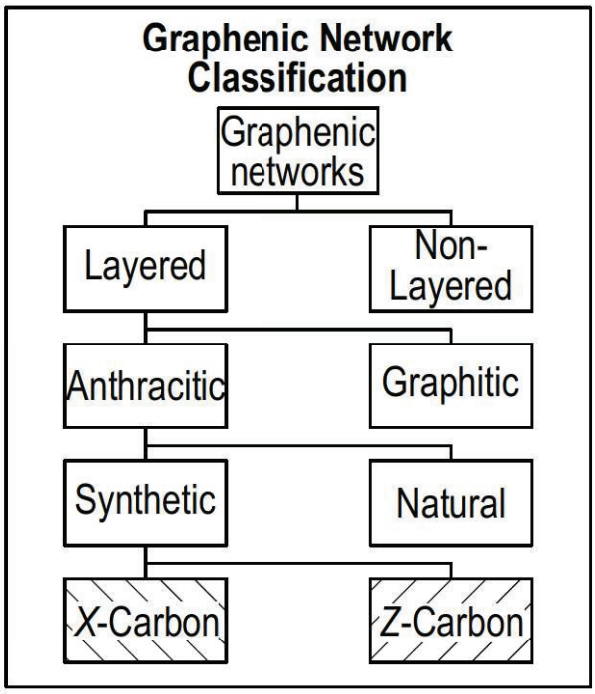
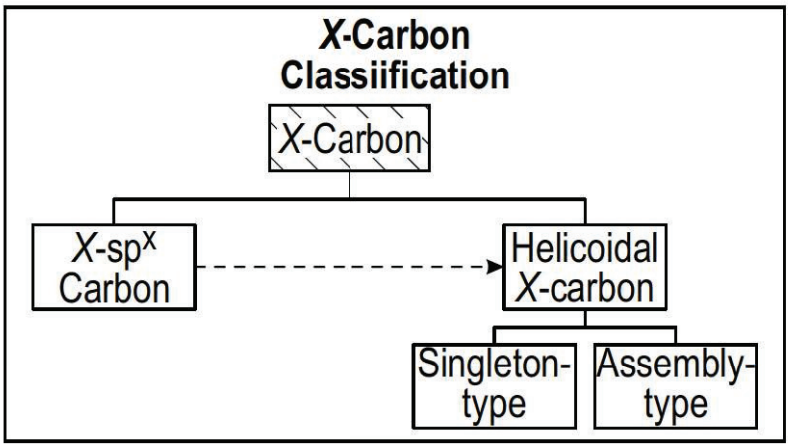

Graphenic Network Classification
Graphenic networks
Layered
Non-Layered
Anthracitic
Graphitic
Synthetic
Natural
X-Carbon
Z-Carbon


X-Carbon Classiification
X-Carbon
X-sp^x Carbon
Helicoidal X-carbon
Singleton-type
Assembly-type

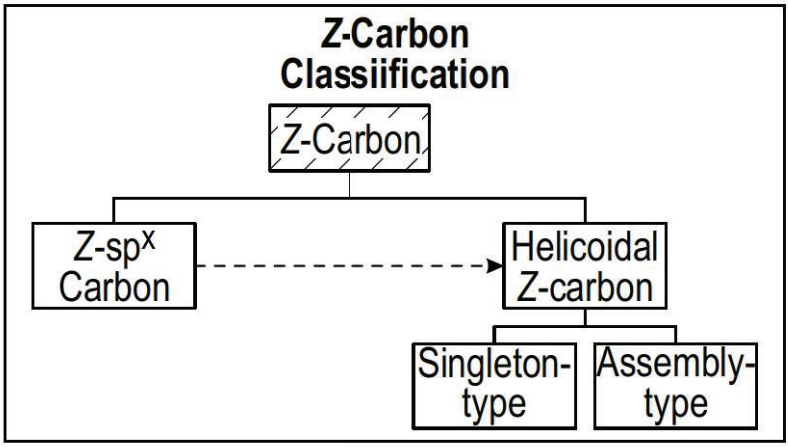

Z-Carbon Classiification
Z-Carbon
Z-sp^x Carbon
Helicoidal Z-carbon
Singleton-type
Assembly-type

FIG. 1

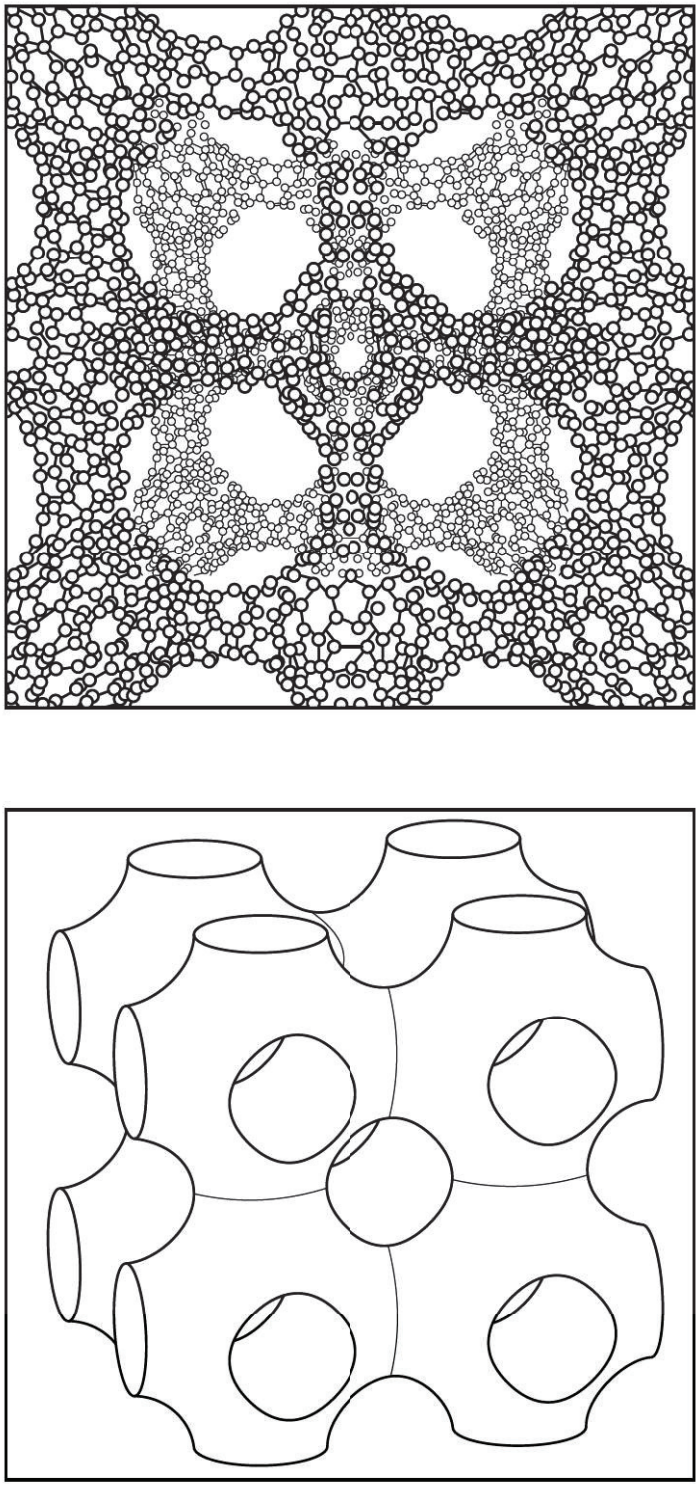


FIG. 2

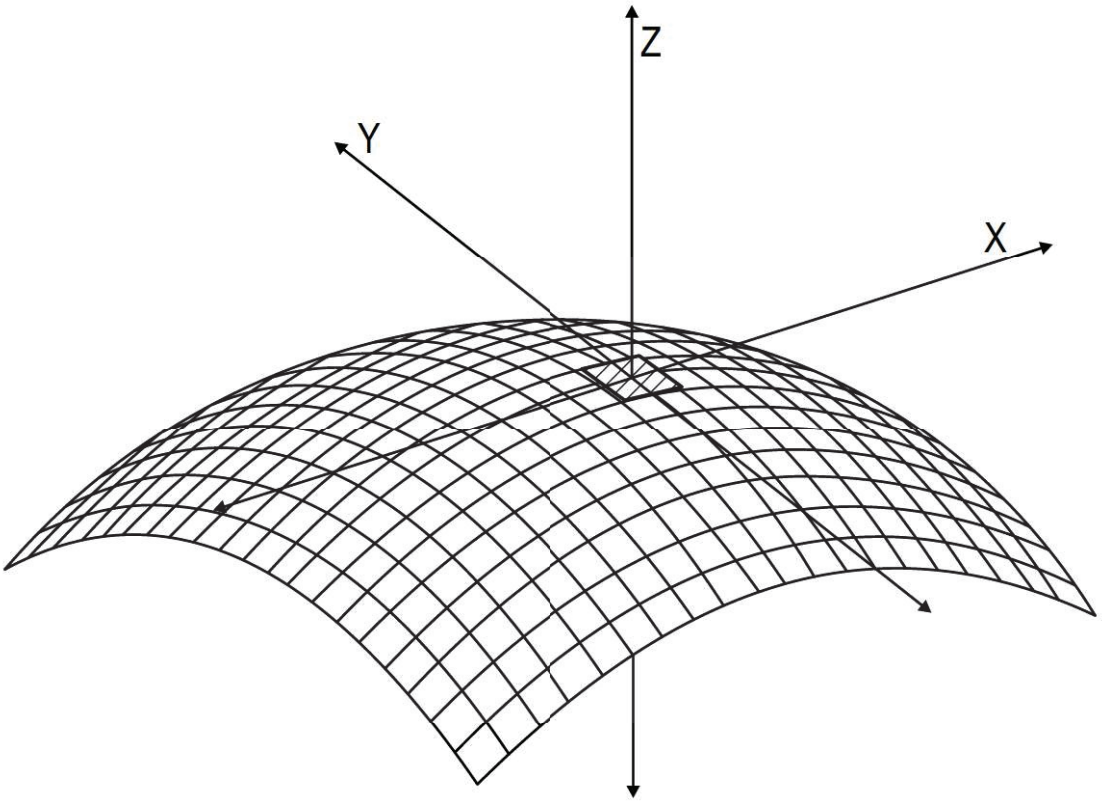


FIG. 3

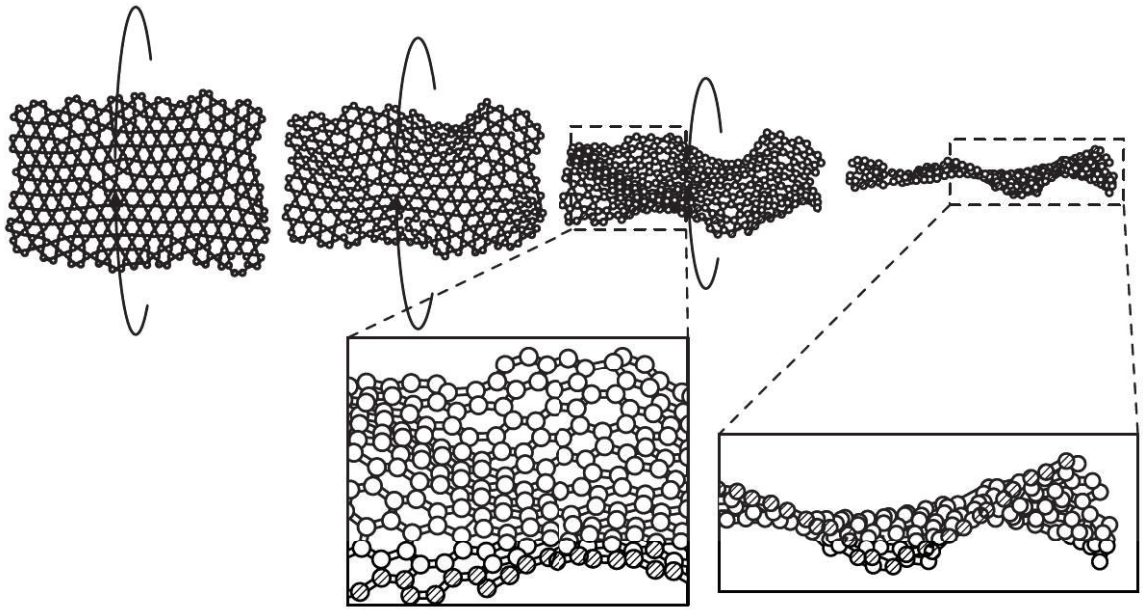


FIG. 4

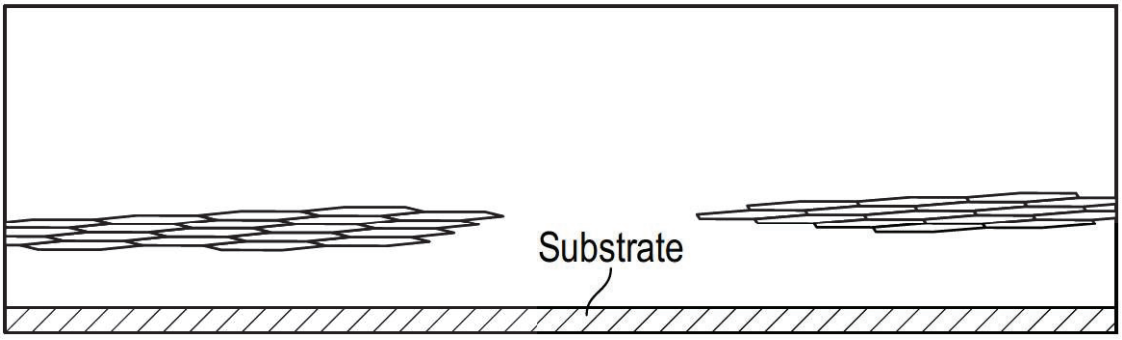


FIG. 5A

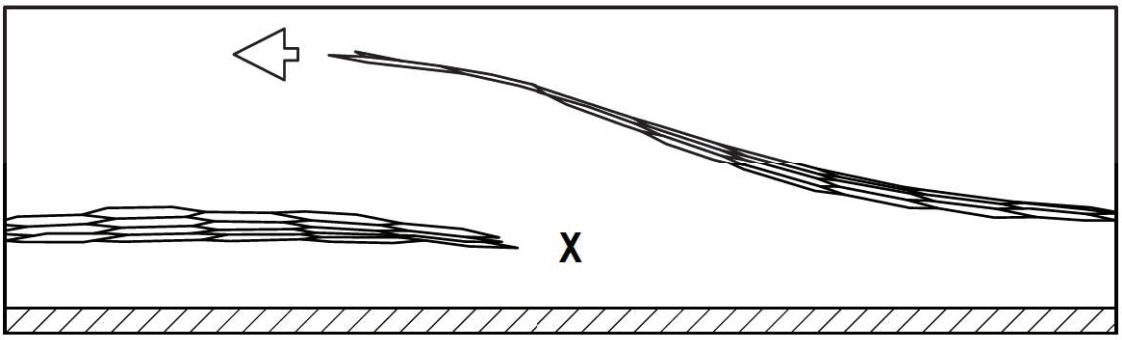


FIG. 5B

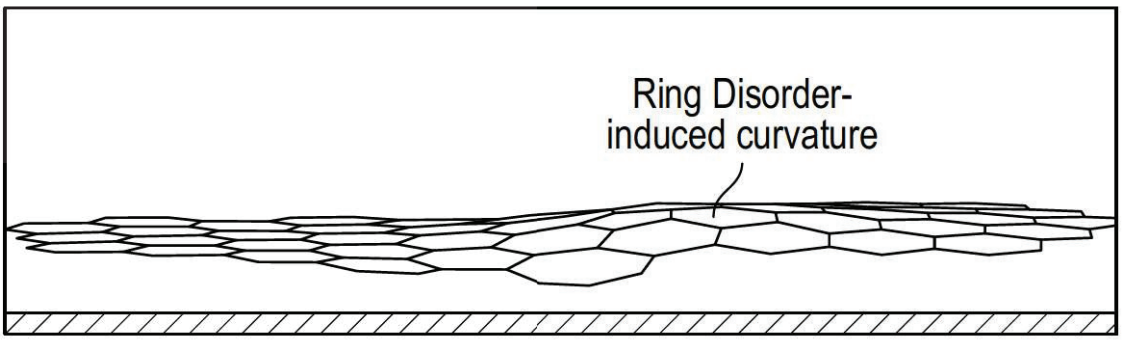


FIG. 5C

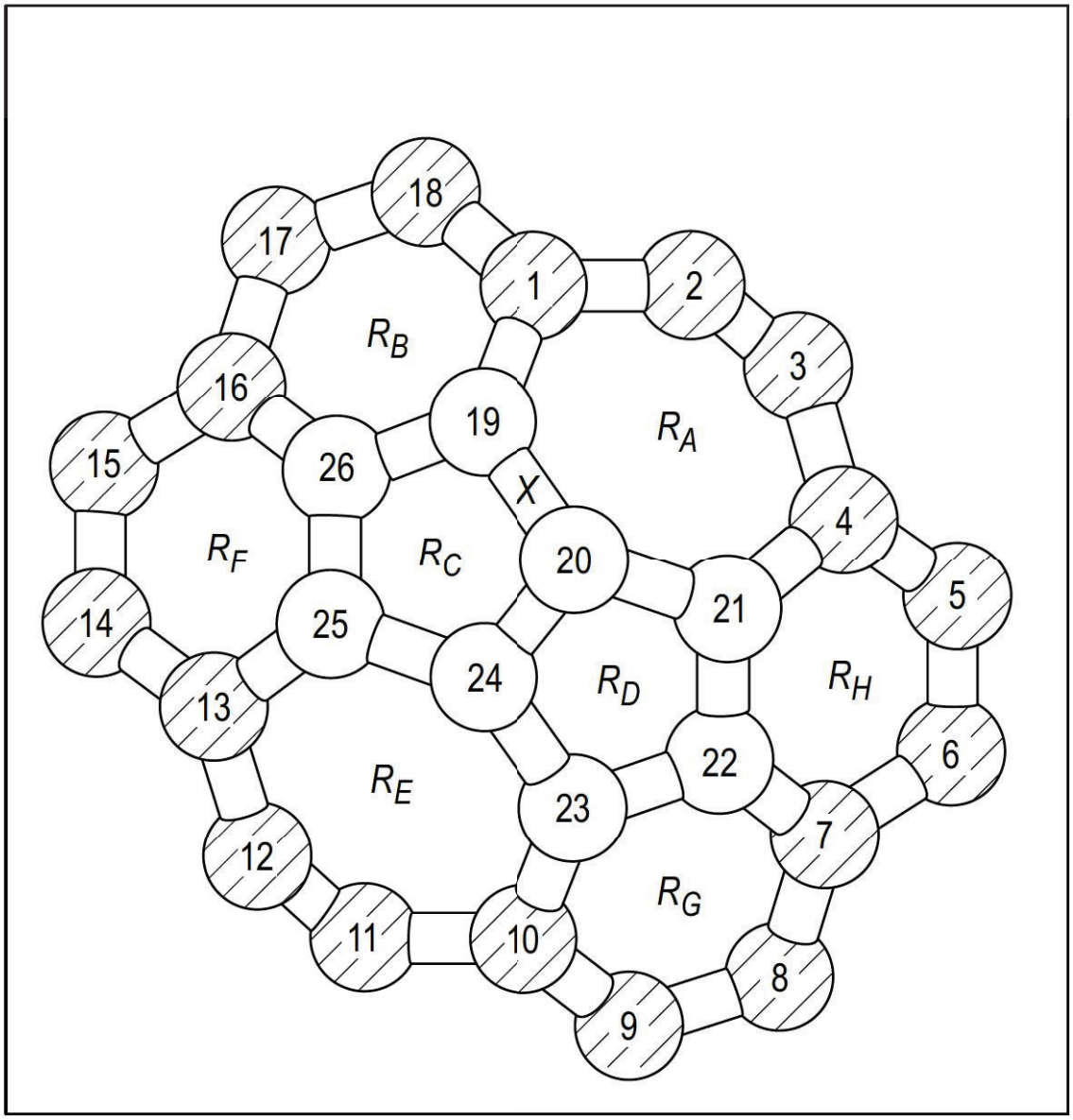

18
17
1
2
R_B
3
16
19
R_A
15
26
X
4
R_F
R_C
20
14
25
21
5
24
R_D
R_H
13
22
6
R_E
23
12
7
R_G
11
10
8
9

FIG. 6A

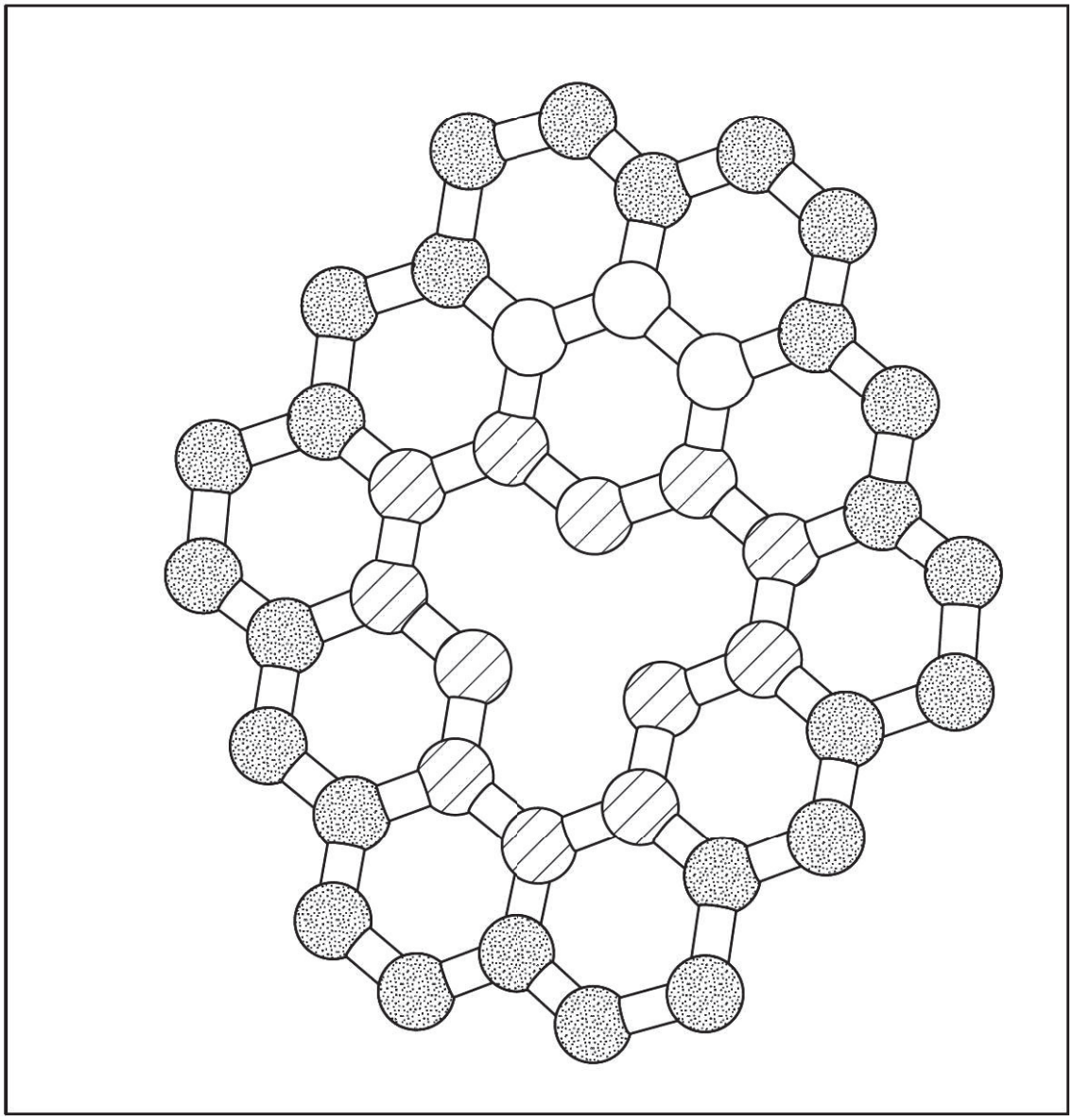


FIG. 6B

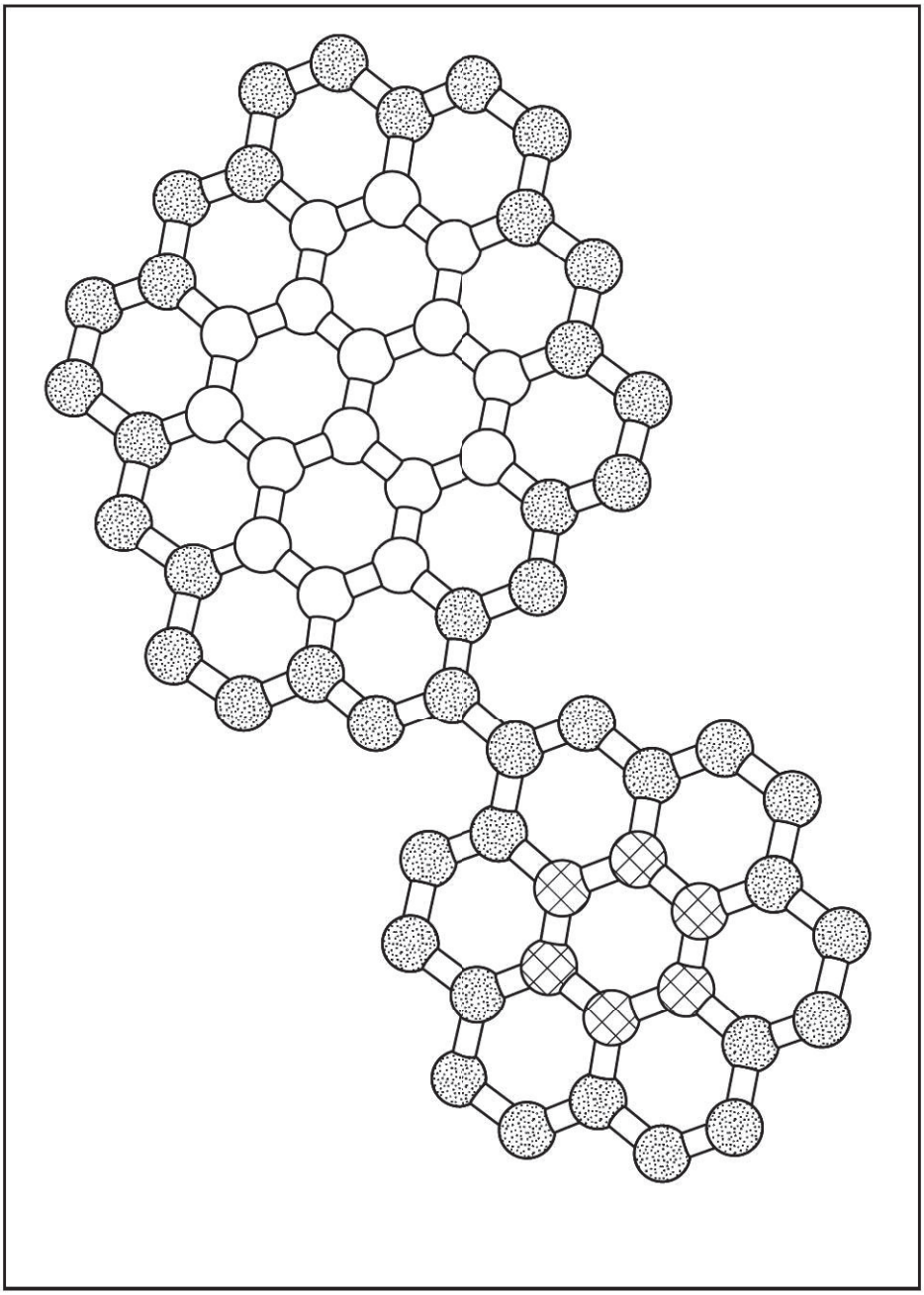


FIG. 6C

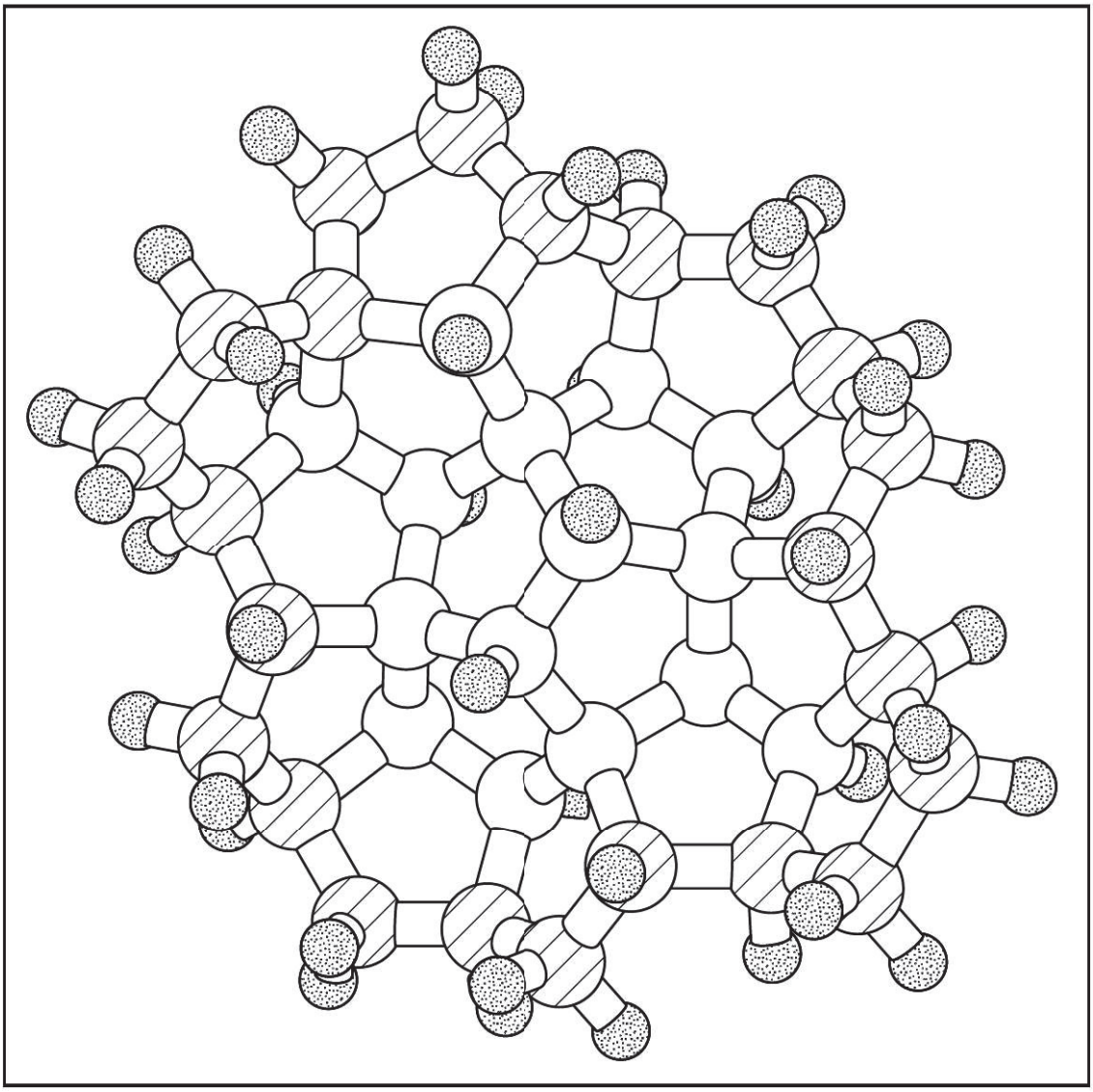


FIG. 6D

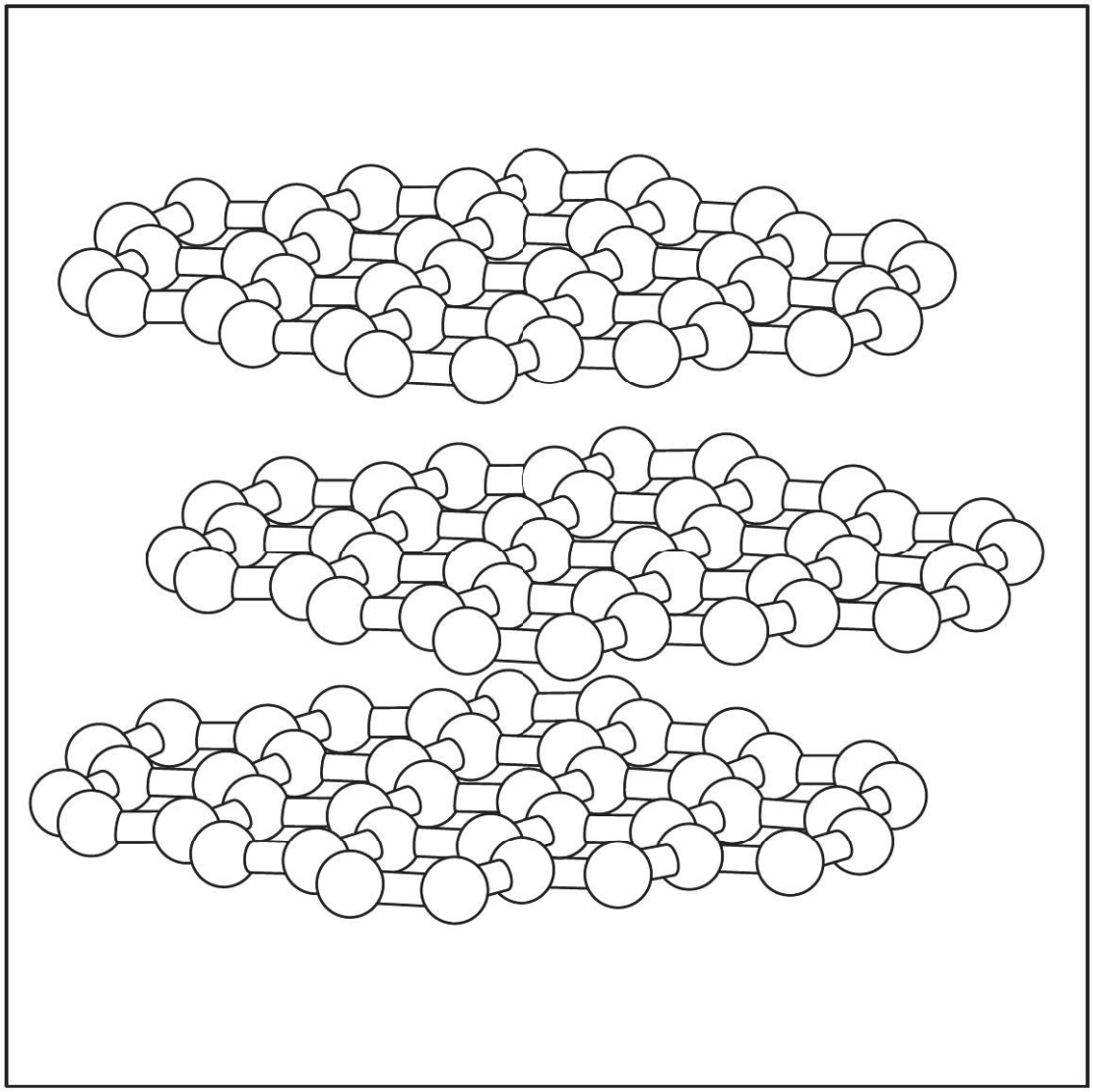


FIG. 6E

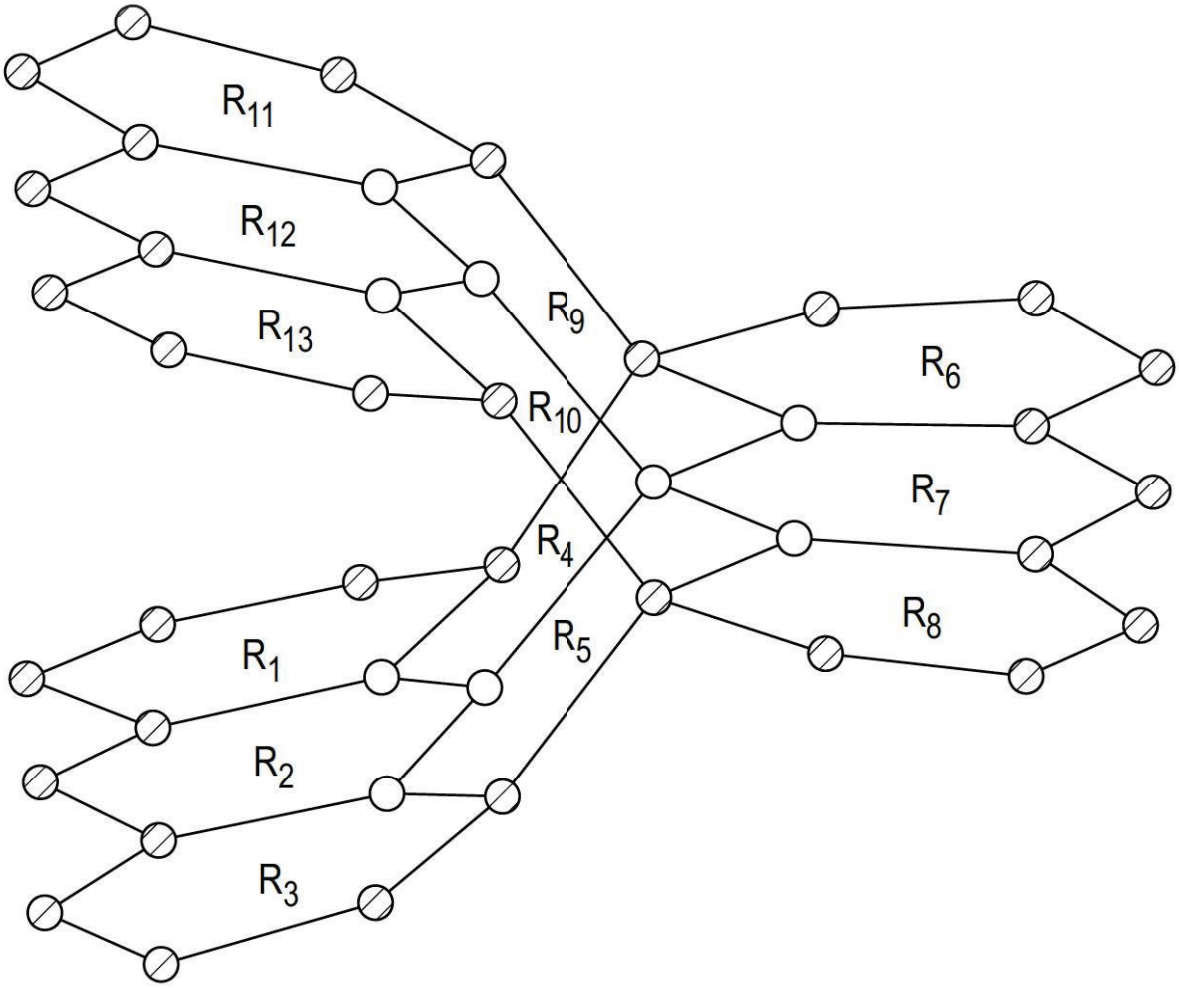


FIG. 7A

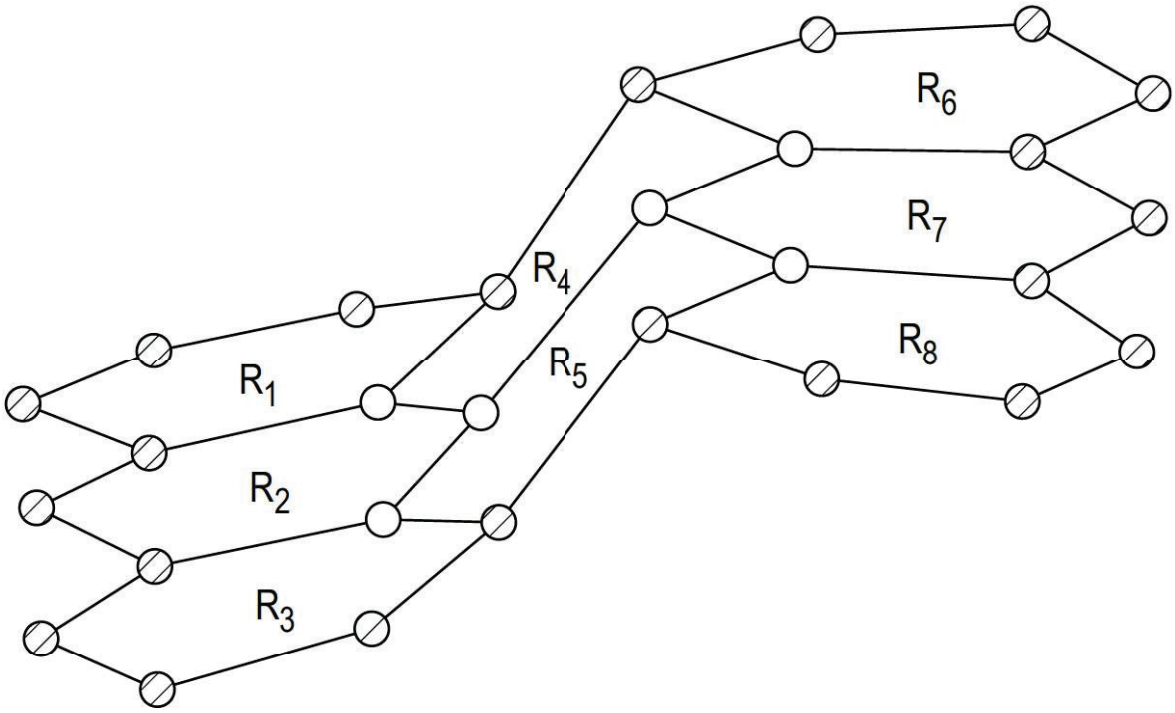


FIG. 7B

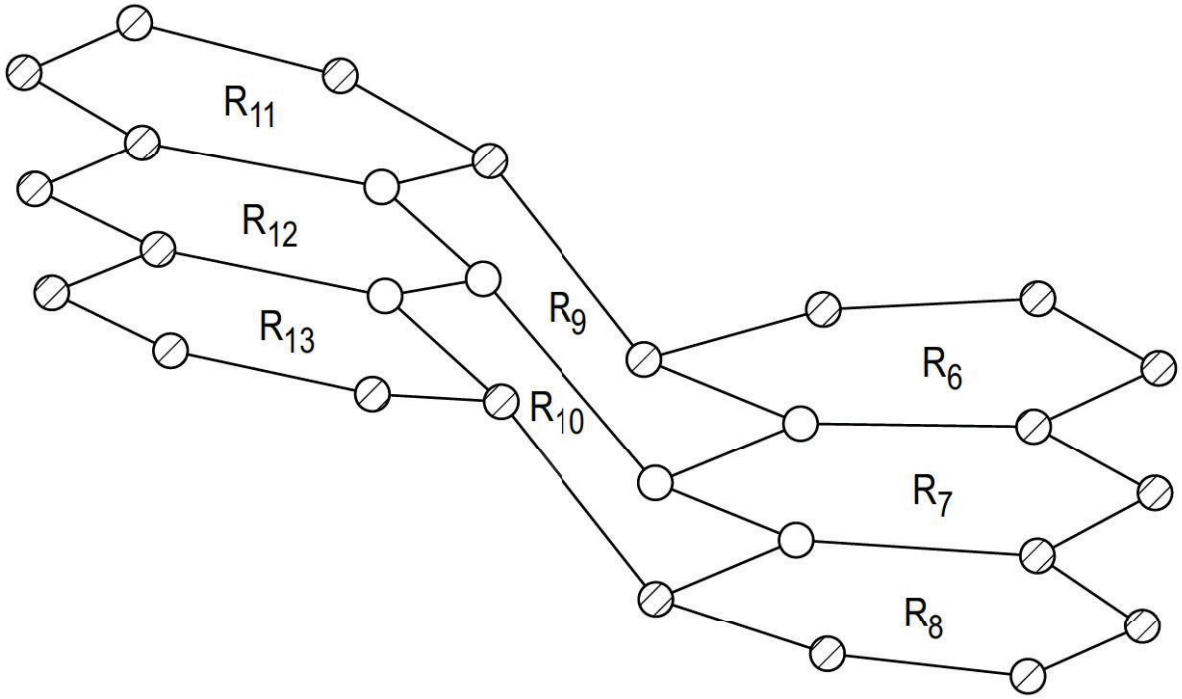


FIG. 7C

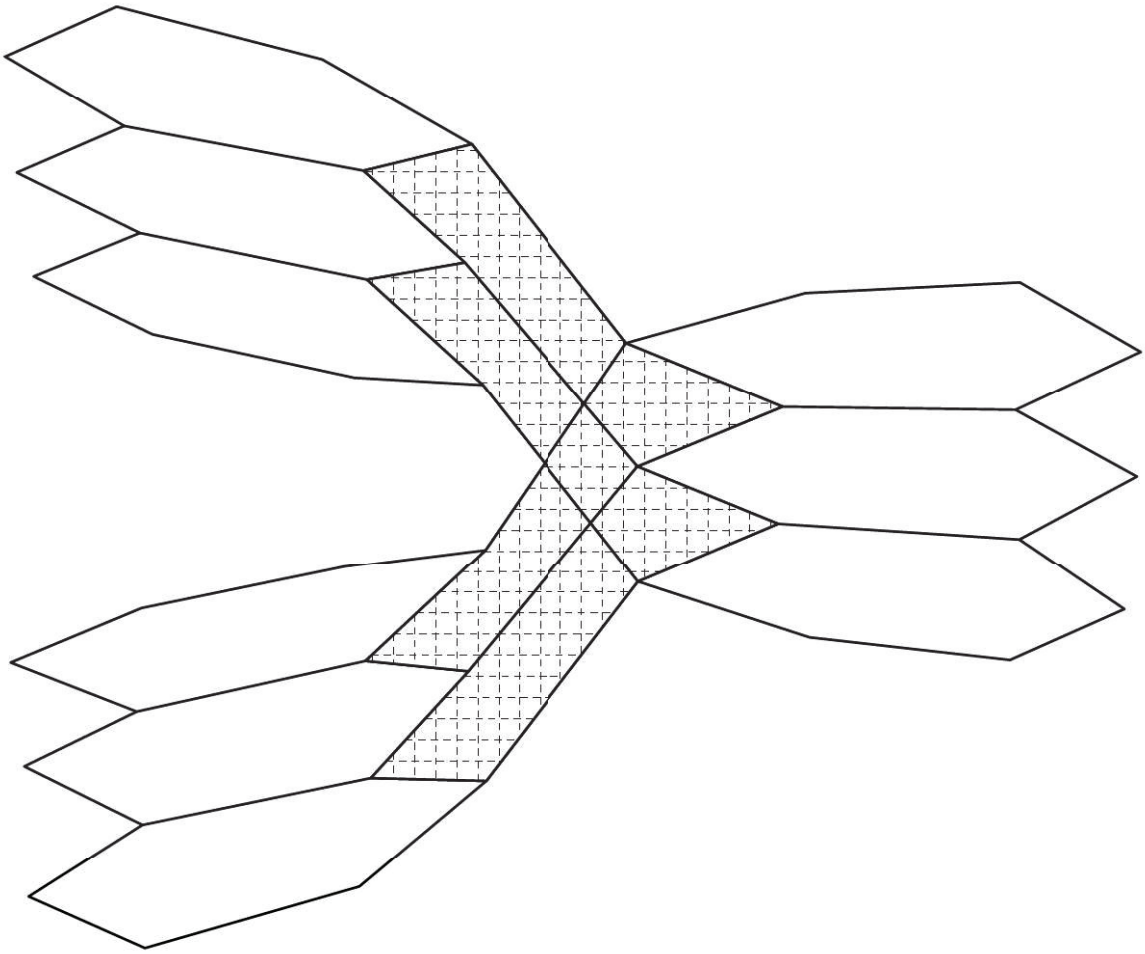


FIG. 7D

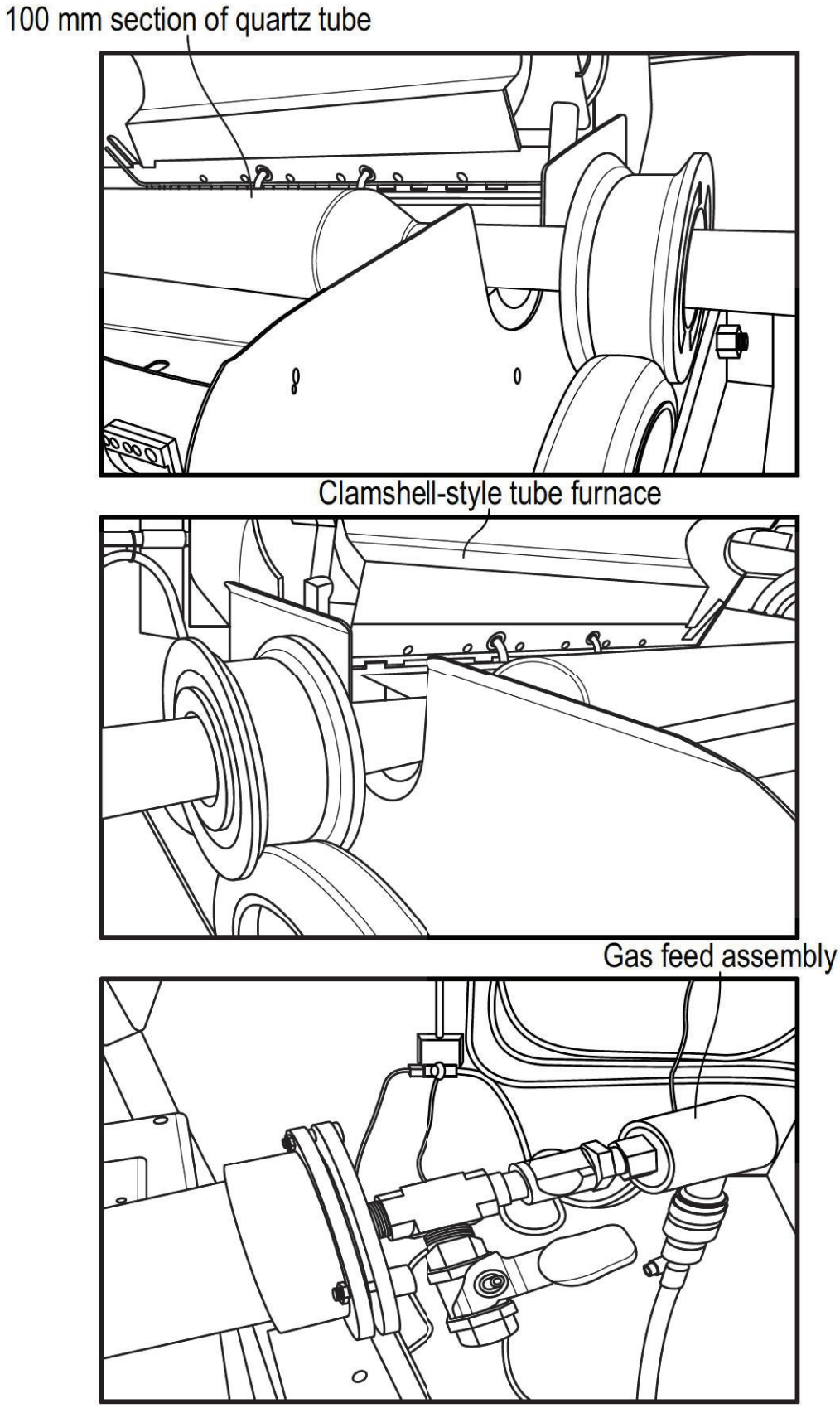

100 mm section of quartz tube
Clamshell-style tube furnace
Gas feed assembly

FIG. 8A

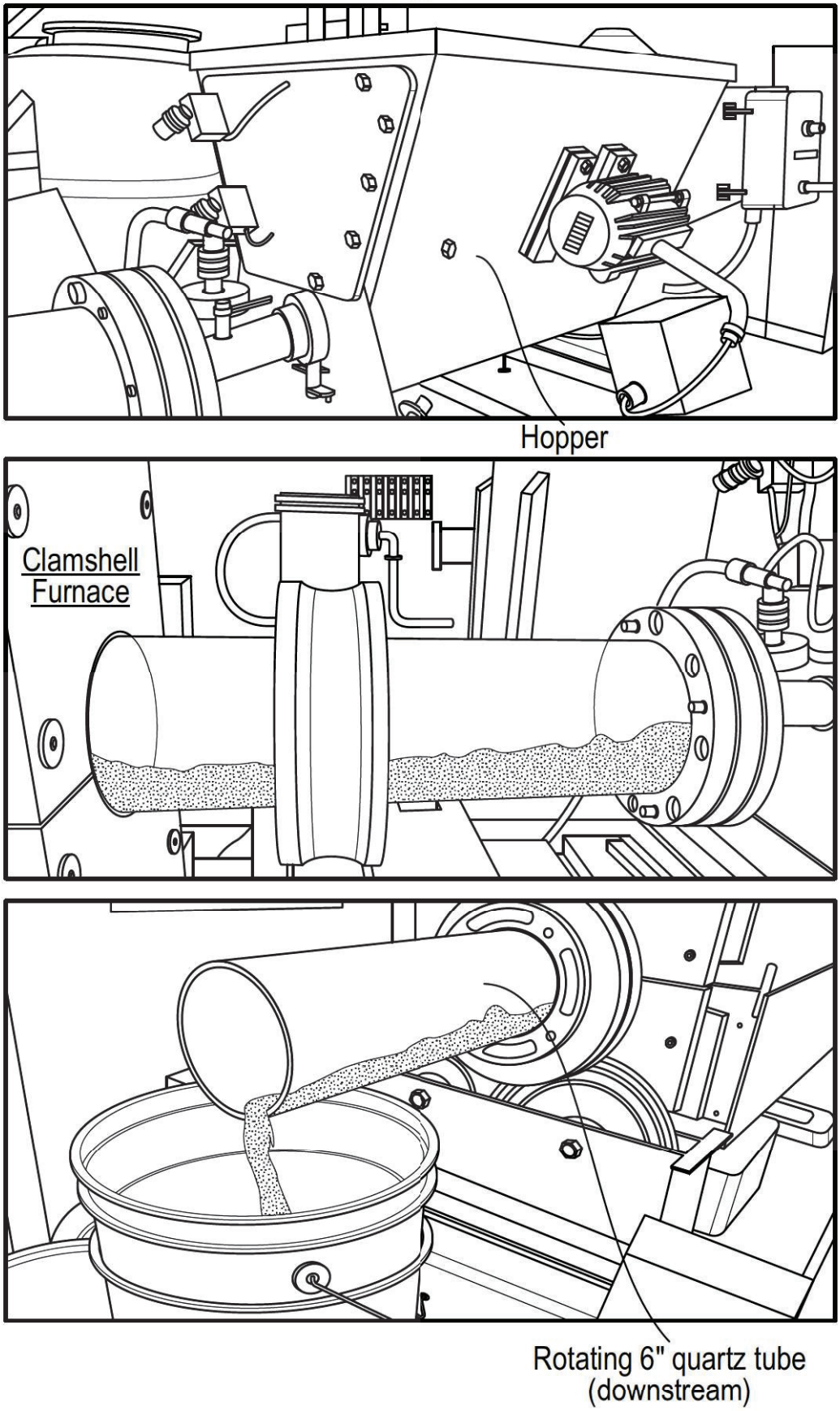

Hopper
Clamshell
Furnace
Rotating 6" quartz tube
(downstream)

FIG. 8B

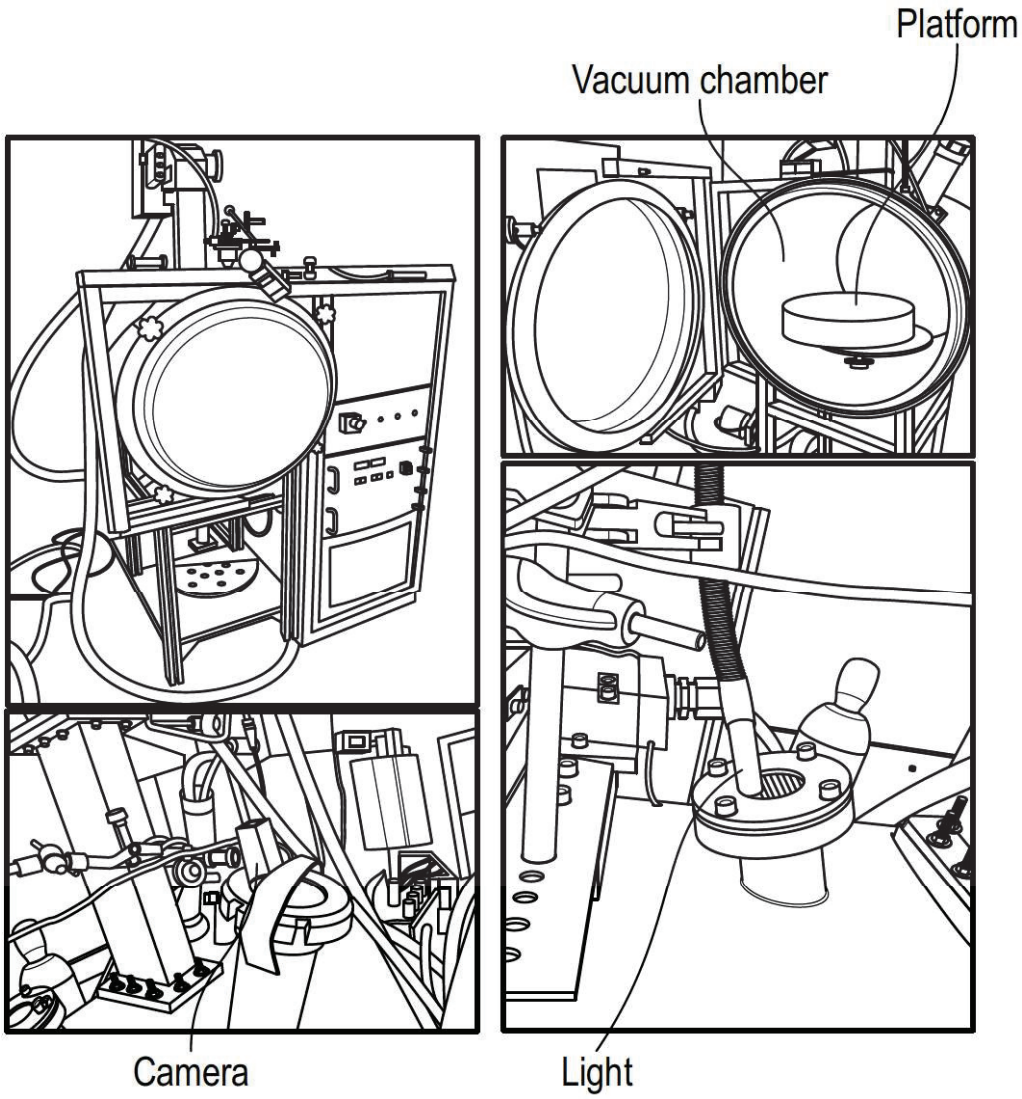


FIG. 8C

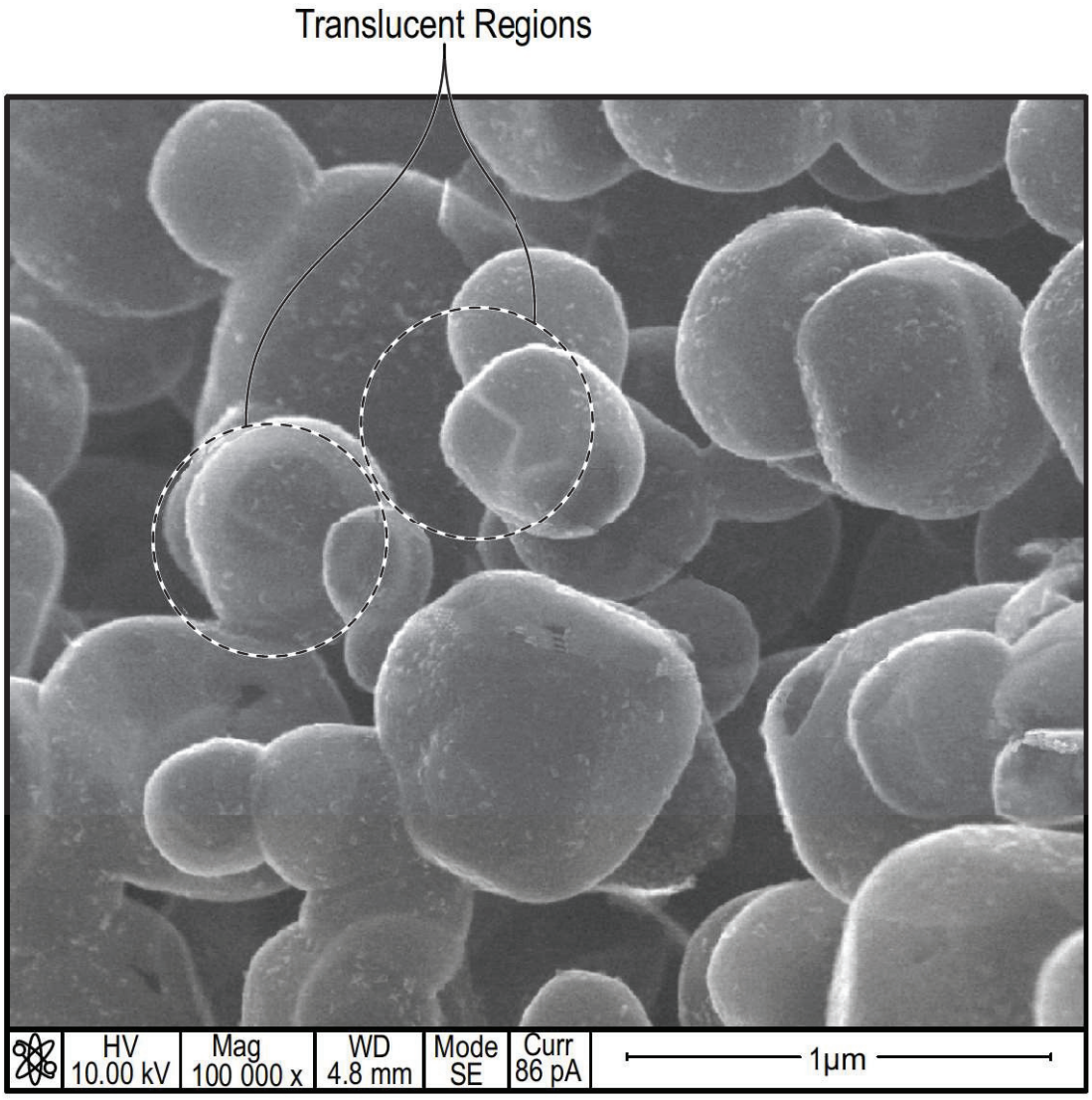

Translucent Regions
HV
10.00 kV
Mag
100 000 x
WD
4.8 mm
Mode
SE
Curr
86 pA
1µm

FIG. 9

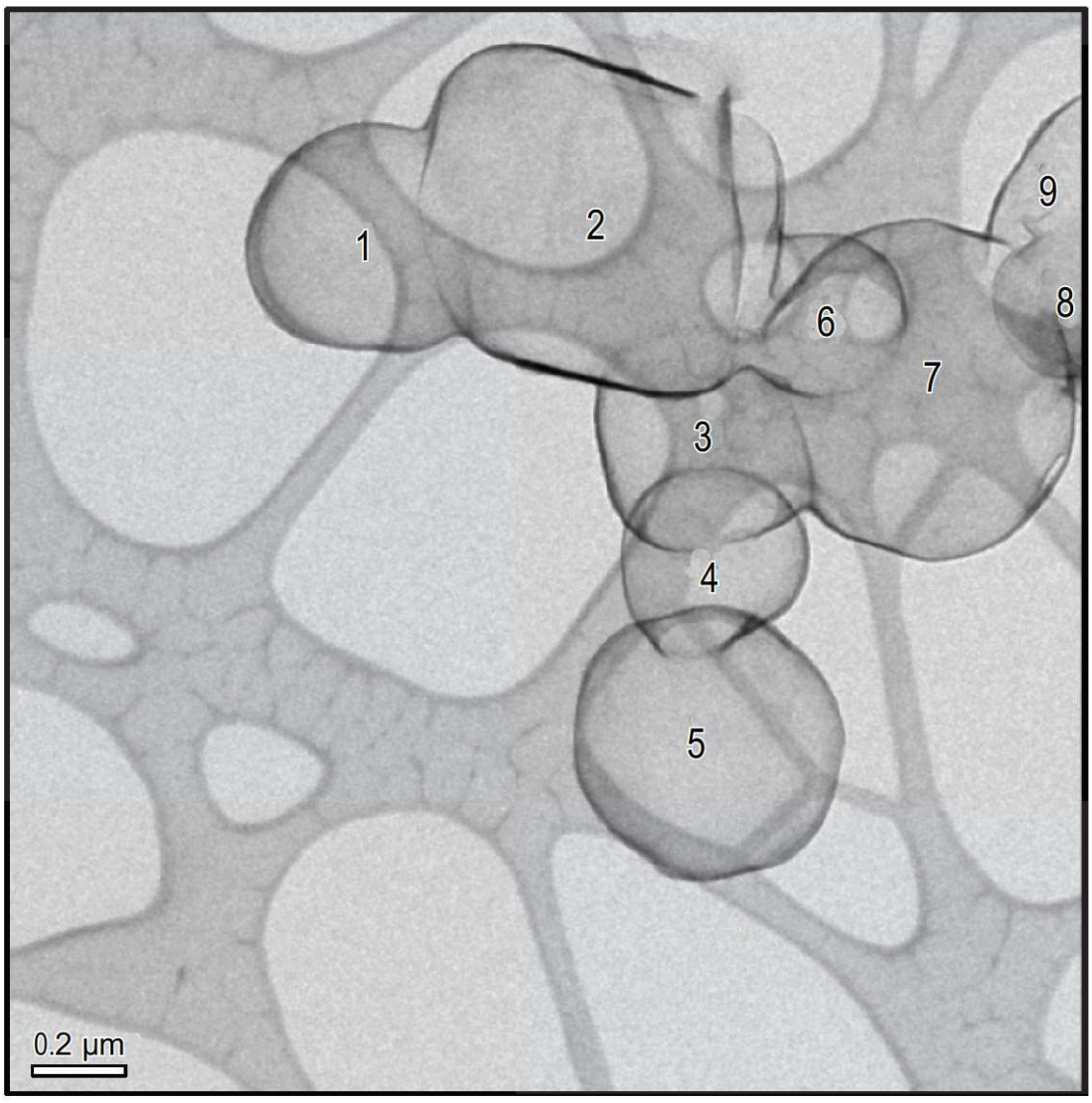


FIG. 10A

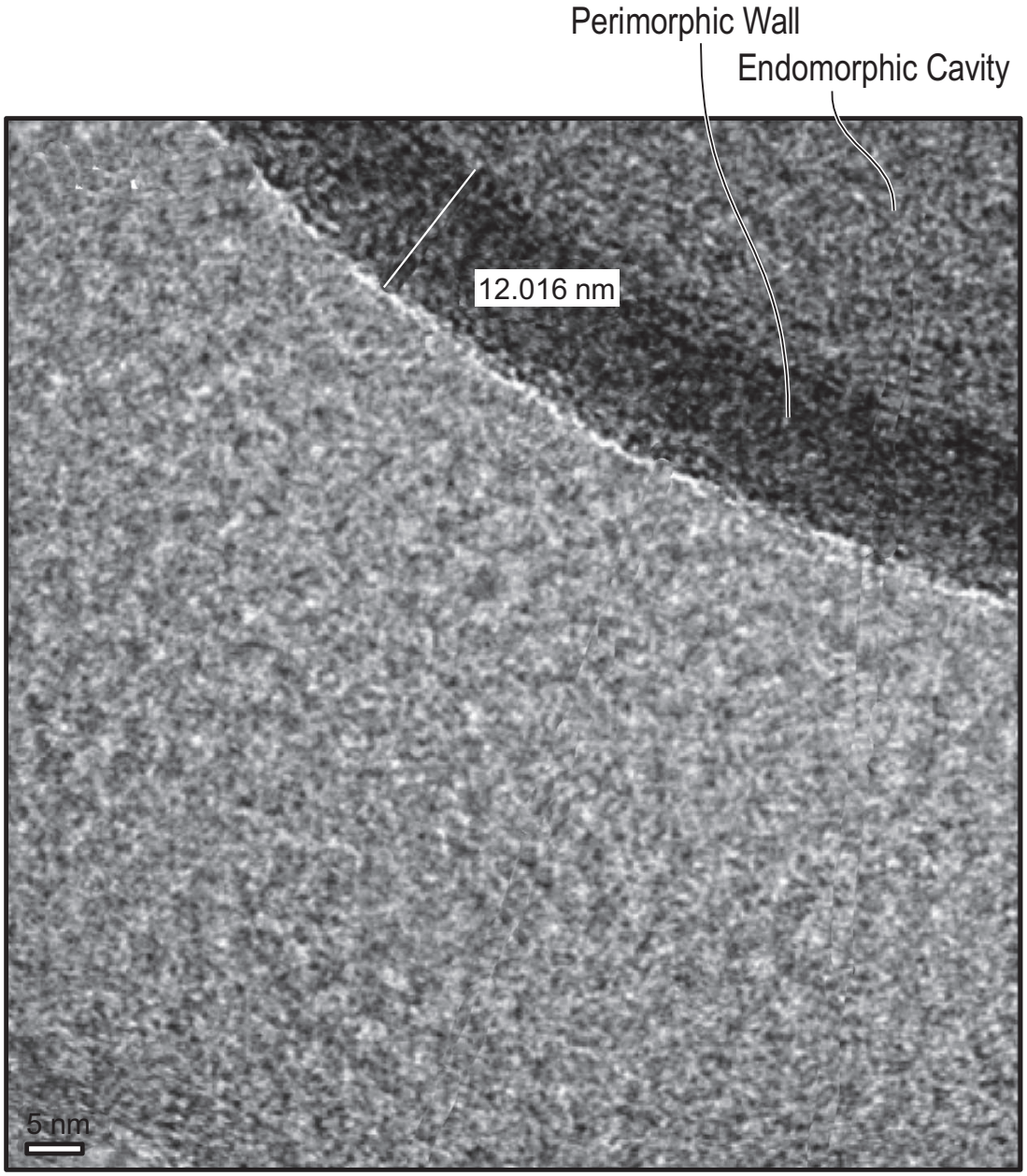


FIG. 10B

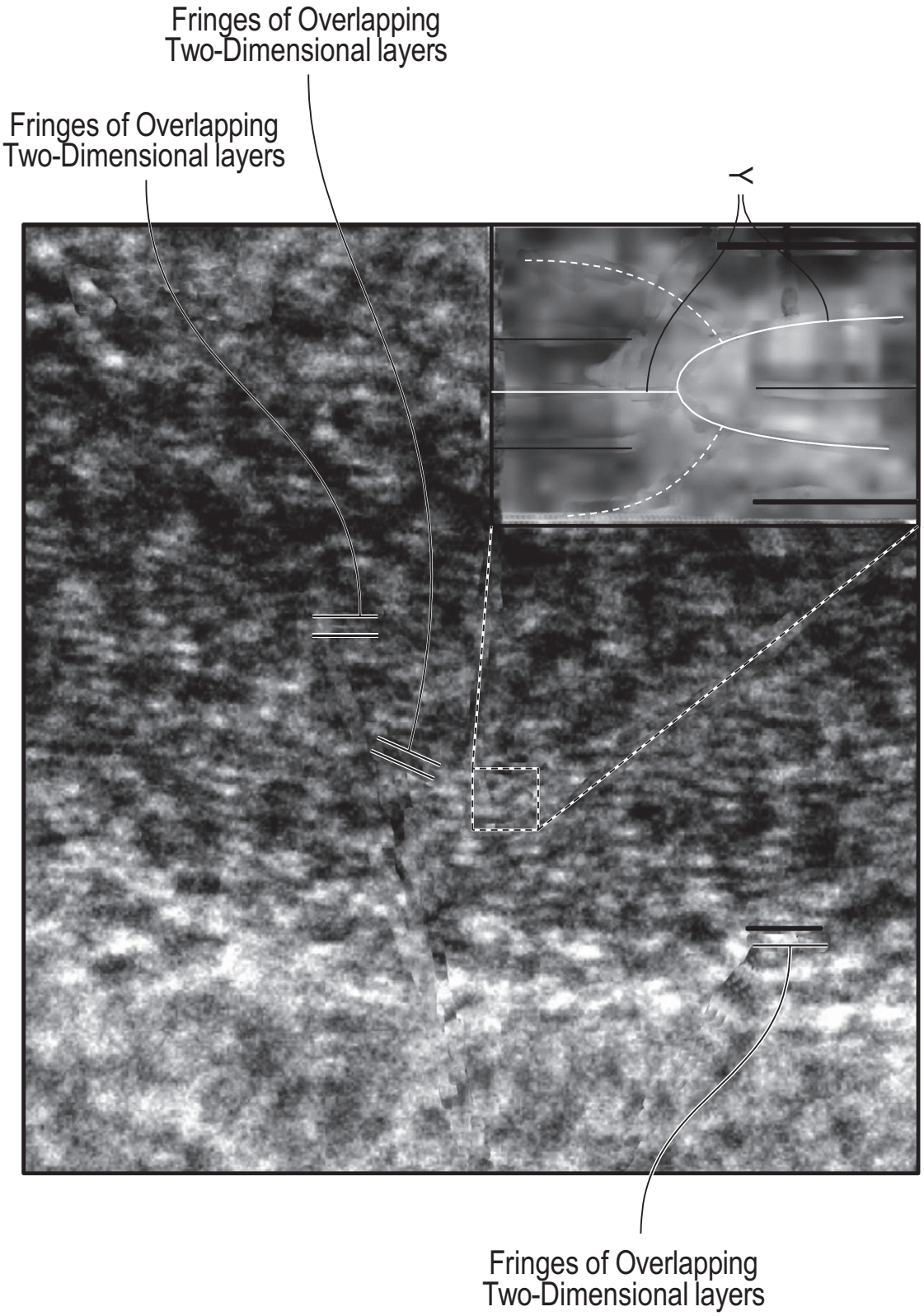

Fringes of Overlapping
Two-Dimensional layers
Fringes of Overlapping
Two-Dimensional layers
Fringes of Overlapping
Two-Dimensional layers

FIG. 10C

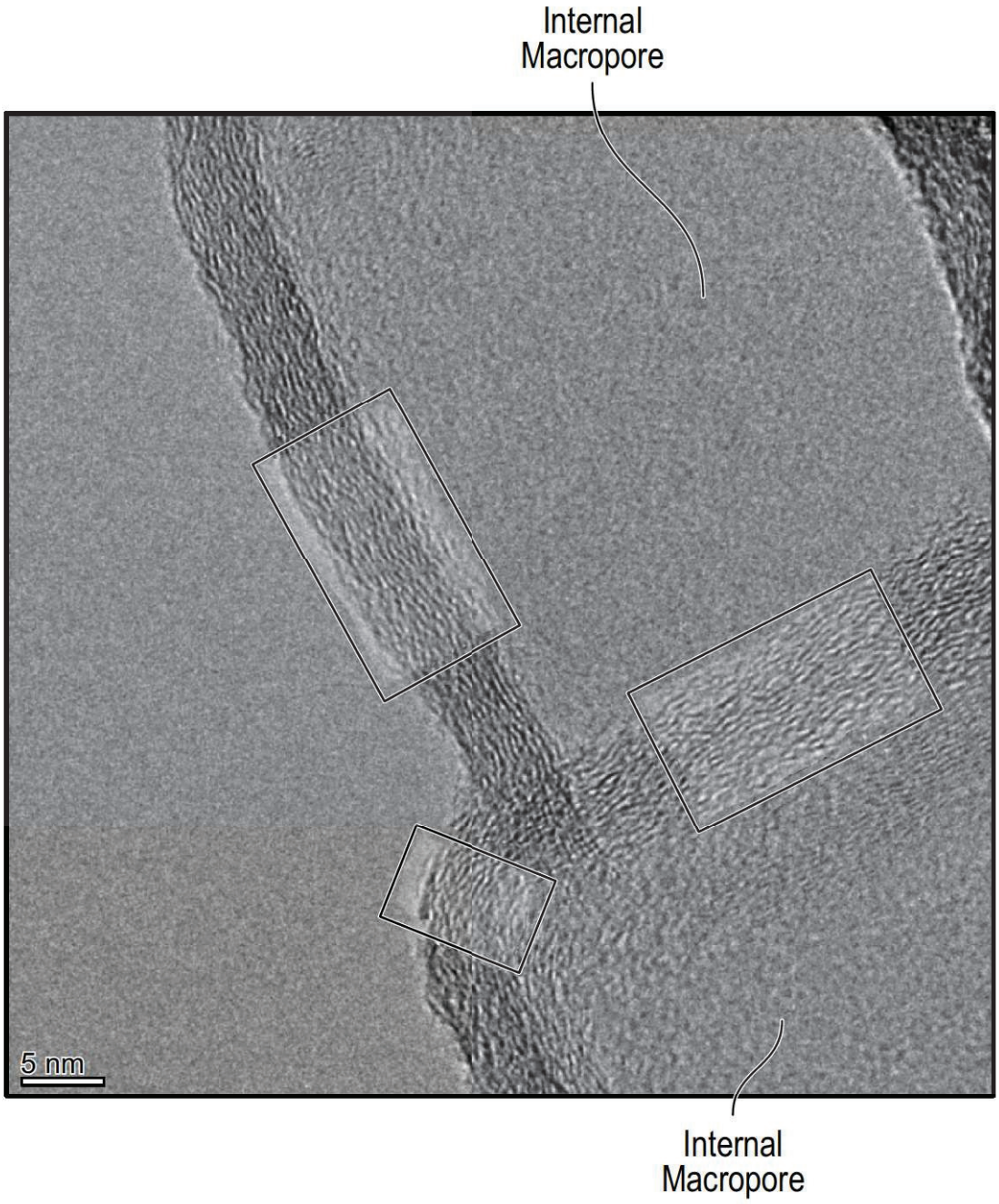


FIG. 11

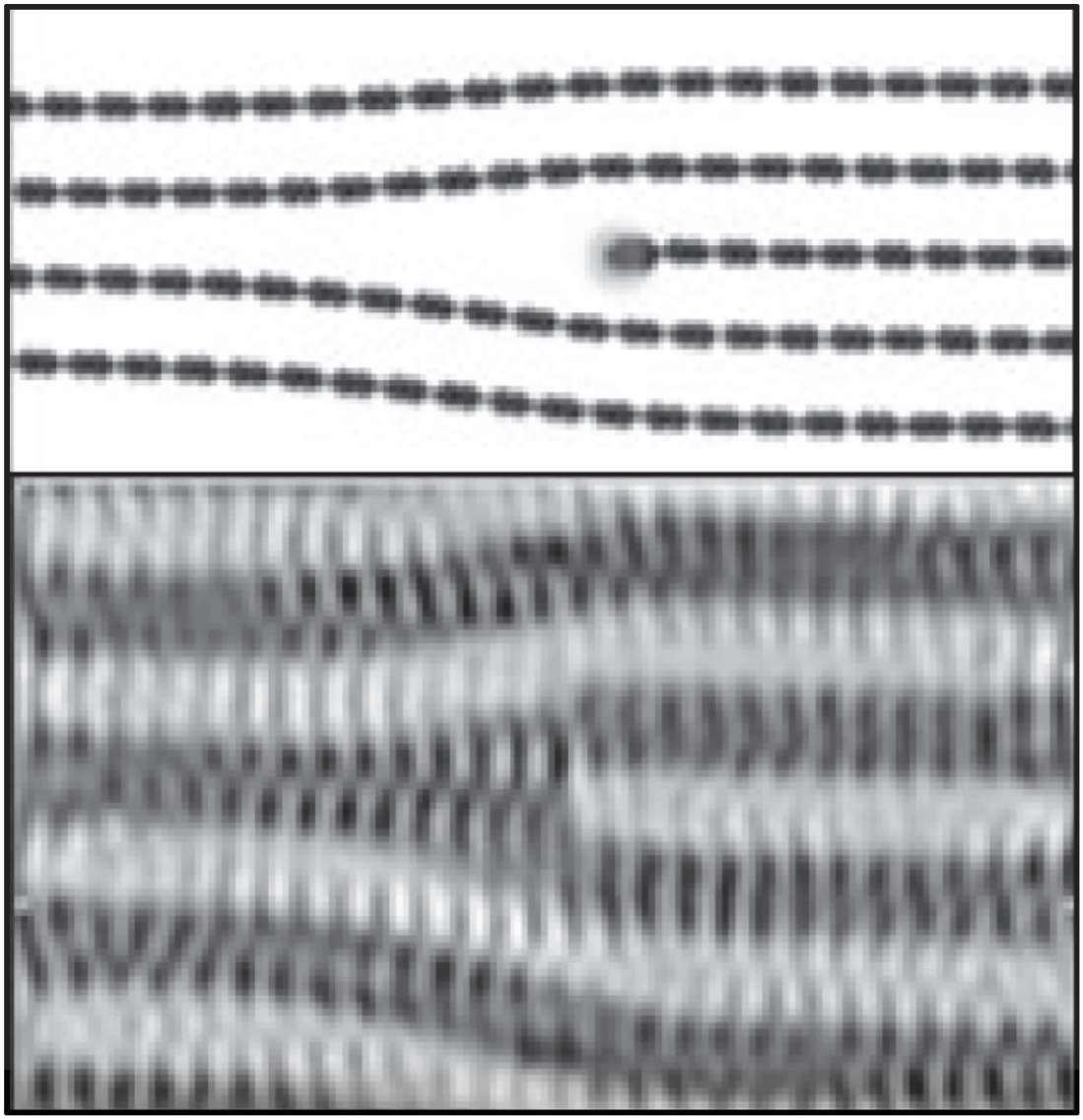


FIG. 12A

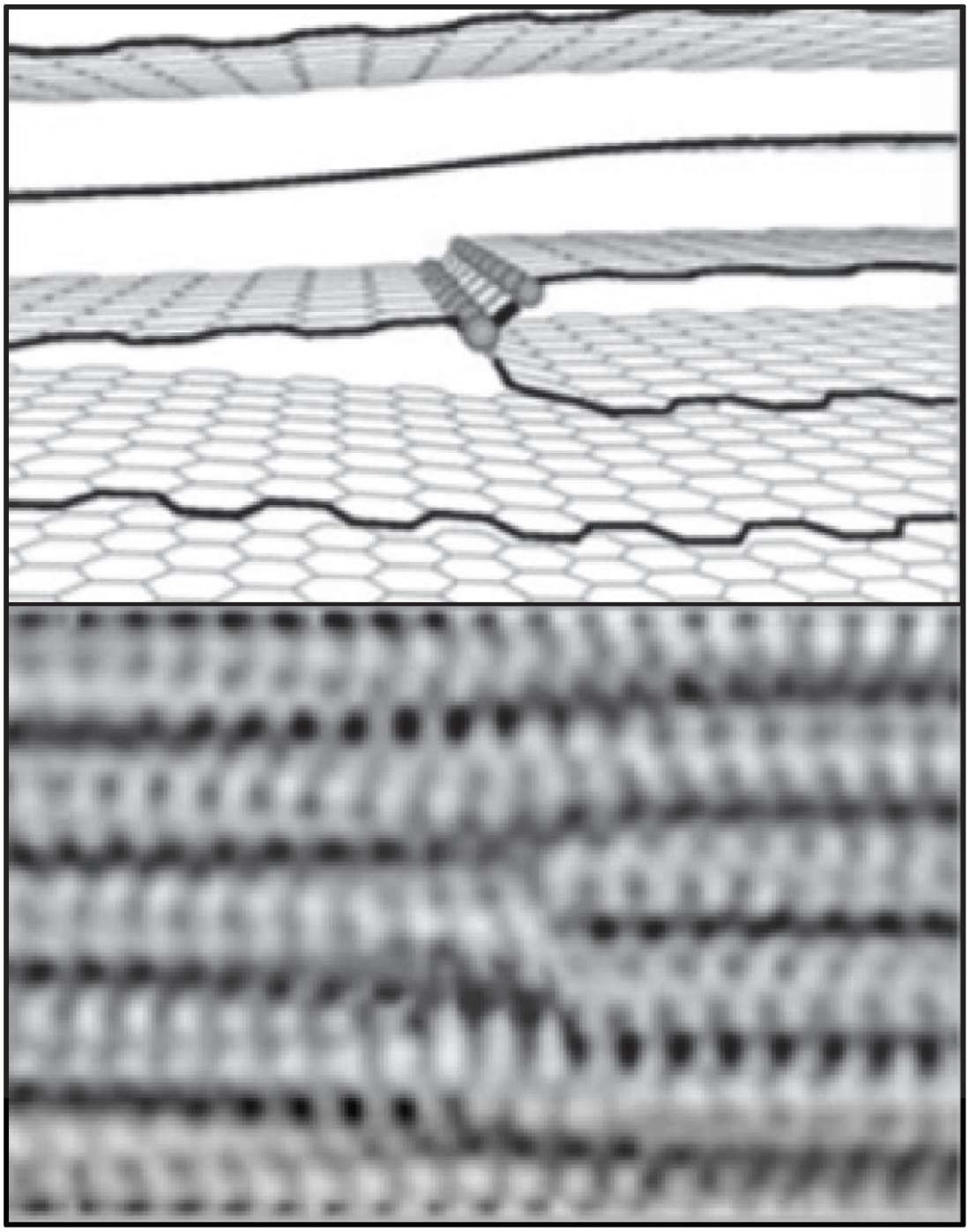


FIG. 12B

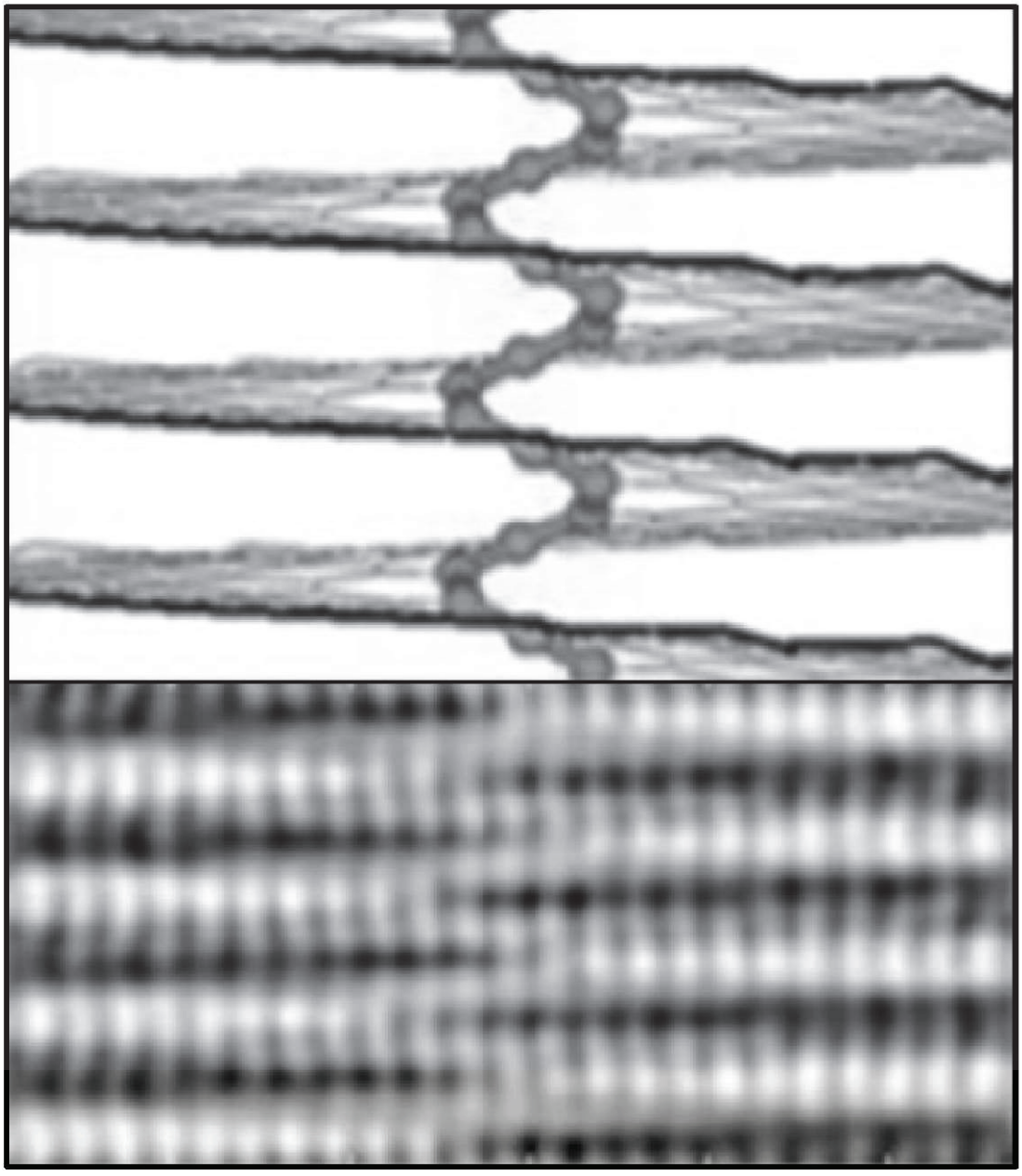


FIG. 12C

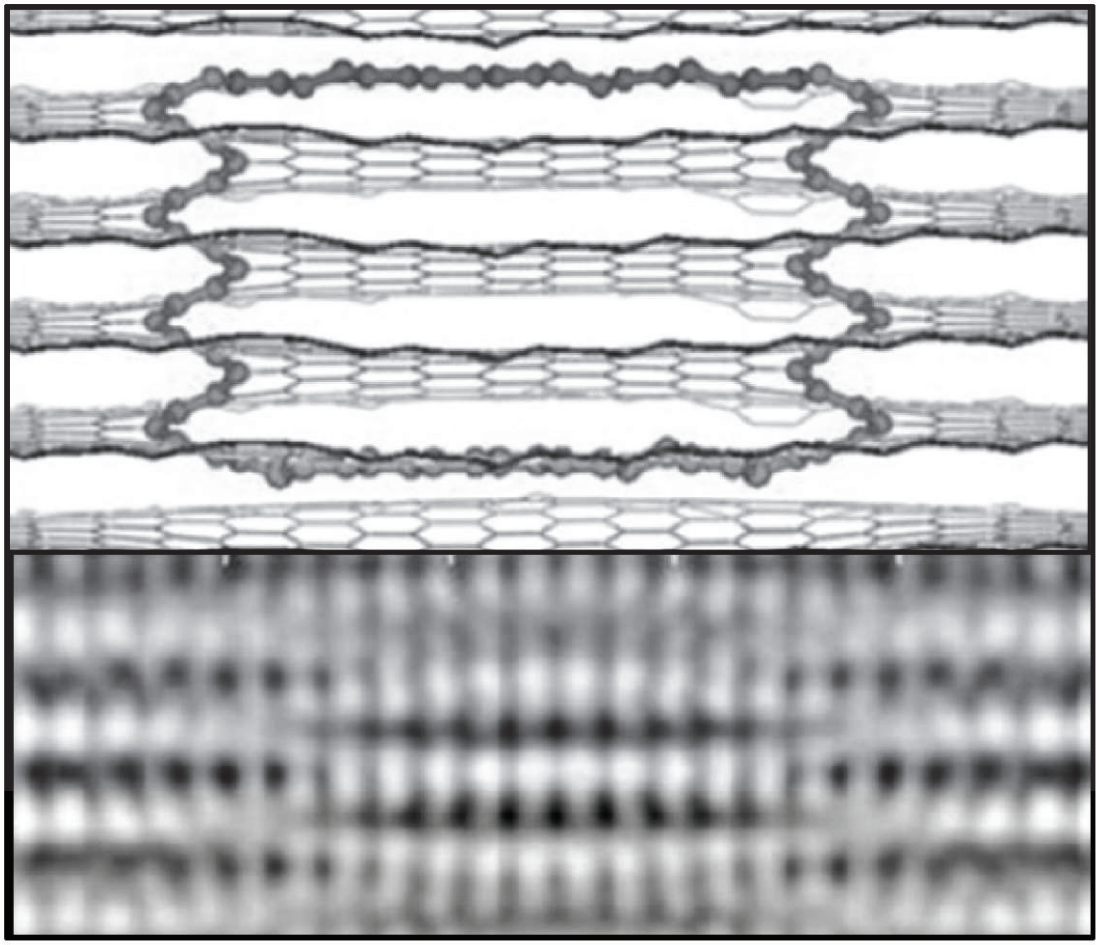


FIG. 12D

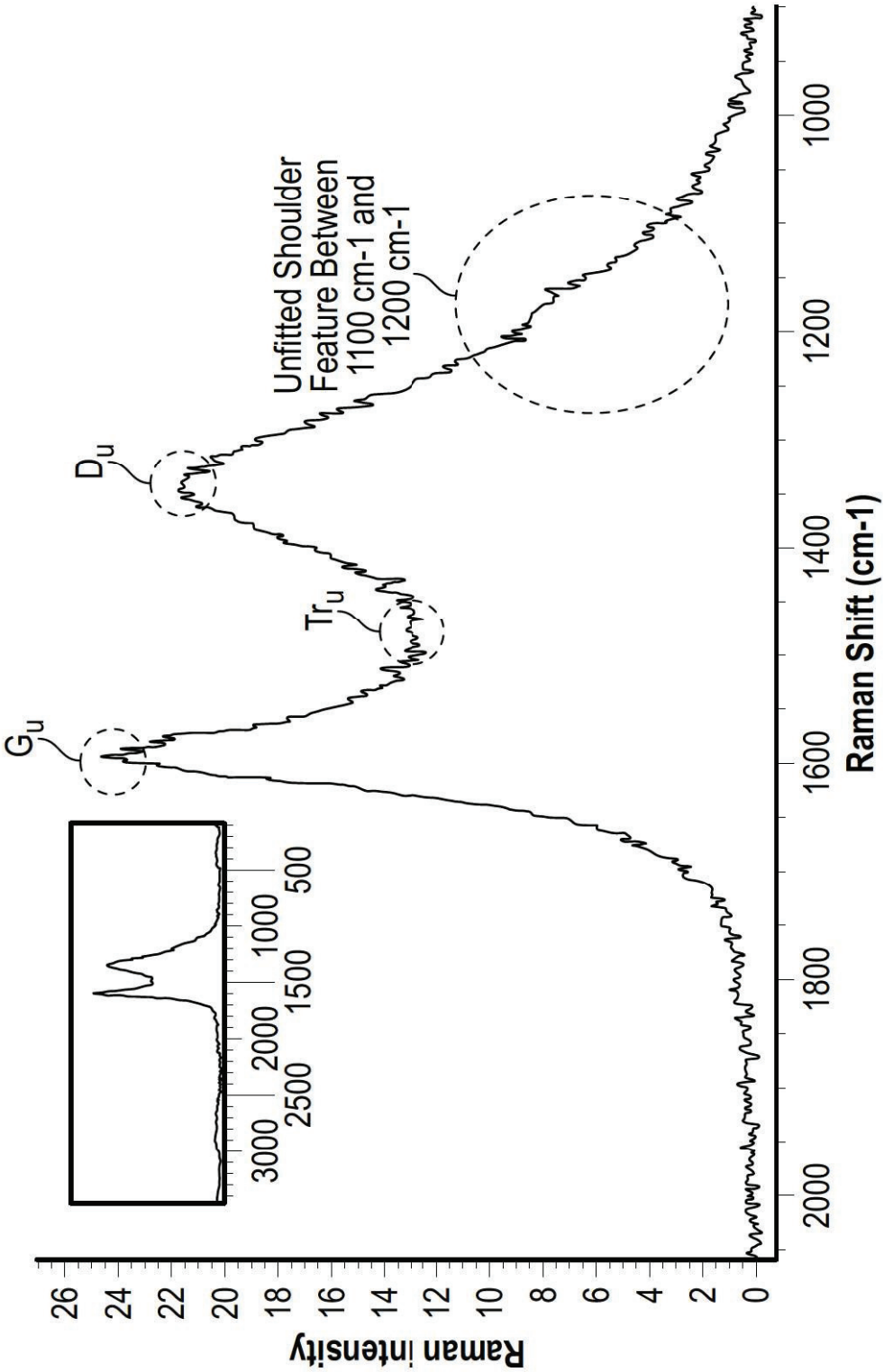
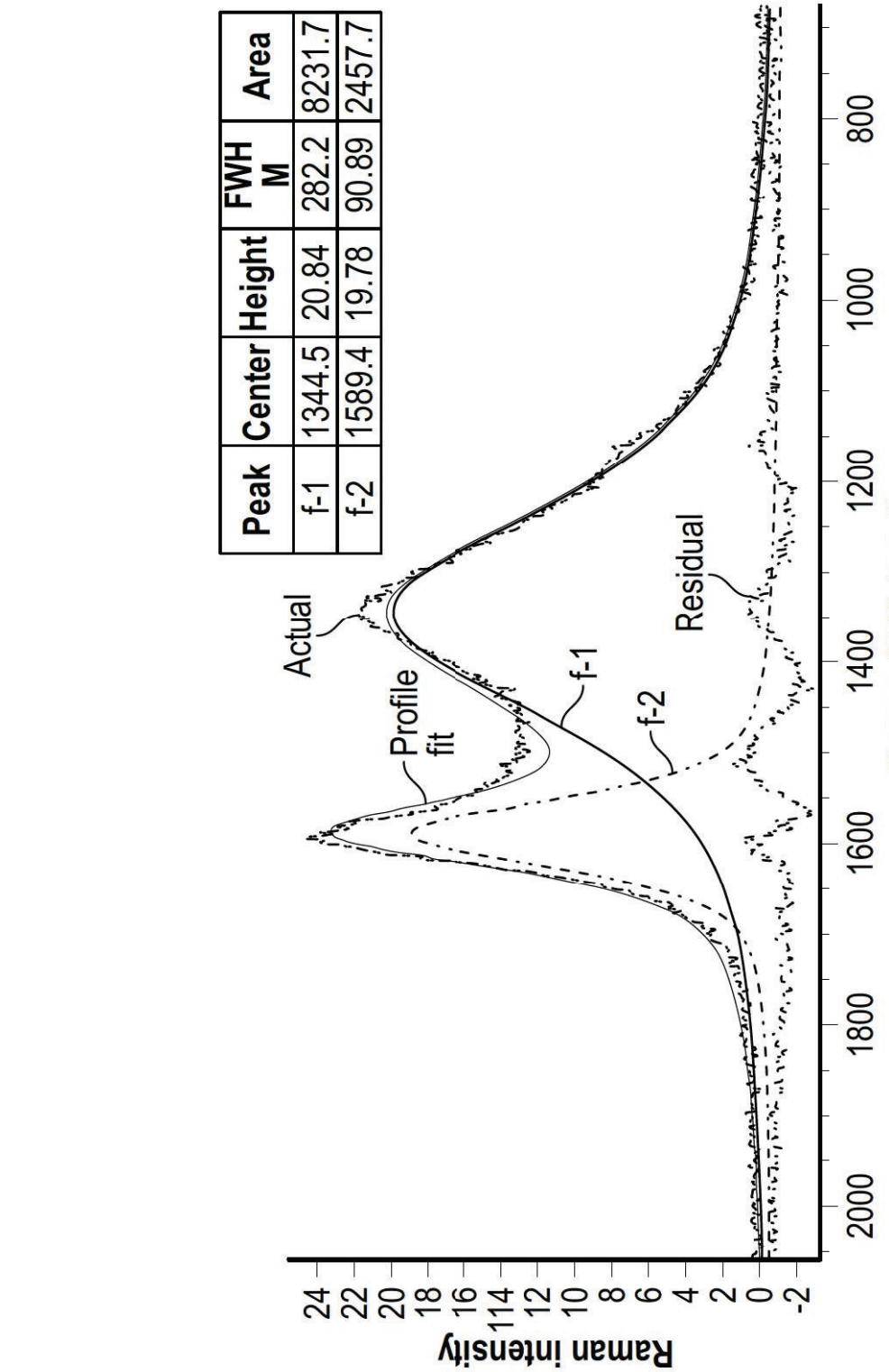

Raman intensity
0
2
4
6
8
10
12
14
16
18
20
22
24
26
2000
1800
1600
1400
1200
1000
Raman Shift (cm-1)
G_u
Tr_u
D_u
Unfitted Shoulder Feature Between 1100 cm-1 and 1200 cm-1
3000
2500
2000
1500
1000
500

FIG. 13



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

FIG. 14

Peak #	Center	Height	FWHM	Area
f-1	1339.8	21.78	252..5	8397.8
f-2	1566.5	9.047	146.9	1415.1
f-3	1596.8	12.57	57.89	927.91

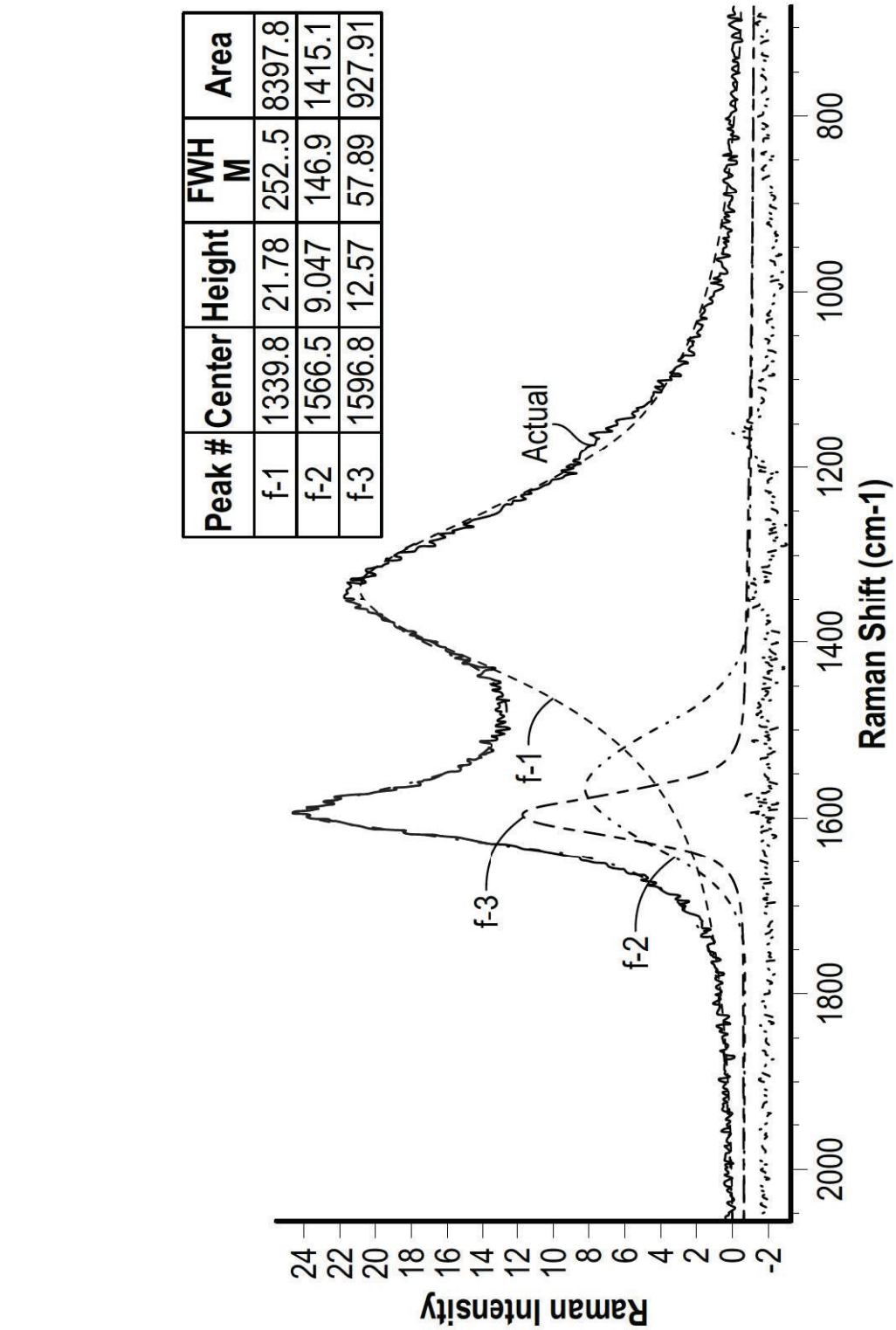


FIG. 15

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	8.99	153.8	.889	1548
f-4	1596	19.51	77.1	.118	2266

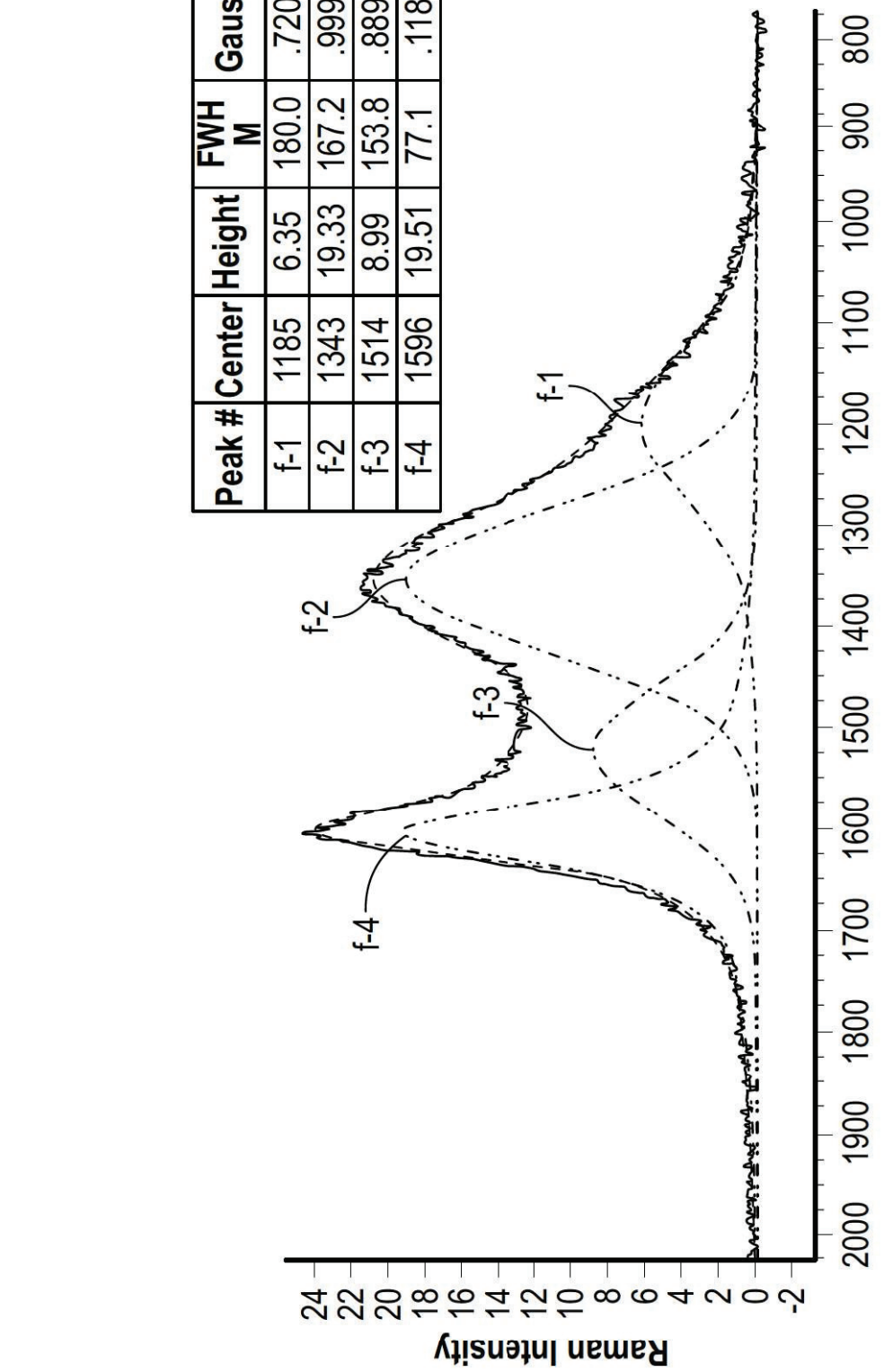


FIG. 16

Peak #	Center	Height	FWHM	Gauss	Area
f-1	1180	1.29	167.1	.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

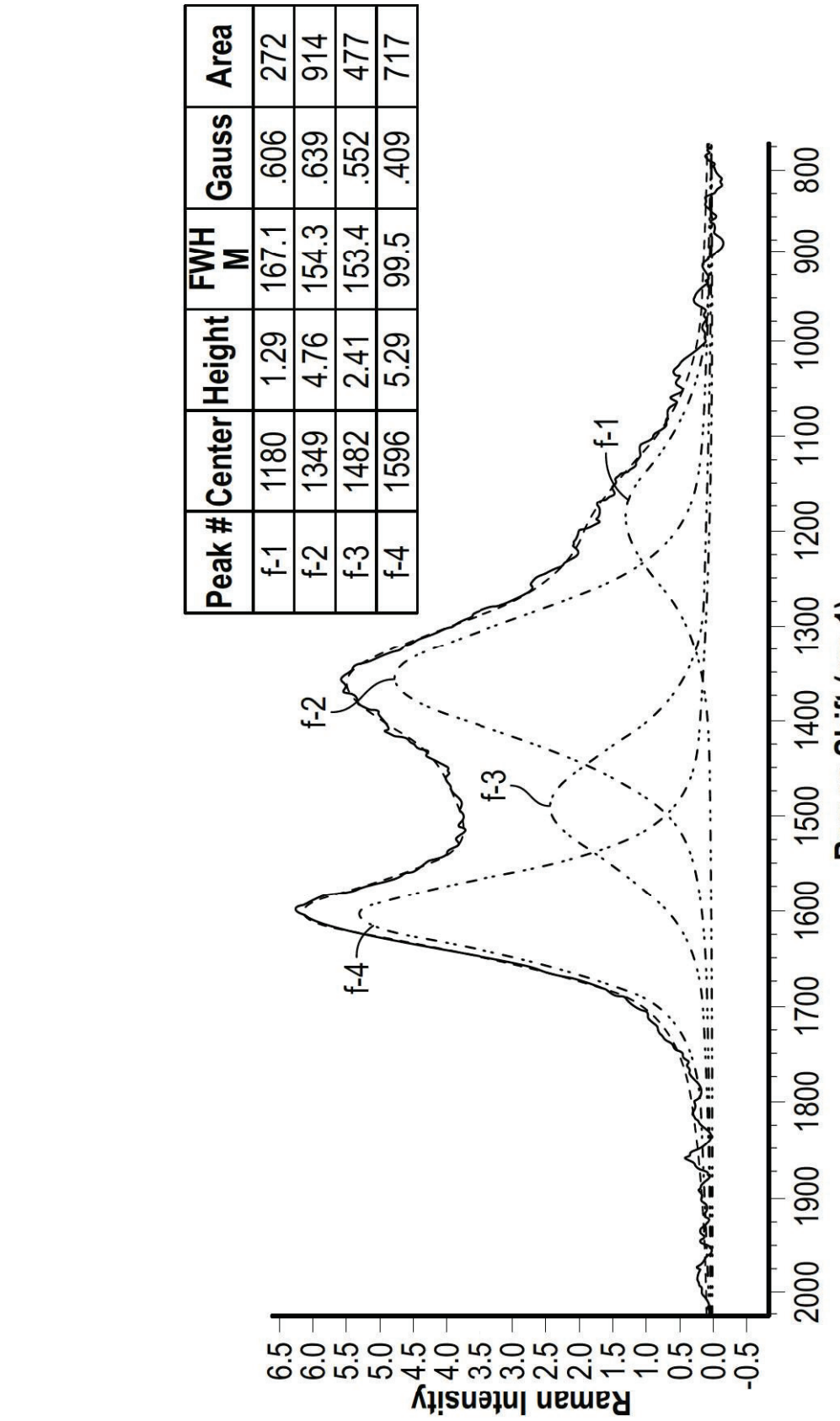


FIG. 17

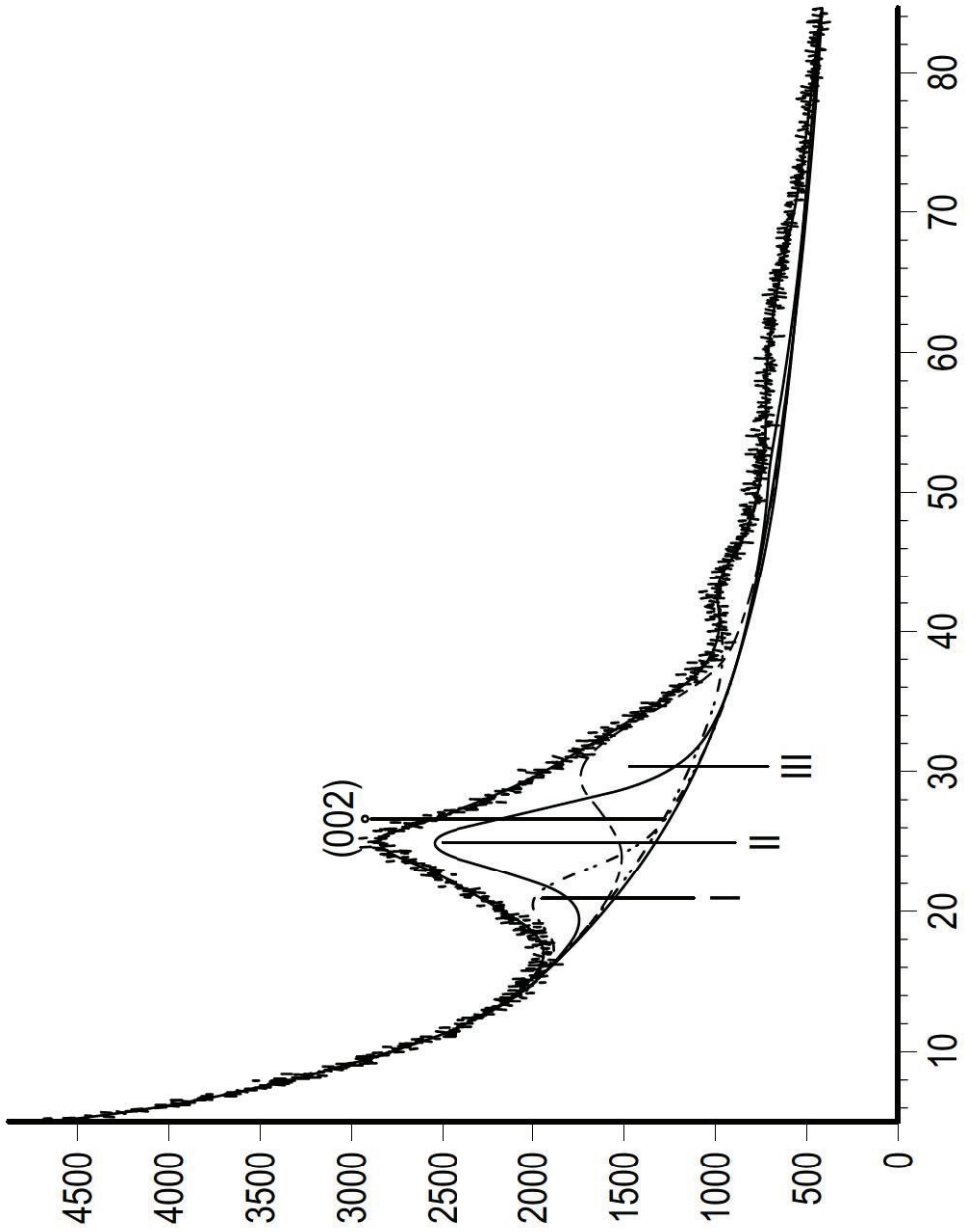

4500
4000
3500
3000
2500
2000
1500
1000
500
0
10
20
30
40
50
60
70
80
(002)
I
II
III

FIG. 18

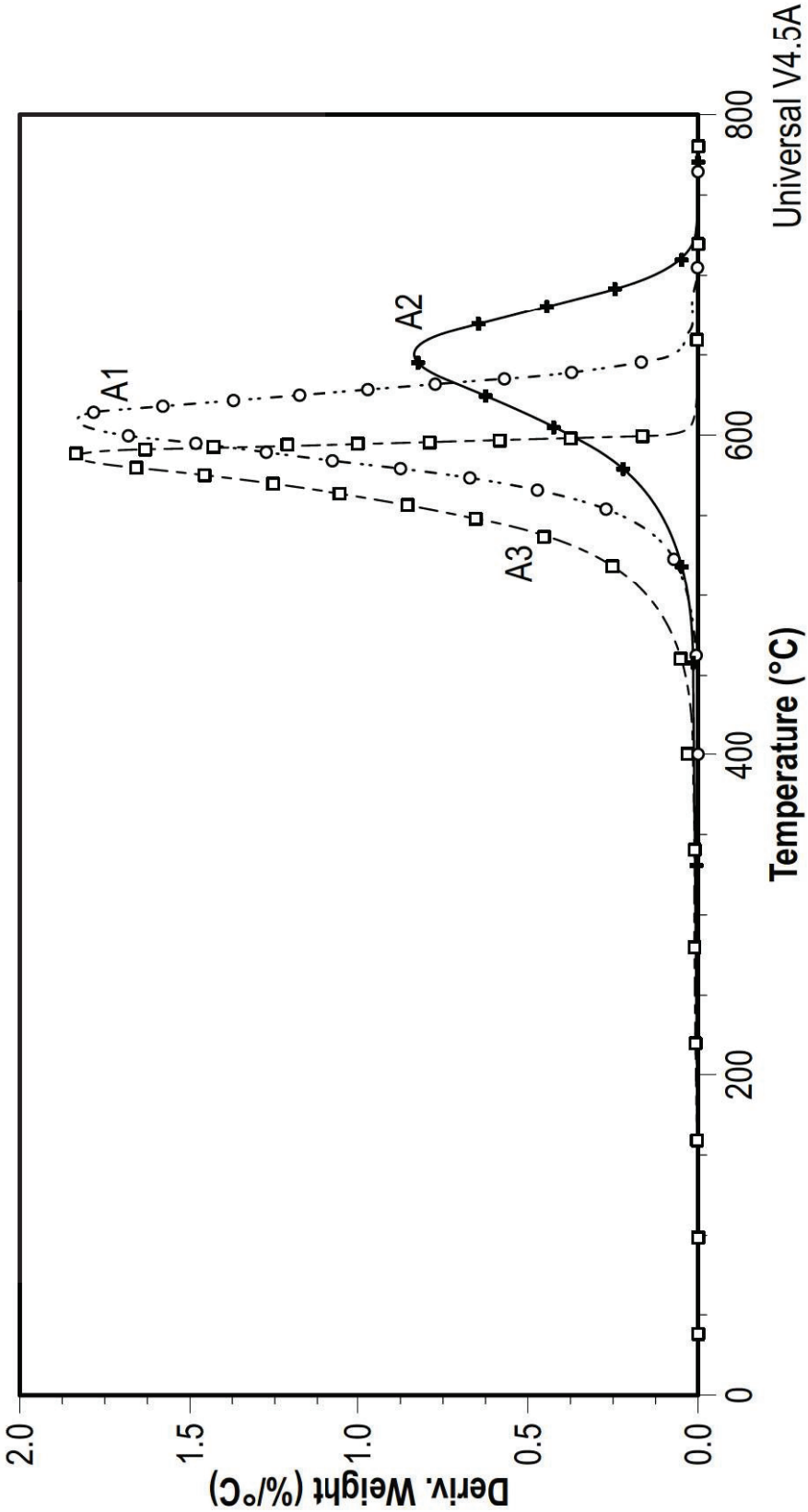

Deriv. Weight (%/°C)
2.0
1.5
1.0
0.5
0.0
0
200
400
600
800
Temperature (°C)
Universal V4.5A
A1
A2
A3

FIG. 19

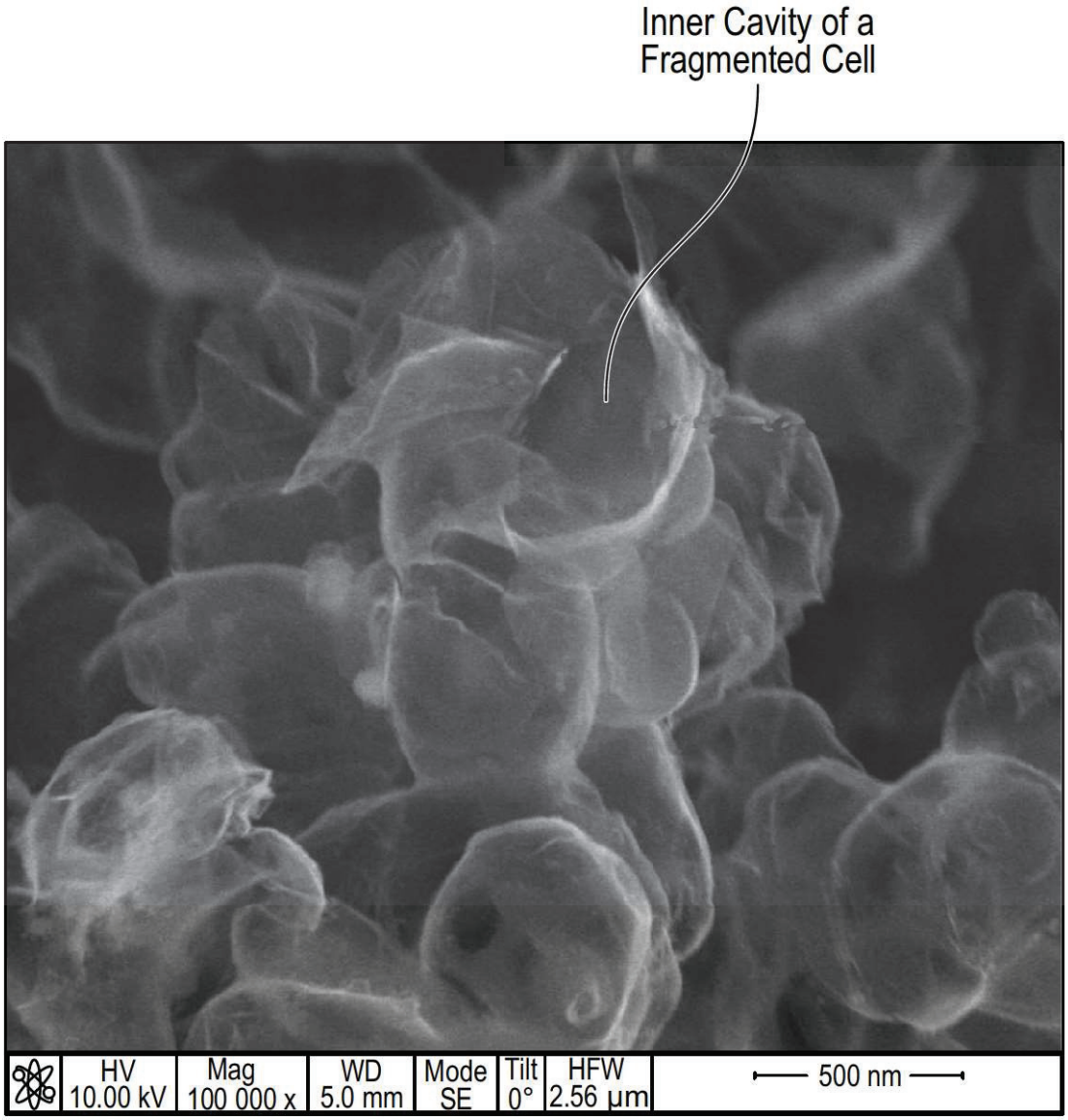

Inner Cavity of a
Fragmented Cell
HV
10.00 kV
Mag
100 000 x
WD
5.0 mm
Mode
SE
Tilt
0°
HFW
2.56 µm
500 nm

FIG. 20

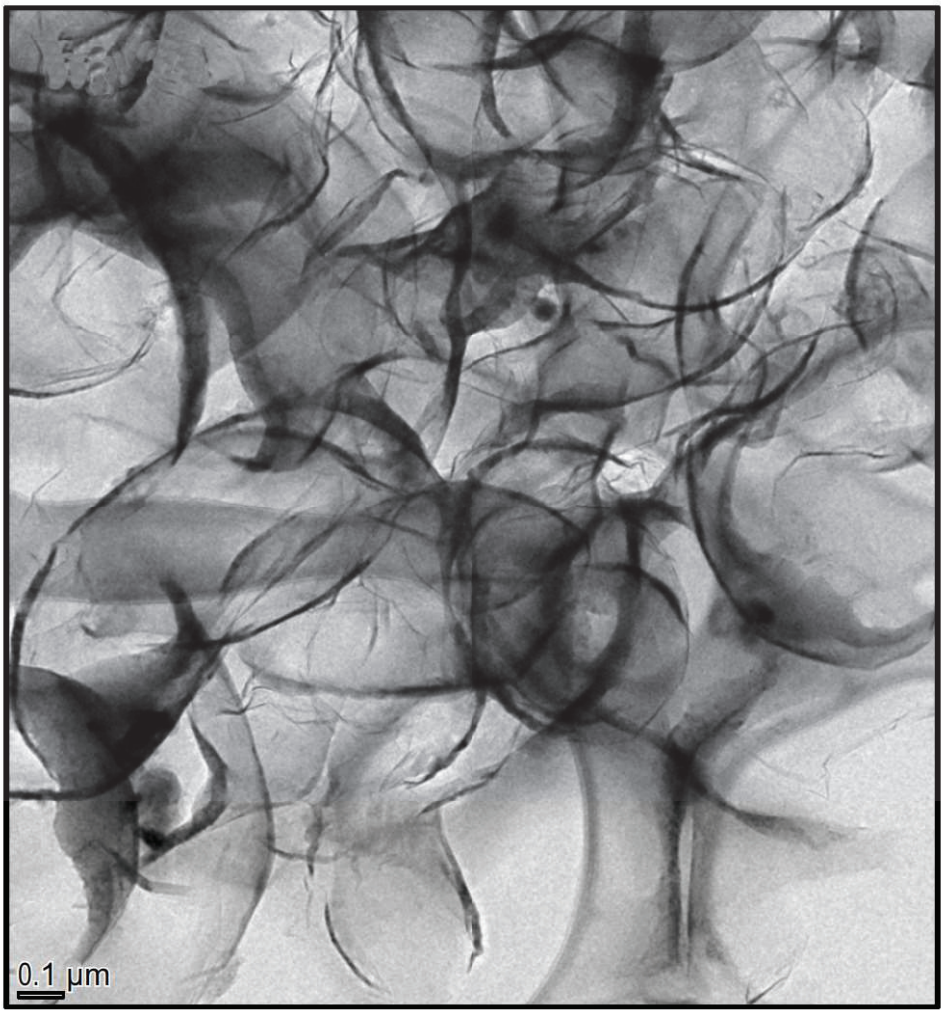


FIG. 21A



FIG. 21B

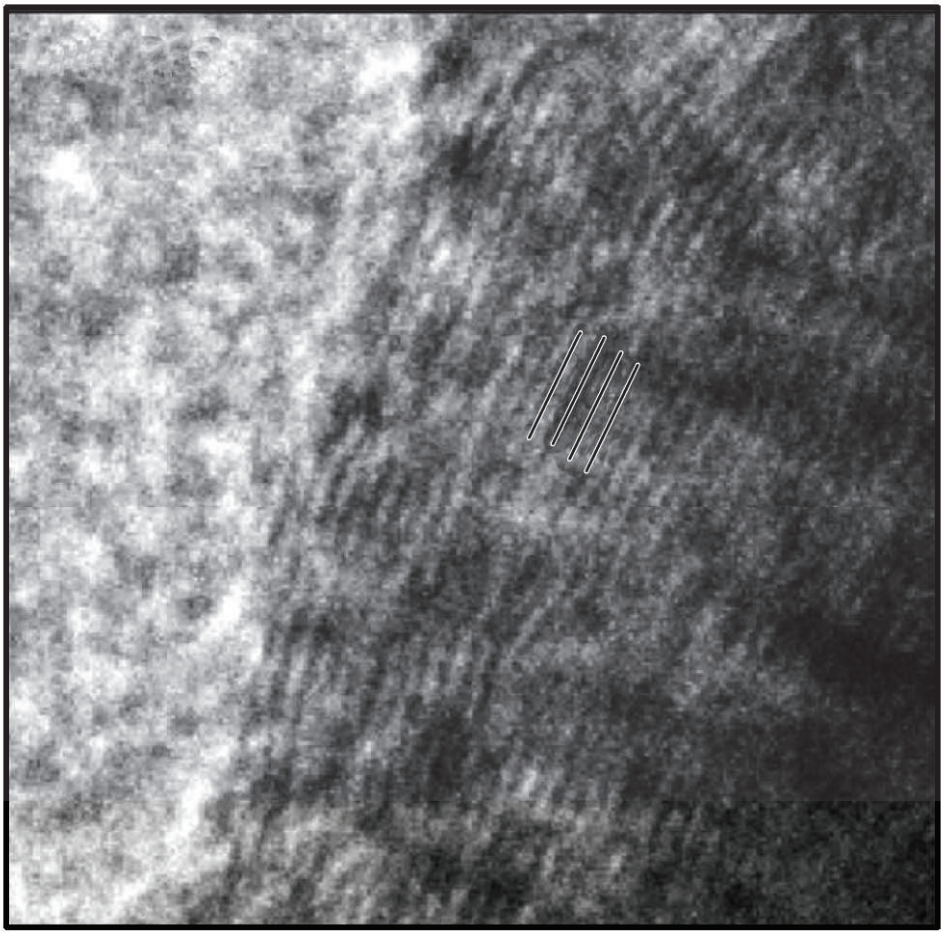


FIG. 21C

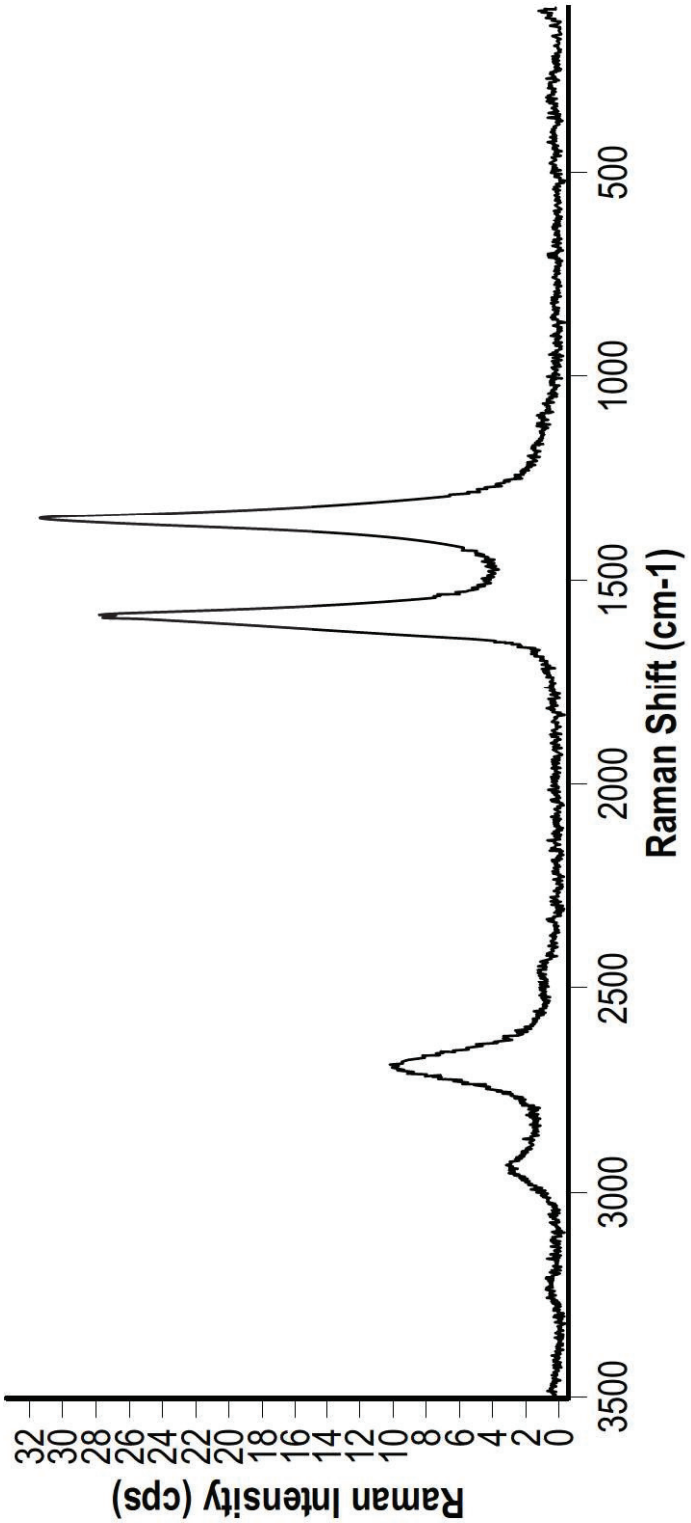

Raman Intensity (cps)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
3500
3000
2500
2000
1500
1000
500
Raman Shift (cm-1)

FIG. 22

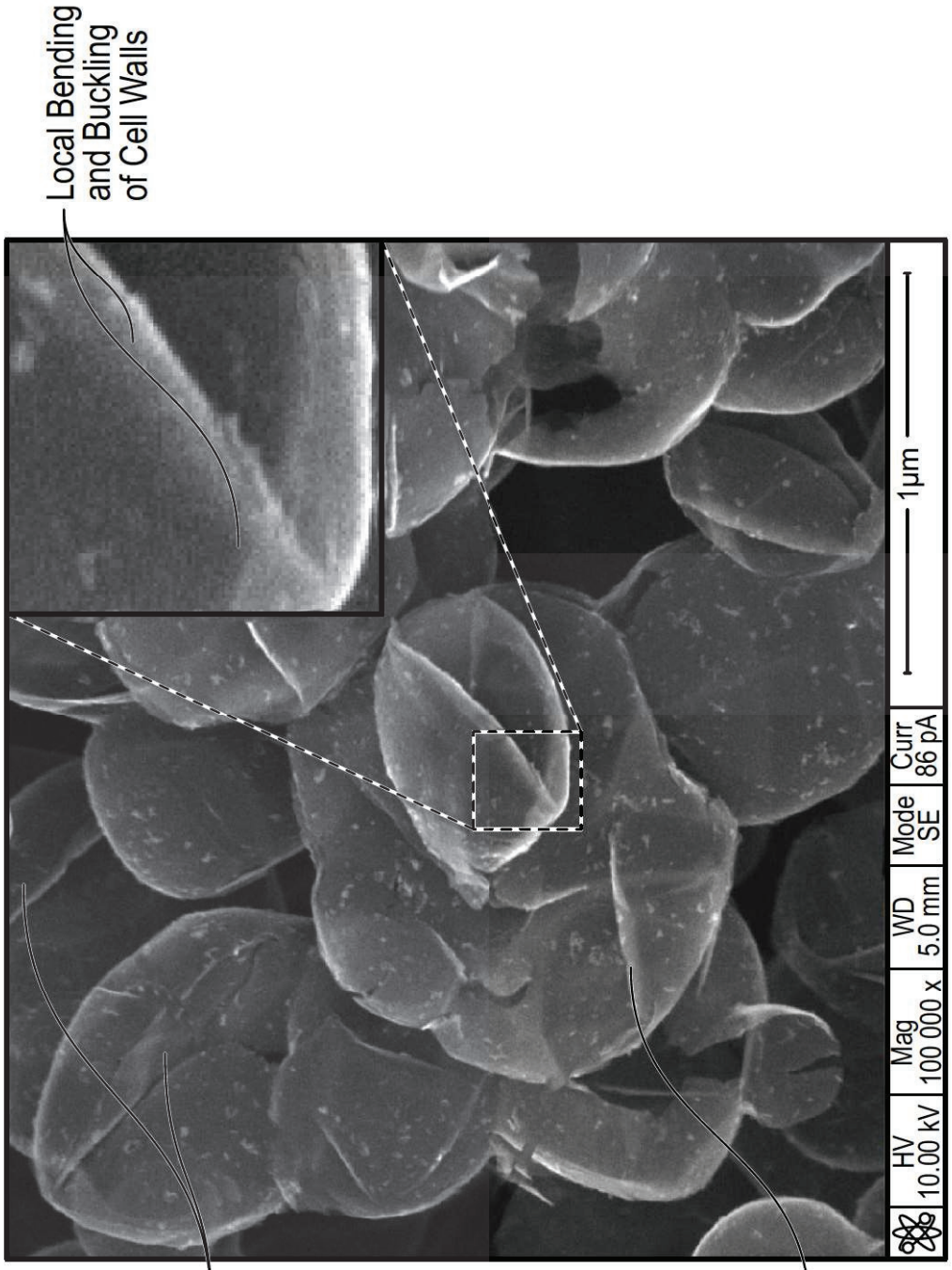

Local Bending and Buckling of Cell Walls
Recurring Linear Features Observed Post-Compression
Recurring Linear Features Observed Post-Compression
HV 10.00 kV
Mag 100 000 x
WD 5.0 mm
Mode SE
Curr 86 pA
1µm

FIG. 23

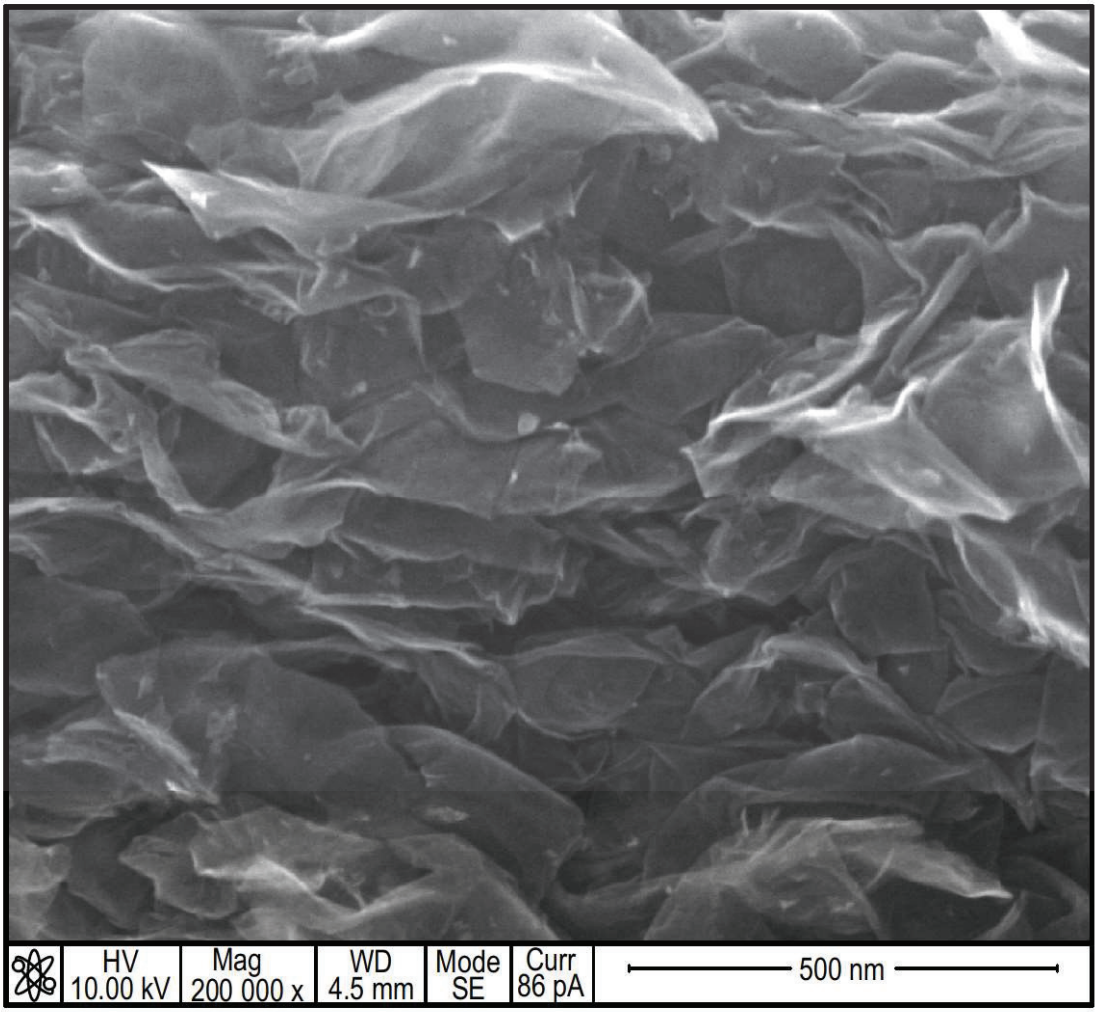


FIG. 24

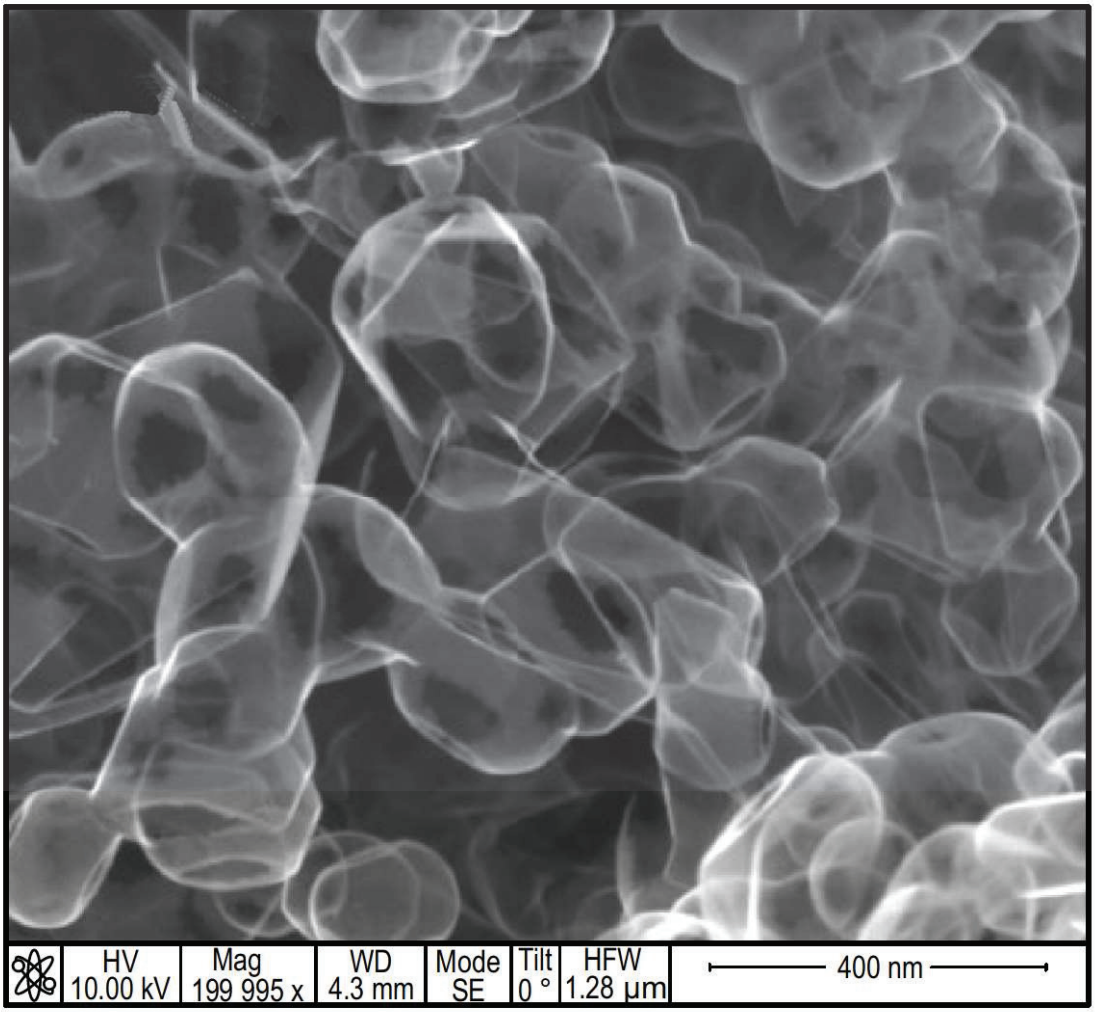


FIG. 25A

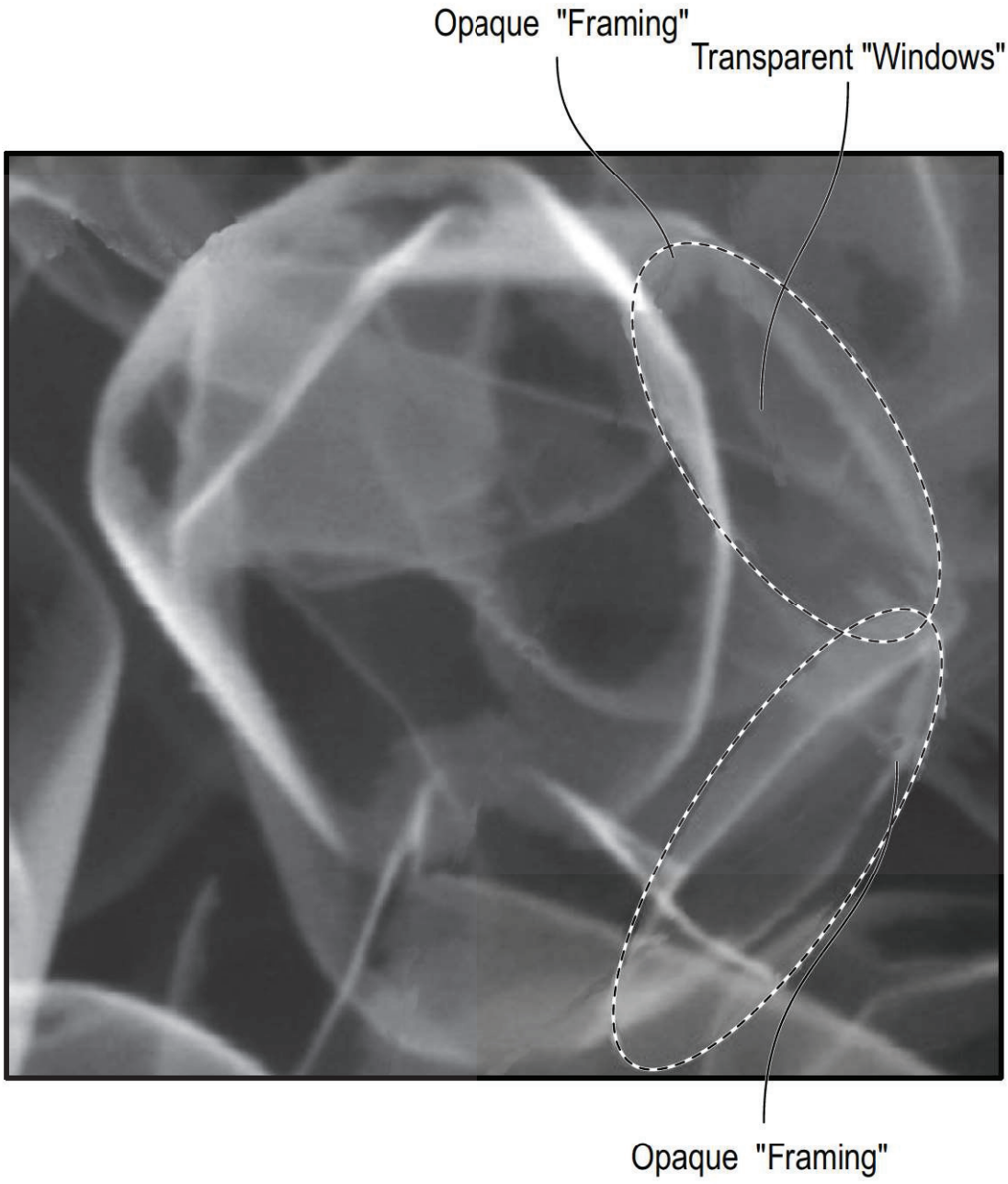


FIG. 25B

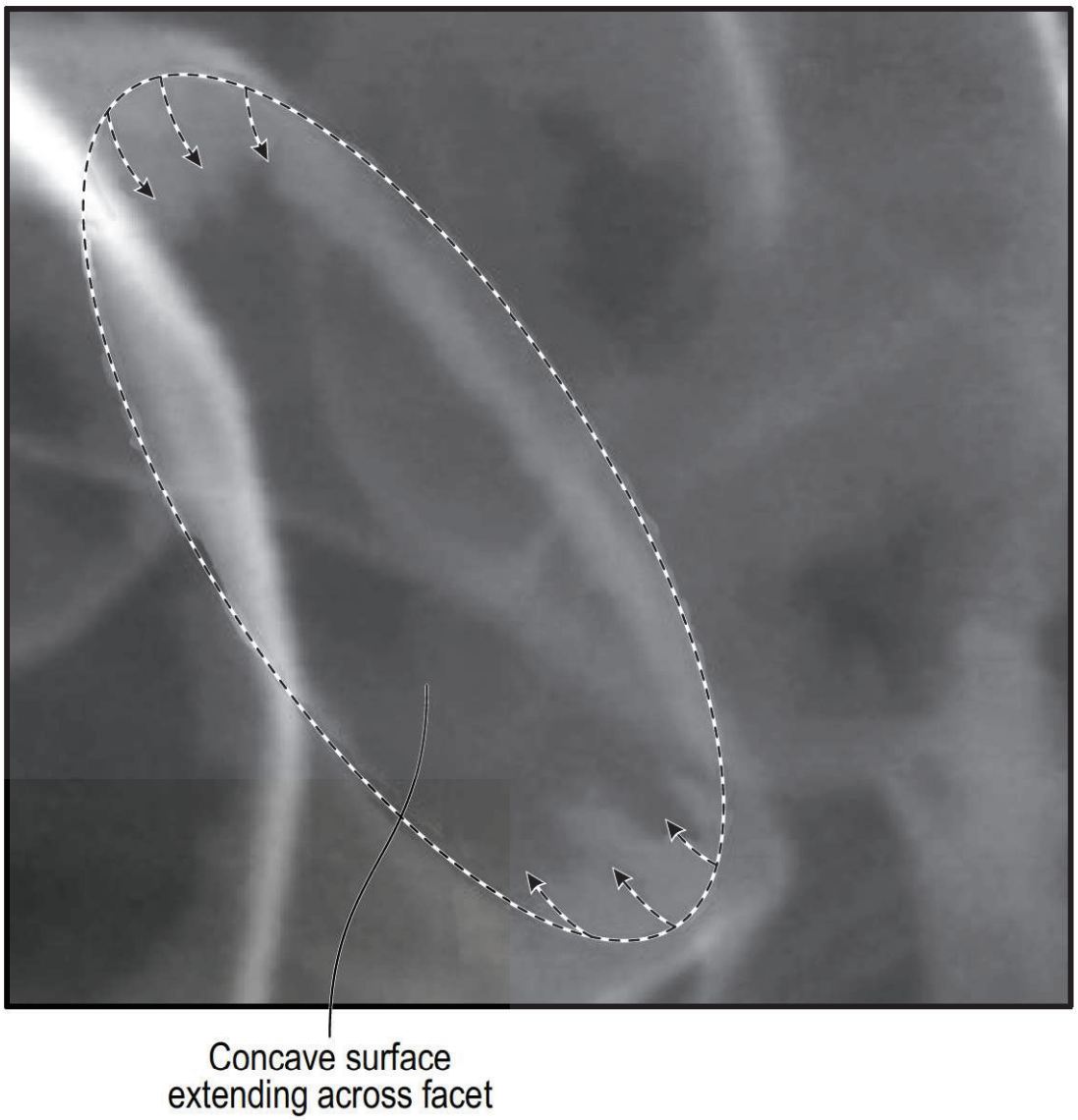


FIG. 25C

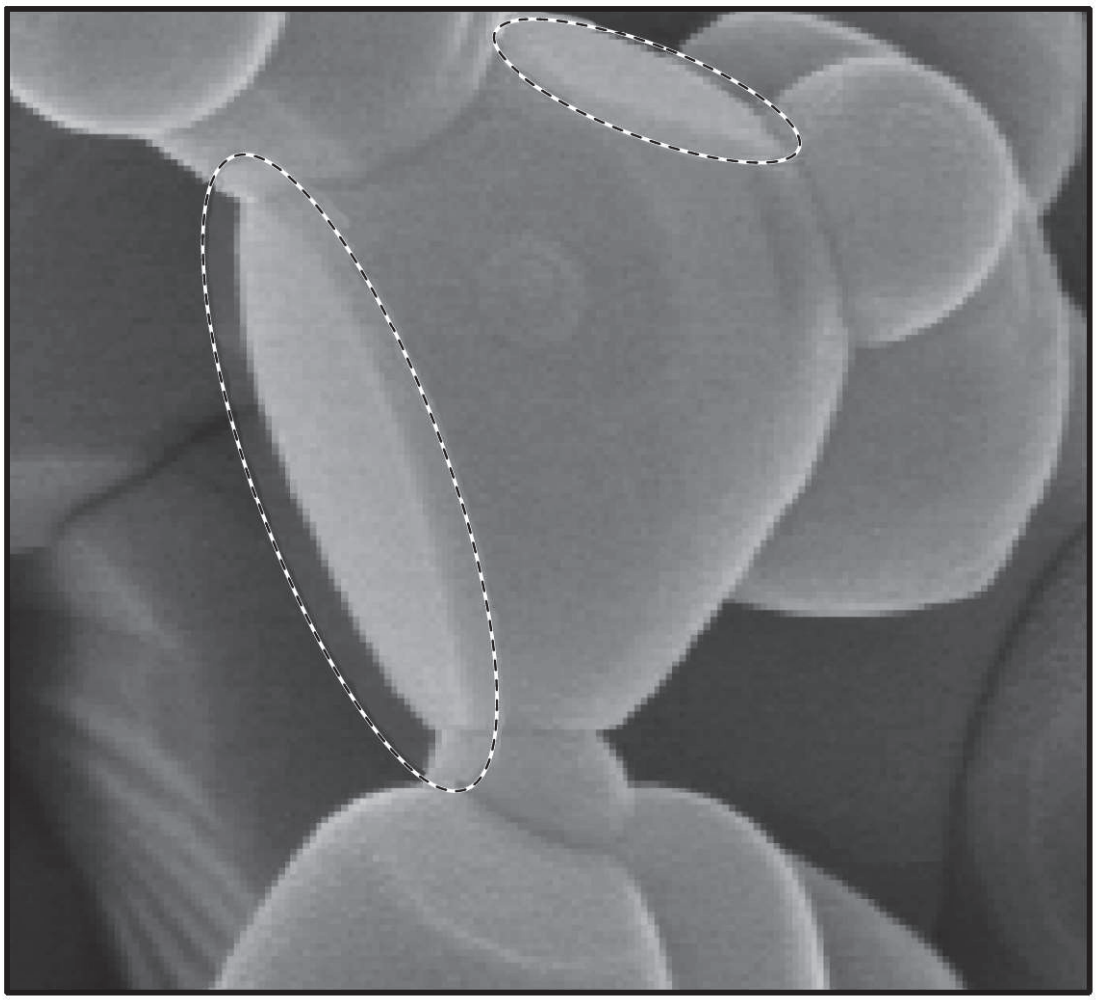


FIG. 26

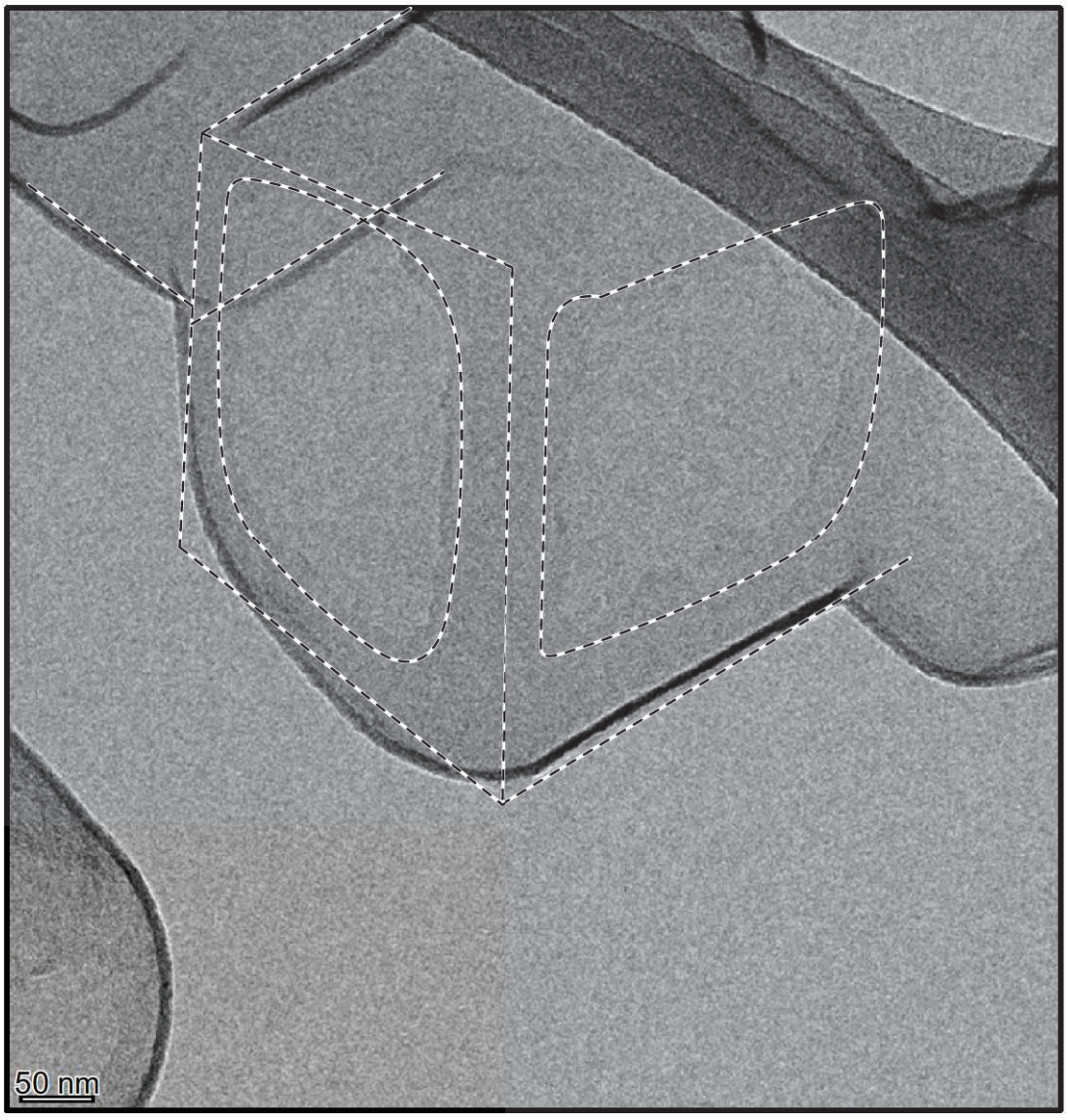


FIG. 27A

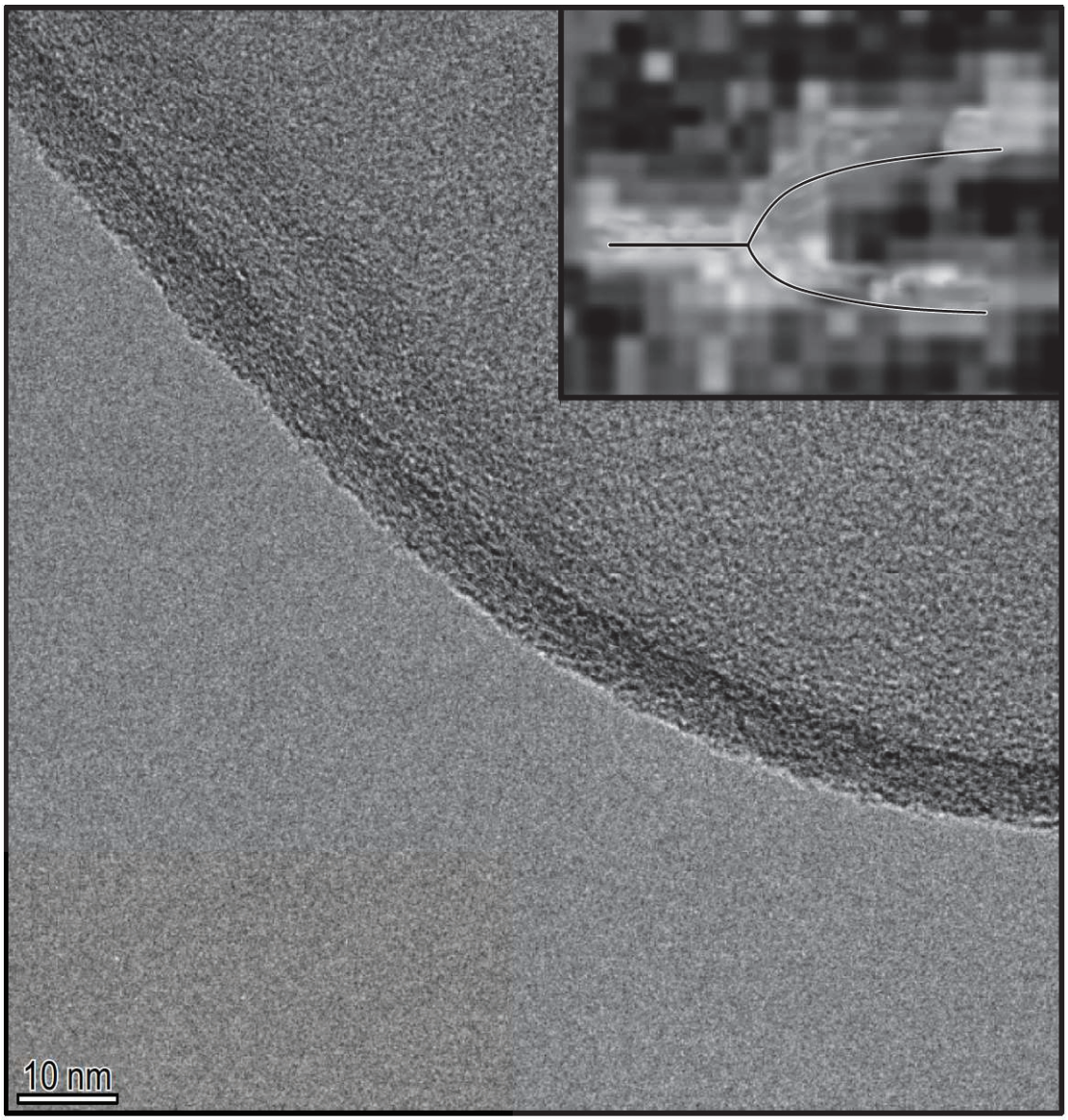


FIG. 27B

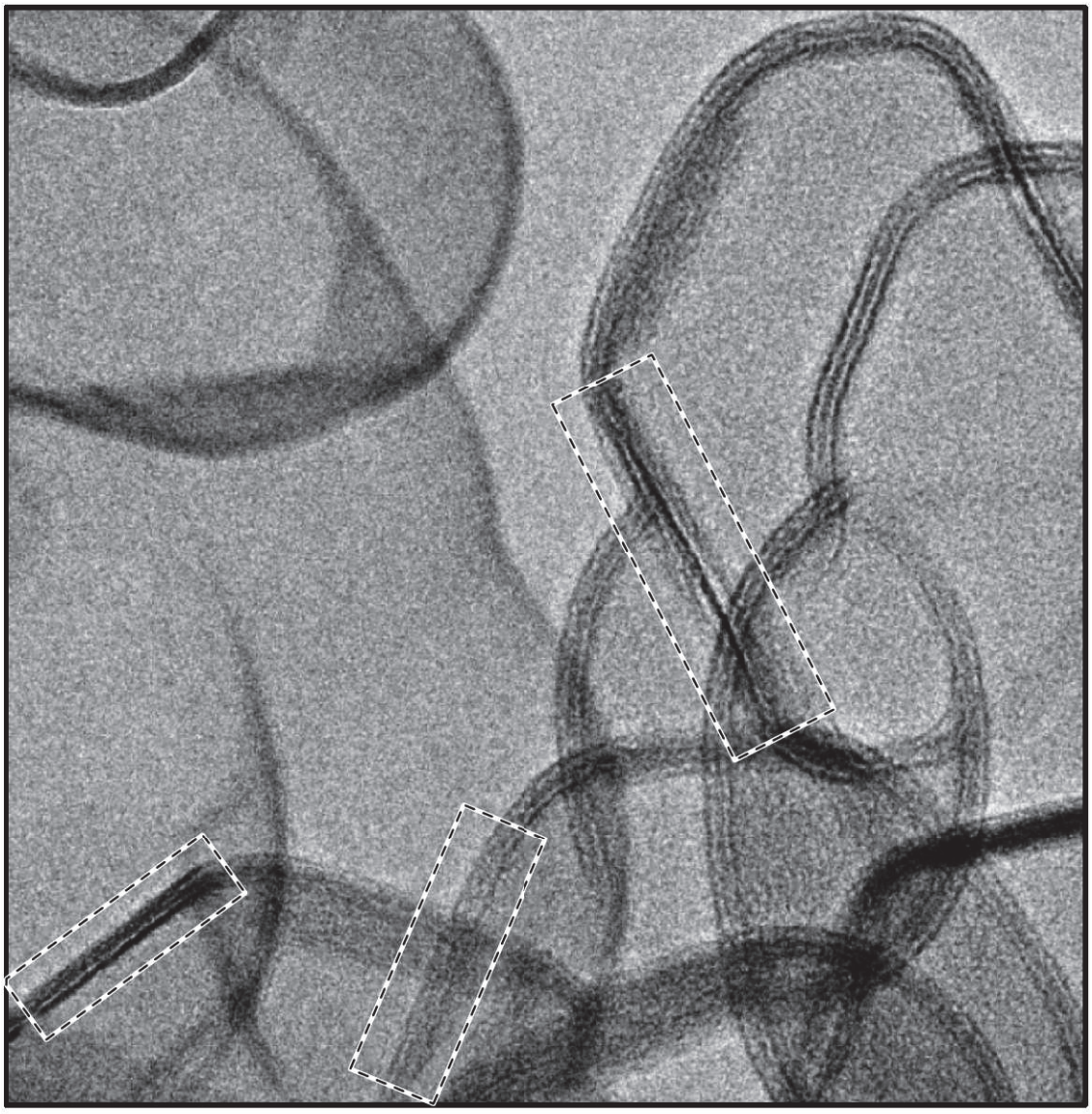


FIG. 27C

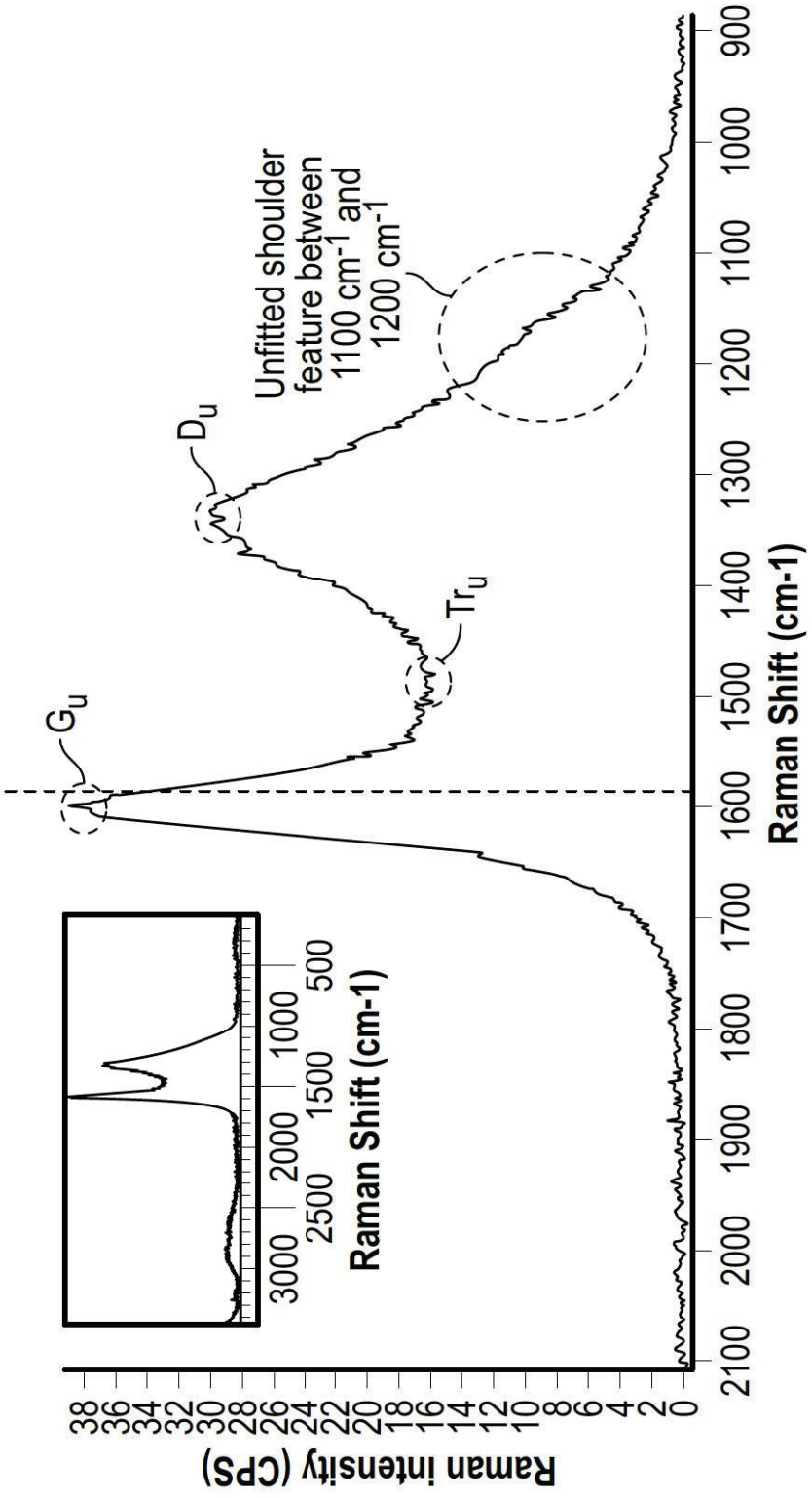

Raman intensity (CPS)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Raman Shift (cm-1)
G_u
Tr_u
D_u
Unfitted shoulder feature between 1100 cm^{-1} and 1200 cm^{-1}
3000
2500
2000
1500
1000
500
Raman Shift (cm-1)

FIG. 28

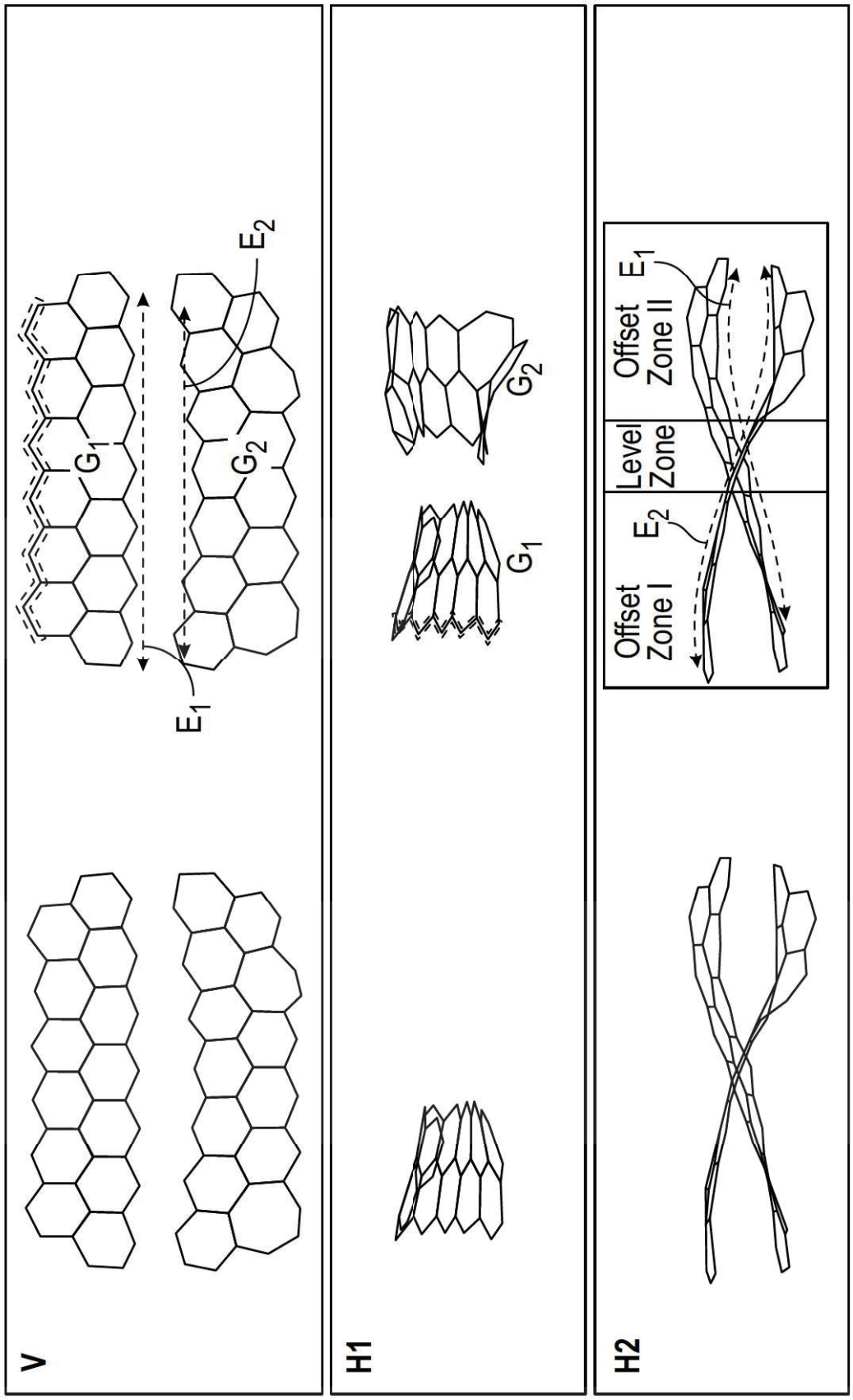


FIG. 29

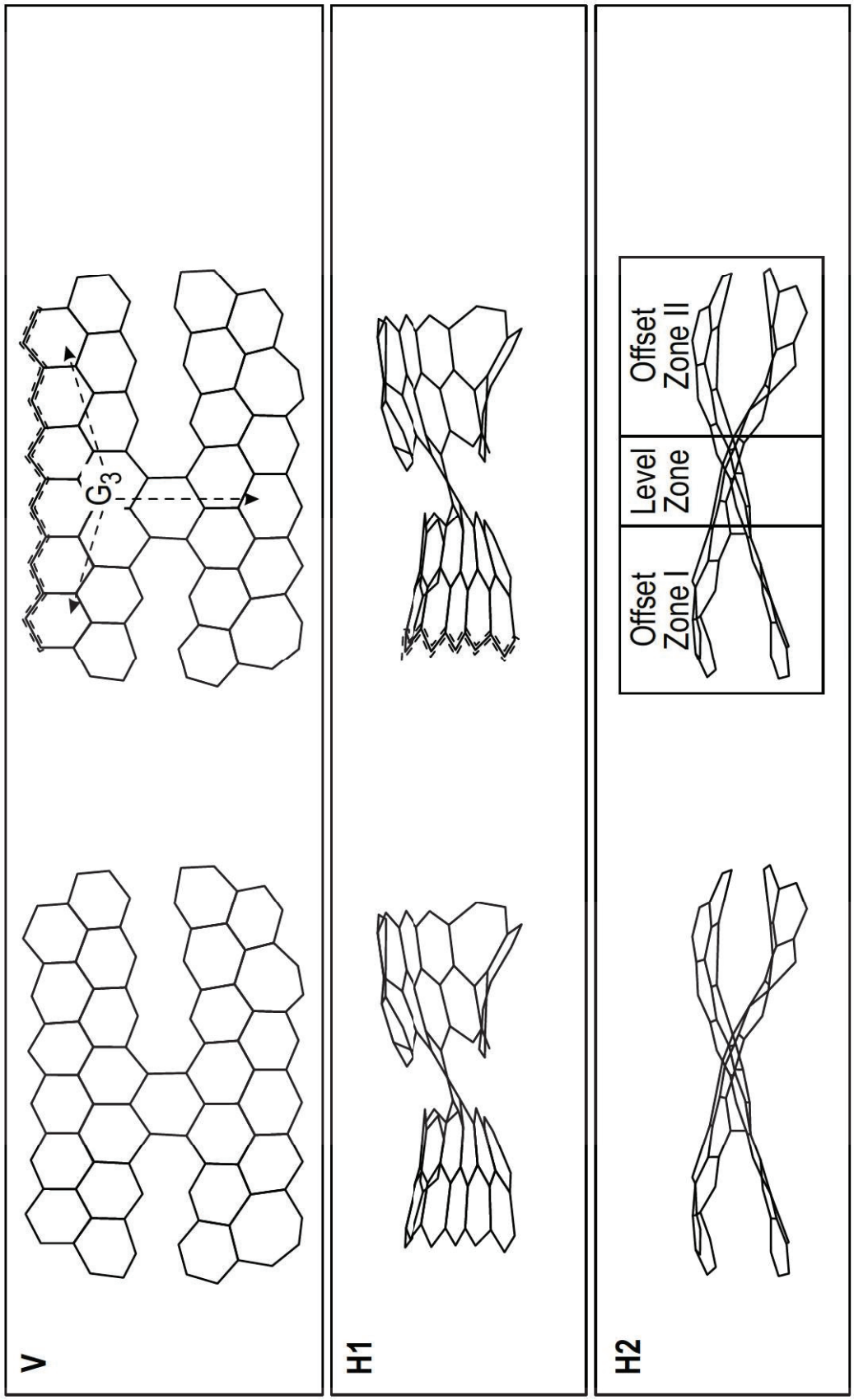


FIG. 30

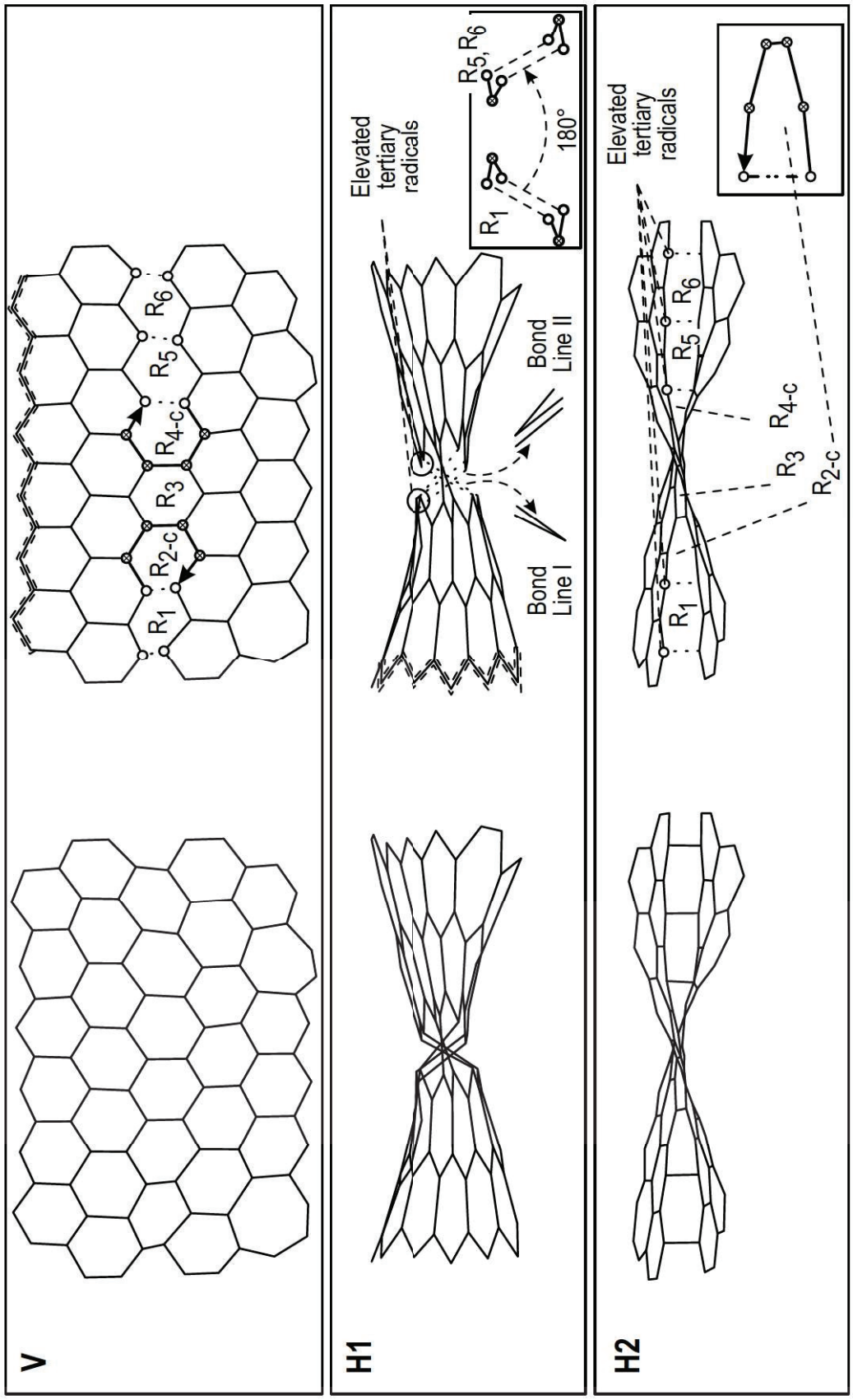

V
H1
H2
R1
R2-c
R3
R4-c
R5
R6
Elevated tertiary radicals
Bond Line I
Bond Line II
180°

FIG. 31

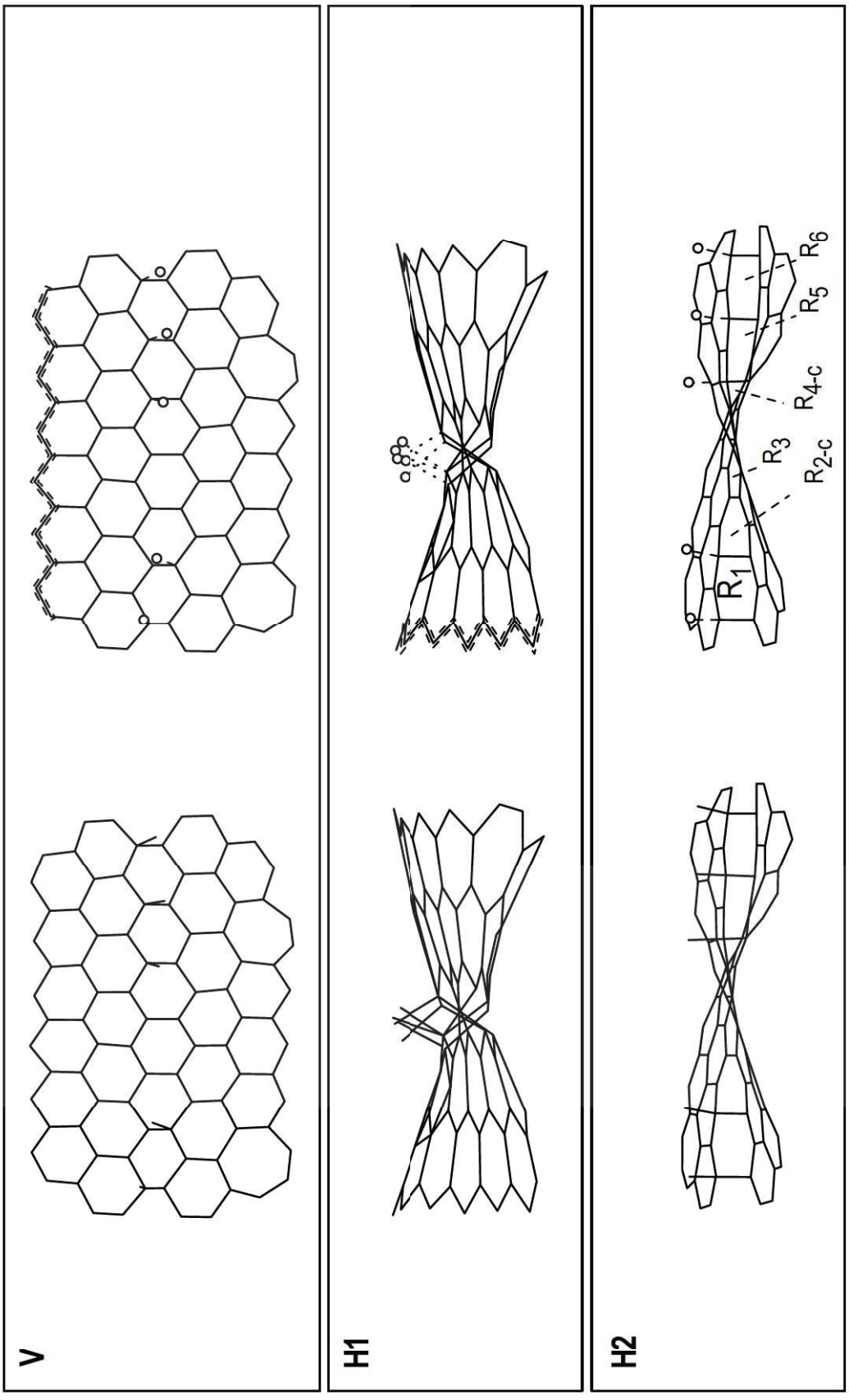


FIG. 32

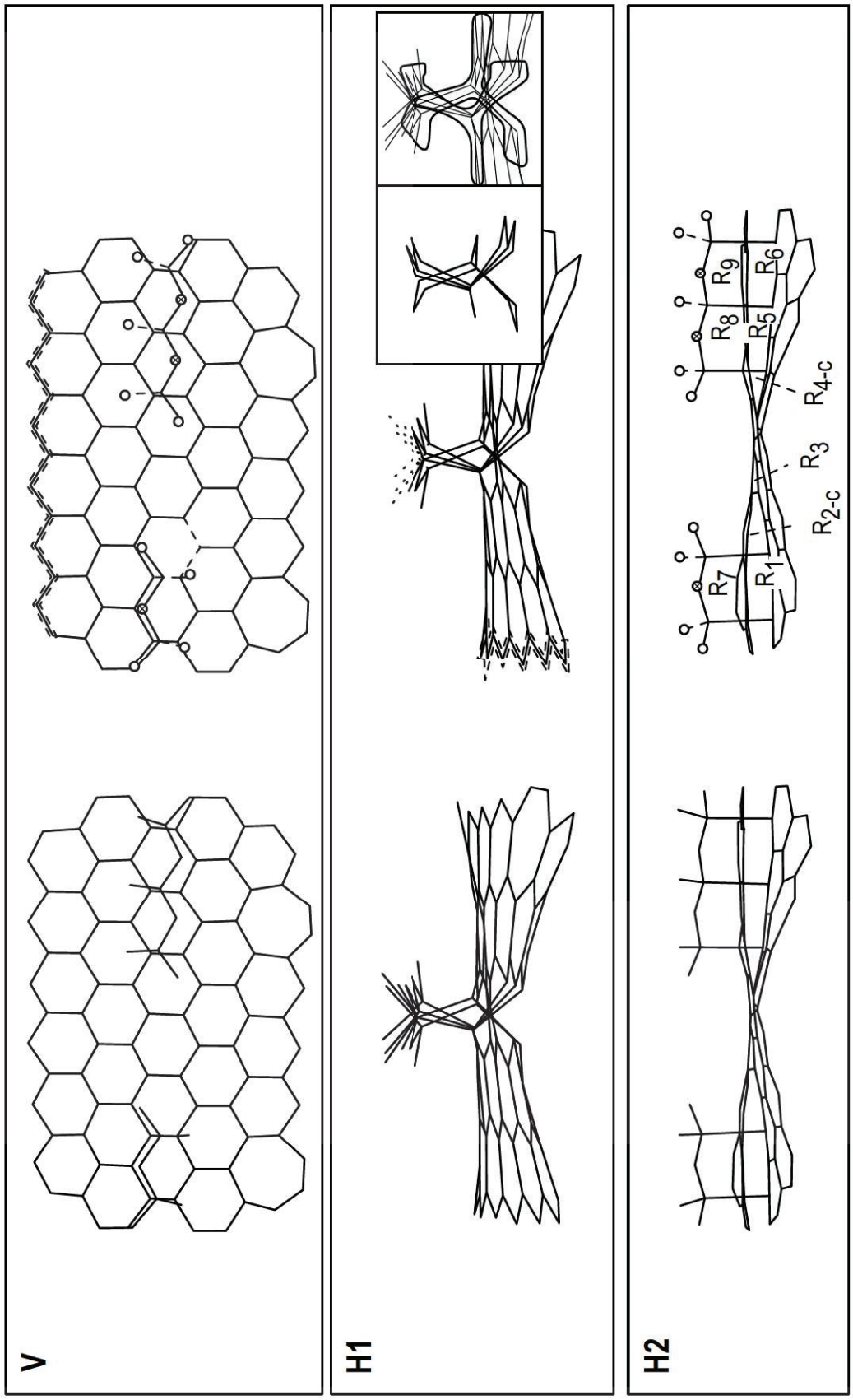


FIG. 33

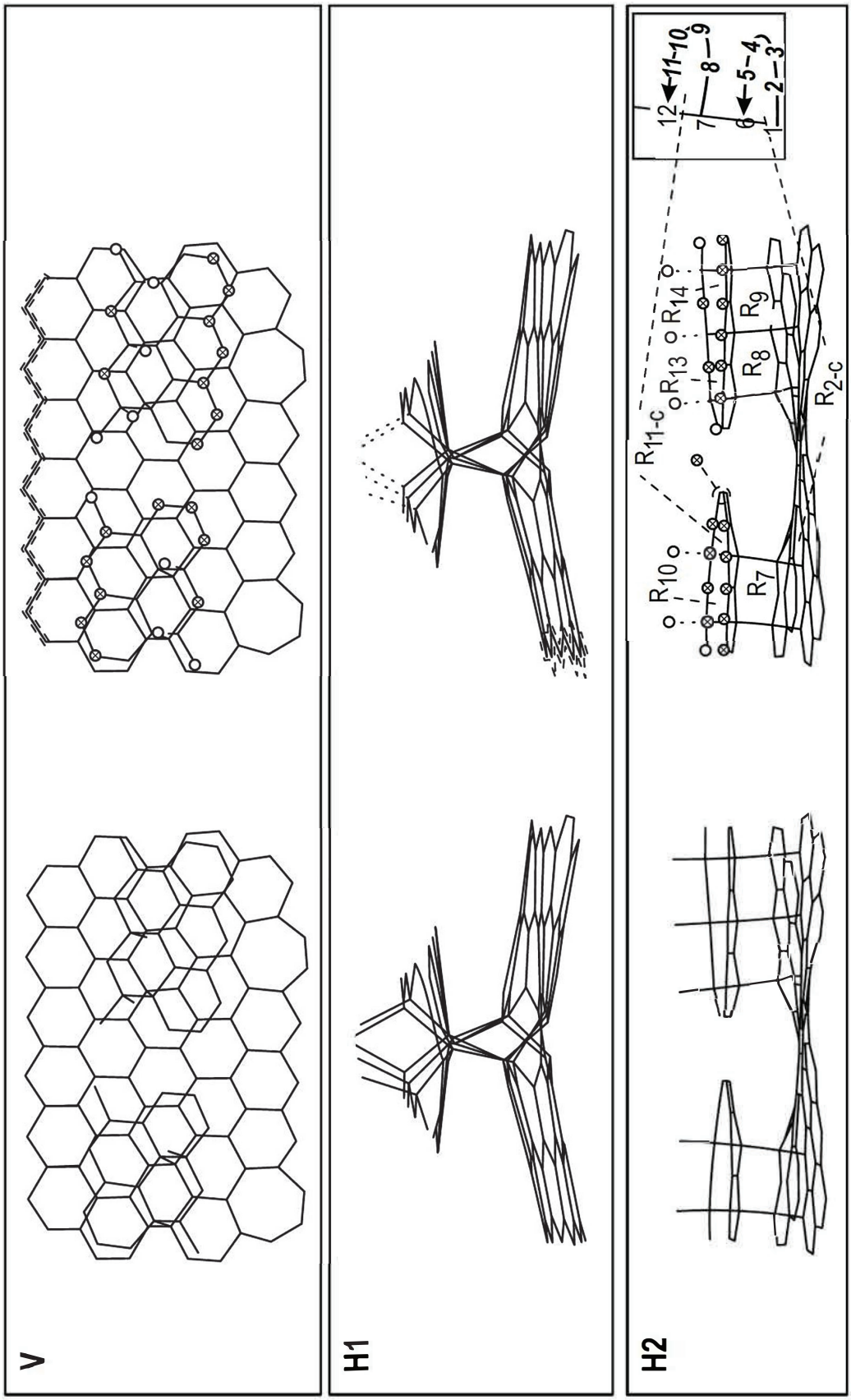


FIG. 34

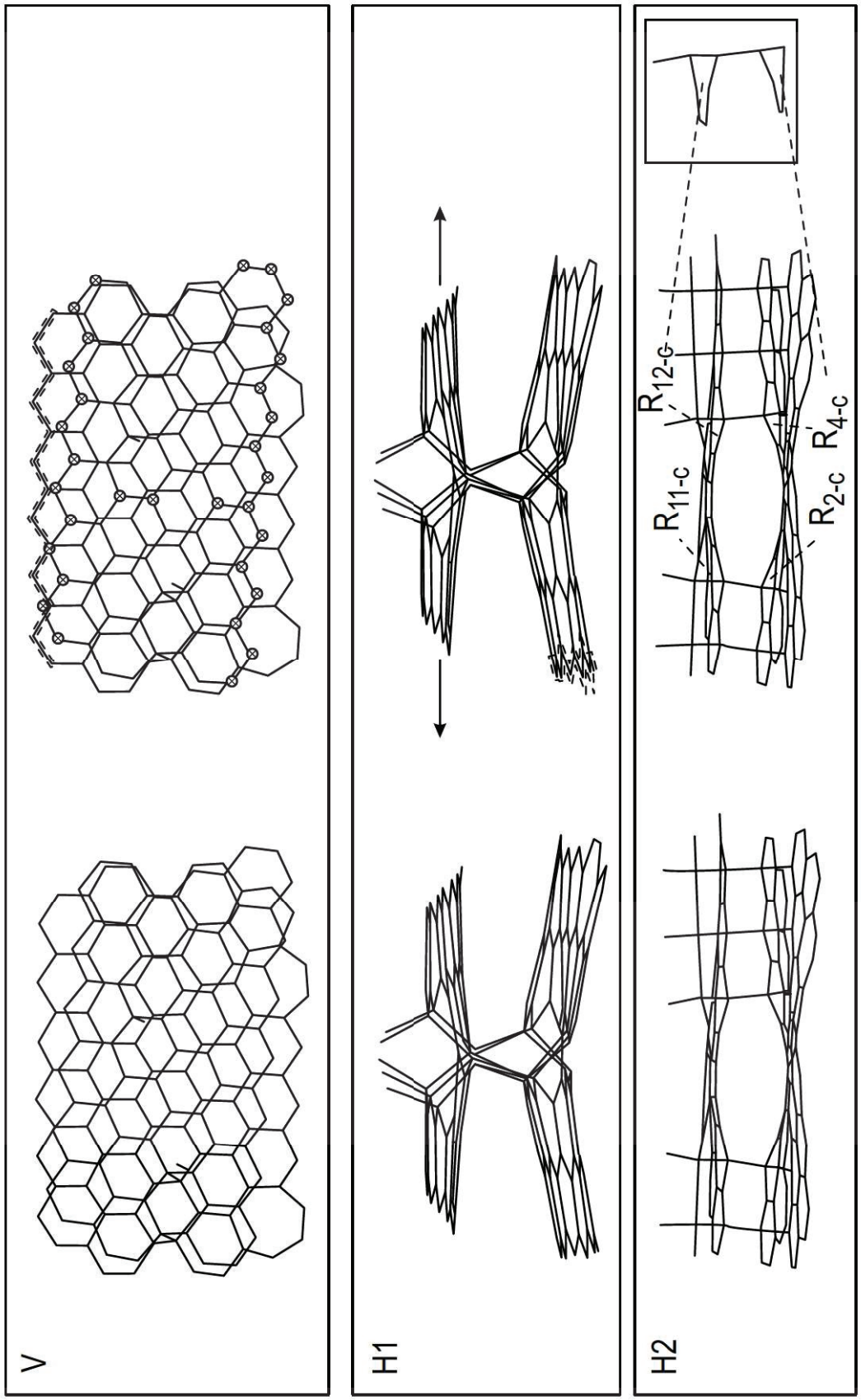


FIG. 35

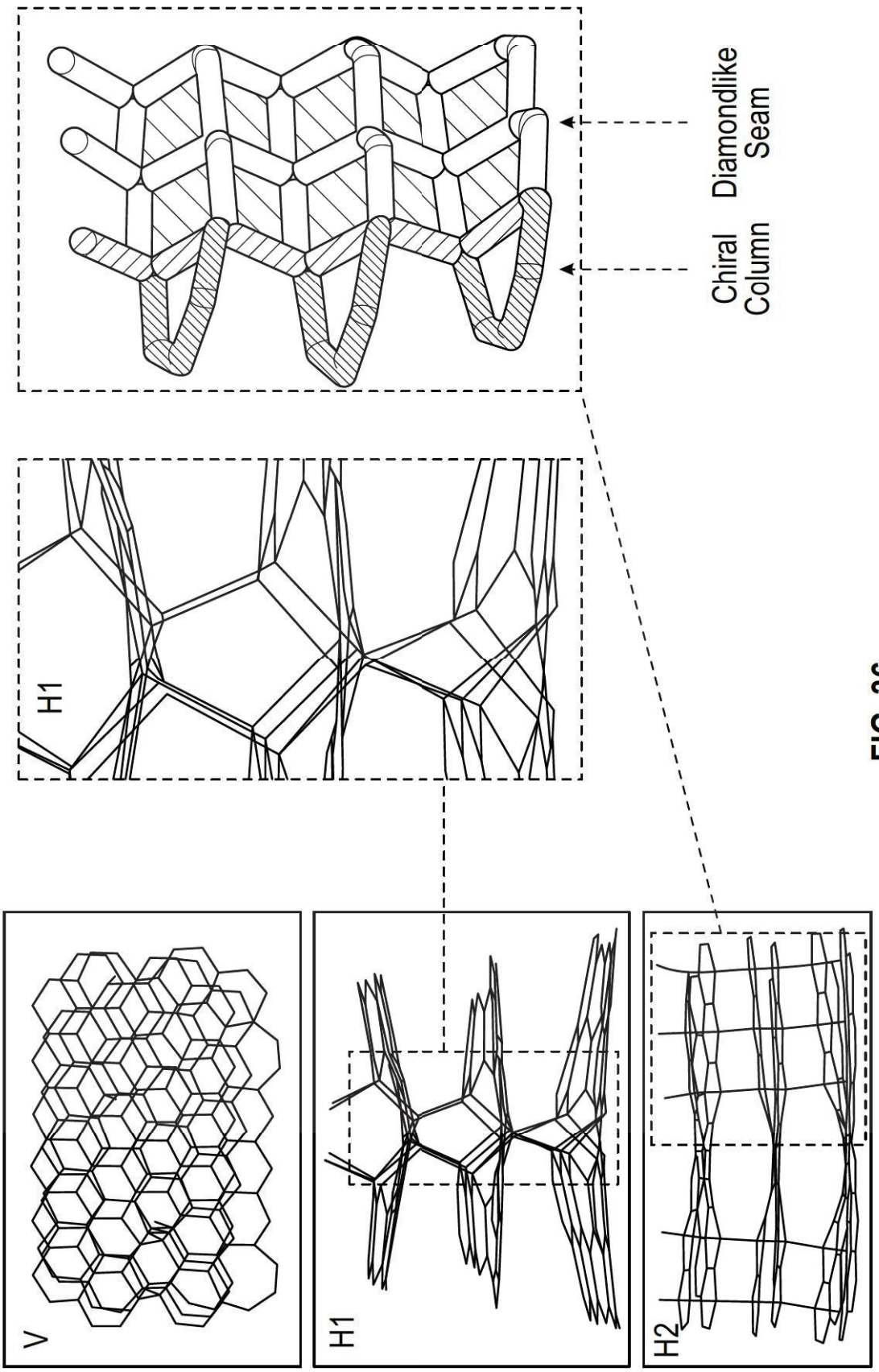


FIG. 36

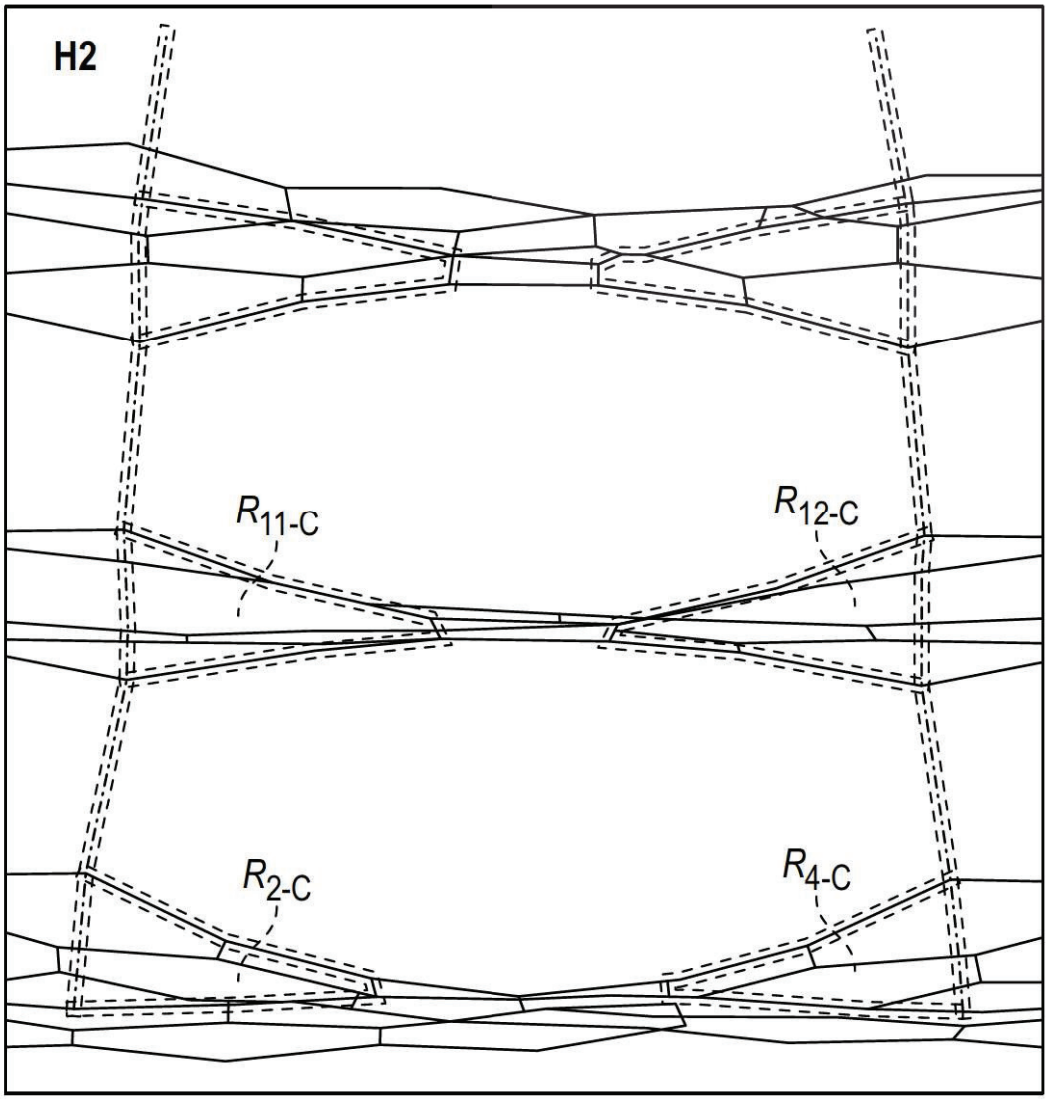


FIG. 37A

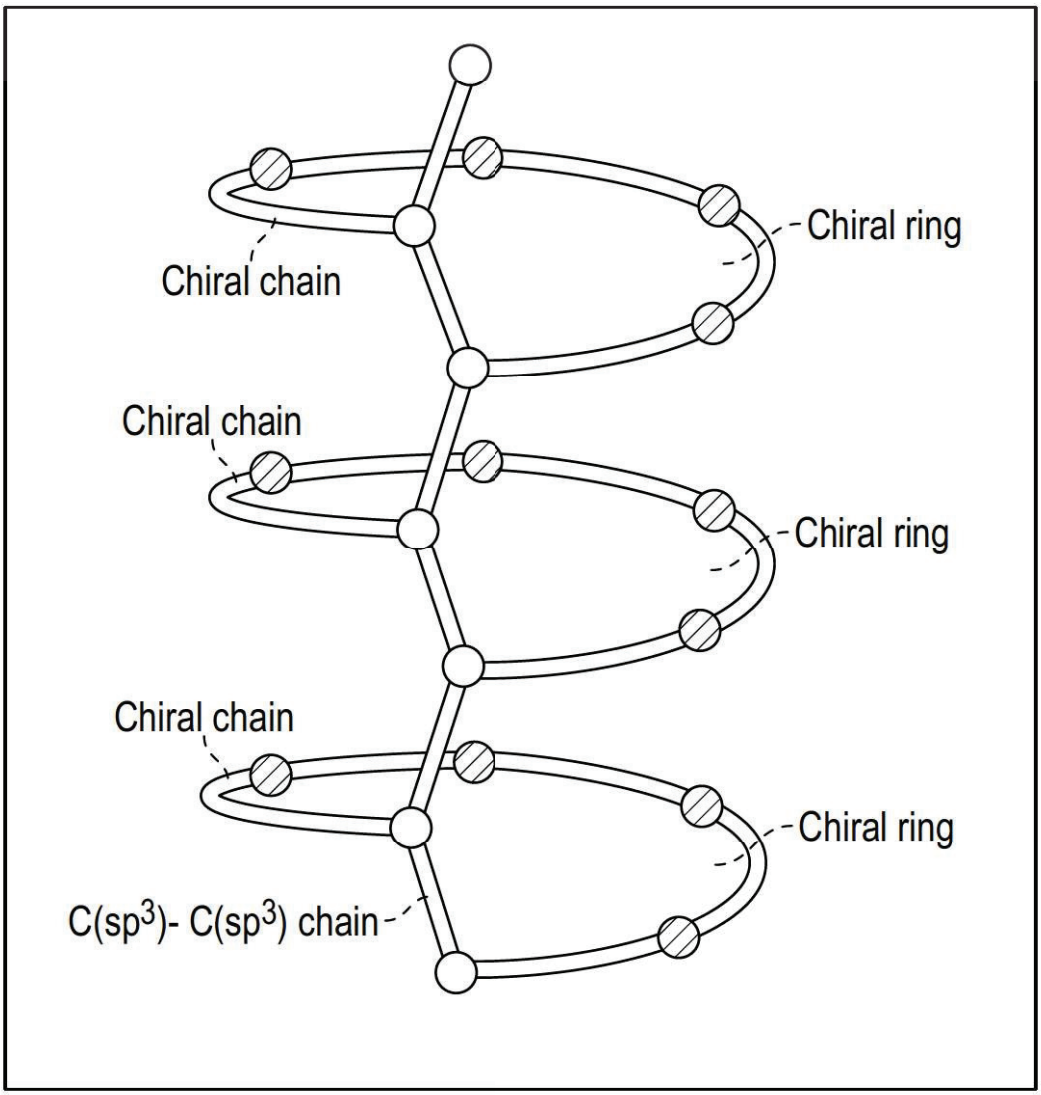

Chiral chain
Chiral ring
Chiral chain
Chiral ring
Chiral chain
Chiral ring
C(sp3)- C(sp3) chain

FIG. 37B

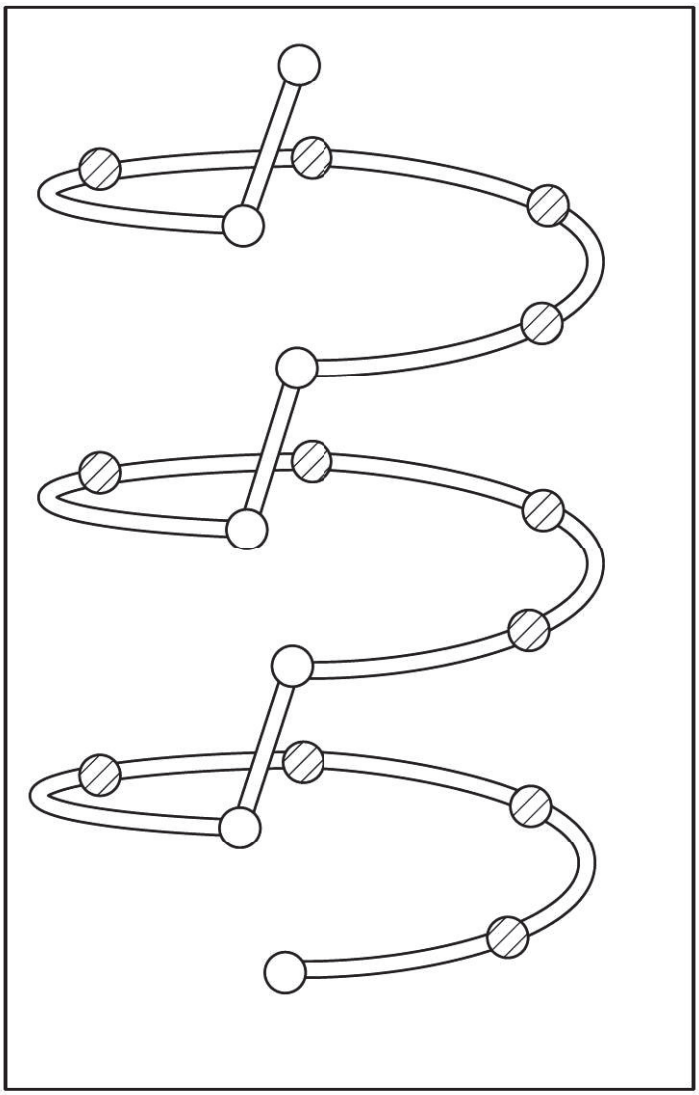


FIG. 37C

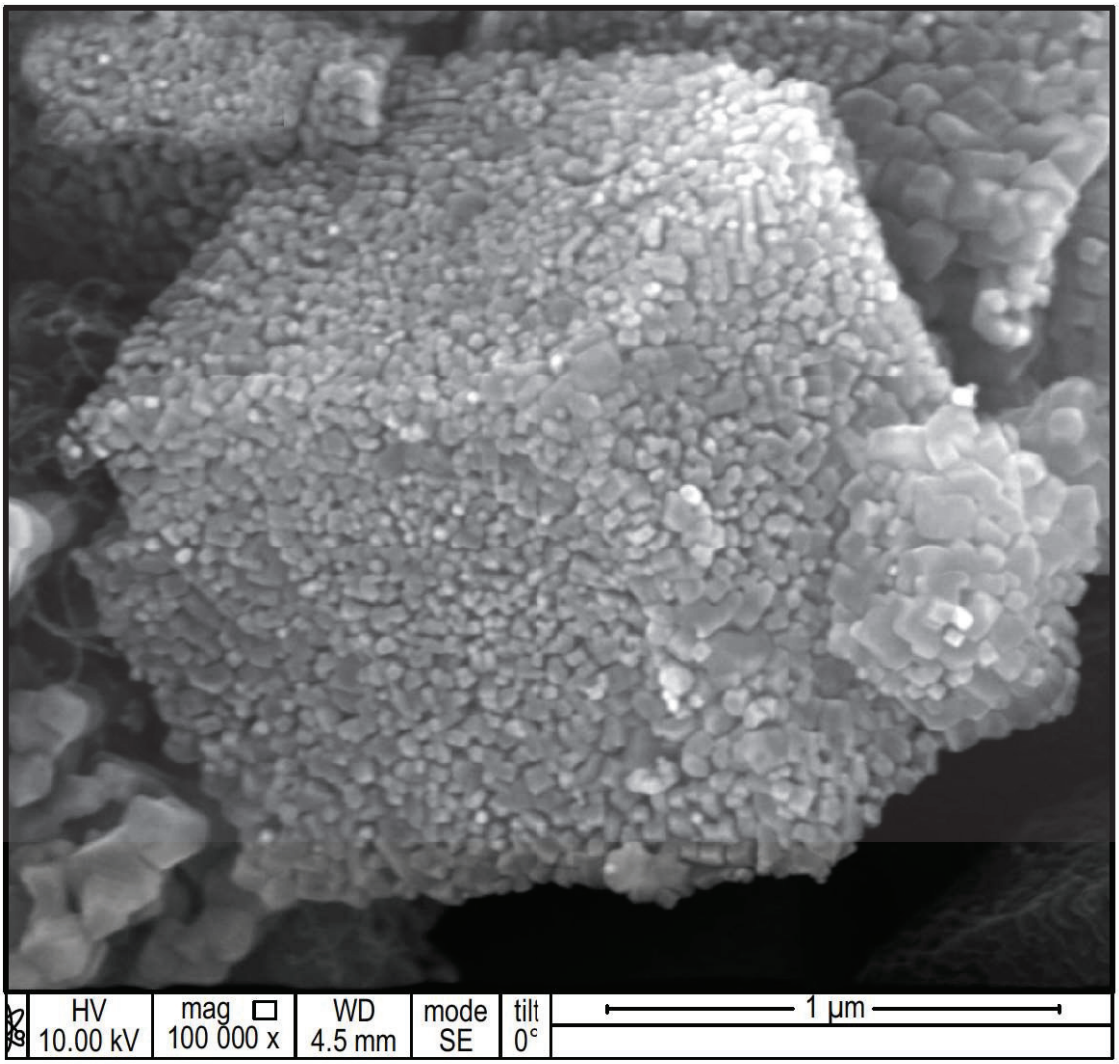


FIG. 38A

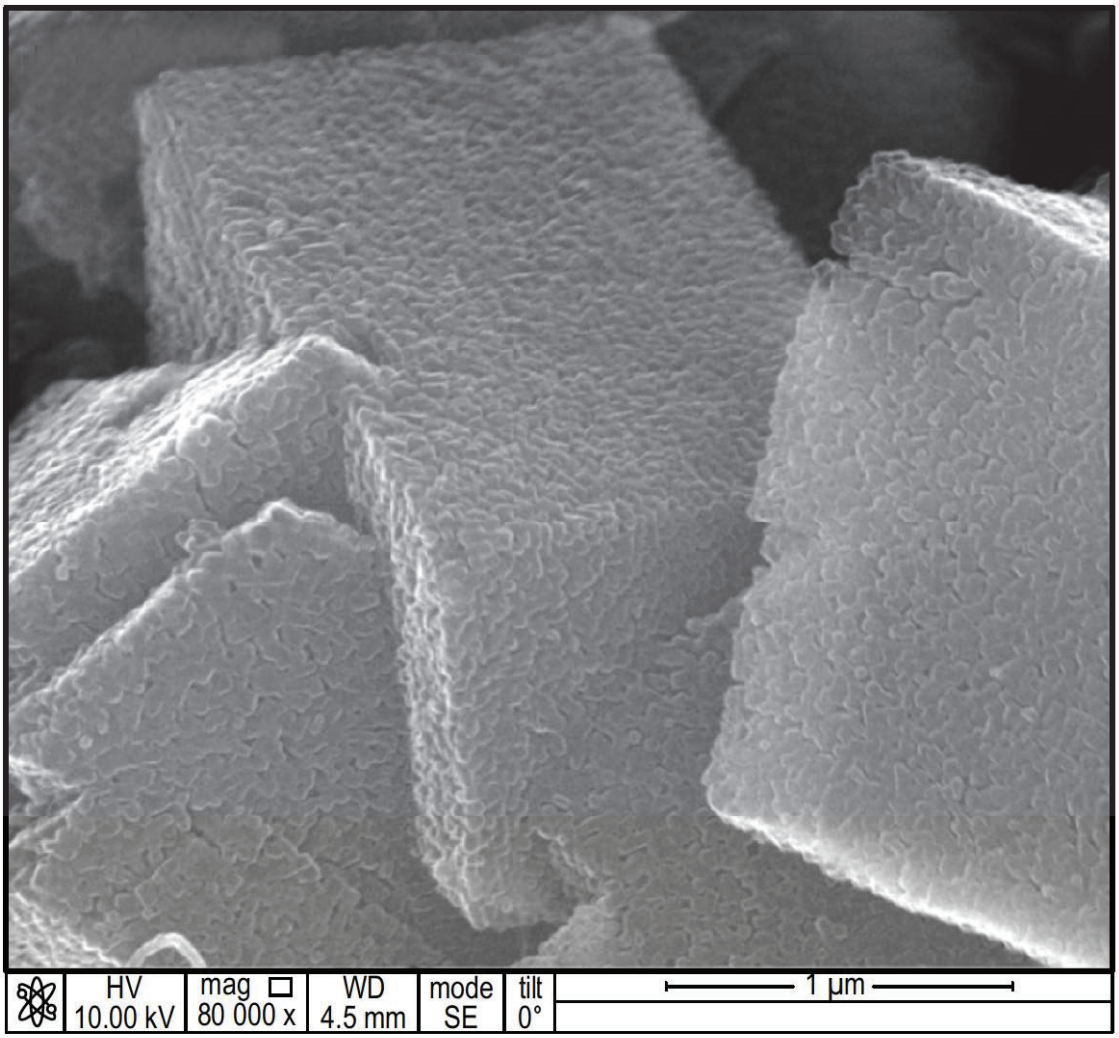


FIG. 38B

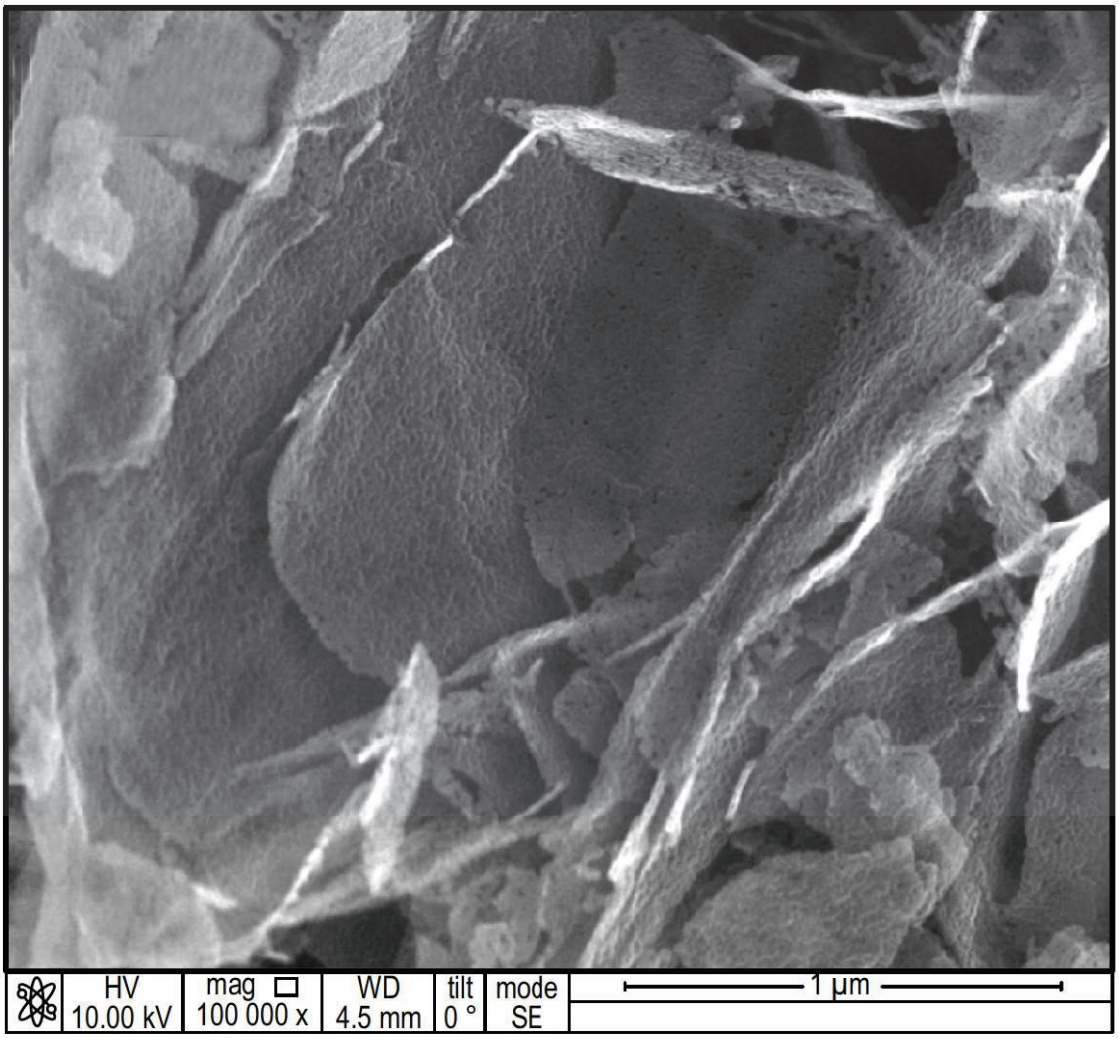


FIG. 38C

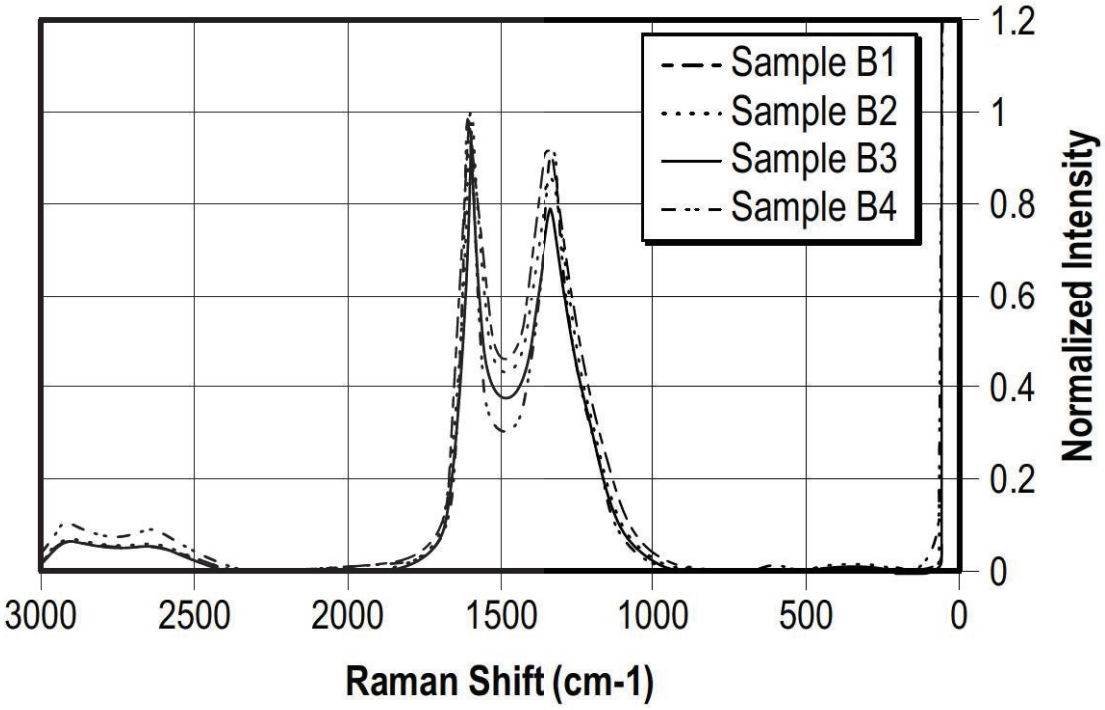

Sample B1
Sample B2
Sample B3
Sample B4
1.2
1
0.8
0.6
0.4
0.2
0
Normalized Intensity
3000
2500
2000
1500
1000
500
0
Raman Shift (cm-1)

FIG. 39A

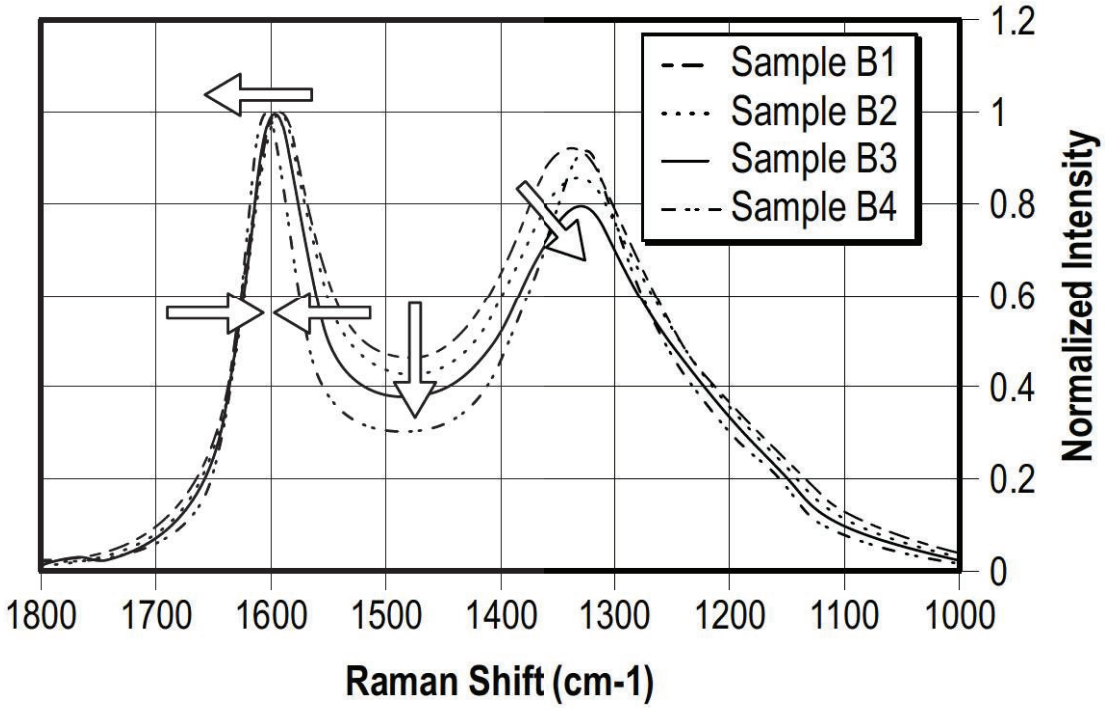

Sample B1
Sample B2
Sample B3
Sample B4
1.2
1
0.8
0.6
0.4
0.2
0
Normalized Intensity
1800
1700
1600
1500
1400
1300
1200
1100
1000
Raman Shift (cm-1)

FIG. 39B

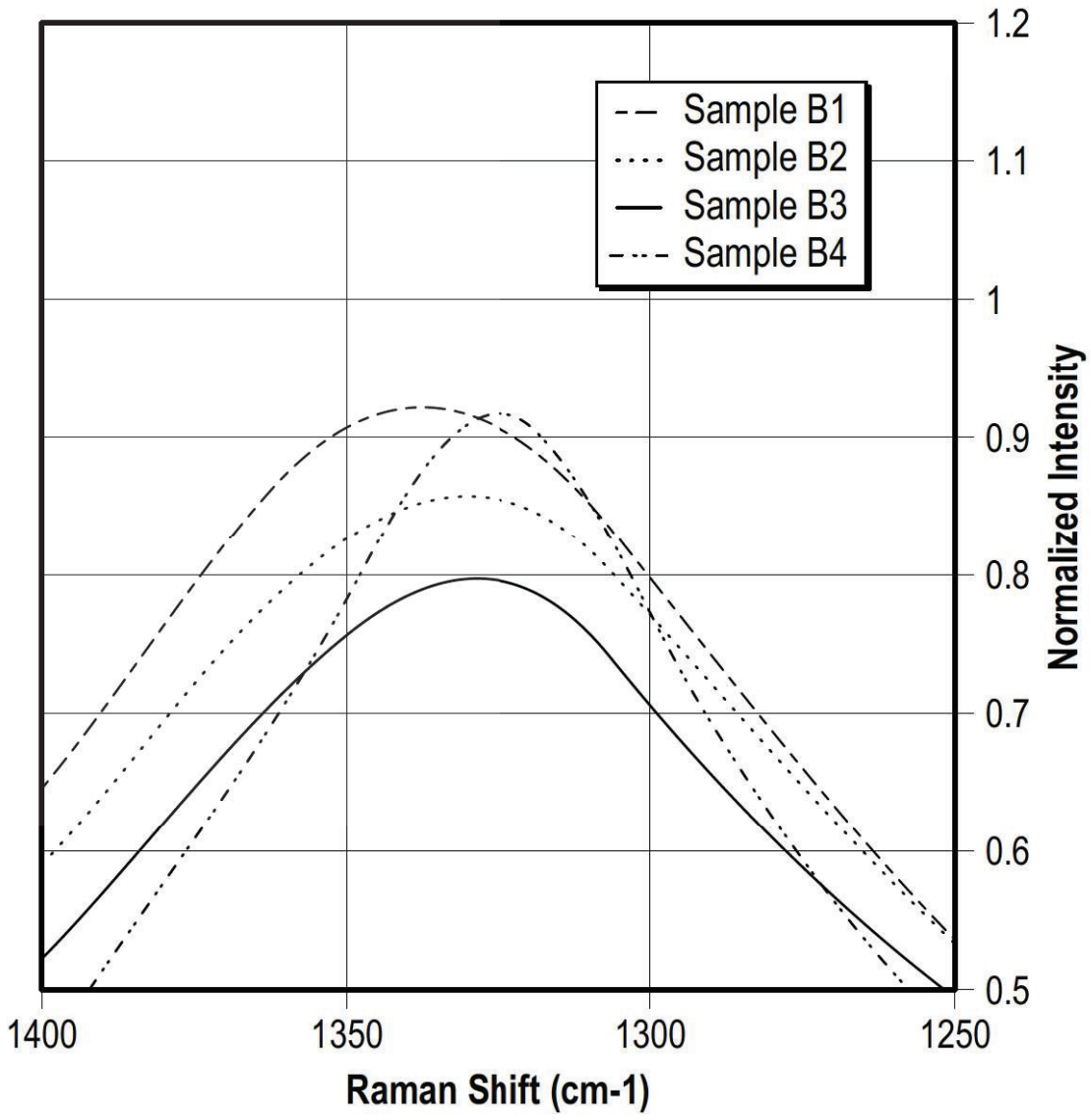

Sample B1
Sample B2
Sample B3
Sample B4
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
Normalized Intensity
1400
1350
1300
1250
Raman Shift (cm-1)

FIG. 39C

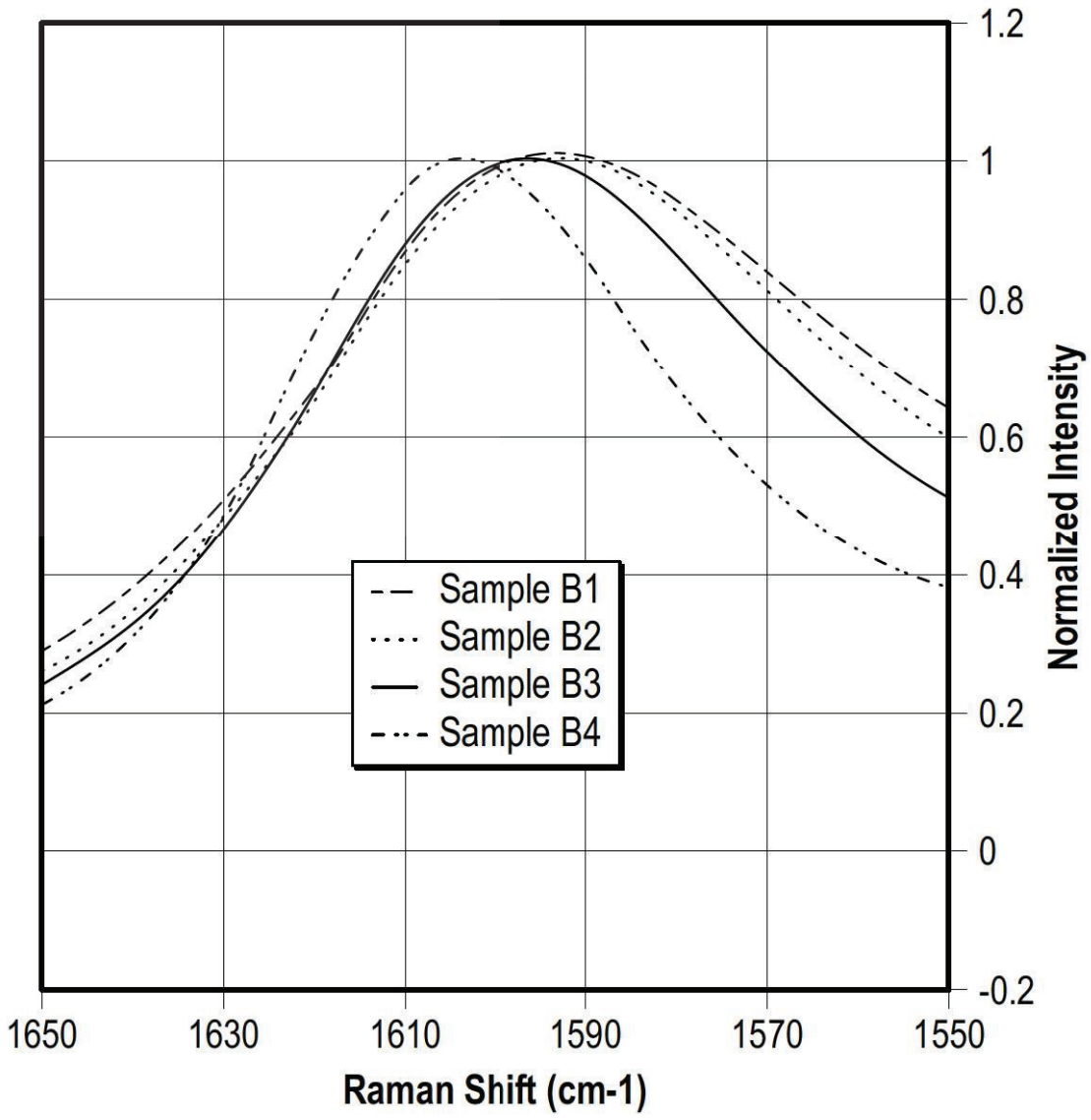

1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Normalized Intensity
Sample B1
Sample B2
Sample B3
Sample B4
1650
1630
1610
1590
1570
1550
Raman Shift (cm-1)

FIG. 39D

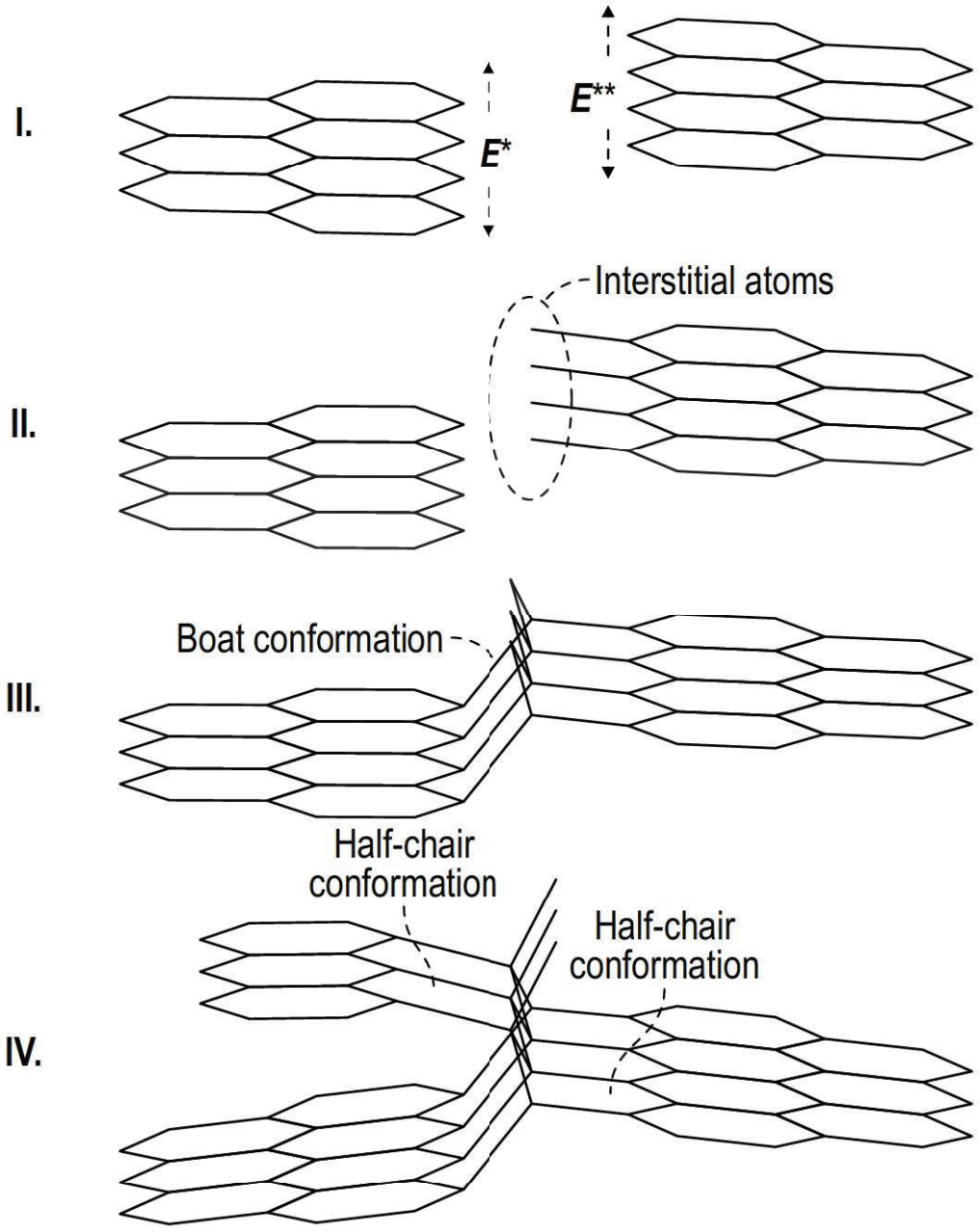

I.
E*
E**
II.
Interstitial atoms
III.
Boat conformation
IV.
Half-chair conformation
Half-chair conformation

FIG. 40

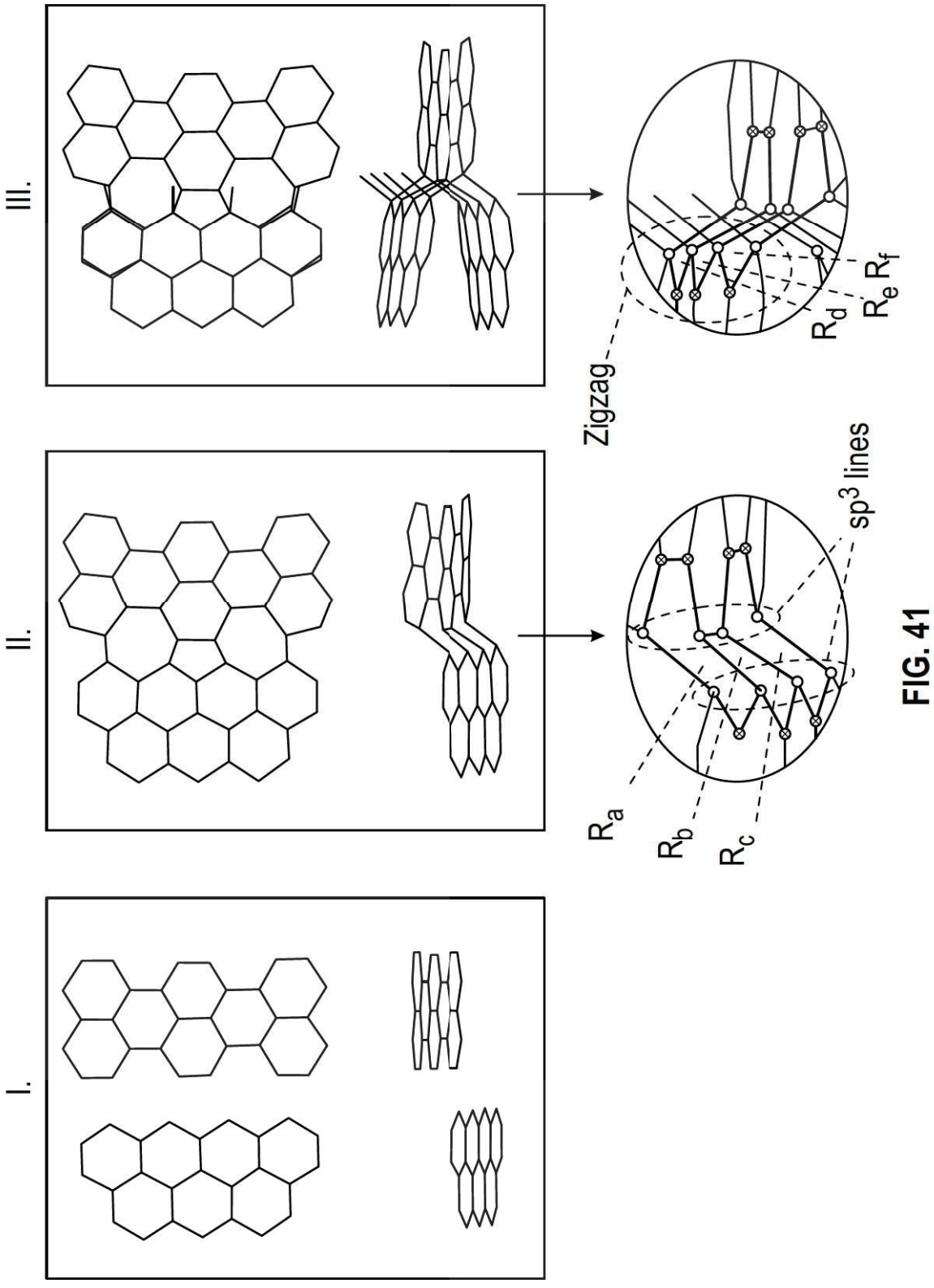


FIG. 41

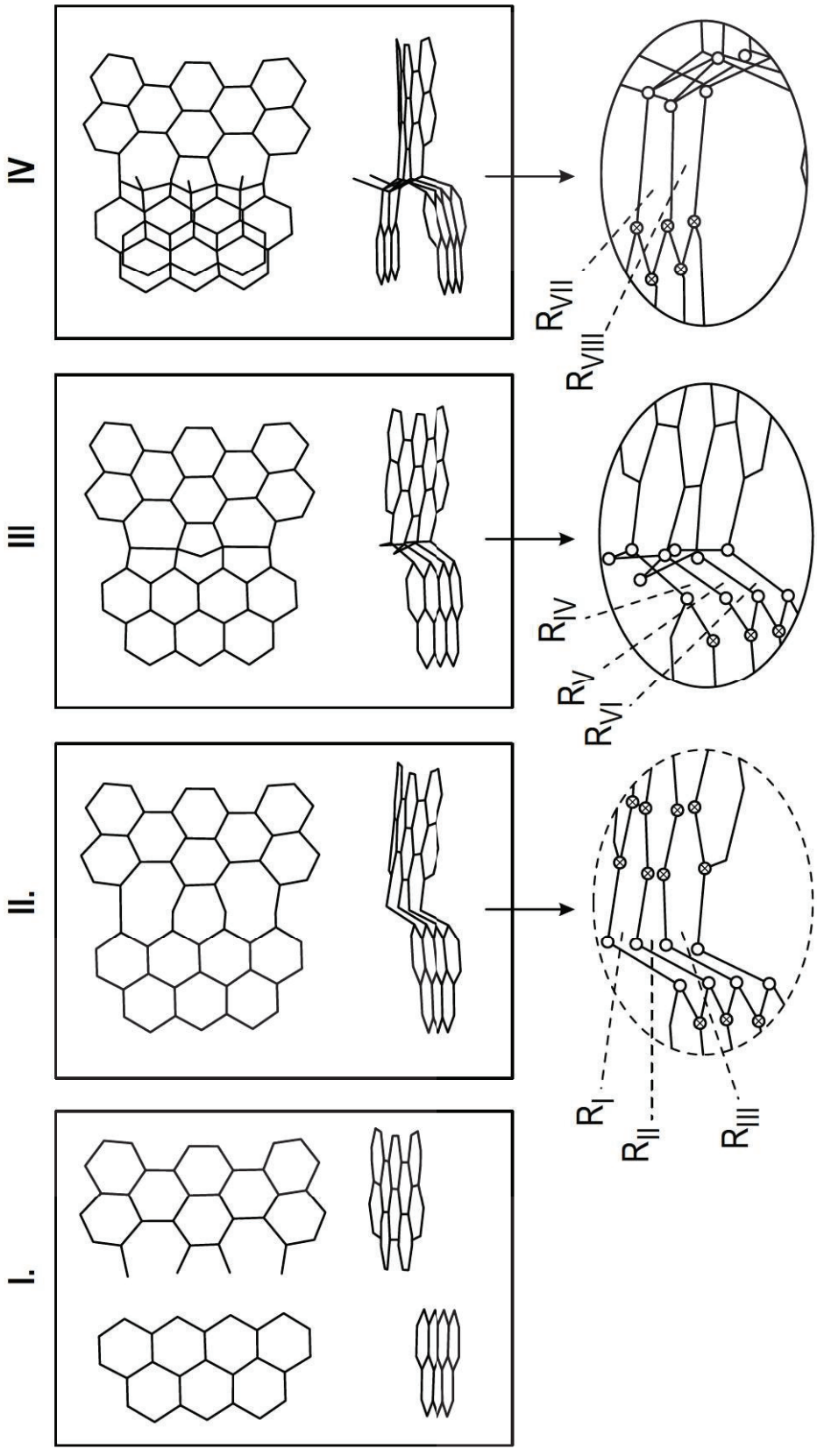


FIG. 42

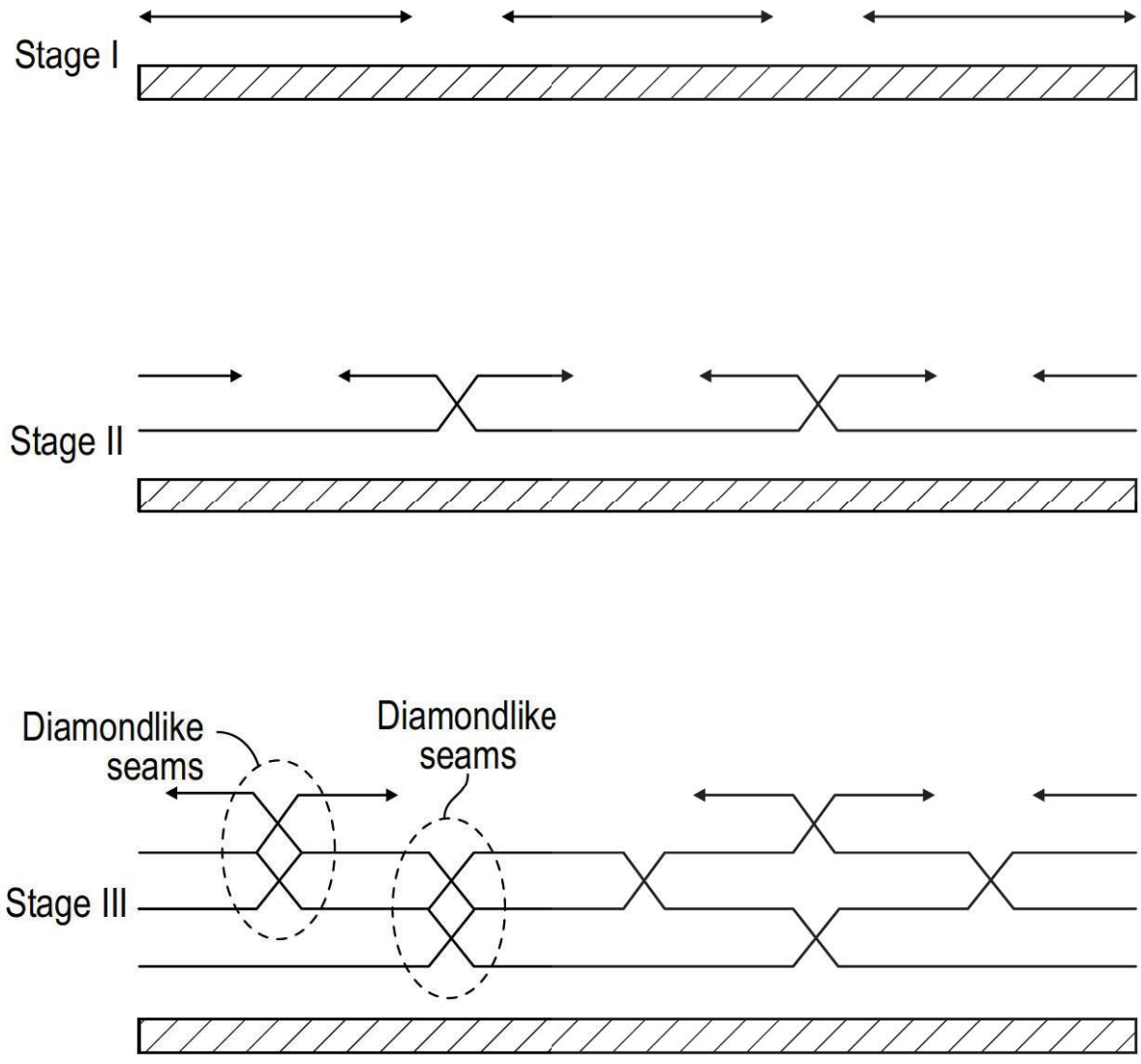

Stage I
Stage II
Diamondlike seams
Diamondlike seams
Stage III

FIG. 43

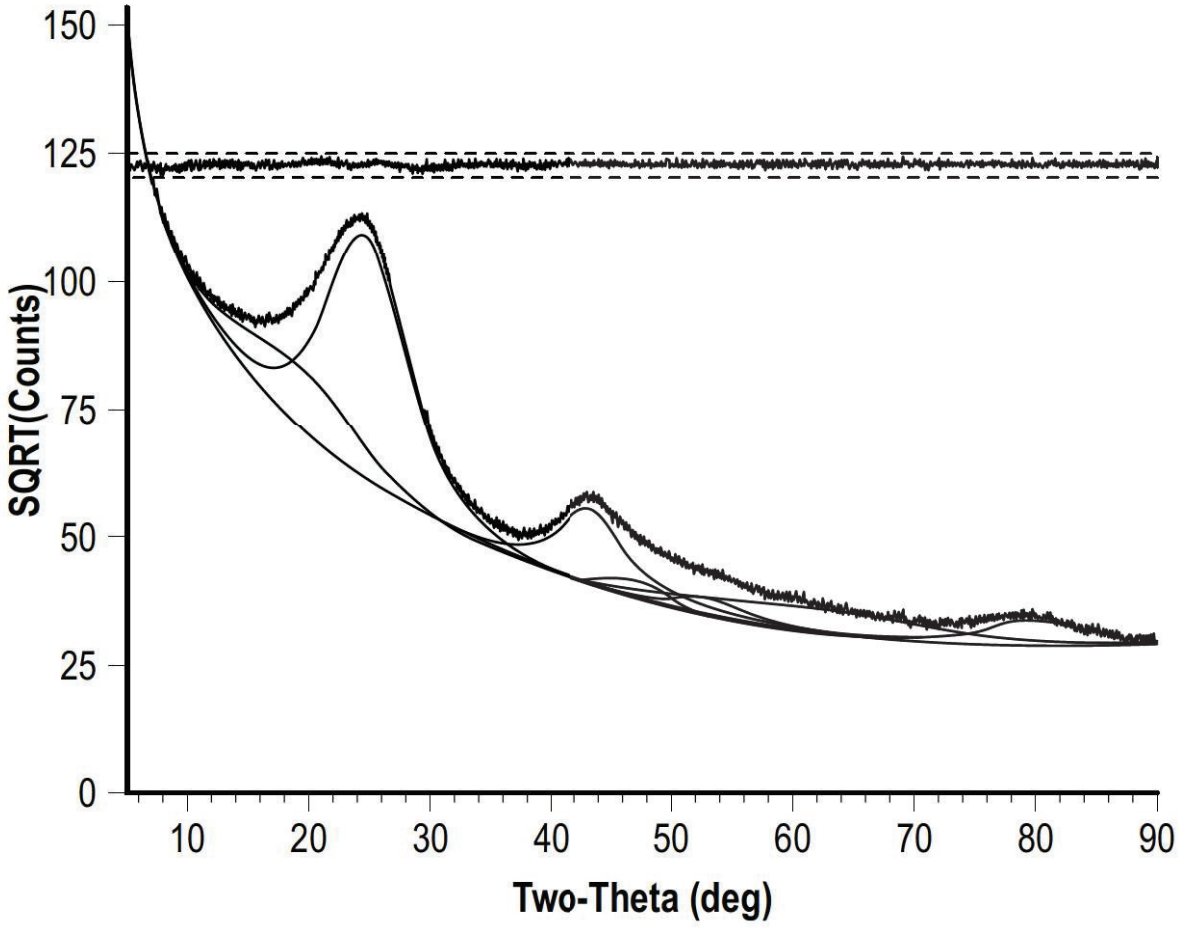

150
125
100
75
50
25
0
SQRT(Counts)
10
20
30
40
50
60
70
80
90
Two-Theta (deg)

FIG. 44



460°C 400°C

FIG. 45

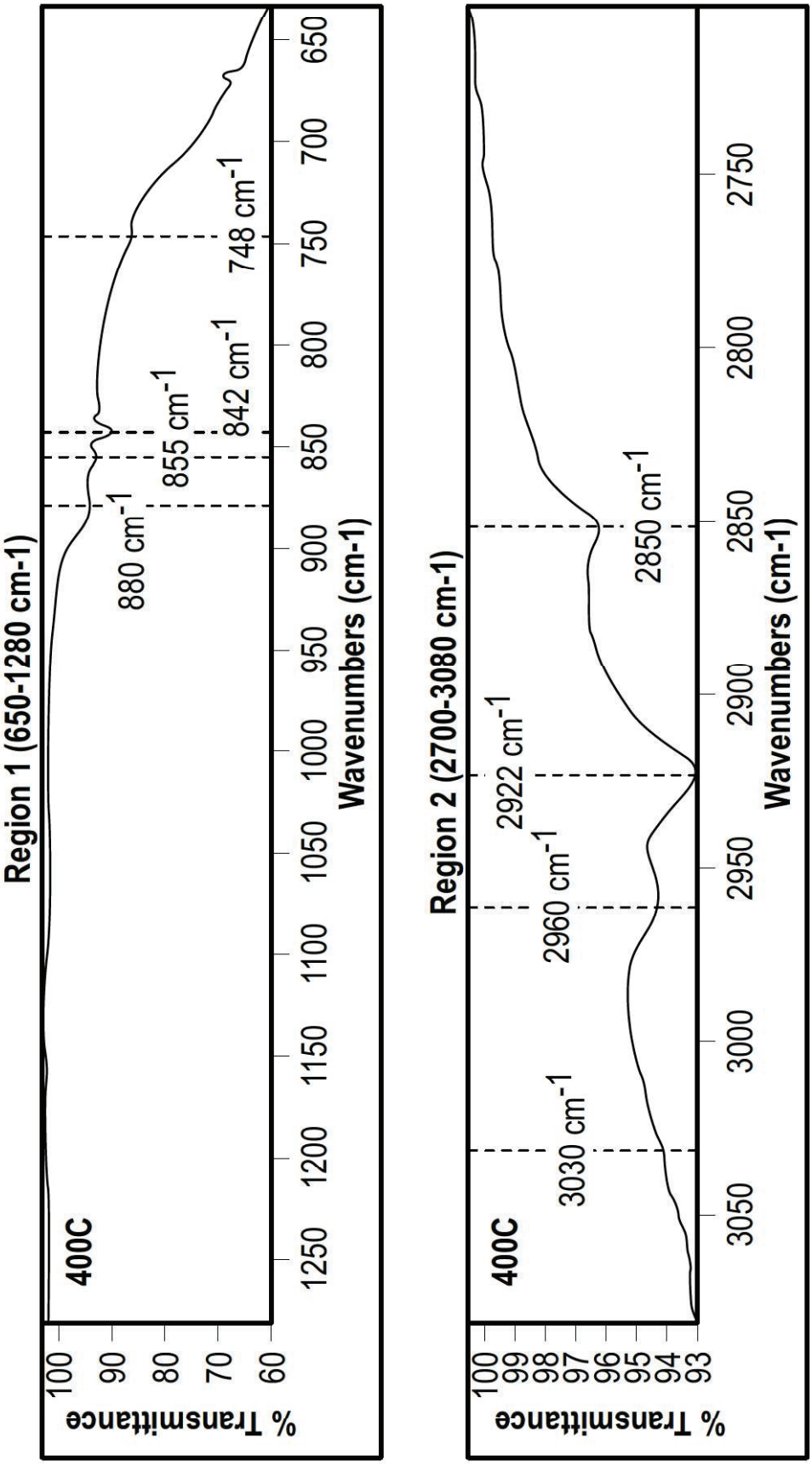

Region 1 (650-1280 cm-1)
400C
% Transmittance
100
90
80
70
60
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
Wavenumbers (cm-1)
880 cm-1
855 cm-1
842 cm-1
748 cm-1
Region 2 (2700-3080 cm-1)
400C
% Transmittance
100
99
98
97
96
95
94
93
3050
3000
2950
2900
2850
2800
2750
Wavenumbers (cm-1)
3030 cm-1
2960 cm-1
2922 cm-1
2850 cm-1

FIG. 46A

	Region 1				Region 2			
Peak pos. (cm^{-1})	880	855	842	748	3030	2960	2922	2850
	X	X	X	X	X	X	X	X
Peak Assignment	geminal disub alkene			mono/orthodi -sub aromatic	sp2 C-H stretch	sp3 C-H stretch		
	sp2 CH bend for aromatics							
	sp2 CH bend for alkenes							

FIG. 46B

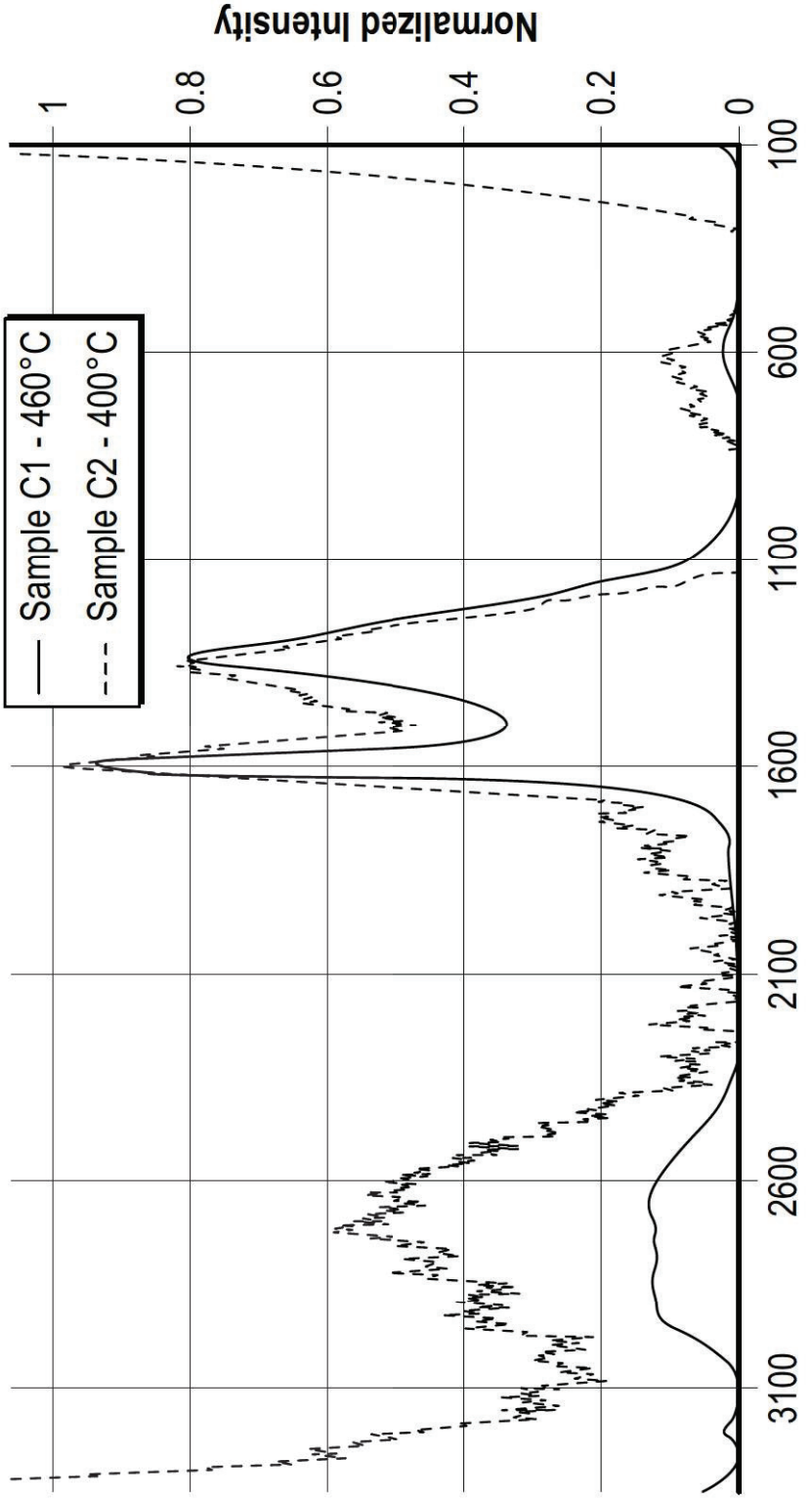

Normalized Intensity
1
0.8
0.6
0.4
0.2
0
Sample C1 - 460°C
Sample C2 - 400°C
100
600
1100
1600
2100
2600
3100
Raman Shift (cm-1)

FIG. 47

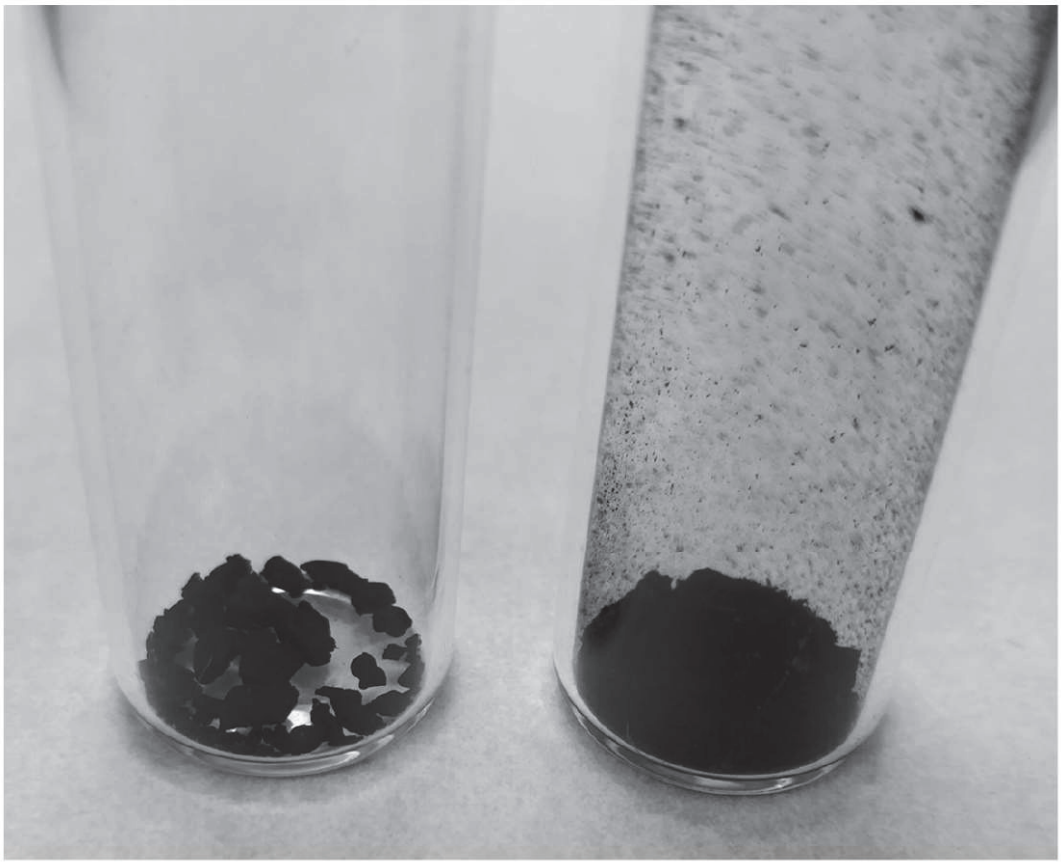


FIG. 48

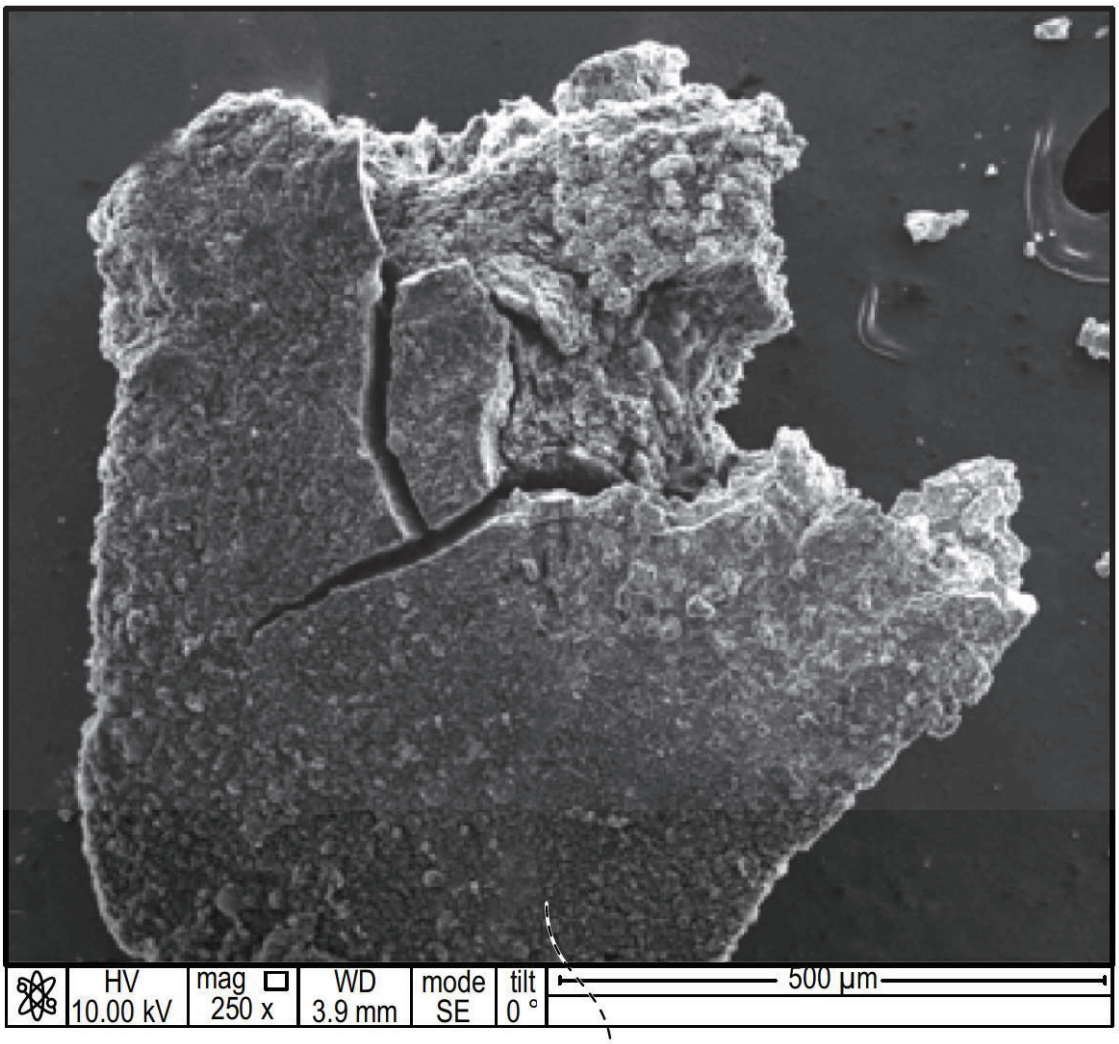

HV
10.00 kV
mag
250 x
WD
3.9 mm
mode
SE
tilt
0 °
500 µm
Dense, macroscopic granules

FIG. 49A

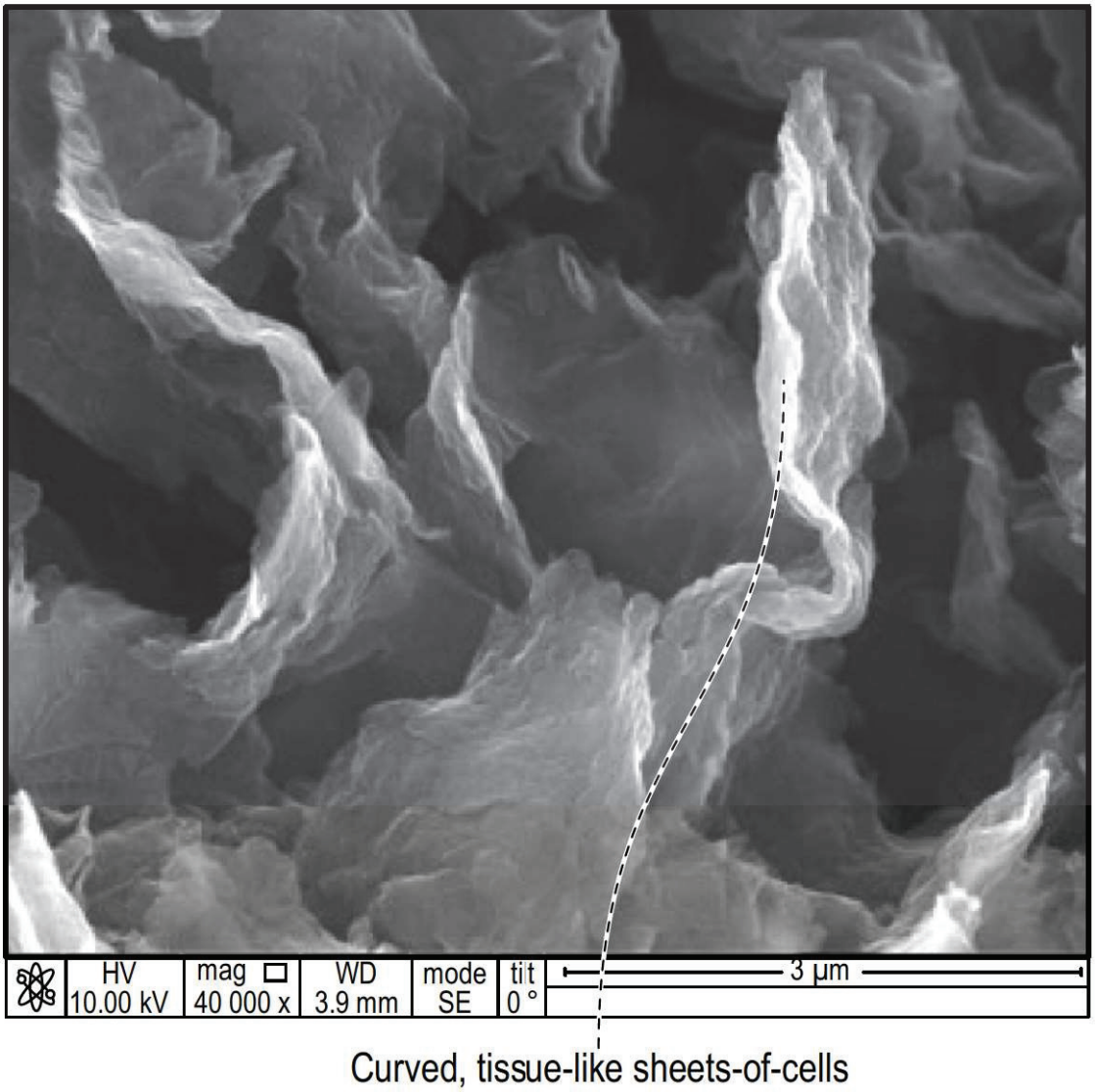

HV
10.00 kV
mag
40 000 x
WD
3.9 mm
mode
SE
tilt
0 °
3 µm
Curved, tissue-like sheets-of-cells

FIG. 49B

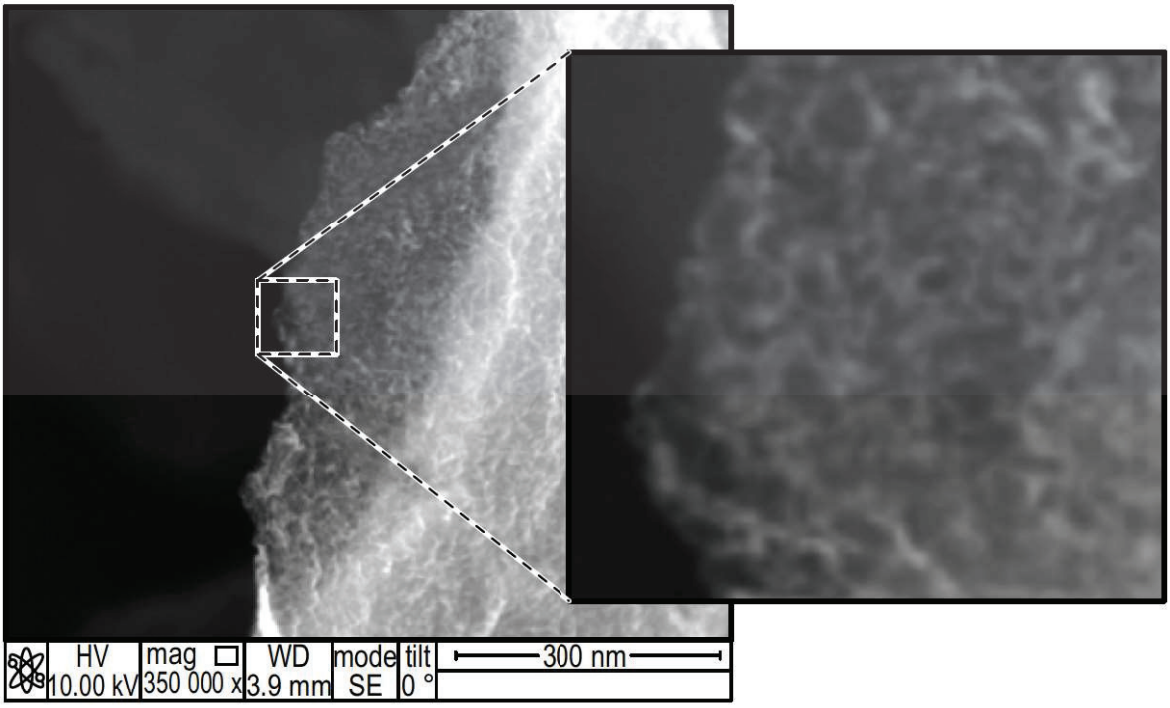


FIG. 49C

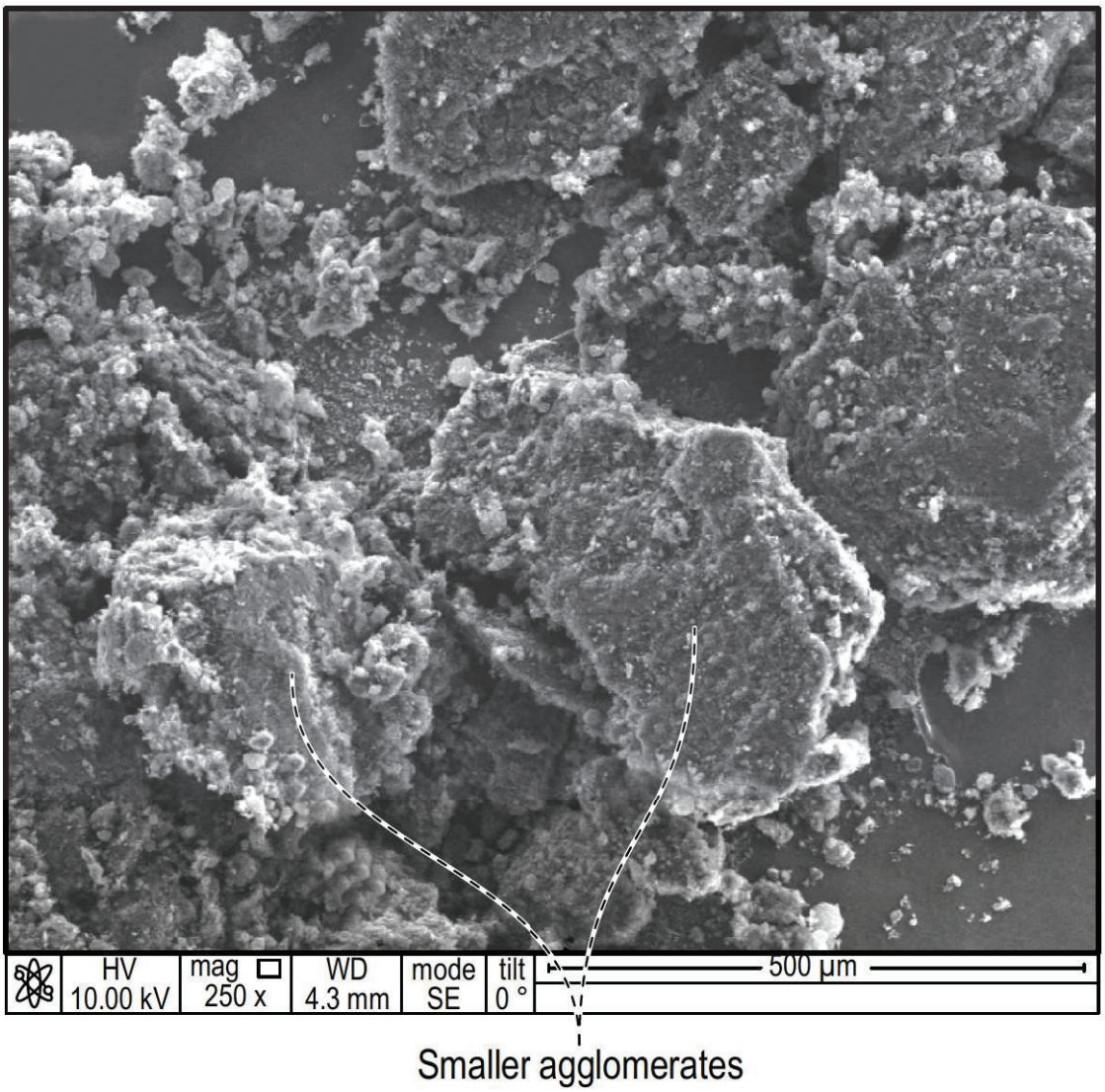

HV
10.00 kV
mag
250 x
WD
4.3 mm
mode
SE
tilt
0 °
500 µm
Smaller agglomerates

FIG. 49D

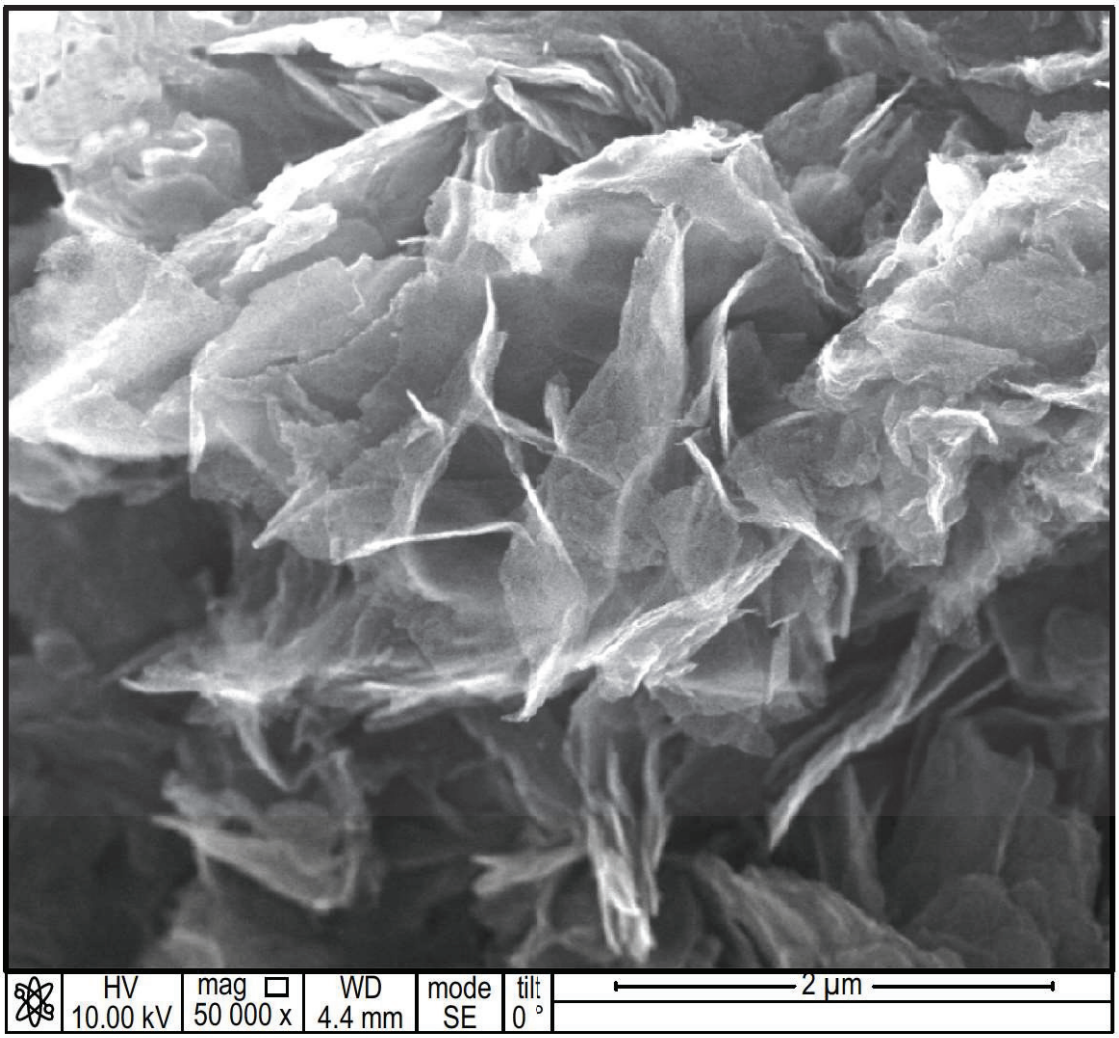


FIG. 49E

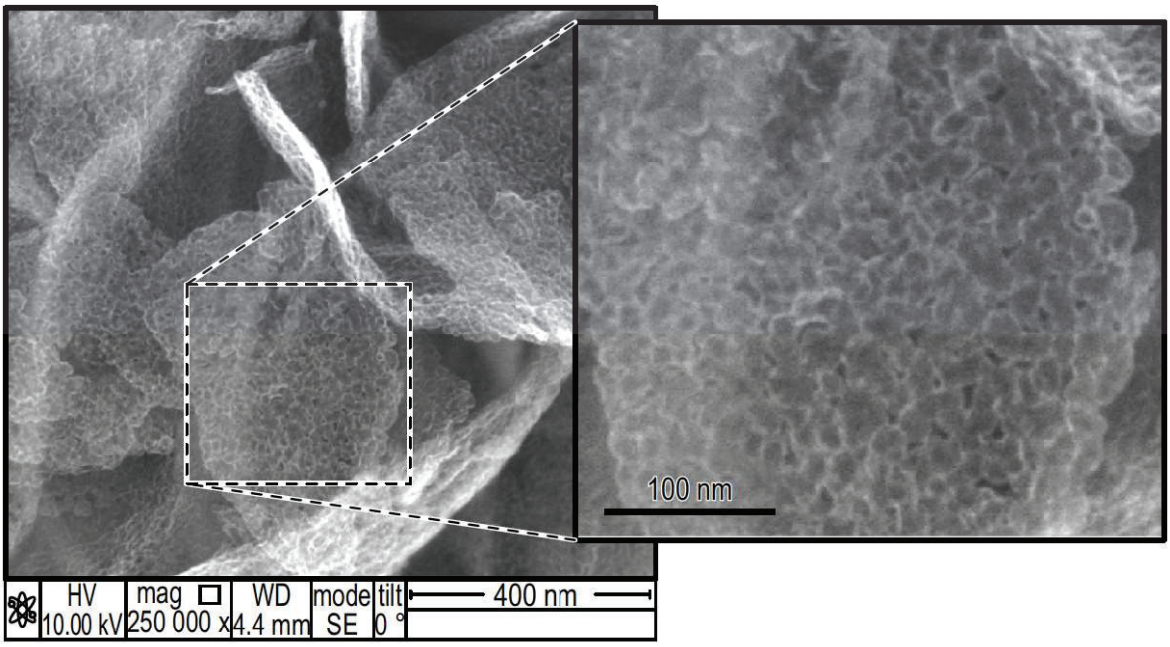


FIG. 49F

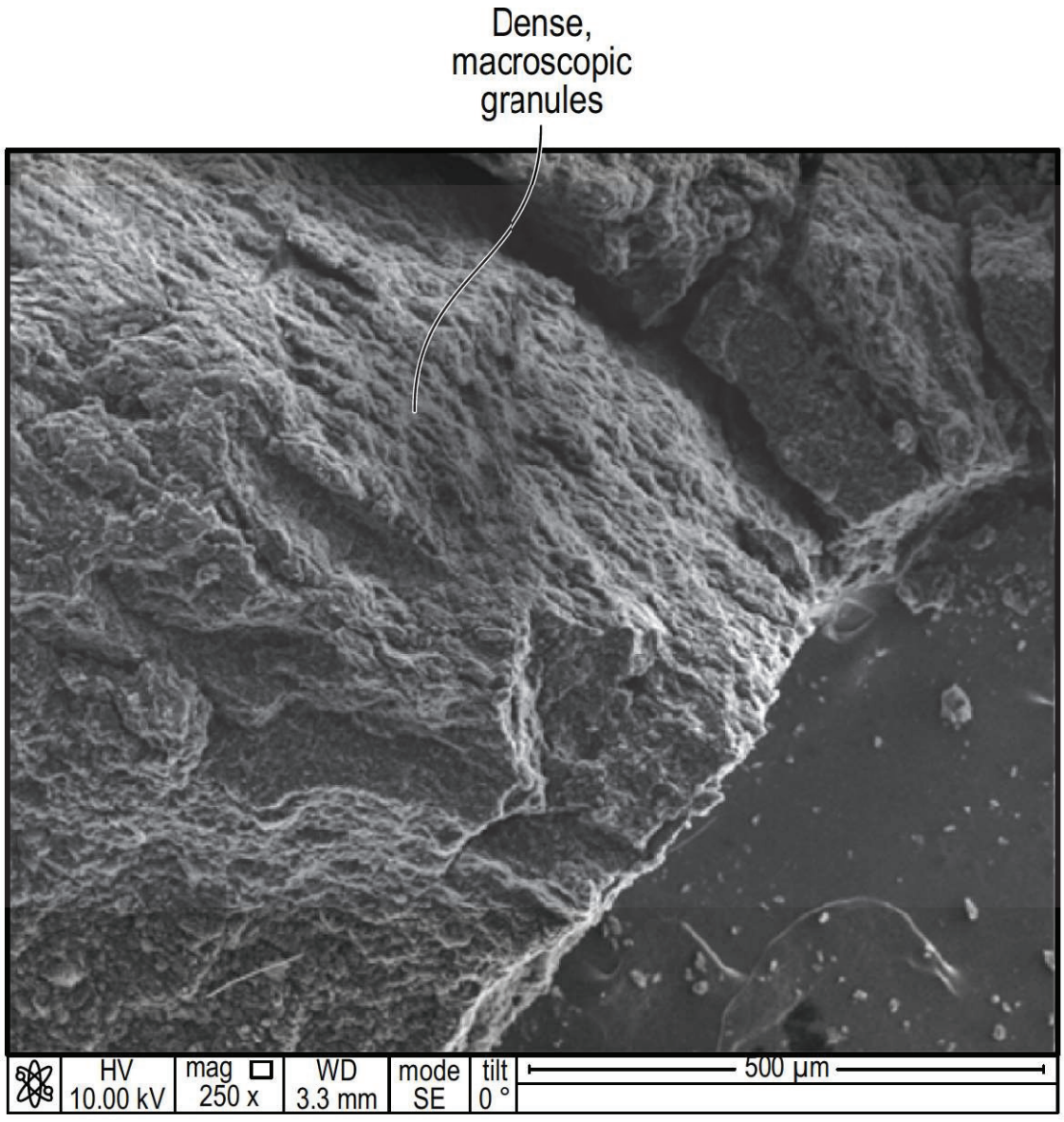

Dense,
macroscopic
granules
HV
10.00 kV
mag
250 x
WD
3.3 mm
mode
SE
tilt
0 °
500 µm

FIG. 50A

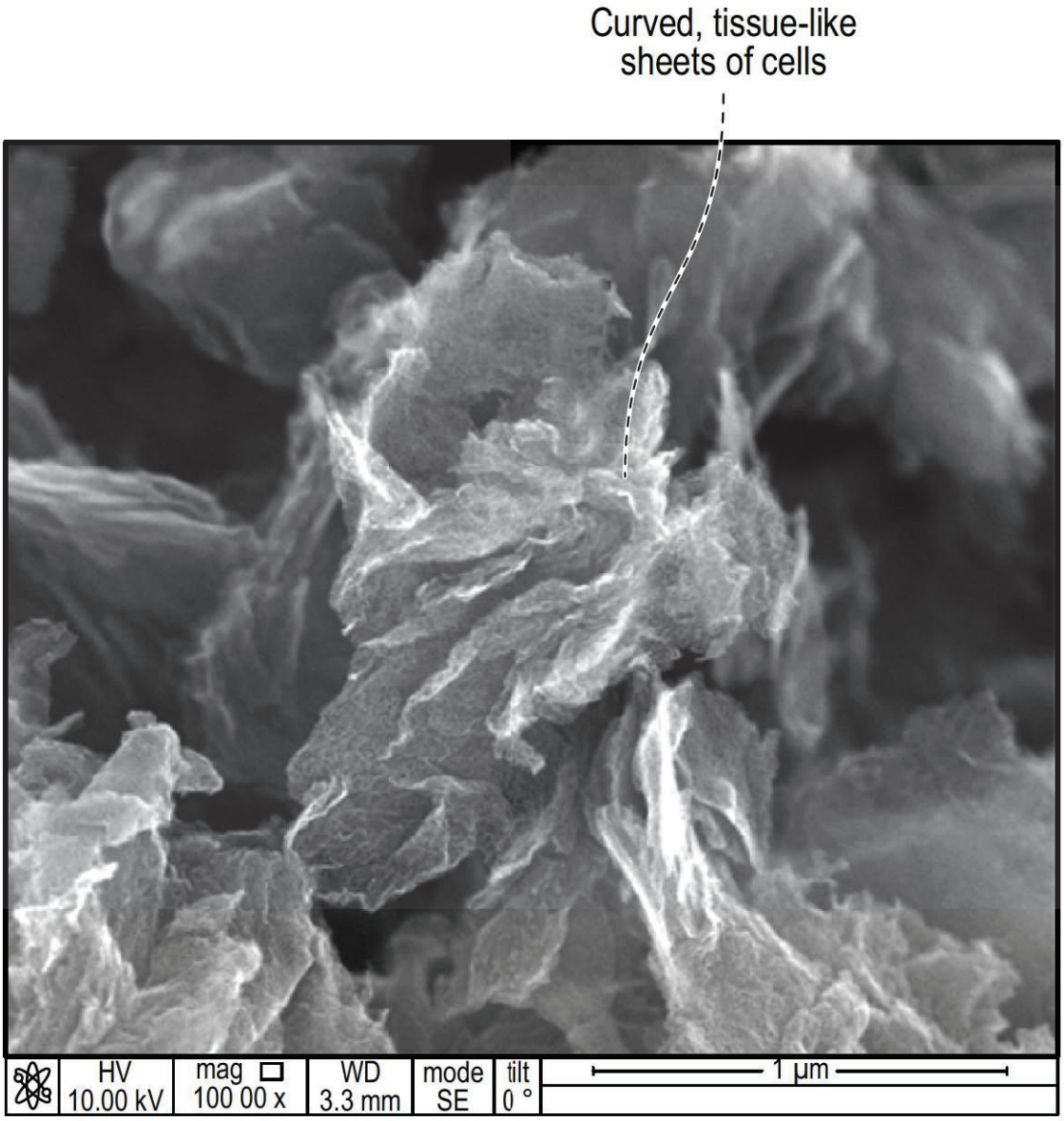

Curved, tissue-like
sheets of cells
HV
10.00 kV
mag
100 00 x
WD
3.3 mm
mode
SE
tilt
0 °
1 µm

FIG. 50B

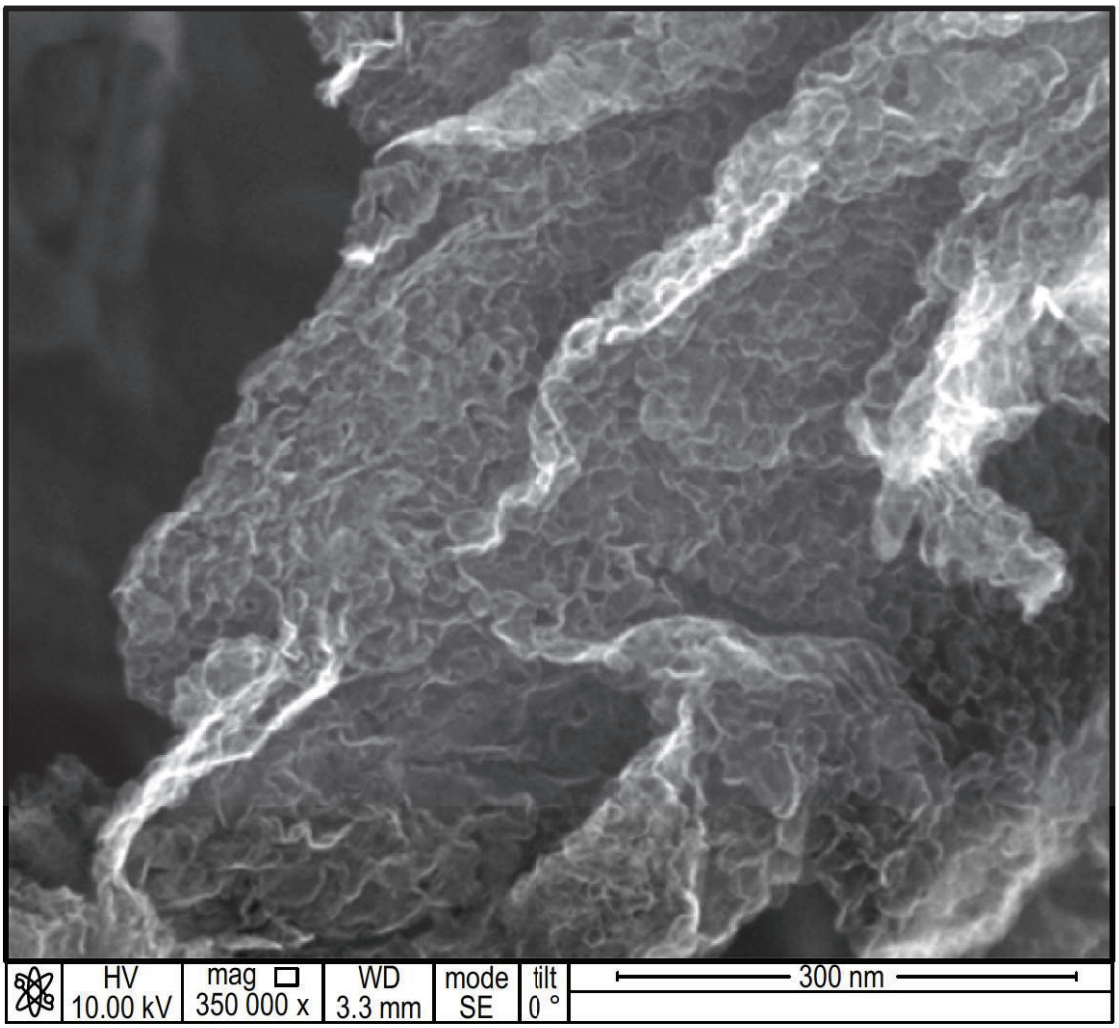


FIG. 50C

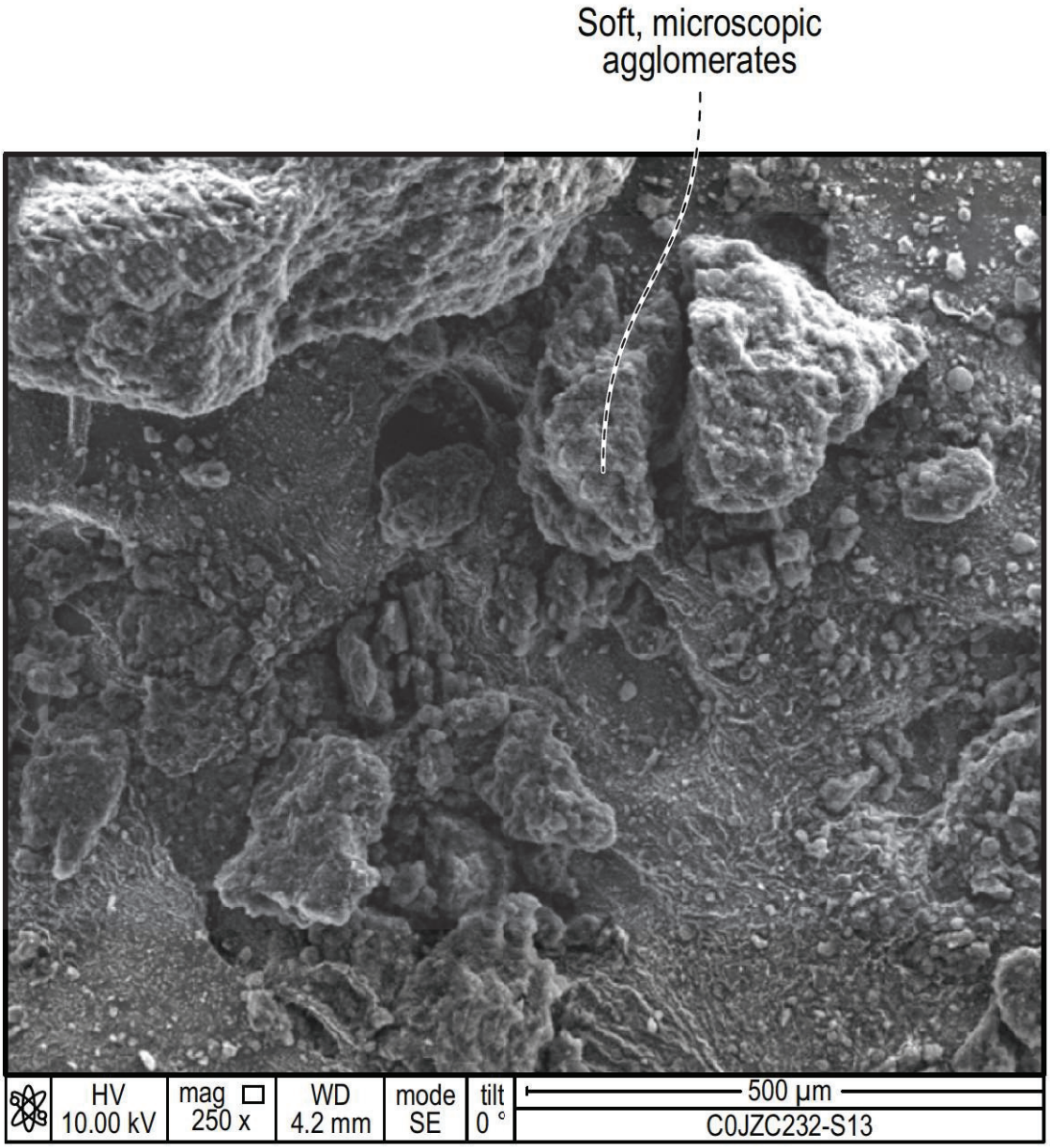

Soft, microscopic agglomerates
HV
10.00 kV
mag
250 x
WD
4.2 mm
mode
SE
tilt
0 °
500 µm
C0JZC232-S13

FIG. 50D

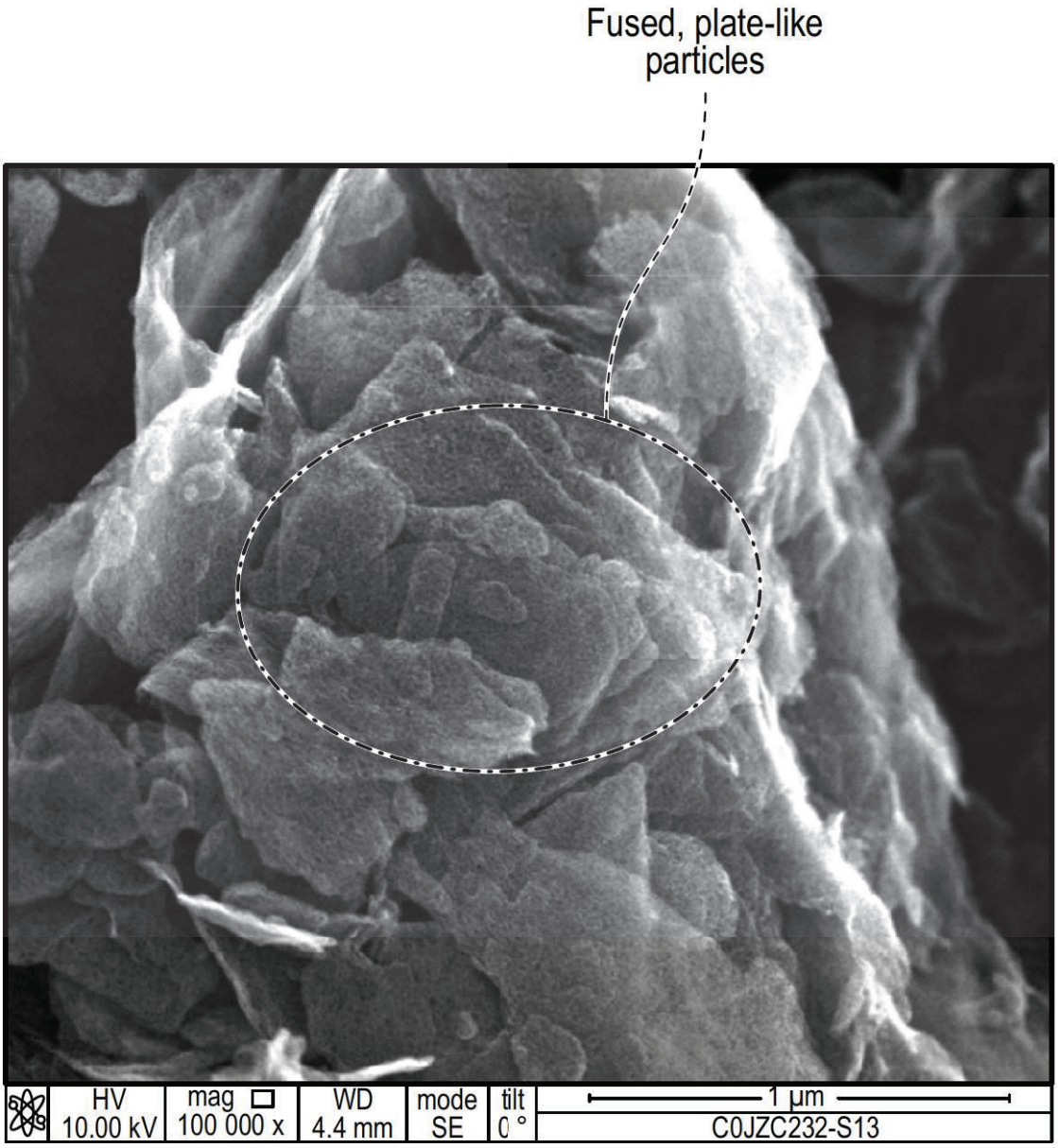

Fused, plate-like particles
HV
10.00 kV
mag
100 000 x
WD
4.4 mm
mode
SE
tilt
0 °
1 µm
C0JZC232-S13

FIG. 50E

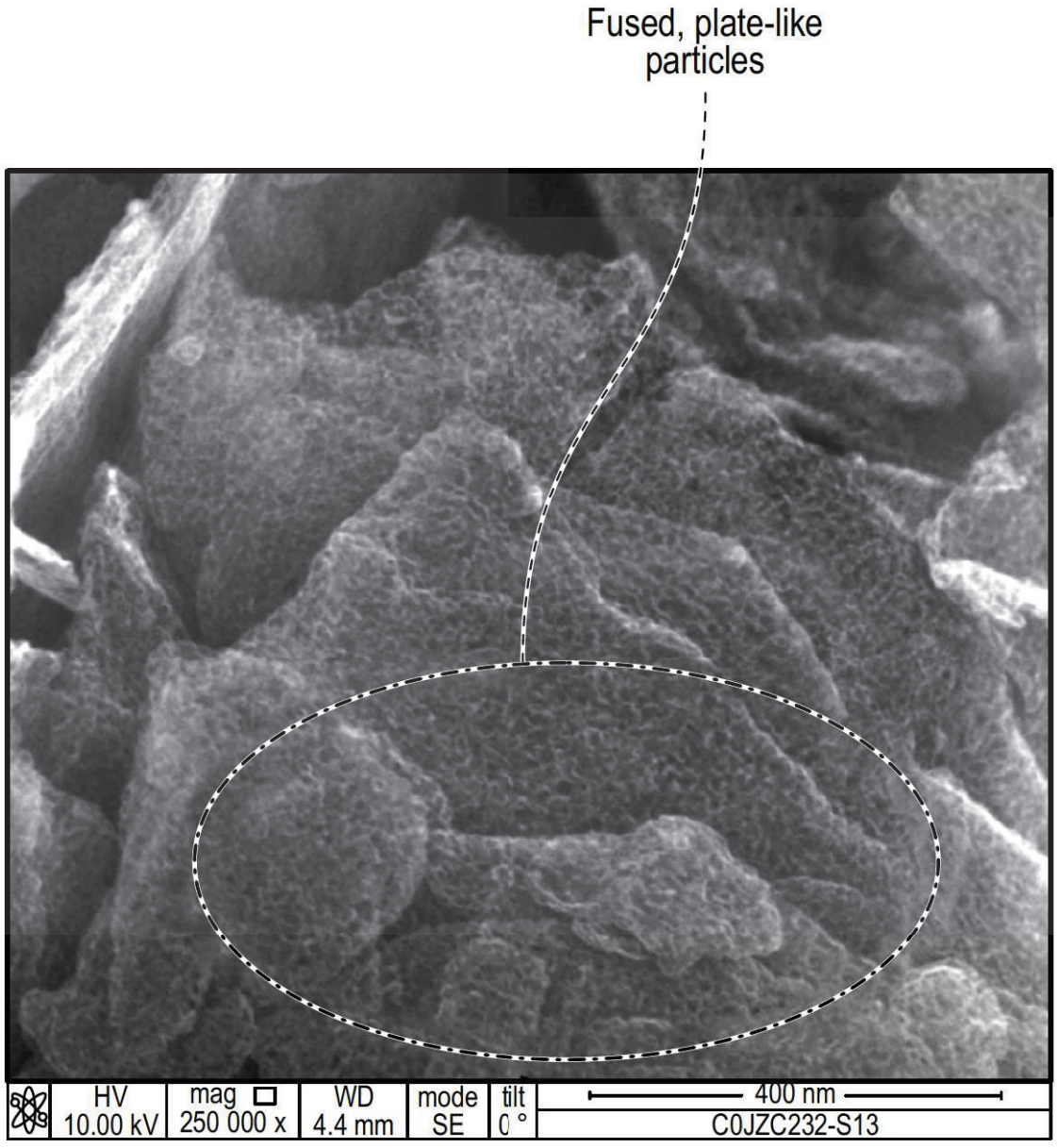

Fused, plate-like particles
HV
10.00 kV
mag
250 000 x
WD
4.4 mm
mode
SE
tilt
0 °
400 nm
C0JZC232-S13

FIG. 50F

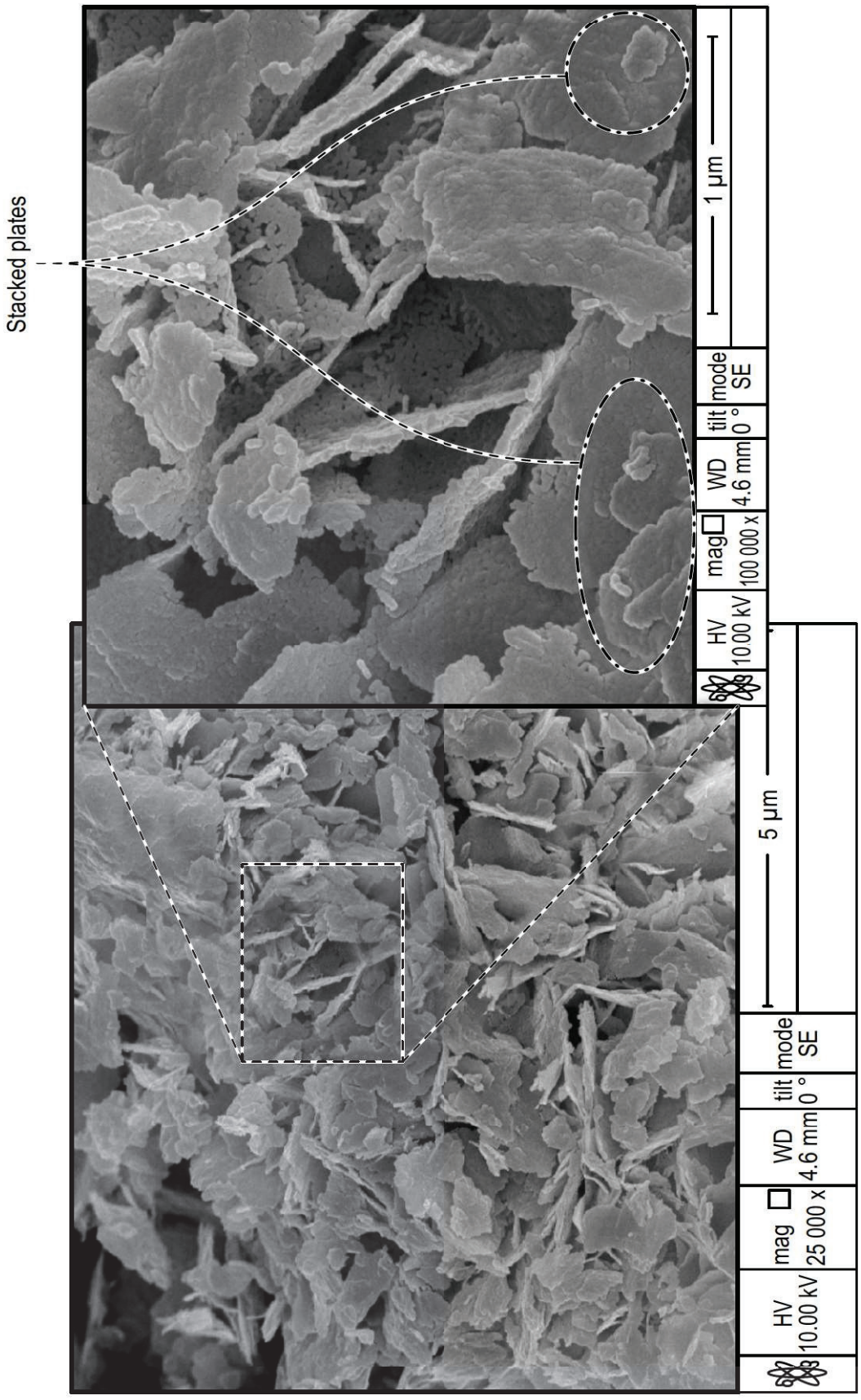

Stacked plates
HV 10.00 kV
mag 25 000 x
WD 4.6 mm
tilt 0 °
mode SE
5 µm
HV 10.00 kV
mag 100 000 x
WD 4.6 mm
tilt 0 °
mode SE
1 µm

FIG. 51

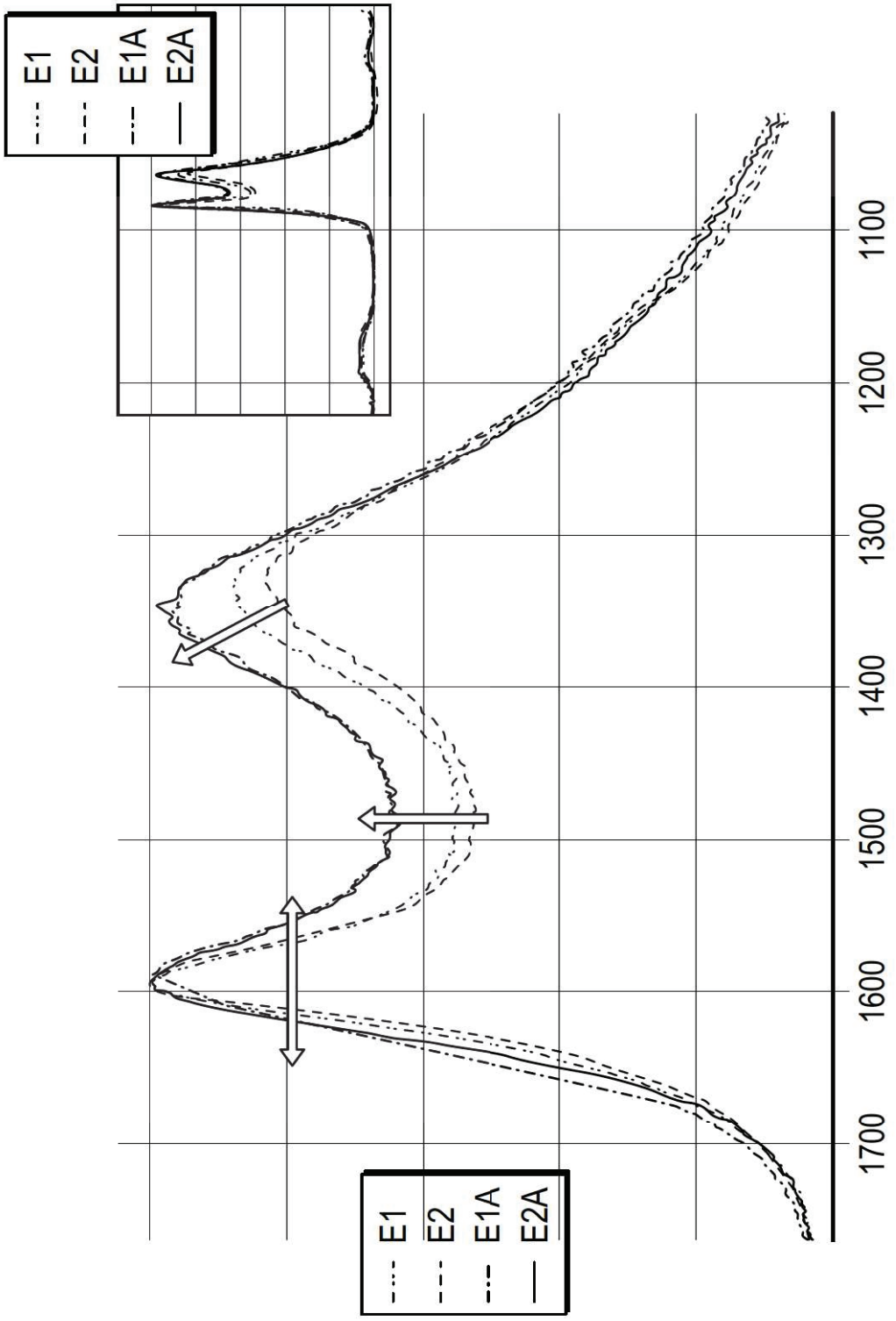


FIG. 52

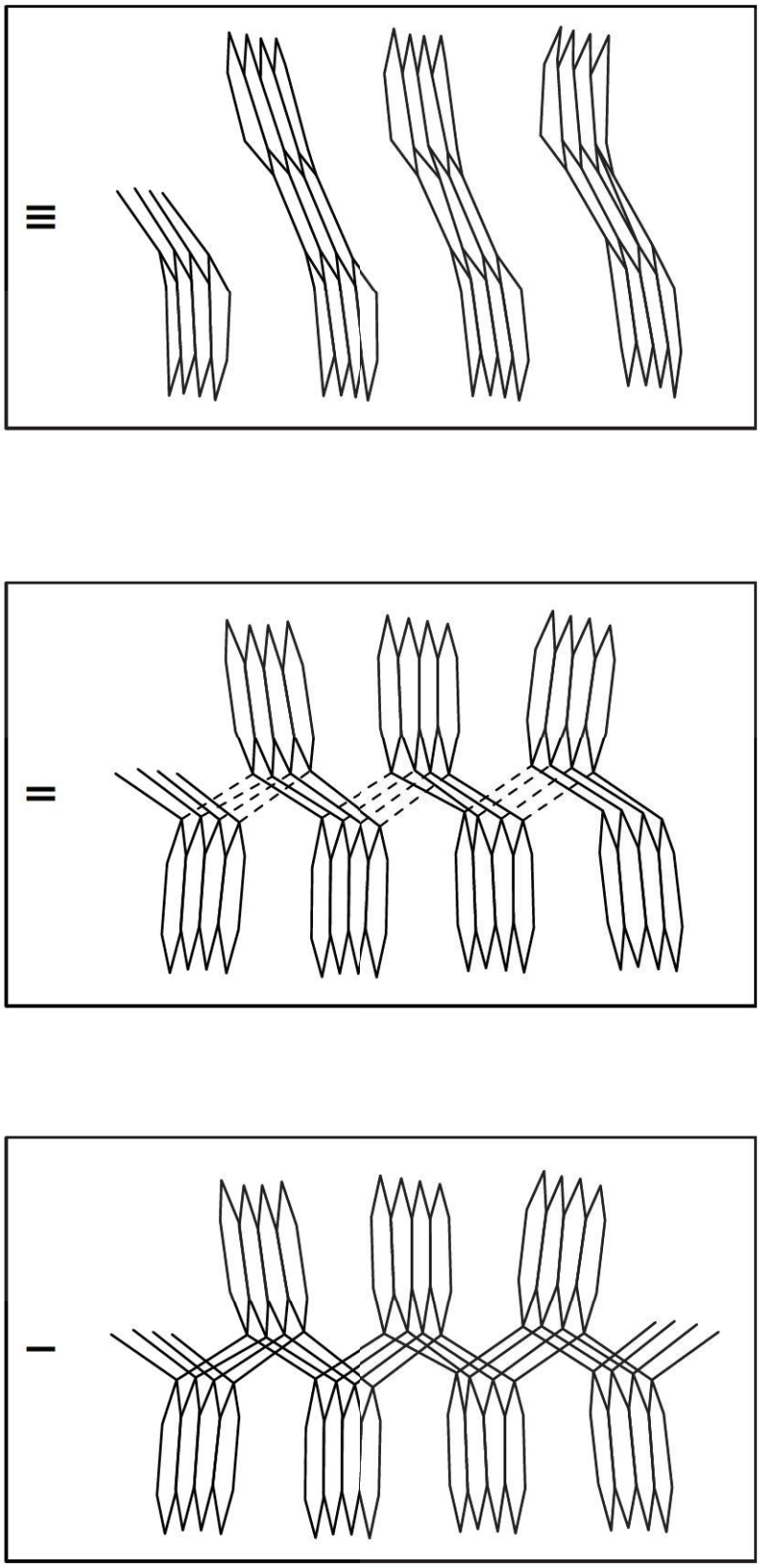


FIG. 53

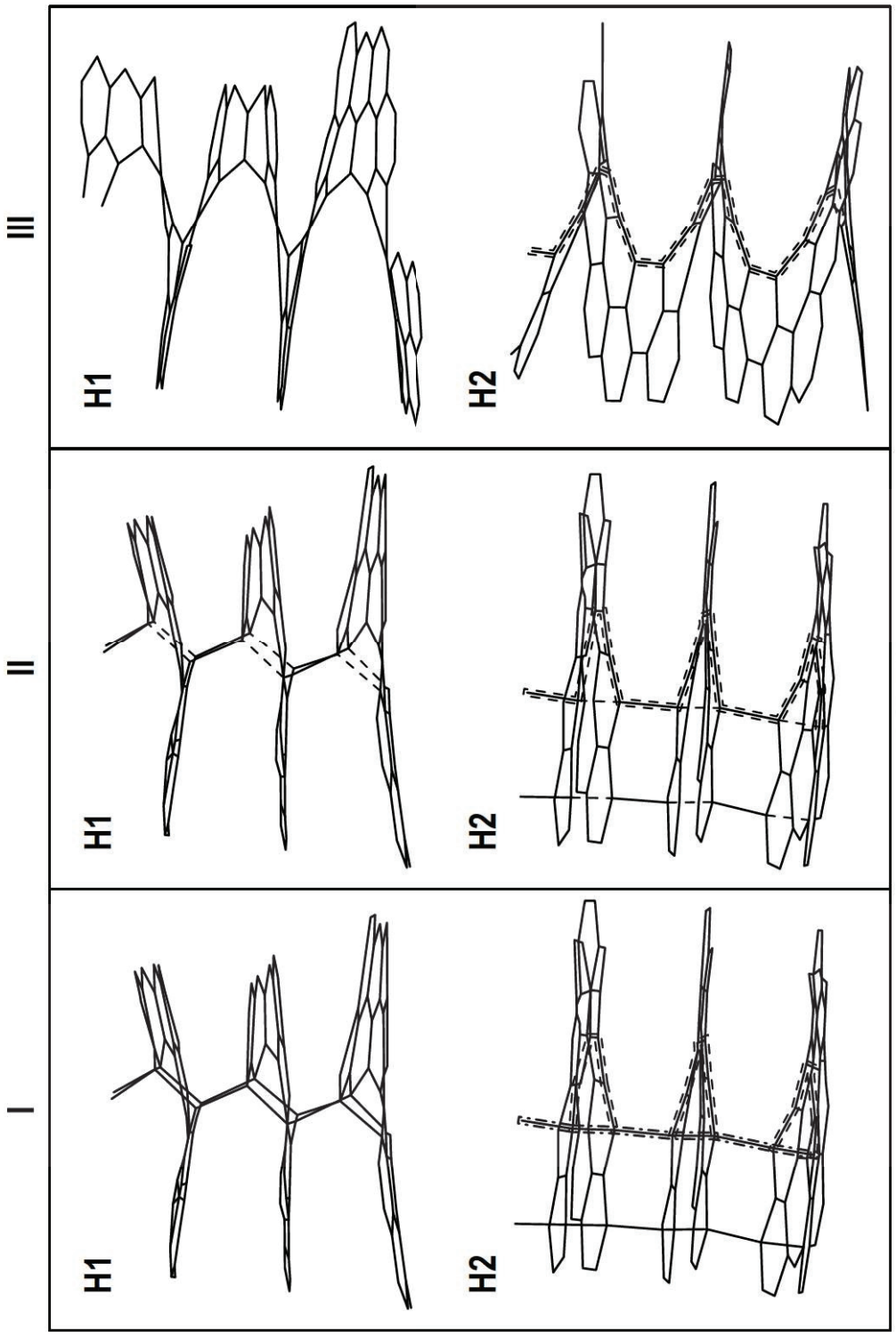


FIG. 54

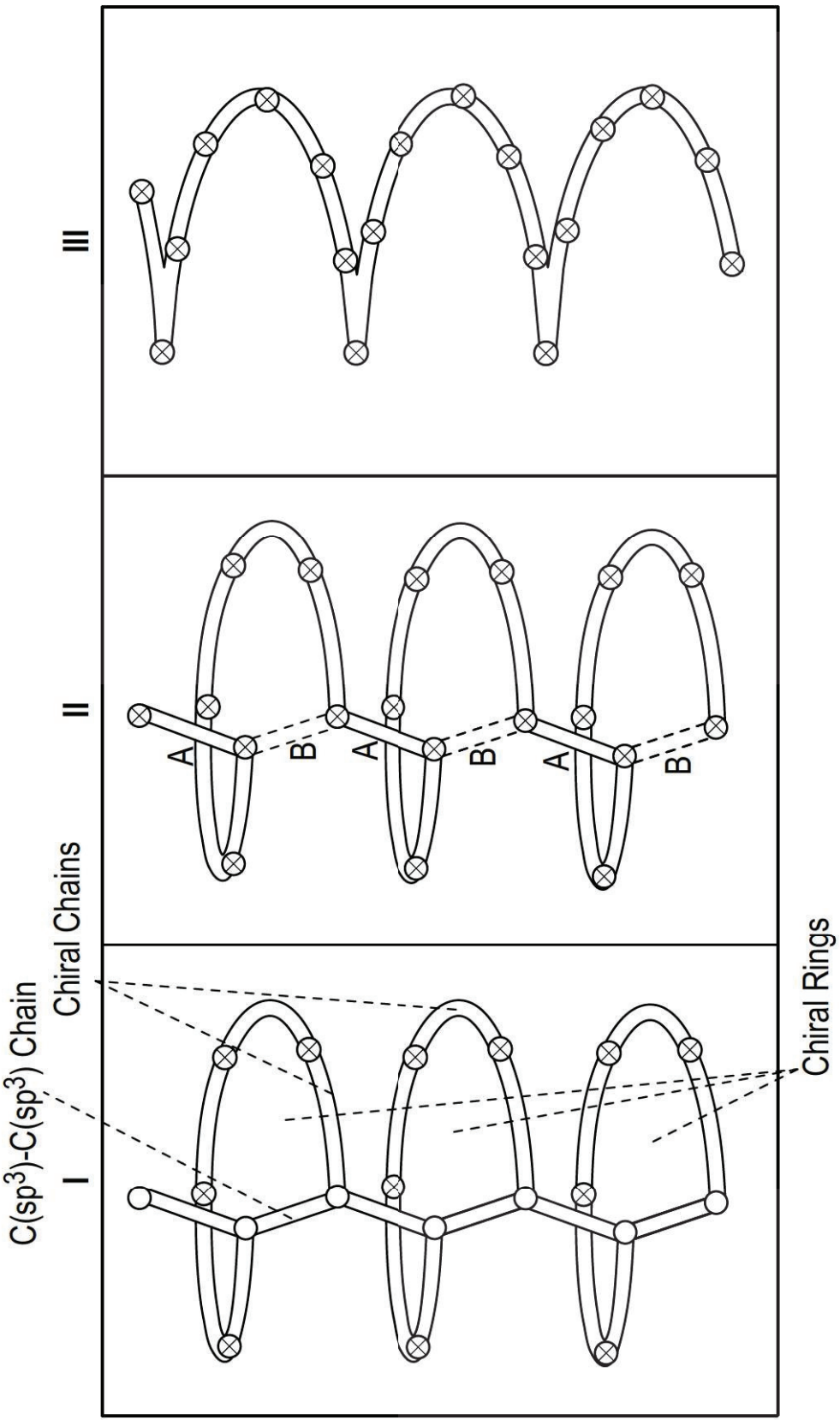


FIG. 55

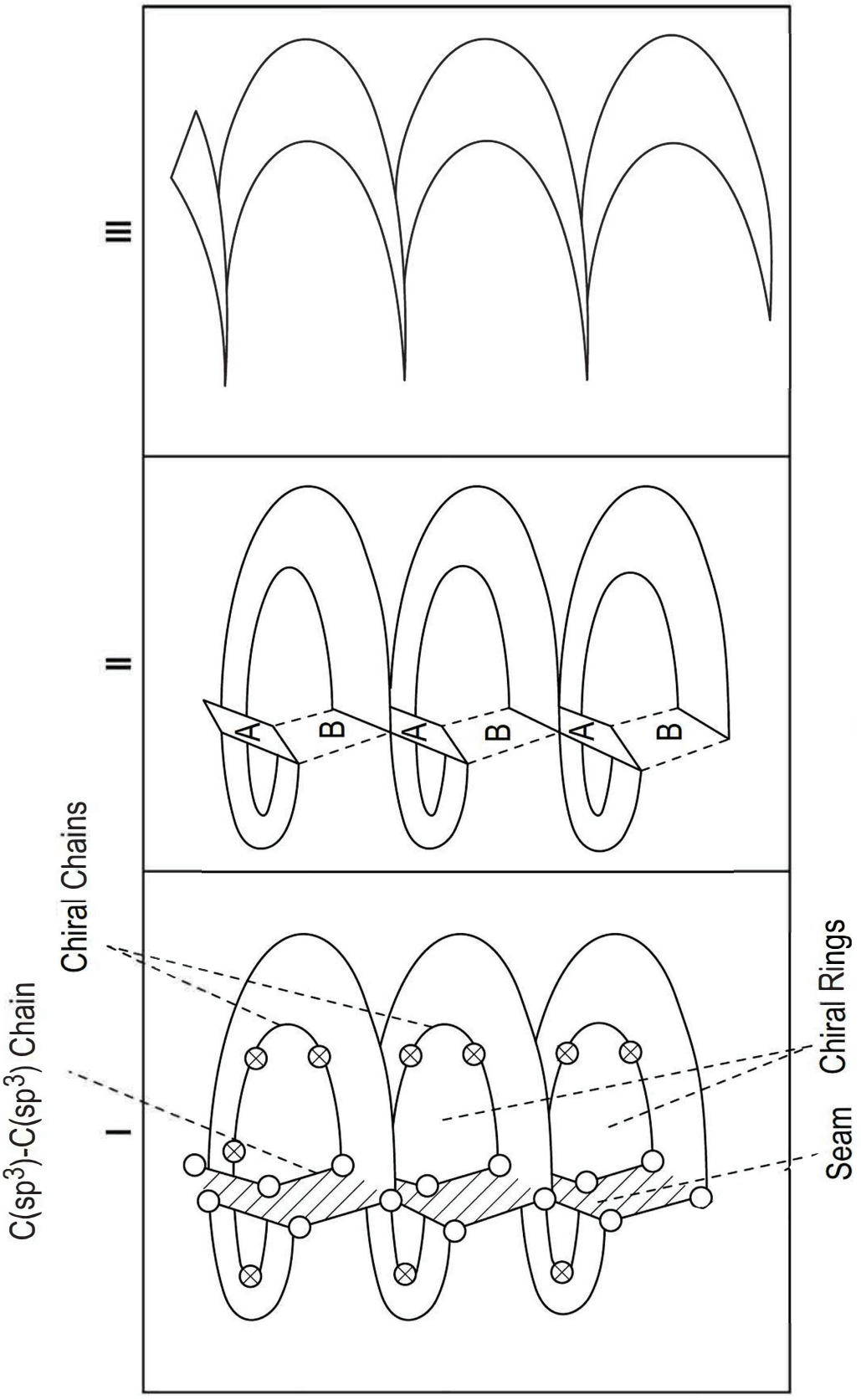

III
II
I
A
B
A
B
A
B
Chiral Chains
C(sp3)-C(sp3) Chain
Seam
Chiral Rings

FIG. 56

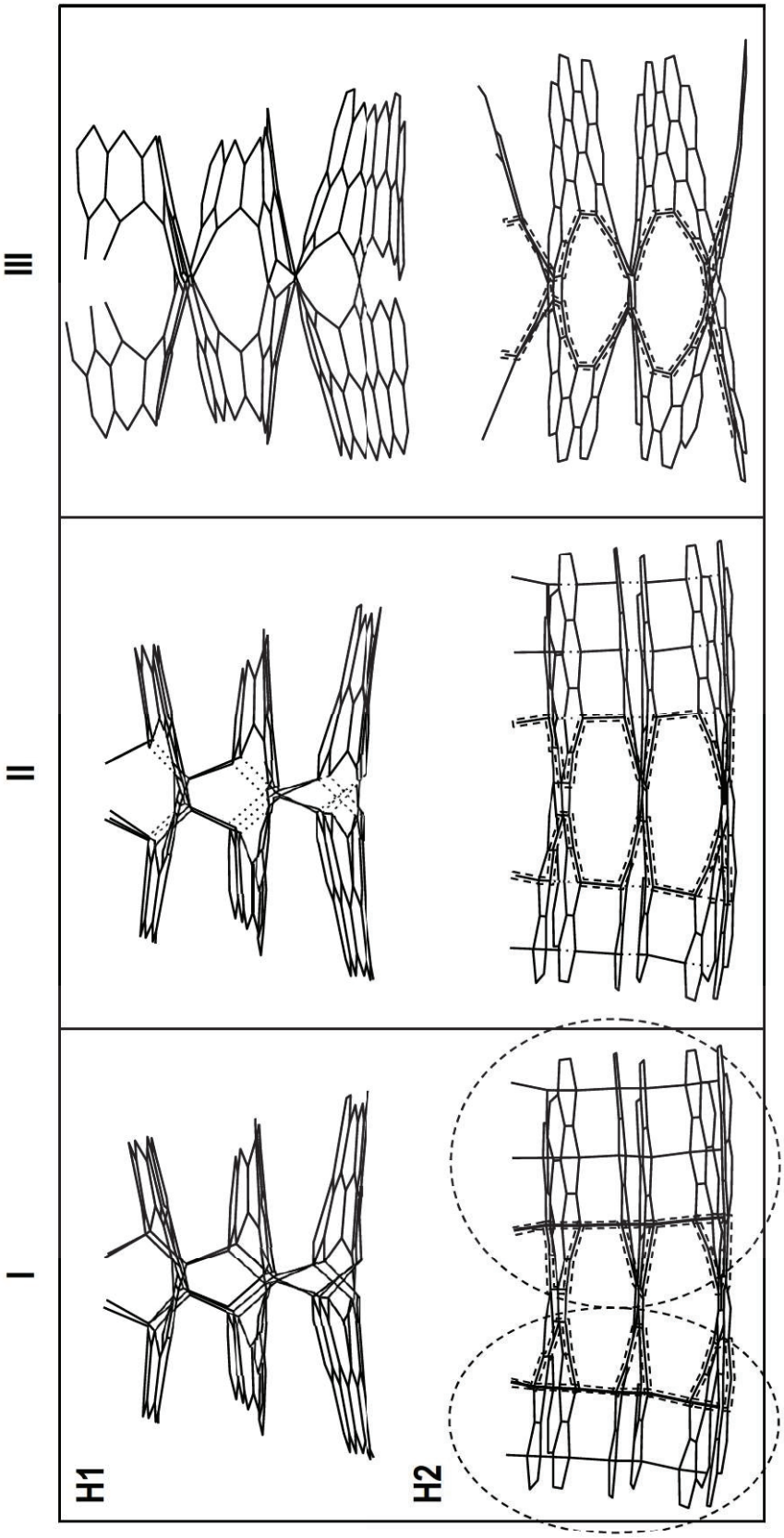


FIG. 57

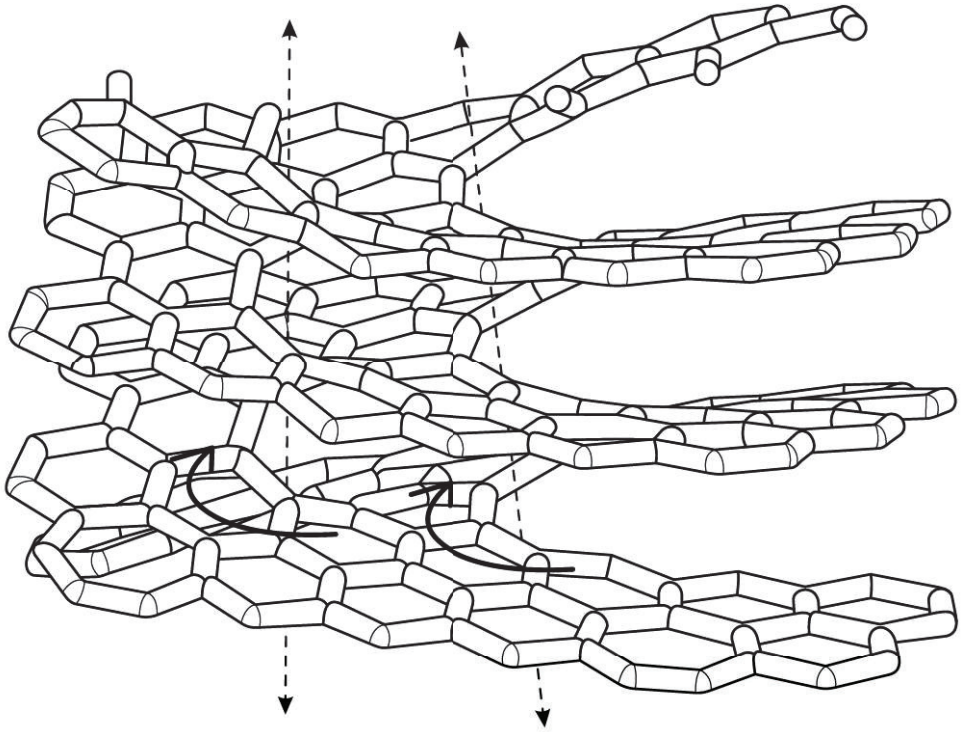


FIG. 58

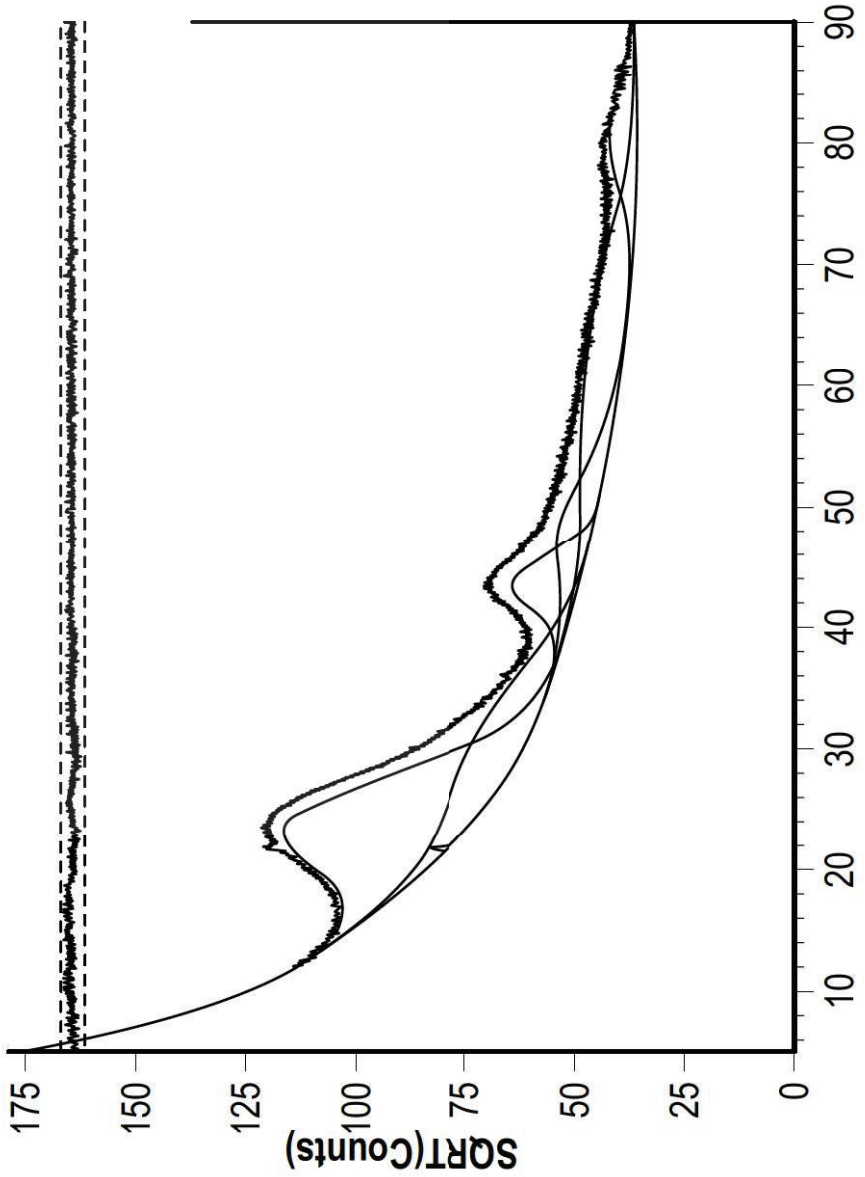

SQRT(Counts)
0
25
50
75
100
125
150
175
10
20
30
40
50
60
70
80
90
Two-Theta (deg)

FIG. 59

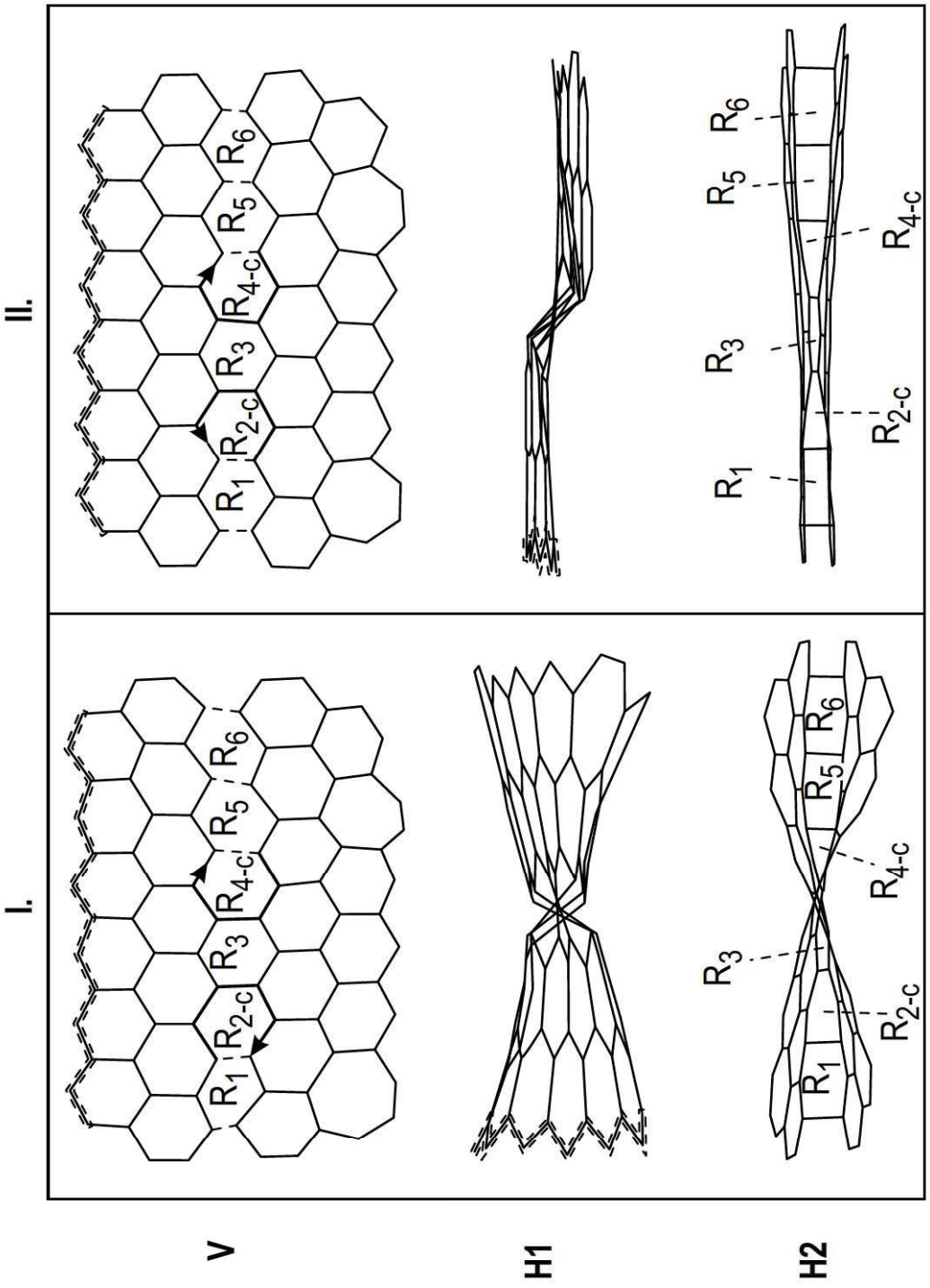


FIG. 60