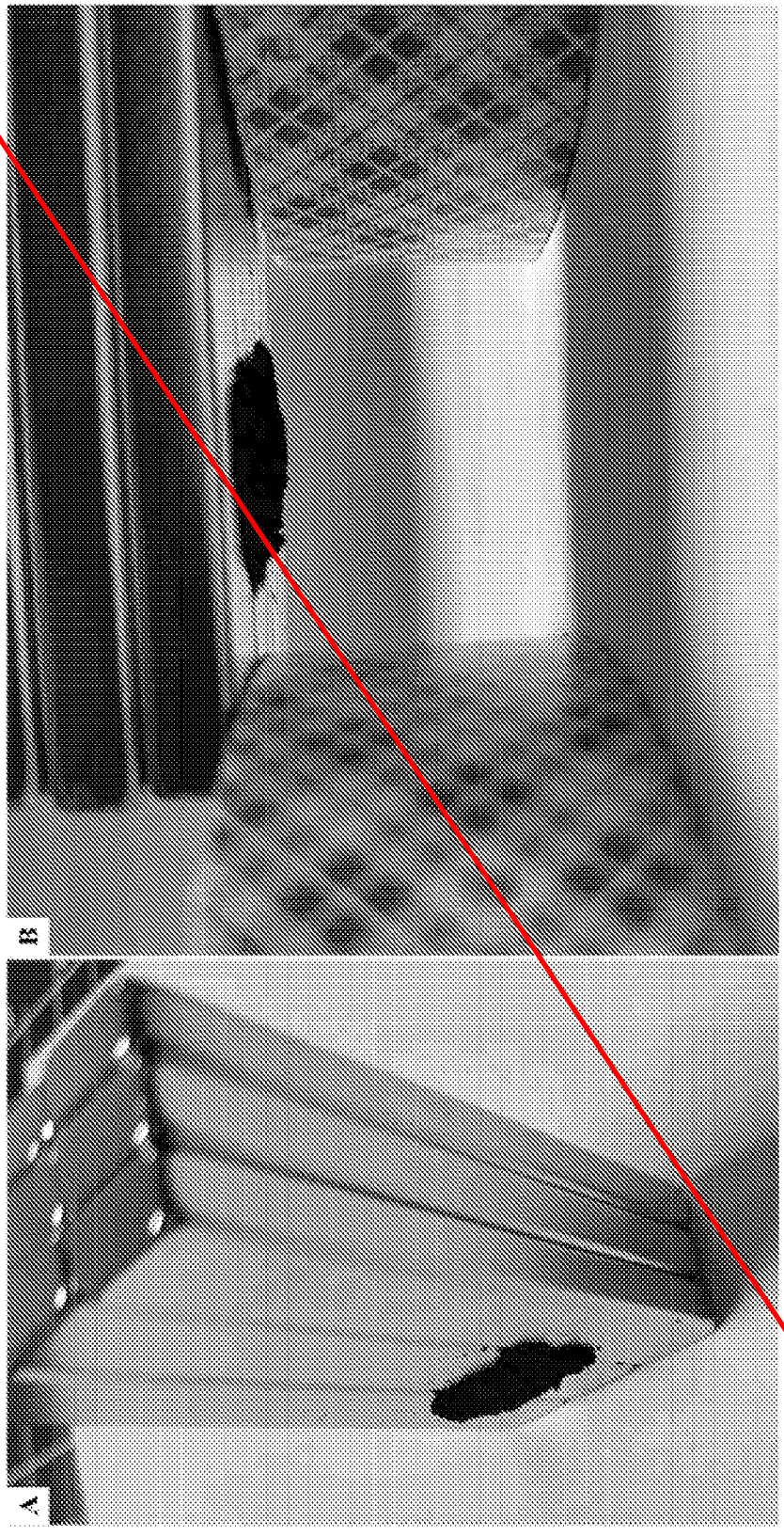


FIG. 100

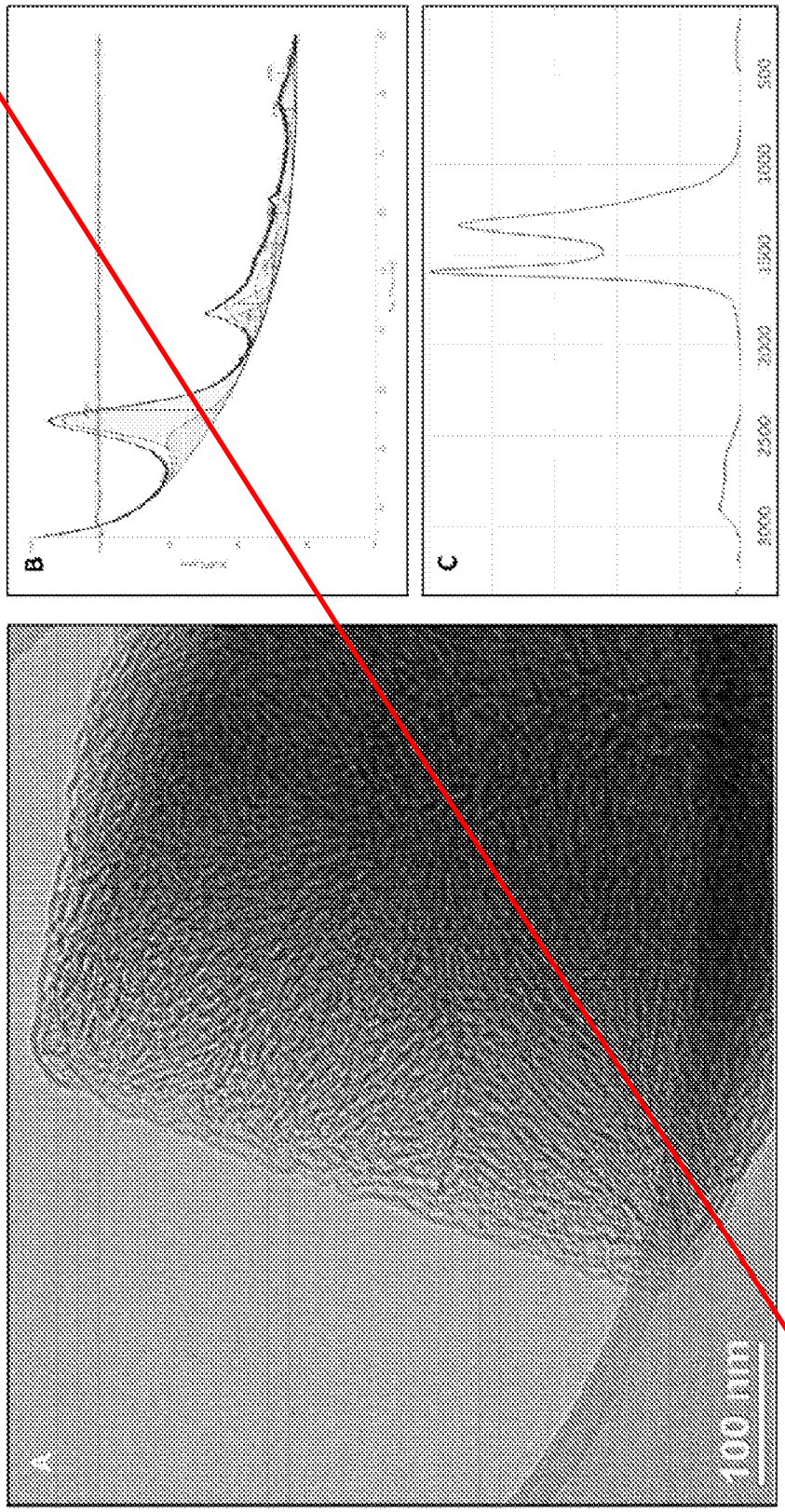


FIG. 101

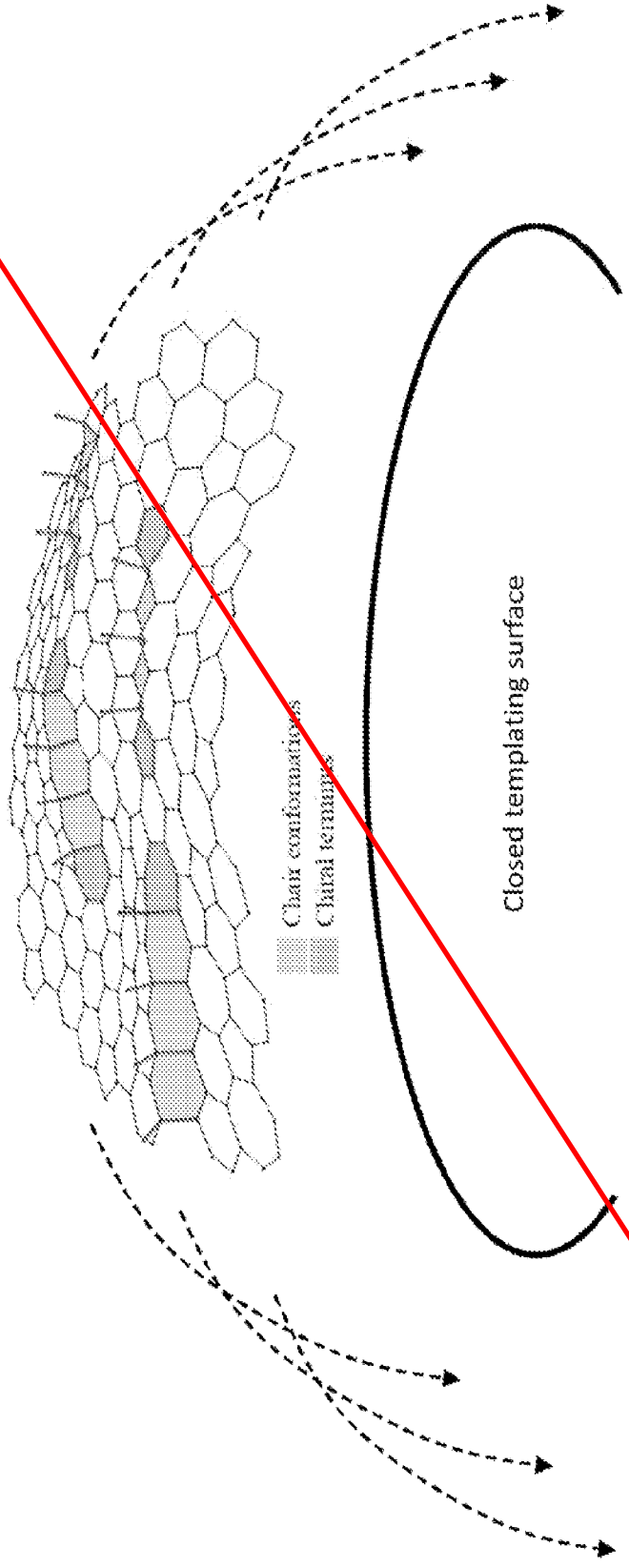

Closed templating surface
Chain conformations
Chiral terminals

FIG. 102

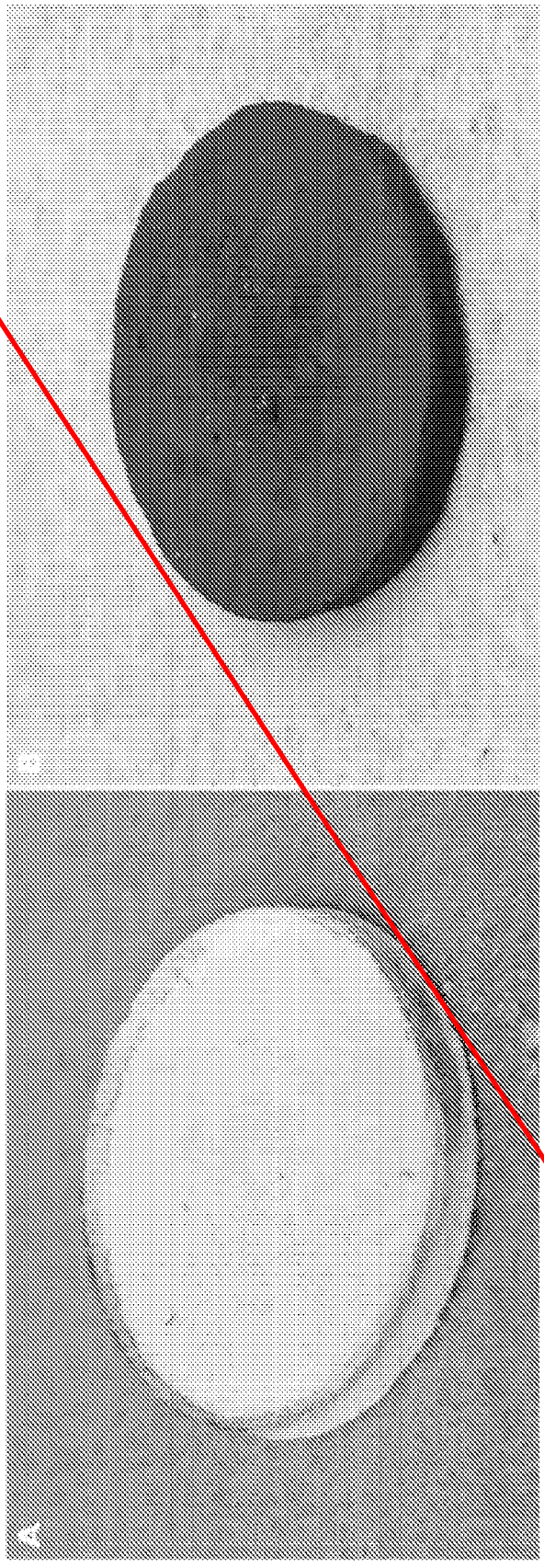


FIG. 103

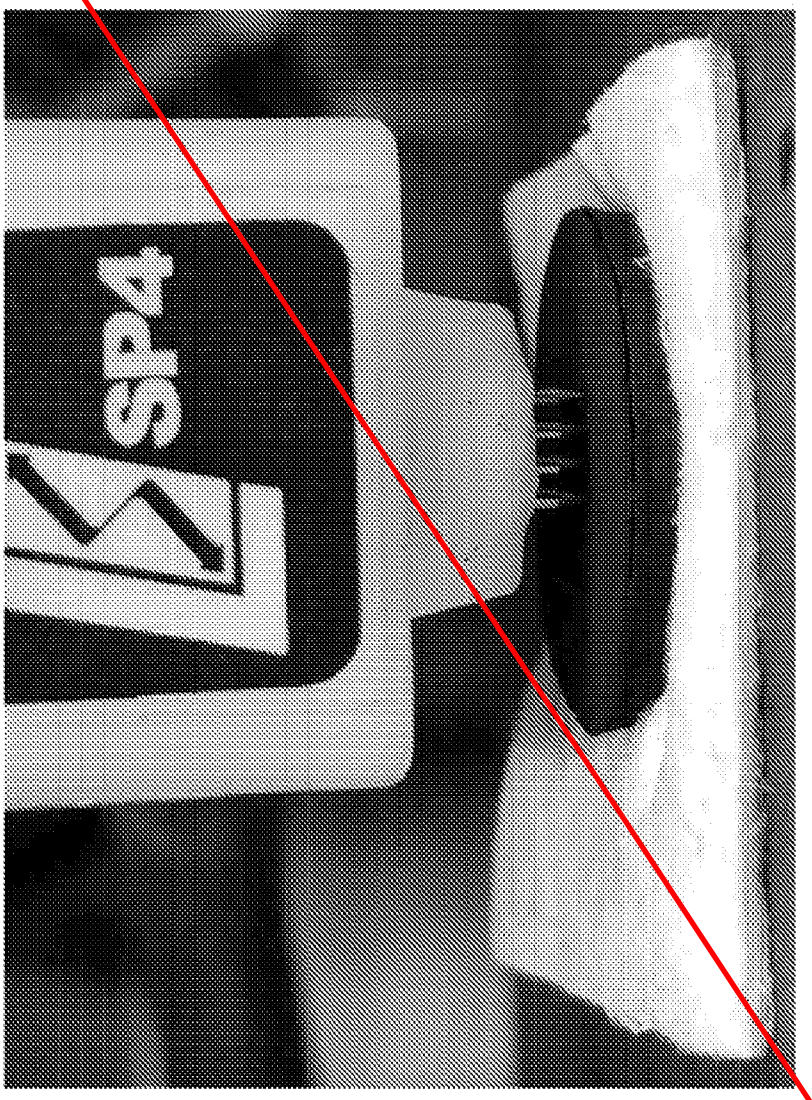


FIG. 104

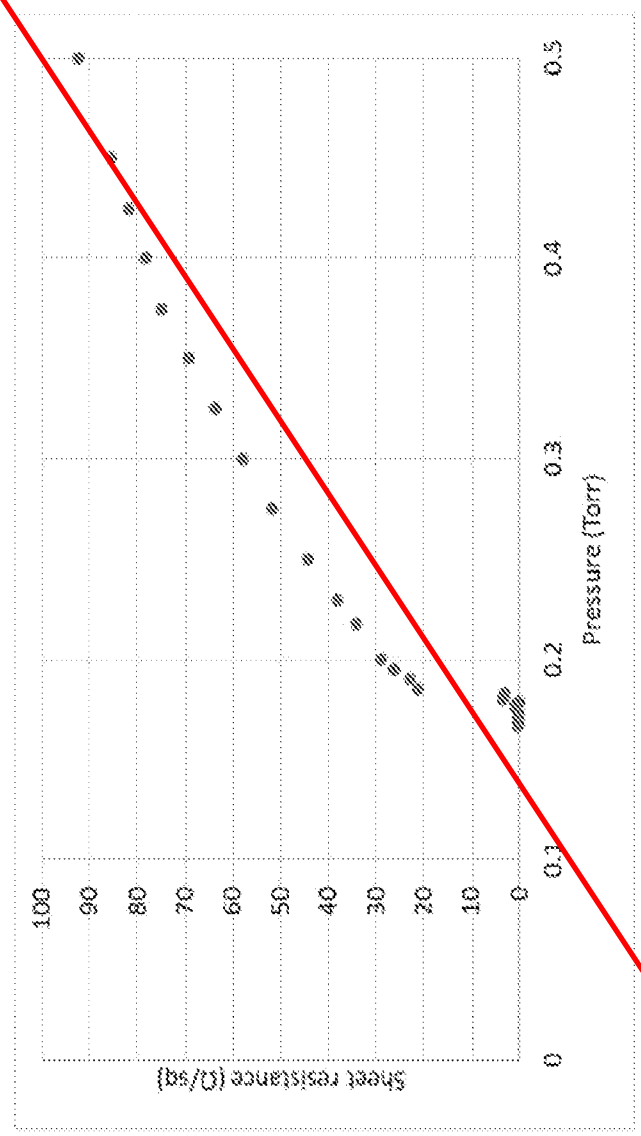

Sheet resistance (Ω/sq)
0
10
20
30
40
50
60
70
80
90
100
0
0.1
0.2
0.3
0.4
0.5
Pressure (Torr)

FIG. 105

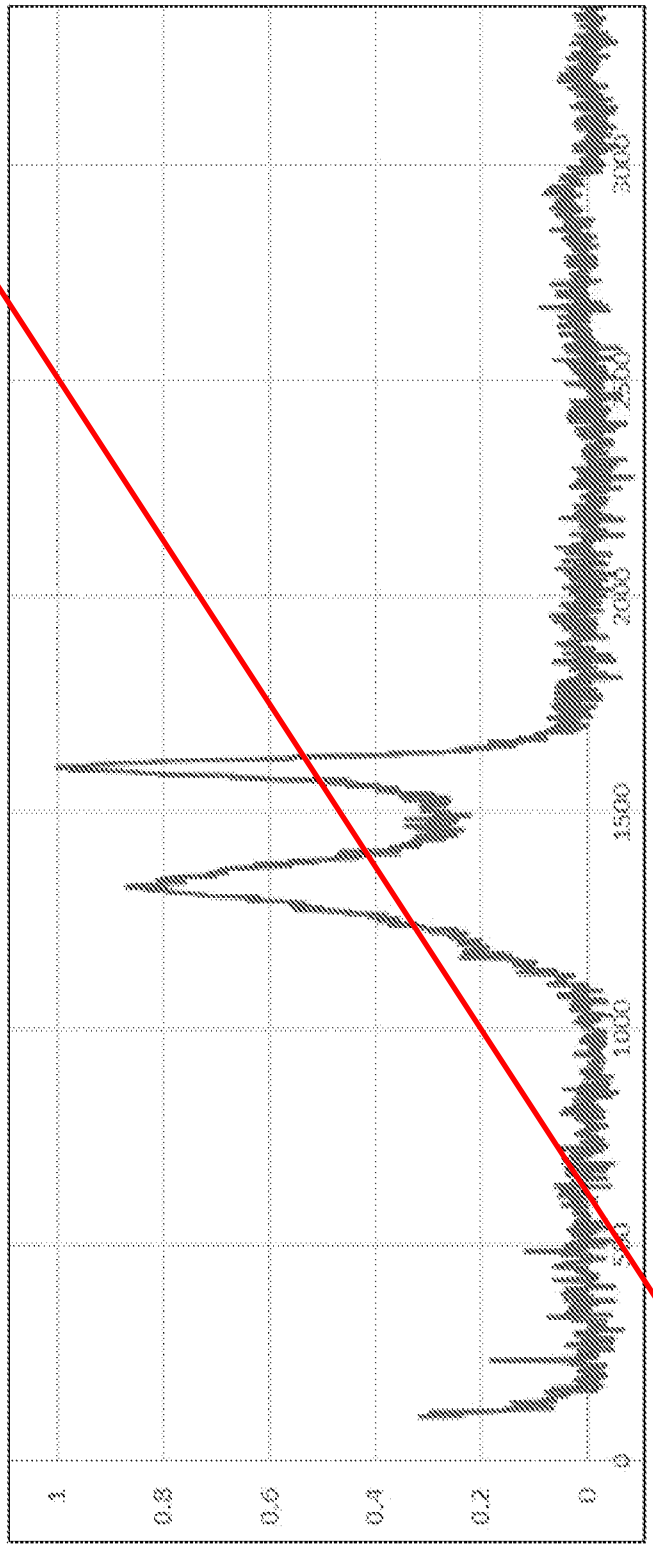


FIG. 106

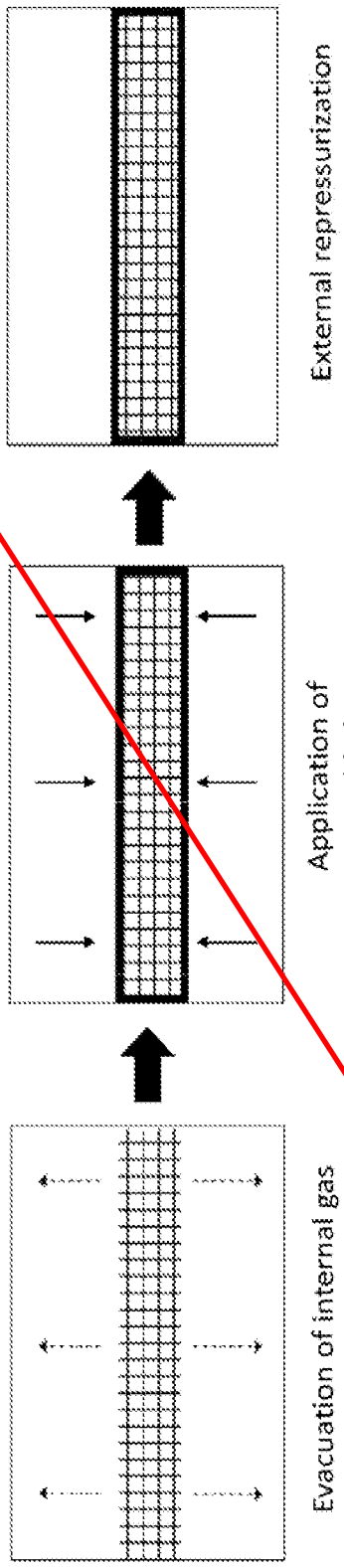

External repressurization
Application of impermeable barrier
Evacuation of internal gas

FIG. 107

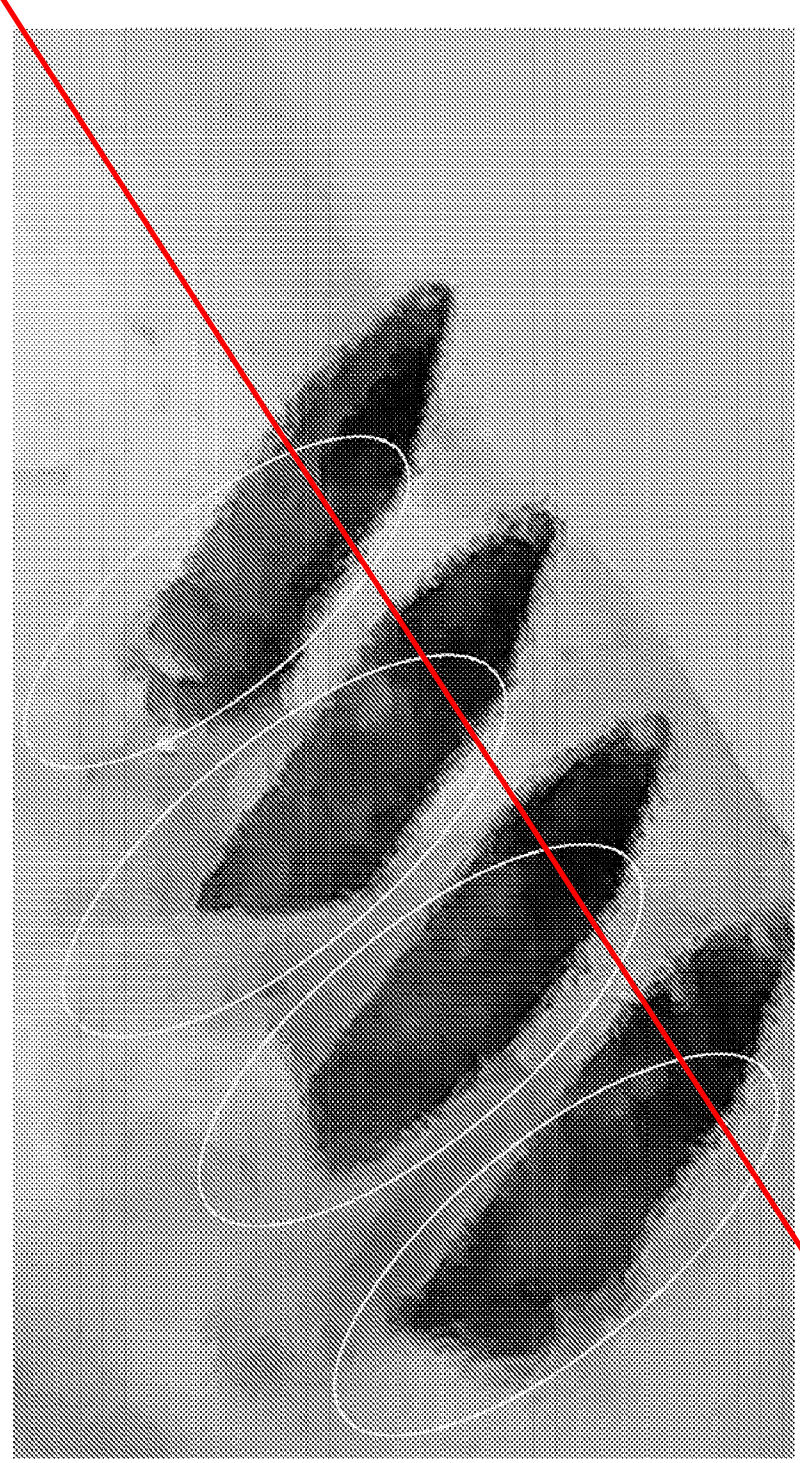


FIG. 108

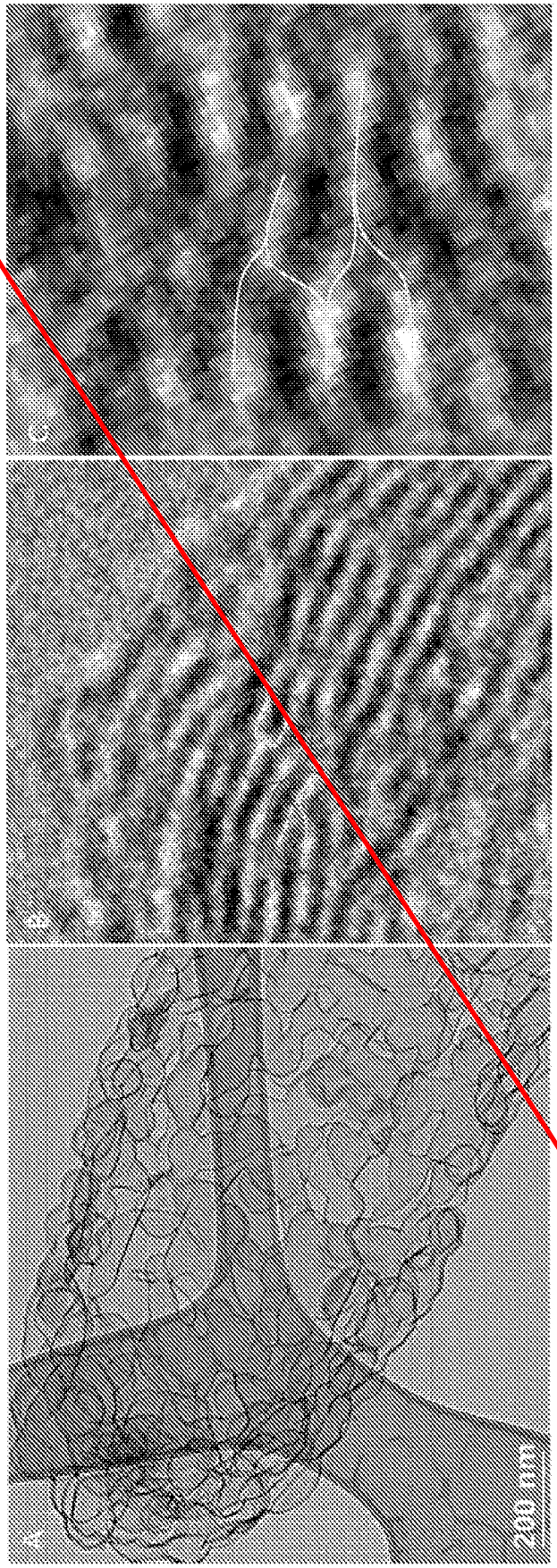


FIG. 109