Fig. 1

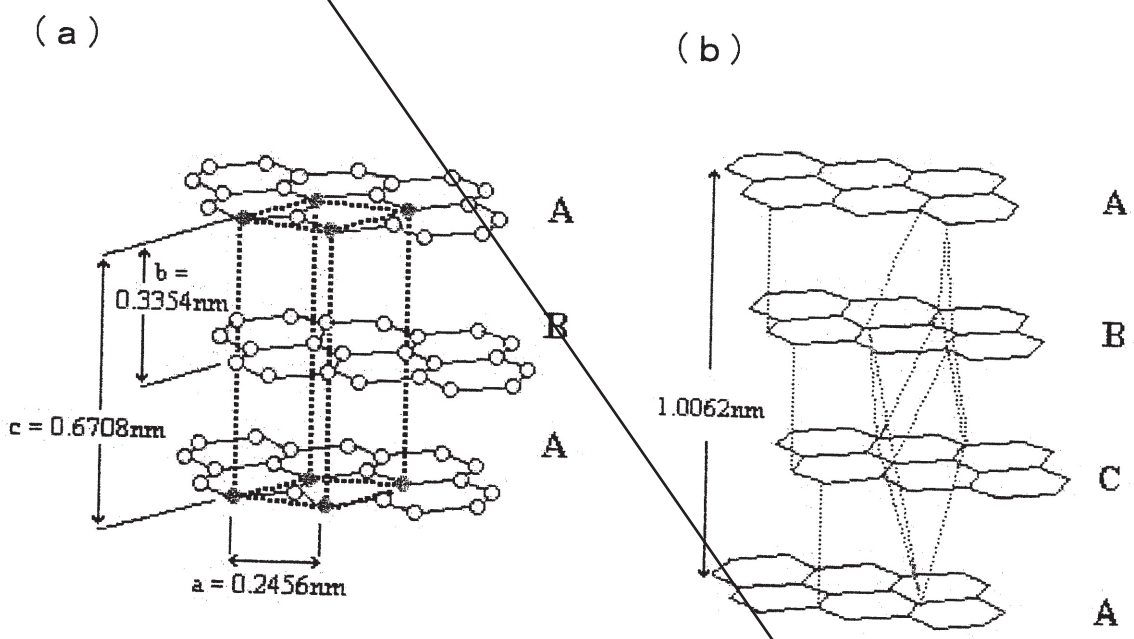


Fig. 2

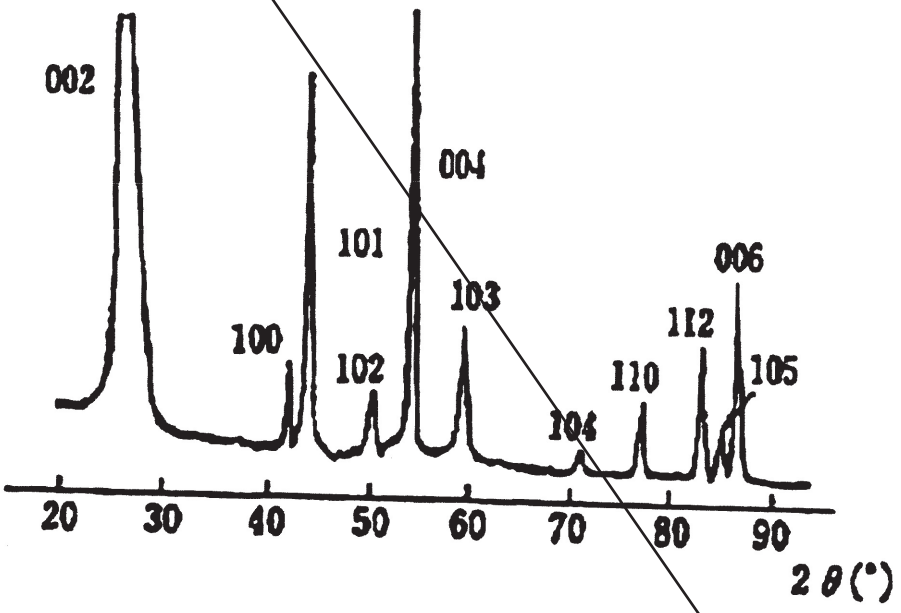

002
100
101
102
004
103
104
110
112
105
006
20
30
40
50
60
70
80
90
2θ(°)

Fig. 3

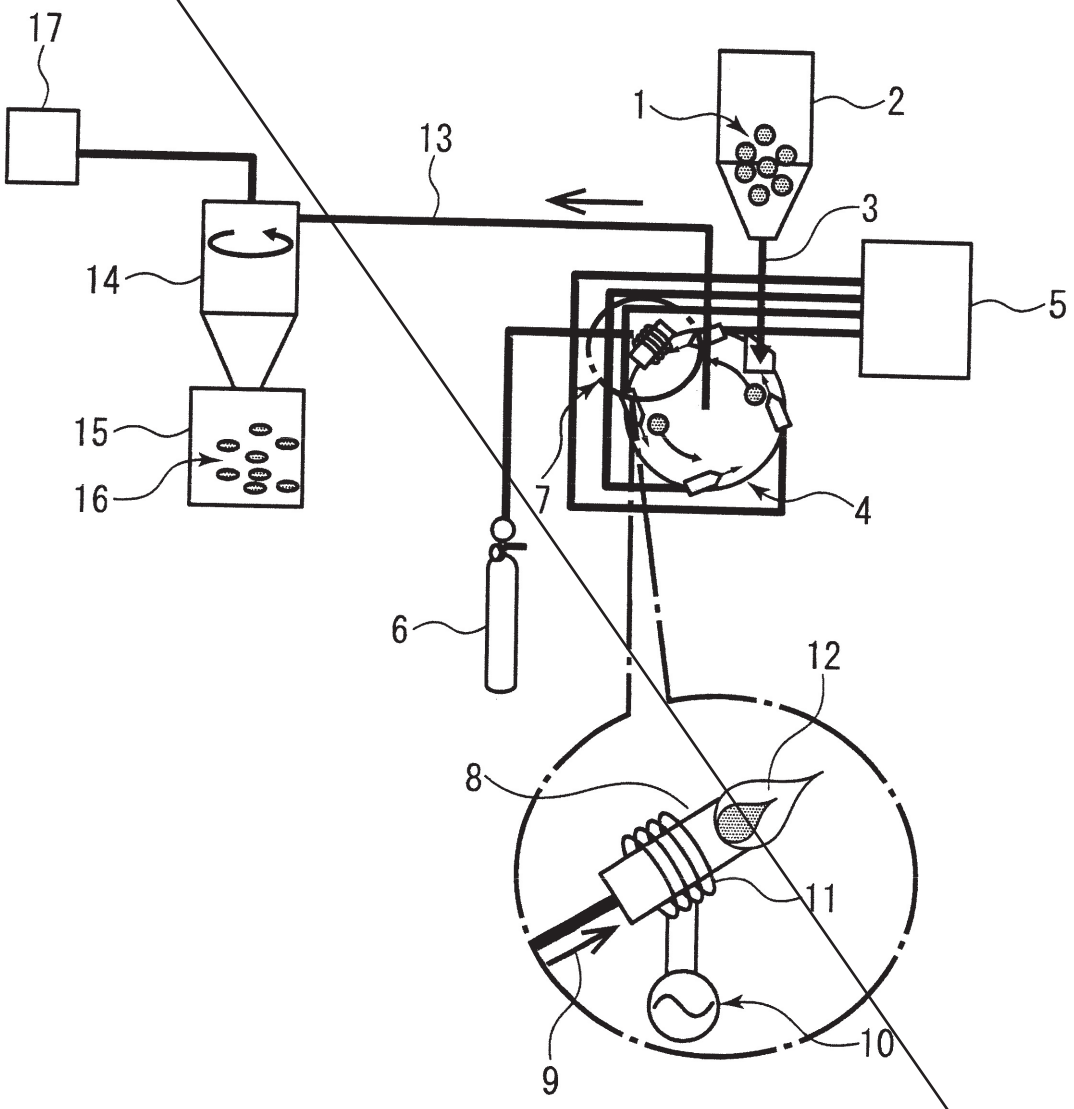
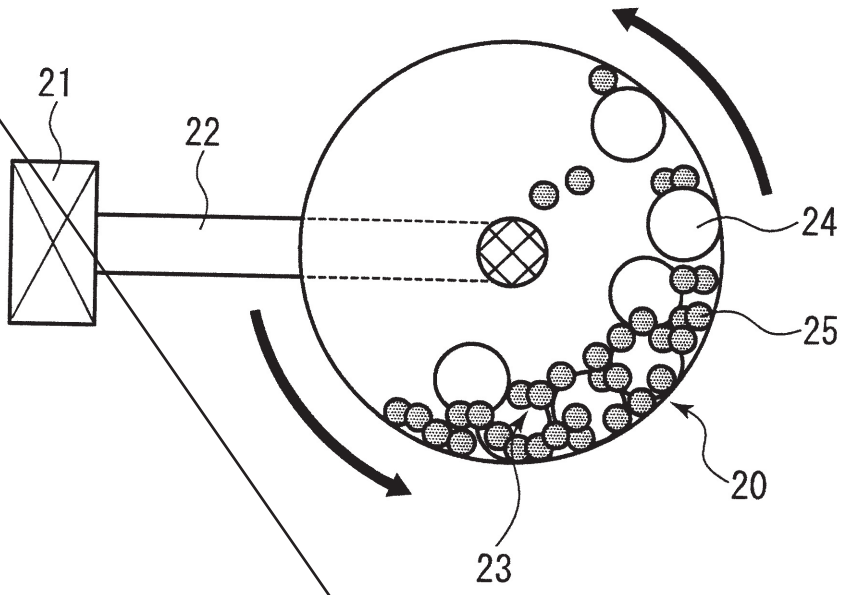


Fig. 4



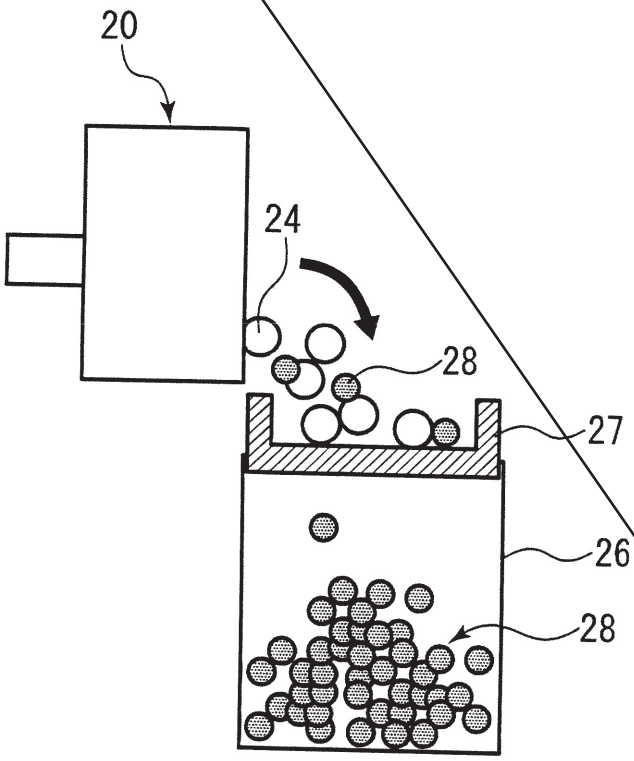


Fig. 5

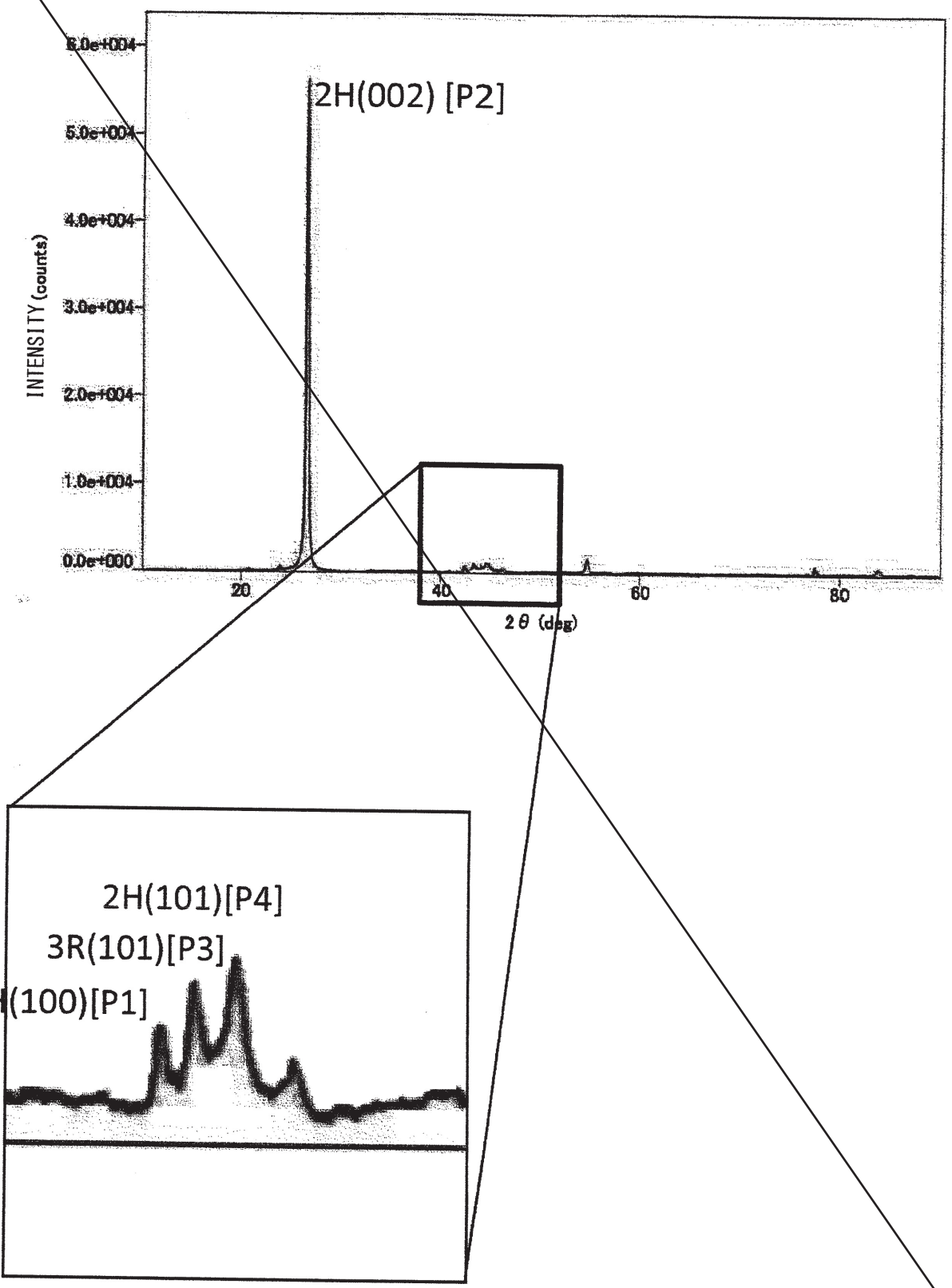

2H(002) [P2]
INTENSITY (counts)
6.0e+004
5.0e+004
4.0e+004
3.0e+004
2.0e+004
1.0e+004
0.0e+000
20
40
60
80
2θ (deg)
2H(101)[P4]
3R(101)[P3]
2H(100)[P1]

Fig. 6

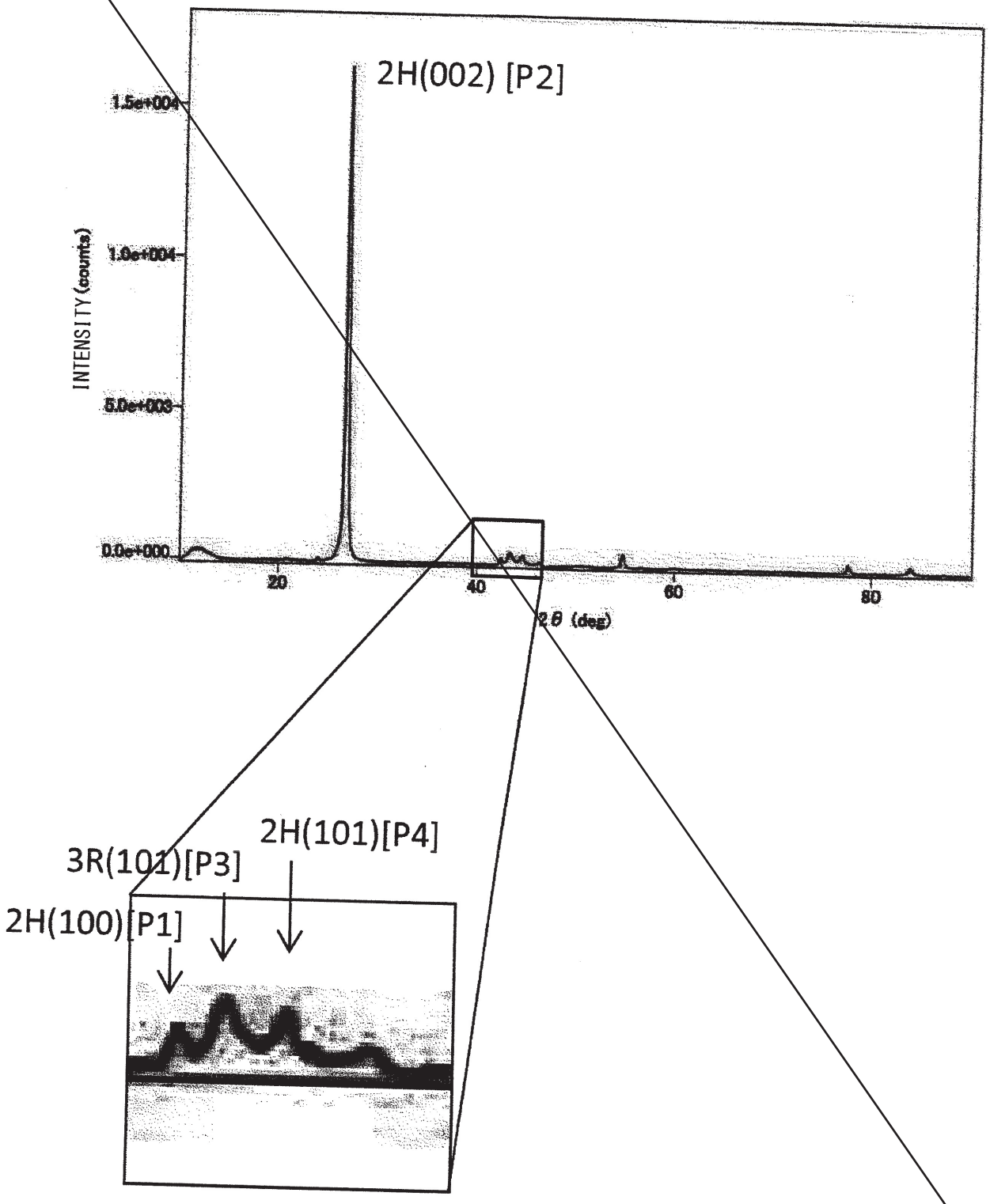

2H(002) [P2]
1.5e+004
1.0e+004
5.0e+003
0.0e+000
INTENSITY (counts)
20
40
60
80
2θ (deg)
2H(101)[P4]
3R(101)[P3]
2H(100)[P1]

Fig. 7

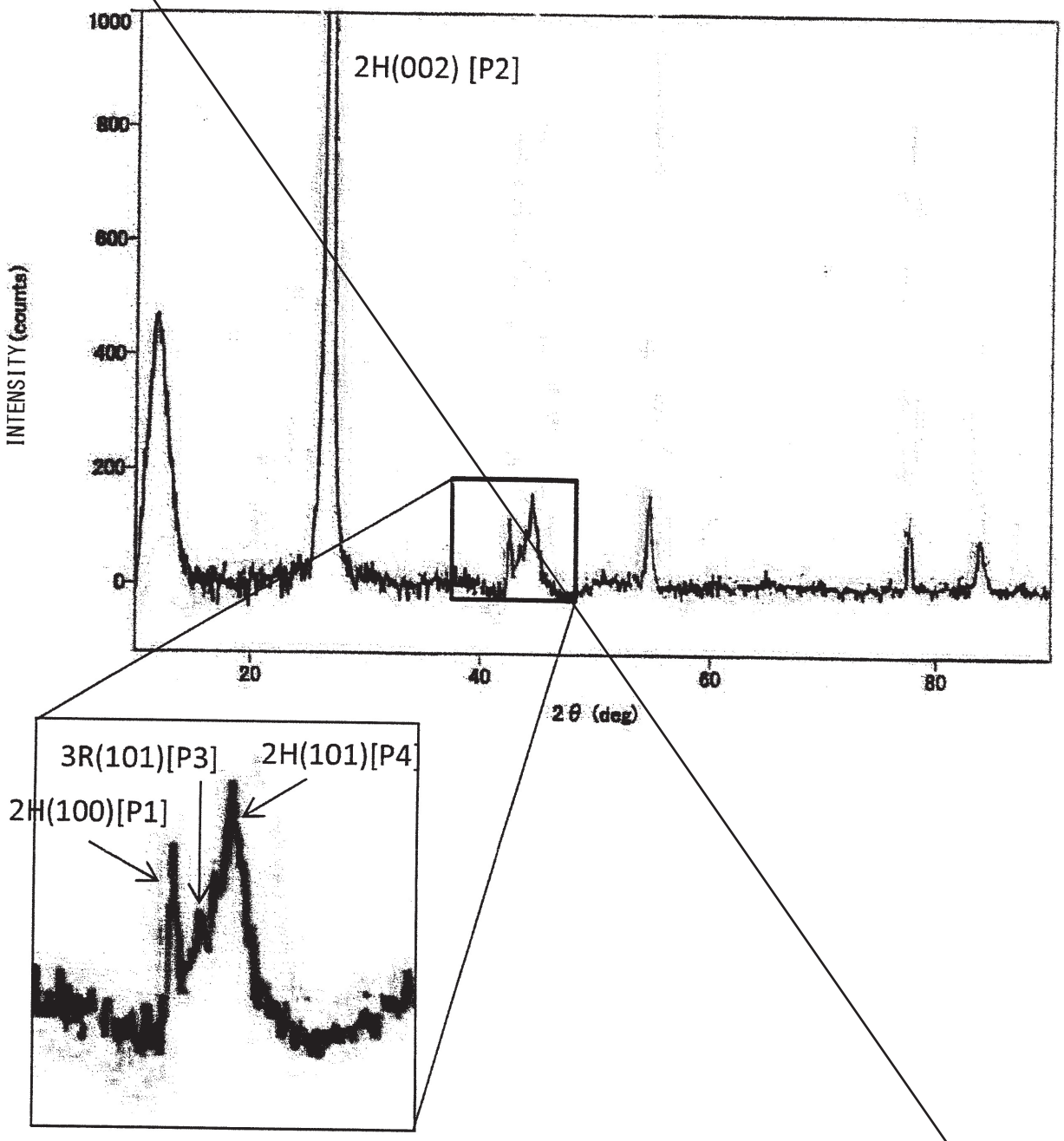

1000
800
600
400
200
0
INTENSITY (counts)
2H(002) [P2]
20
40
60
80
2θ (deg)
3R(101)[P3]
2H(101)[P4]
2H(100)[P1]

Fig. 8

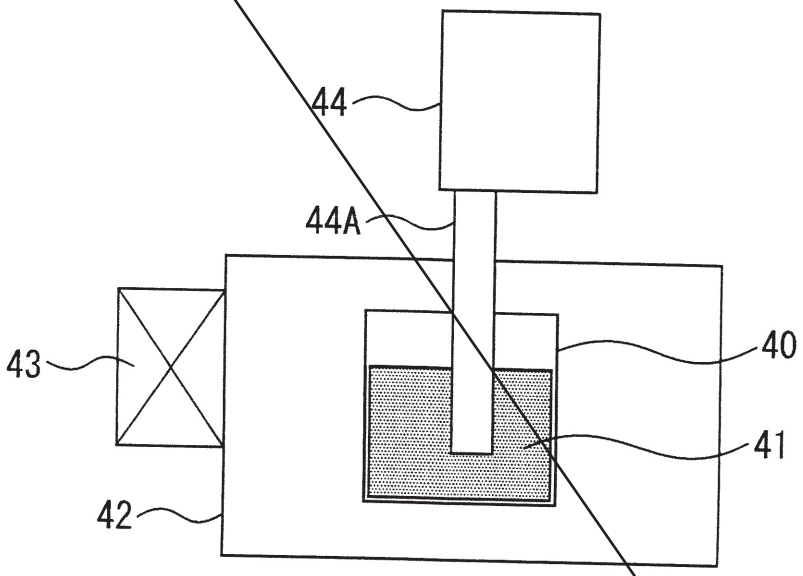
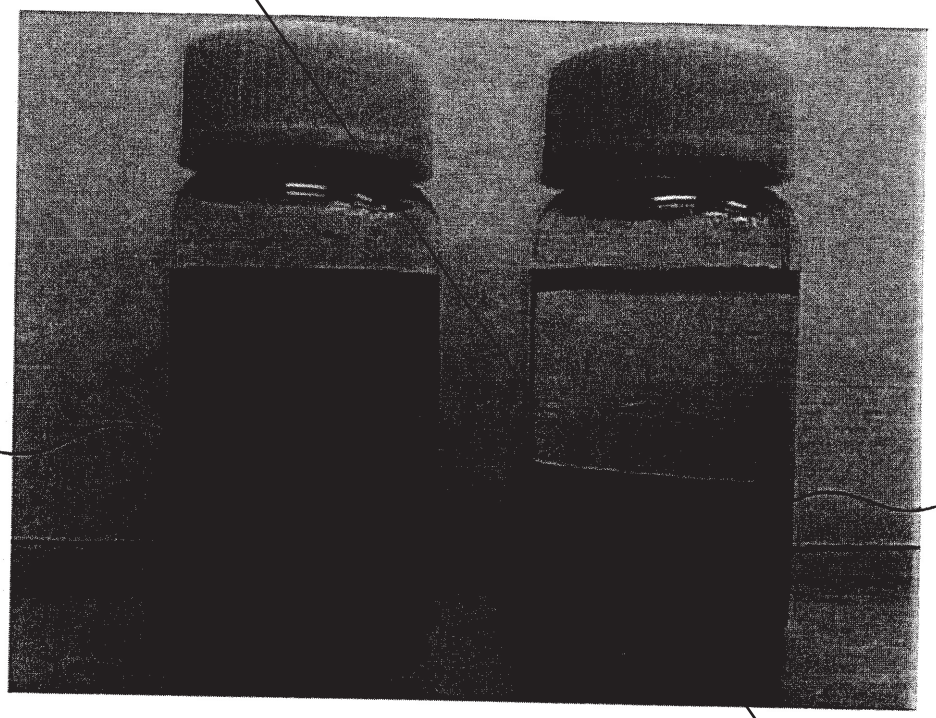


Fig. 9



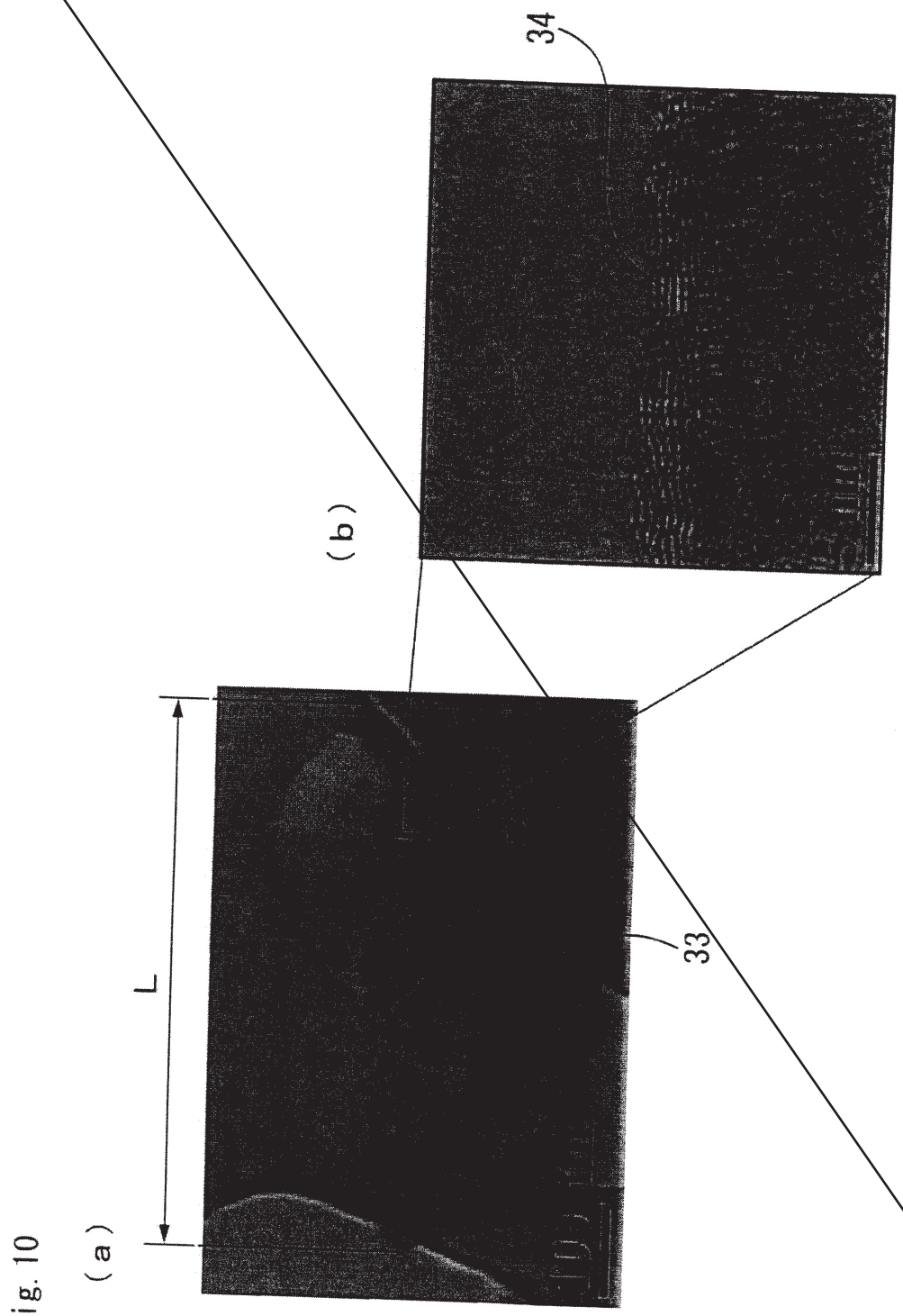
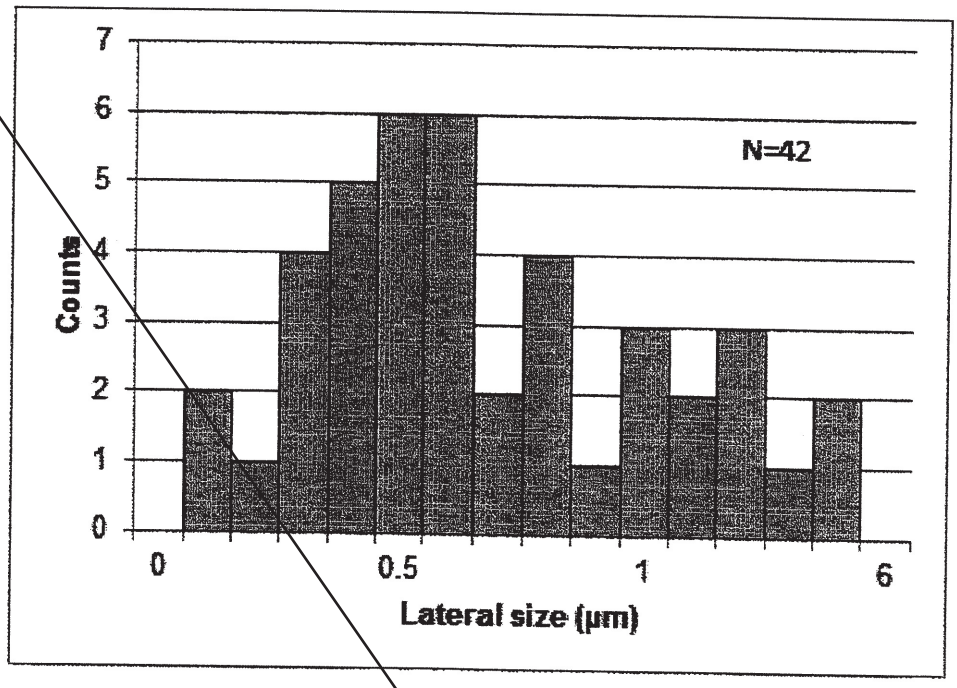


Fig. 10

Fig. 11

(a)


N=42
Counts
Lateral size (μm)
0
1
2
3
4
5
6
7
0
0.5
1
6

(b)

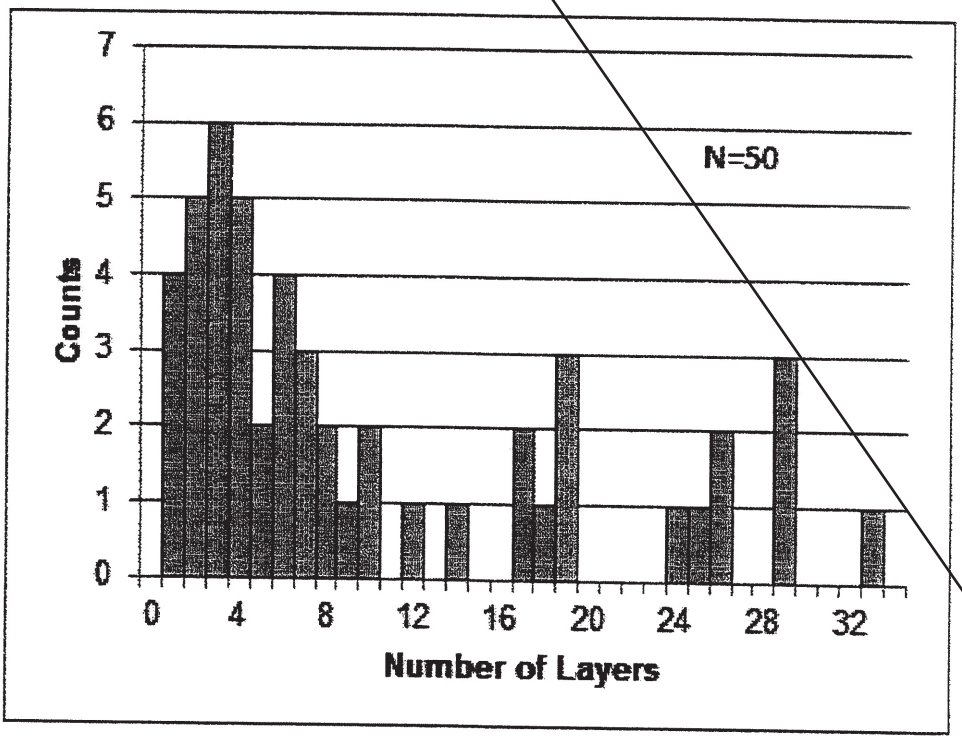
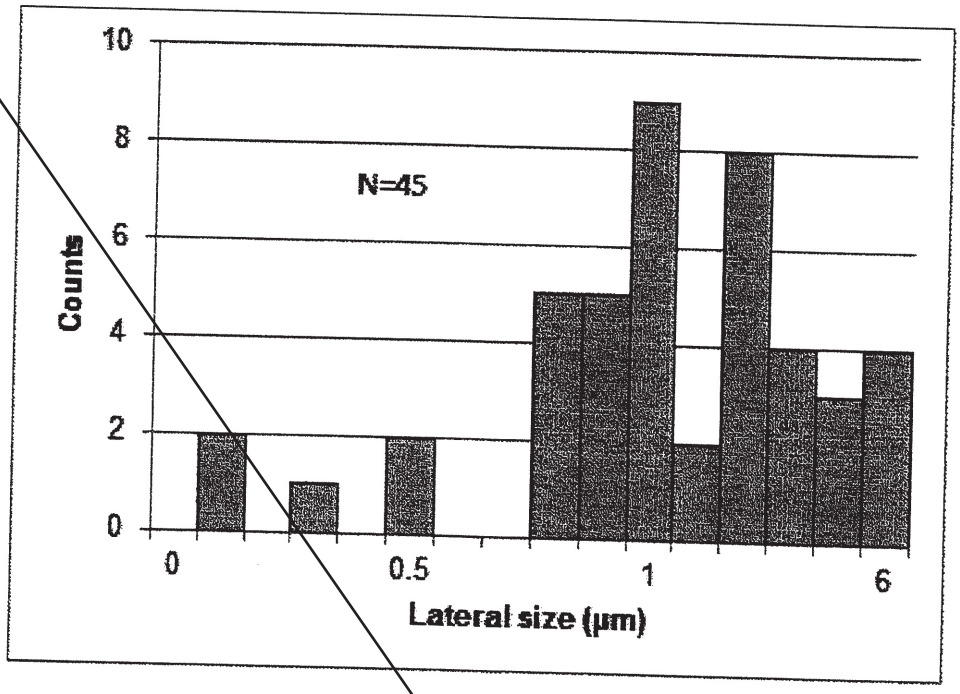

N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

Fig. 12

(a)


10
8
6
4
2
0
Counts
N=45
0
0.5
1
6
Lateral size (μm)

(b)

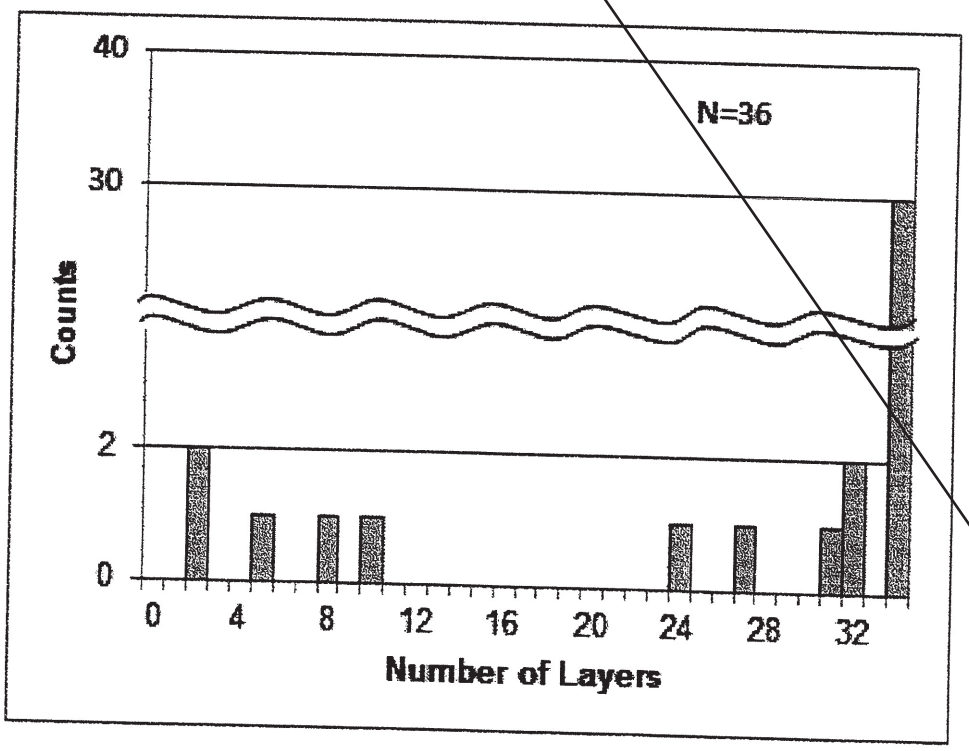
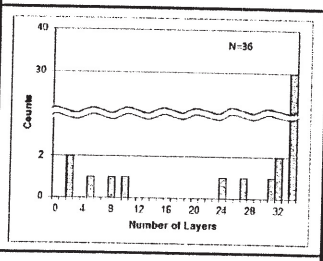
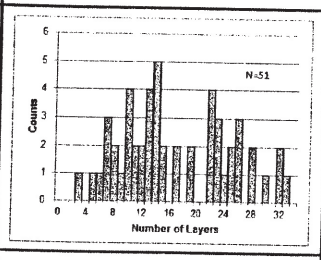
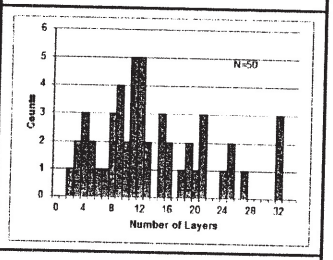

40
30
2
0
Counts
N=36
0
4
8
12
16
20
24
28
32
Number of Layers

Fig. 13

SAMPLE No.	1	2	3
DISTRIBUTION OF LAYERS			
P3/(P3+P4)	23%	31%	38%
TEN LAYERS OR LESS	10%	25%	38%
P1/P2	0.008	0.016	0.016
P1	120	342	128
P2	15000	20993	8253
P3	50	321	173
P4	160	698	282

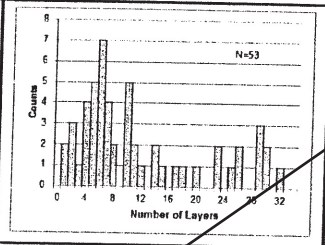
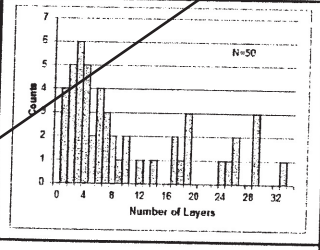
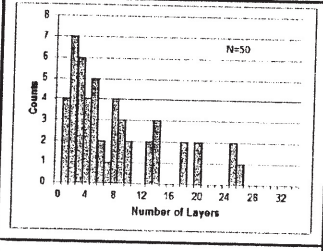
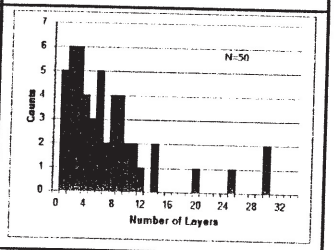
SAMPLE No.	4	5	6	7
DISTRIBUTION OF LAYERS				
P3/(P3+P4)	42%	46%	51%	58%
TEN LAYERS OR LESS	62%	68%	76%	82%
P1/P2	0.014	0.012	0.014	0.012
P1	253	162	66	151
P2	18226	13157	4675	12850
P3	320	396	170	452
P4	435	466	162	325

Fig. 14

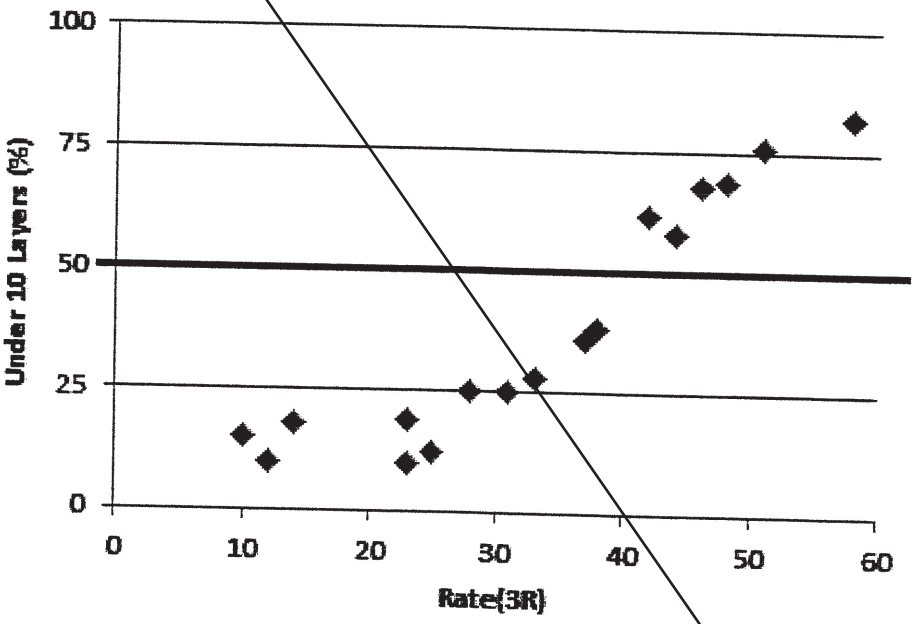
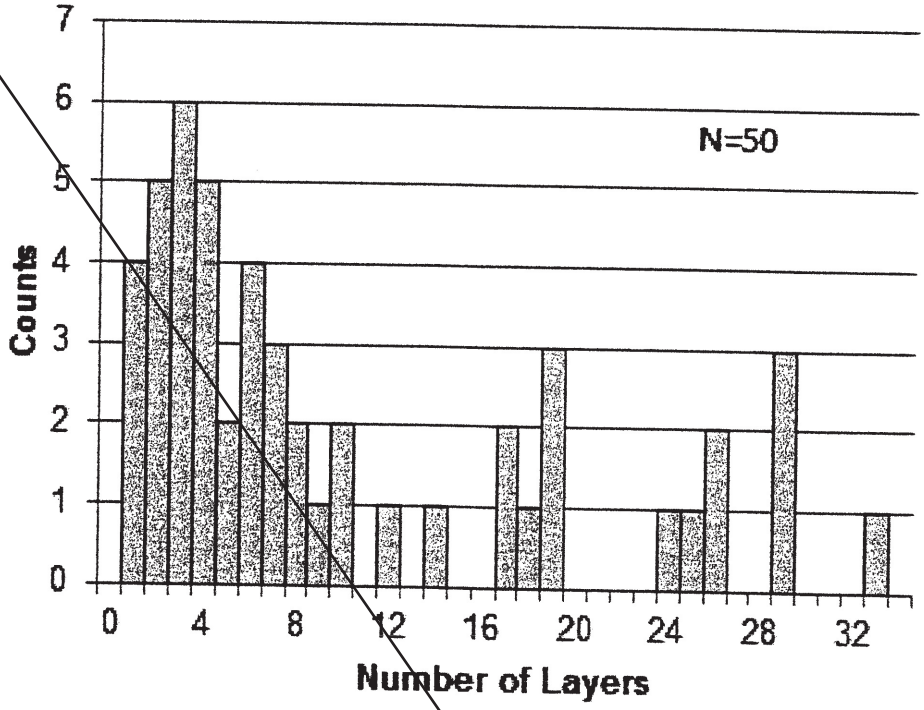


Fig. 15

(a)


N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

(b)

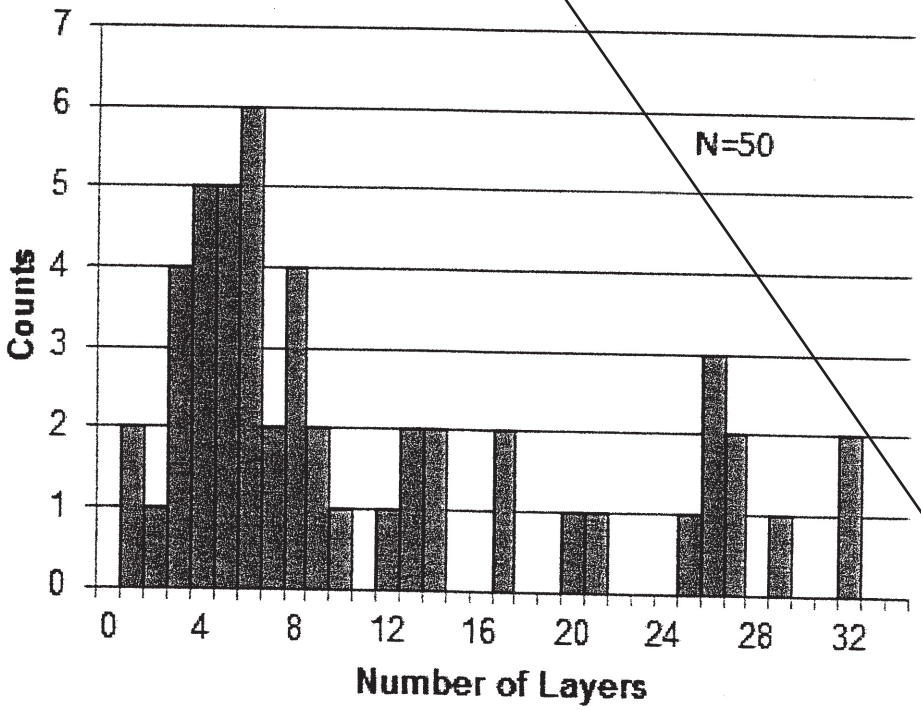

N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

Fig. 16

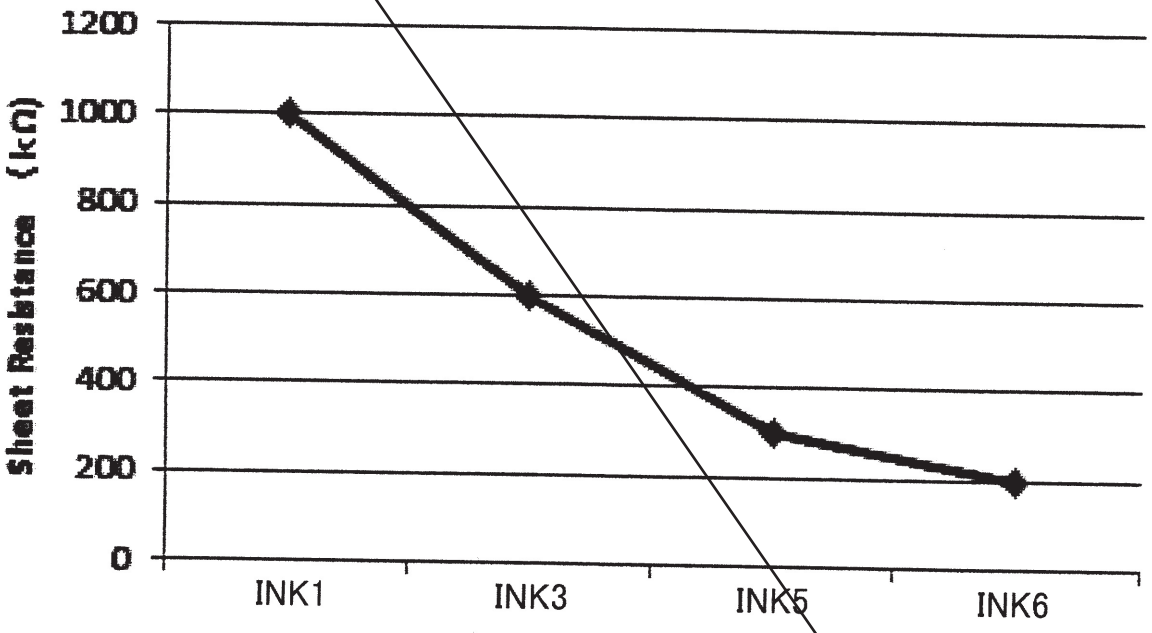

Sheet Resistance (kΩ)
1200
1000
800
600
400
200
0
INK1
INK3
INK5
INK6

Fig. 17

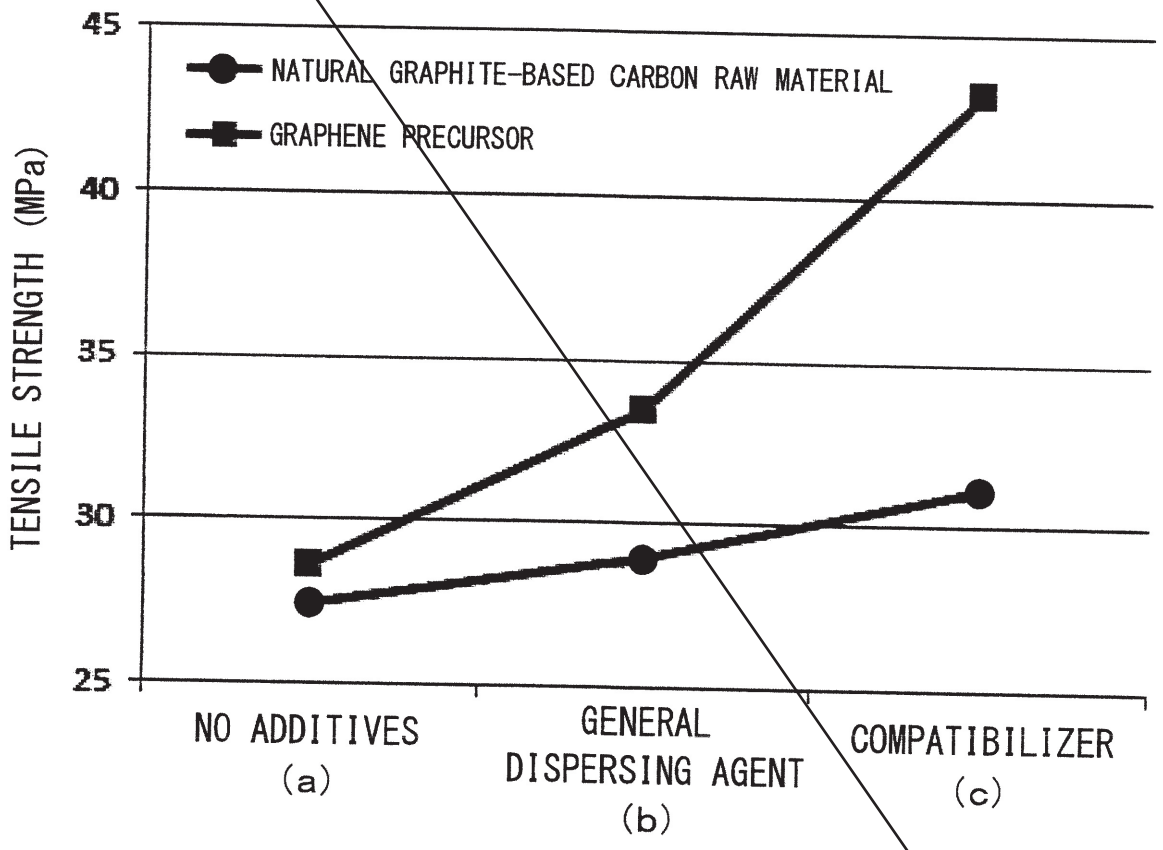

45
40
35
30
25
TENSILE STRENGTH (MPa)
NATURAL GRAPHITE-BASED CARBON RAW MATERIAL
GRAPHENE PRECURSOR
NO ADDITIVES
(a)
GENERAL
DISPERSING AGENT
(b)
COMPATIBILIZER
(c)

Fig. 18

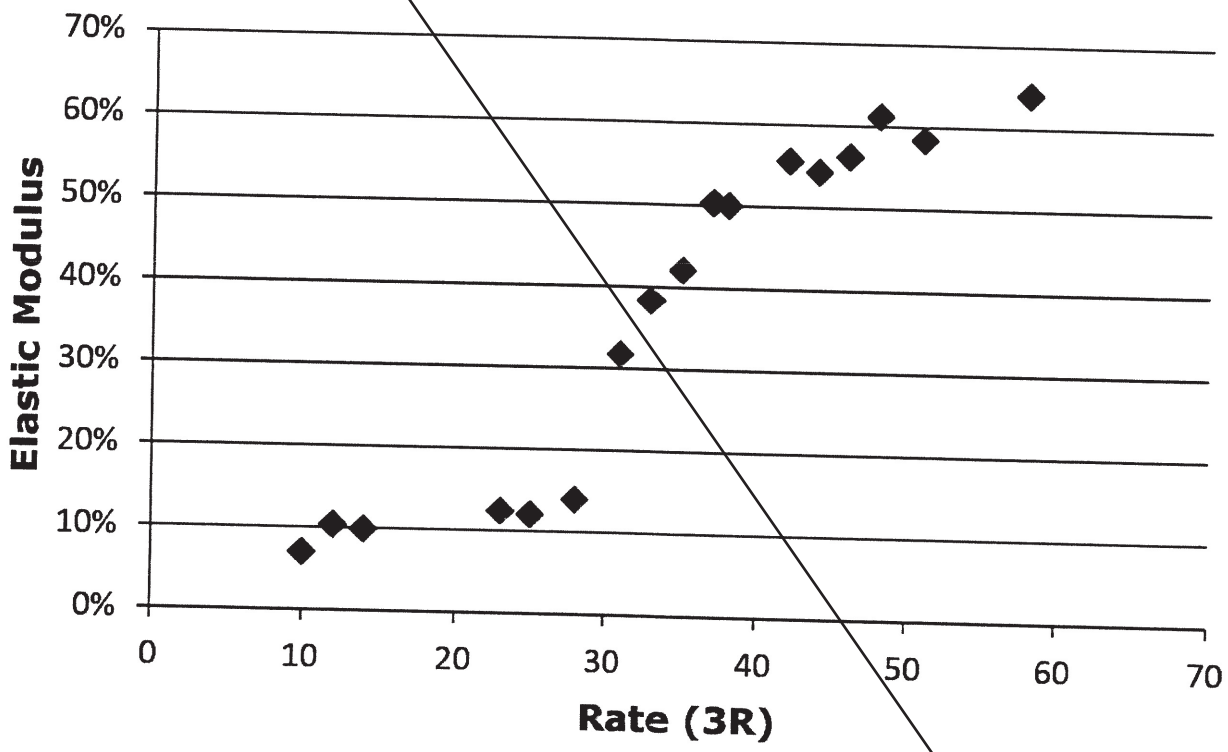
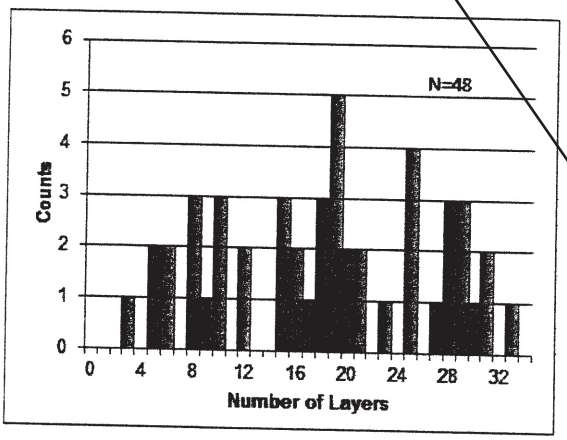

70%
60%
50%
40%
30%
20%
10%
0%
Elastic Modulus
0
10
20
30
40
50
60
70
Rate (3R)

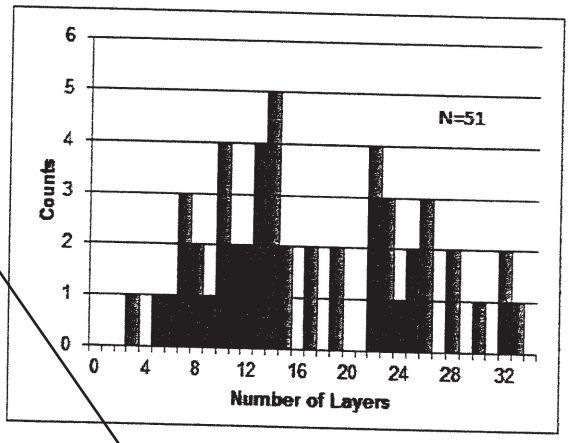
Fig. 19

(a)



P3/(P3+P4)=28%
TEN LAYERS OR LESS: 25%

(b)



P3/(P3+P4)=31%
TEN LAYERS OR LESS: 25%

Fig. 20

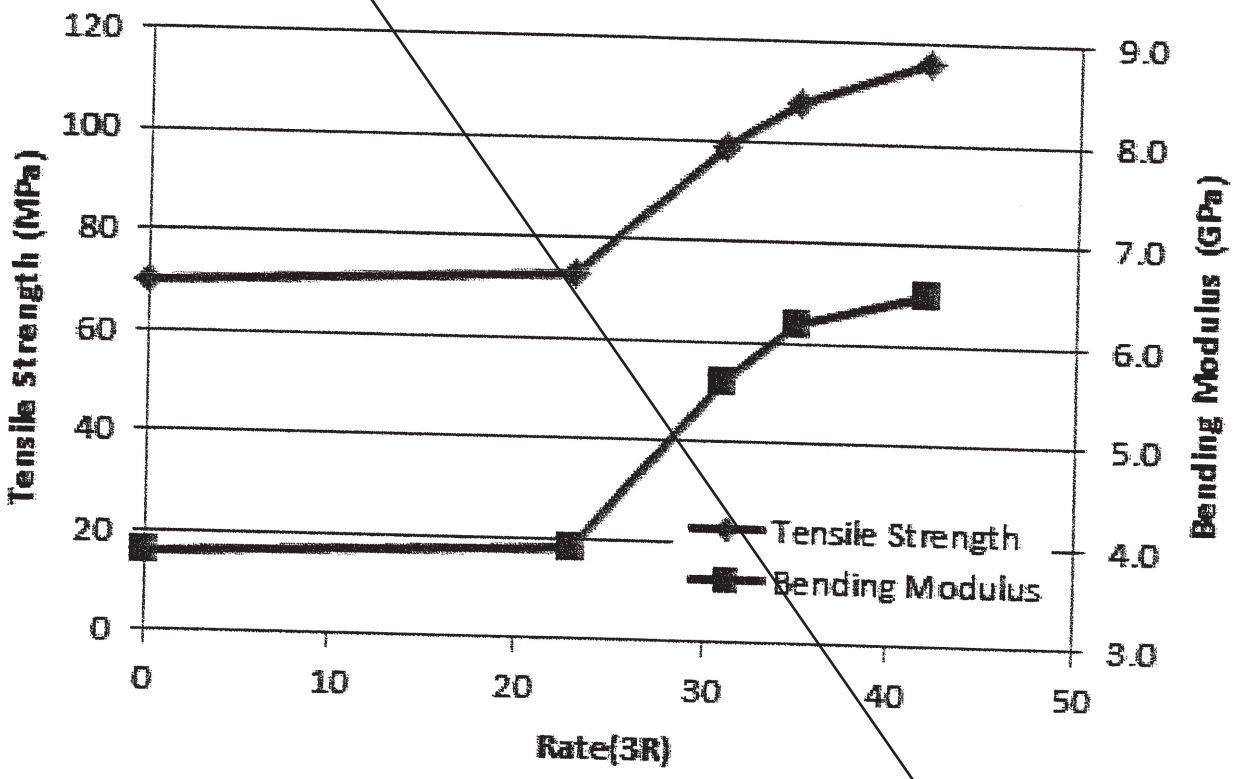

120
100
80
60
40
20
0
Tensile Strength (MPa)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
Bending Modulus (GPa)
0
10
20
30
40
50
Rate(3R)
Tensile Strength
Bending Modulus

Fig. 21

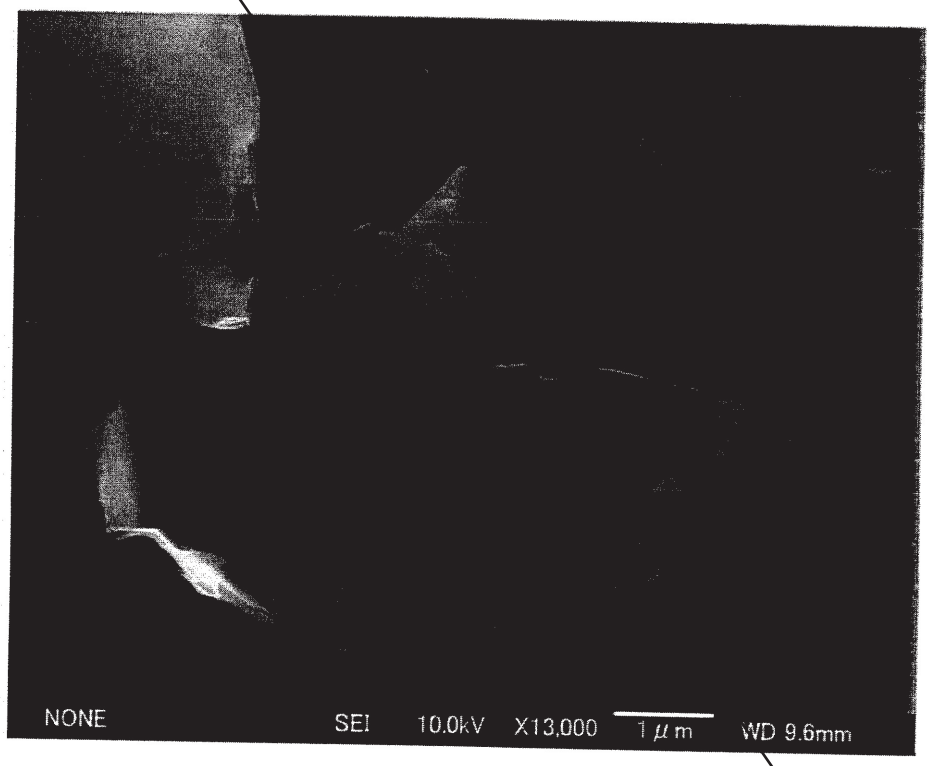


Fig. 22

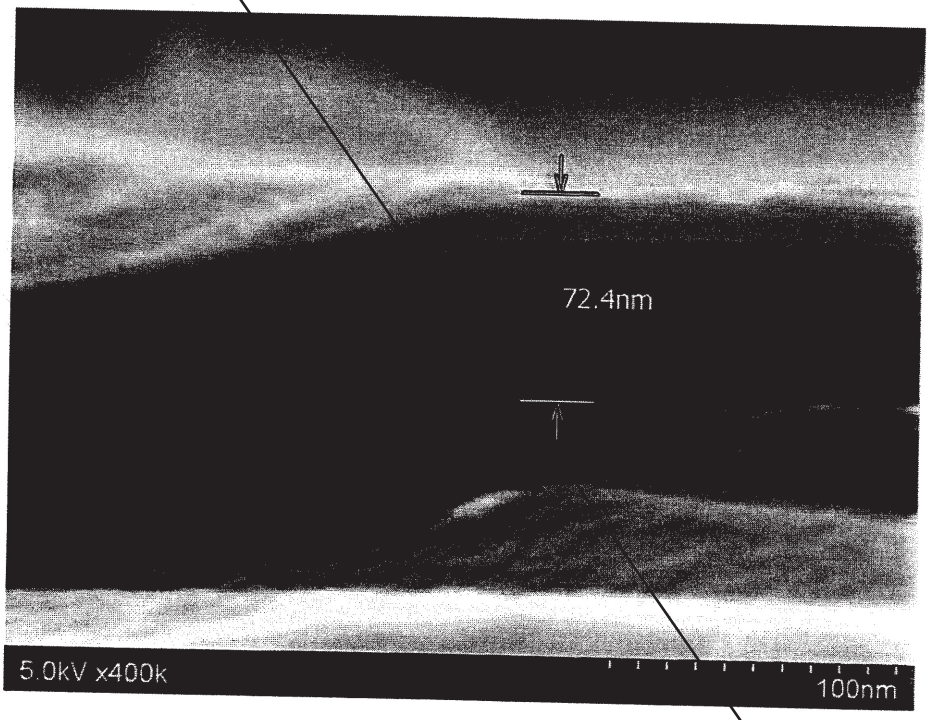


Fig. 23

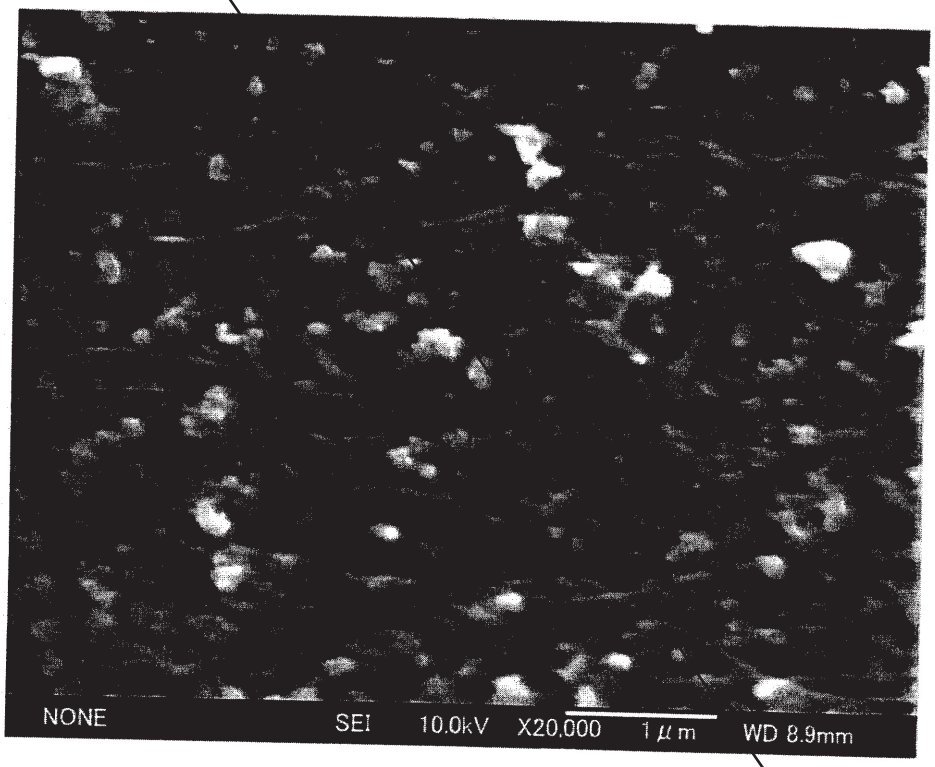


Fig. 24

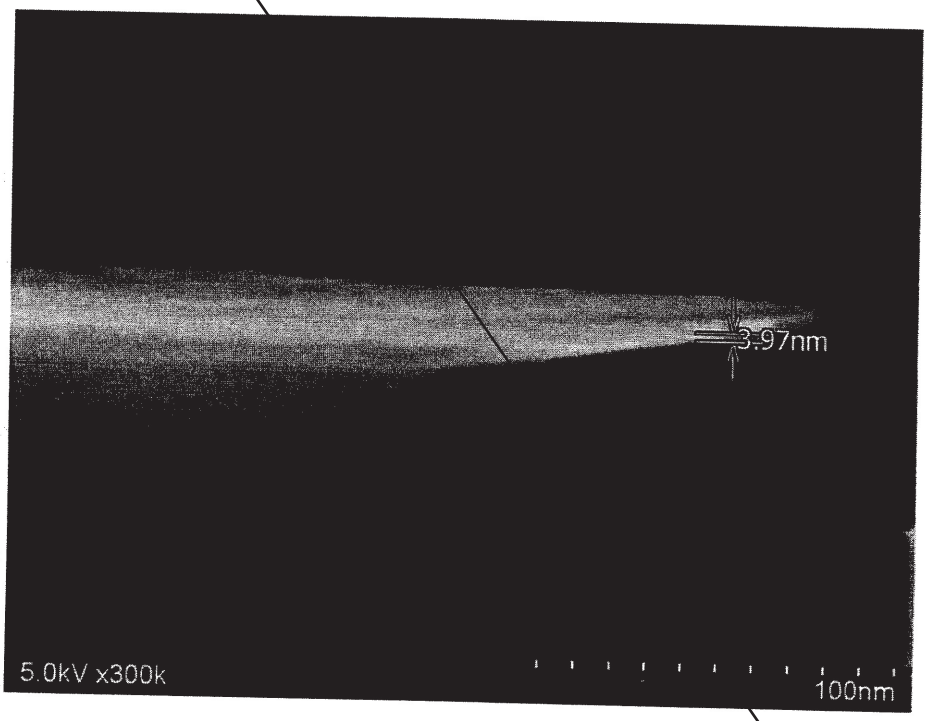


Fig. 25

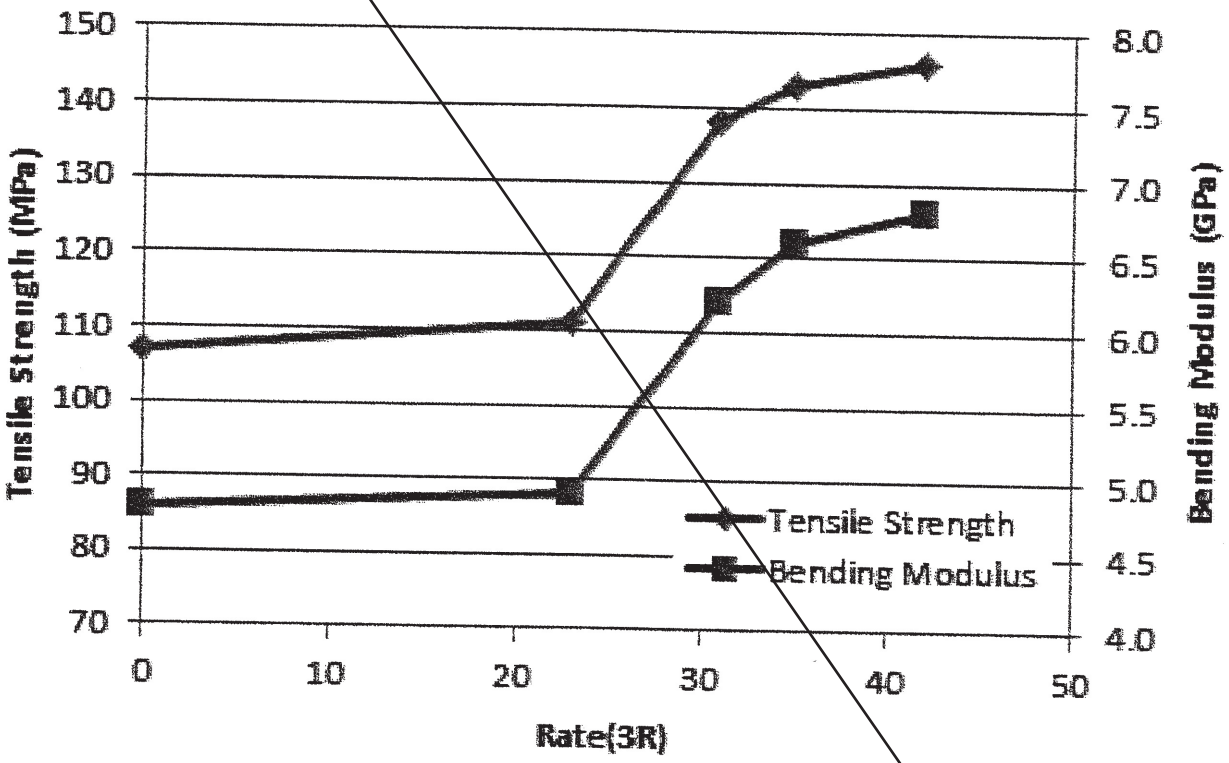

150
140
130
120
110
100
90
80
70
Tensile Strength (MPa)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Bending Modulus (GPa)
0
10
20
30
40
50
Rate(3R)
Tensile Strength
Bending Modulus

Fig. 26

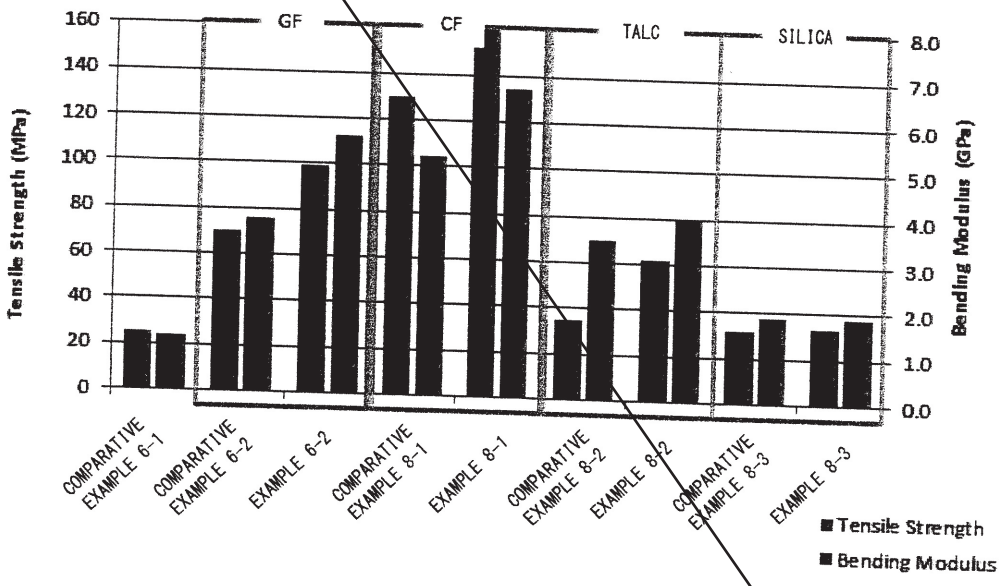

GF
CF
TALC
SILICA
Tensile Strength (MPa)
Bending Modulus (GPa)
160
140
120
100
80
60
40
20
0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
COMPARATIVE EXAMPLE 6-1
COMPARATIVE EXAMPLE 6-2
EXAMPLE 6-2
COMPARATIVE EXAMPLE 8-1
EXAMPLE 8-1
COMPARATIVE EXAMPLE 8-2
EXAMPLE 8-2
COMPARATIVE EXAMPLE 8-3
EXAMPLE 8-3
Tensile Strength
Bending Modulus

Fig. 27

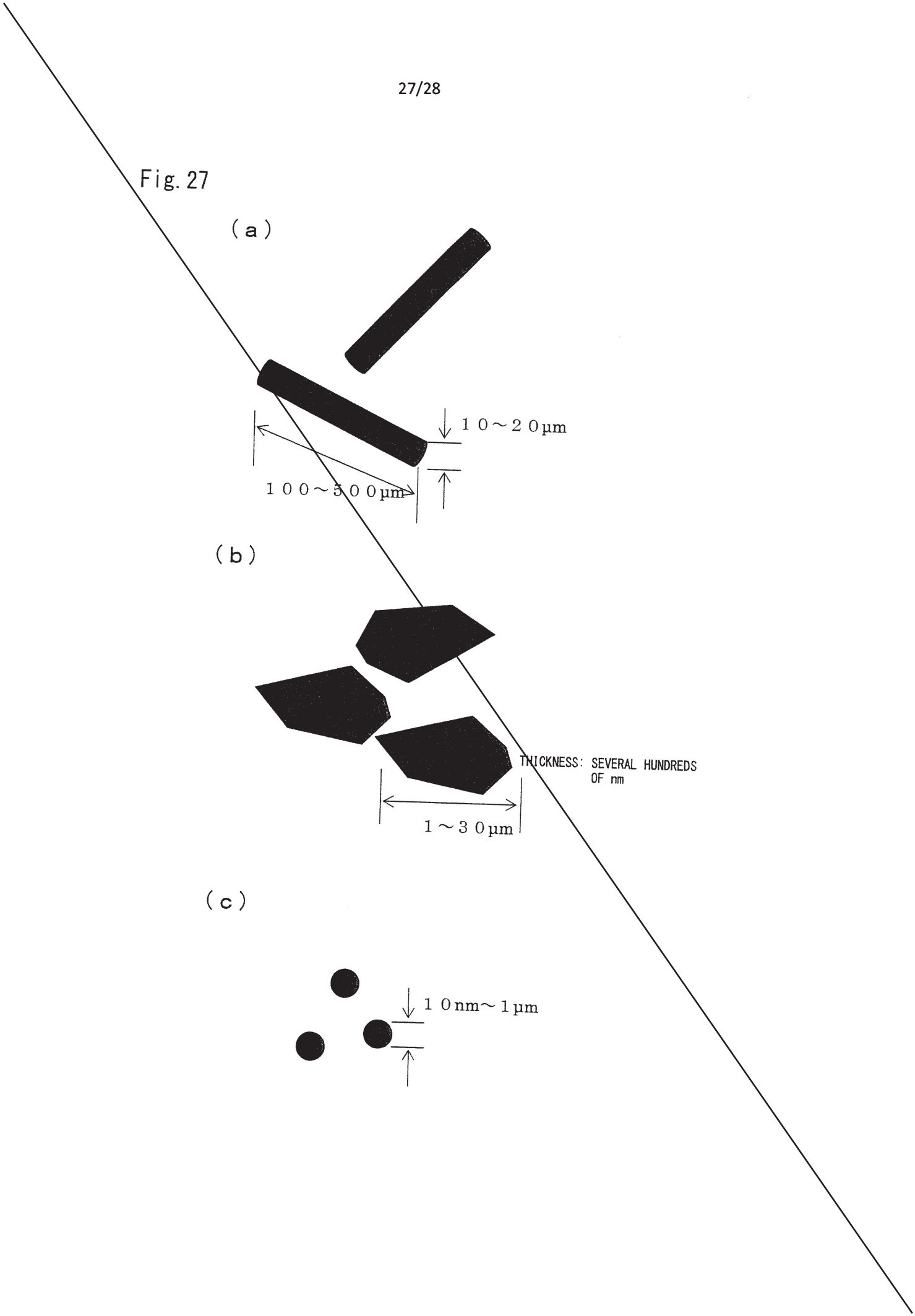

(a)
10～20μm
100～500μm
(b)
THICKNESS: SEVERAL HUNDREDS OF nm
1～30μm
(c)
10nm～1μm

Fig. 28

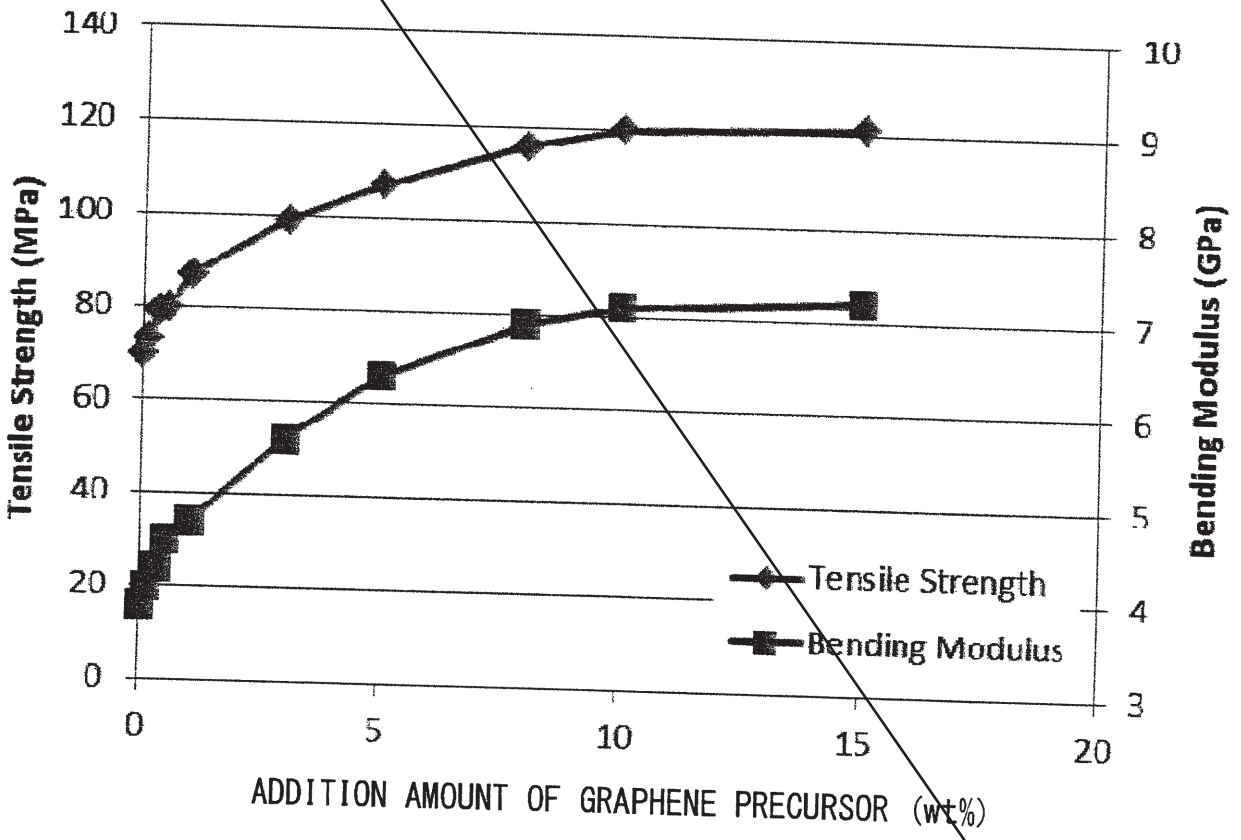

140
120
100
80
60
40
20
0
Tensile Strength (MPa)
10
9
8
7
6
5
4
3
Bending Modulus (GPa)
0
5
10
15
20
ADDITION AMOUNT OF GRAPHENE PRECURSOR (wt%)
Tensile Strength
Bending Modulus

Fig. 1

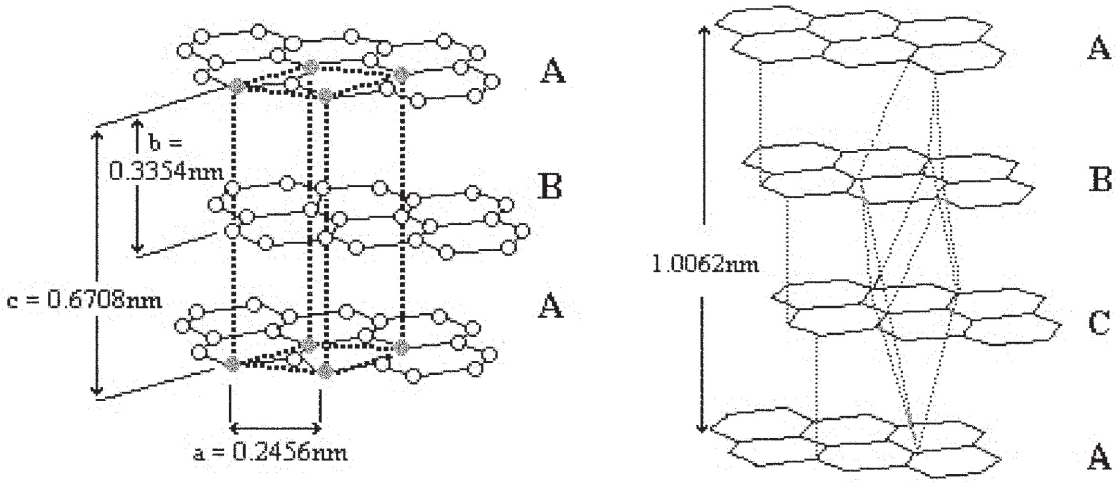


Fig. 2

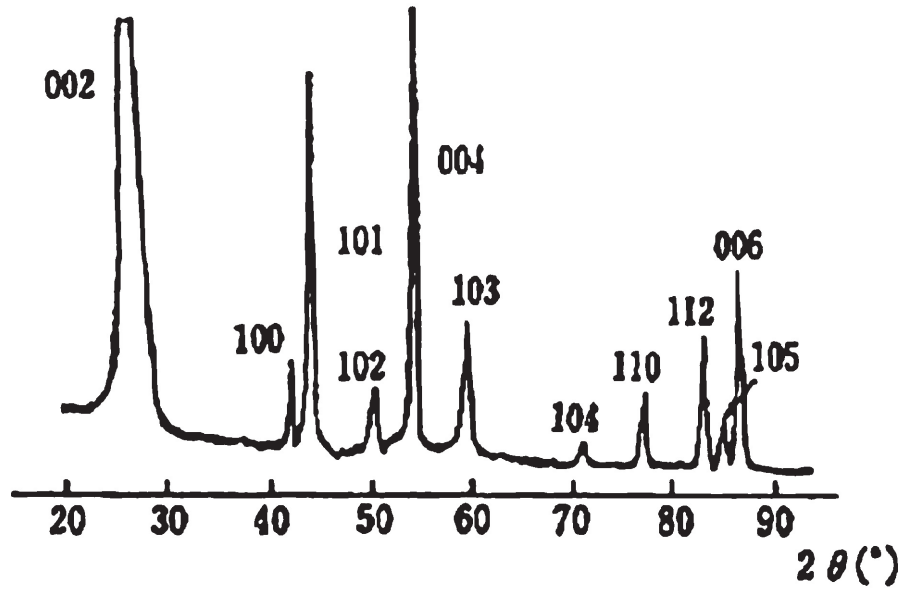

002
100
101
102
004
103
104
110
112
105
006
20
30
40
50
60
70
80
90
2θ(°)

Fig. 3

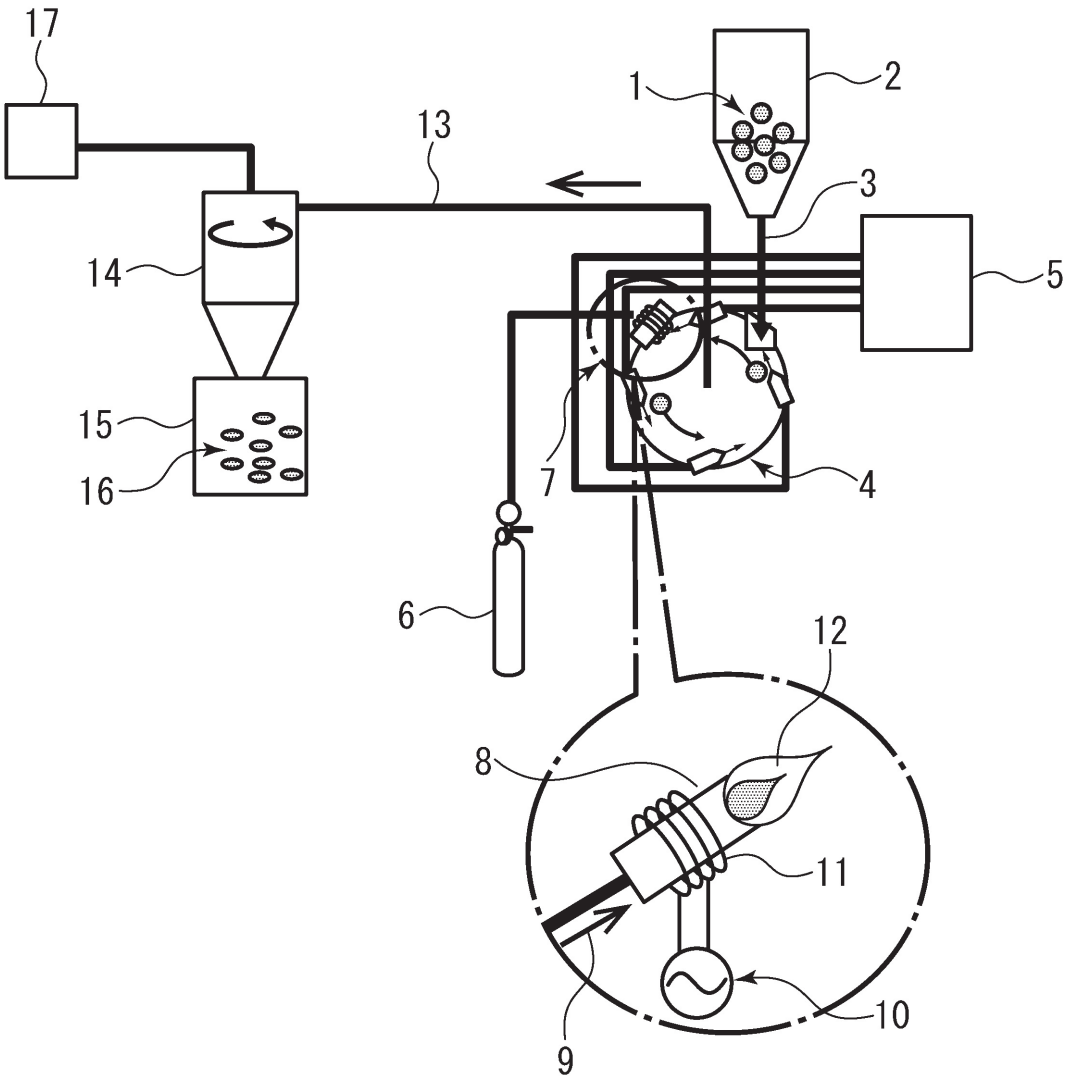
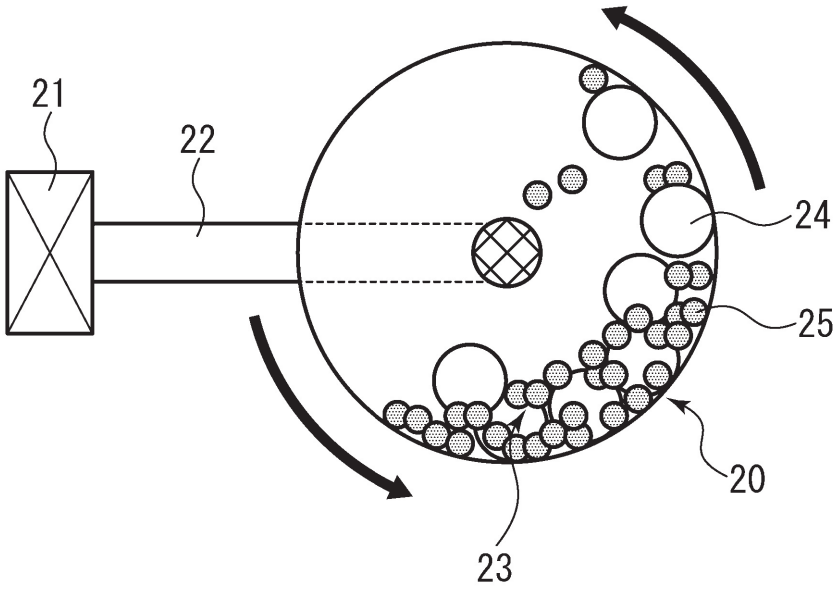


Fig. 4

(a)



(b)

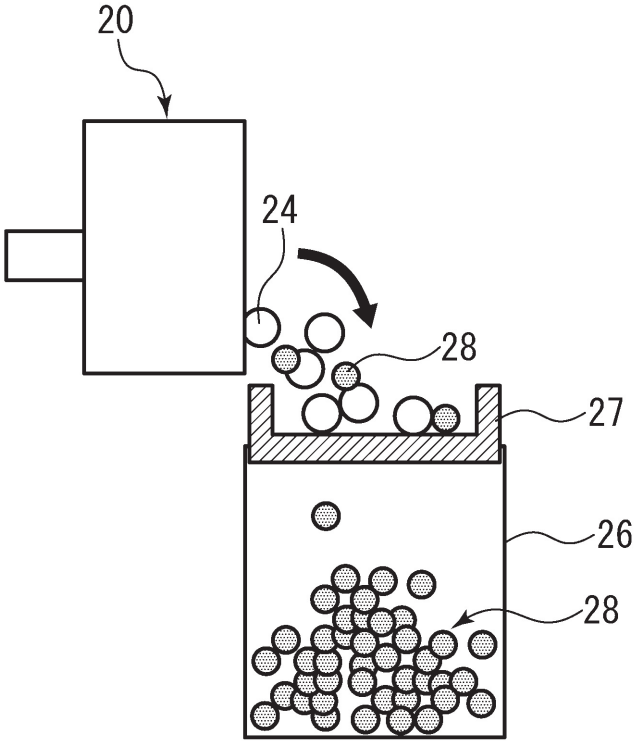


Fig. 5

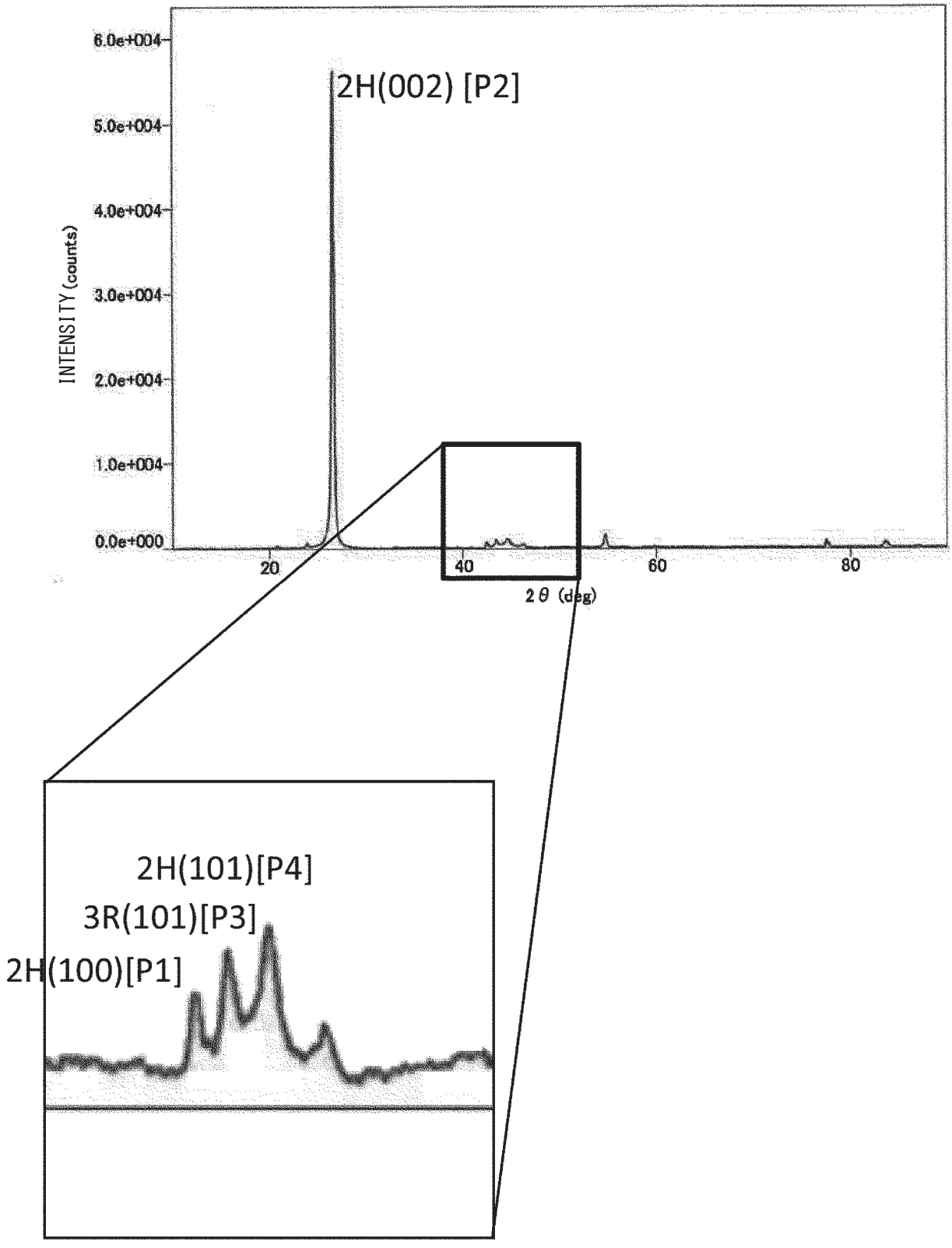

6.0e+004
5.0e+004
4.0e+004
3.0e+004
2.0e+004
1.0e+004
0.0e+000
INTENSITY (counts)
2H(002) [P2]
20
40
60
80
2θ (deg)
2H(101)[P4]
3R(101)[P3]
2H(100)[P1]

Fig. 6

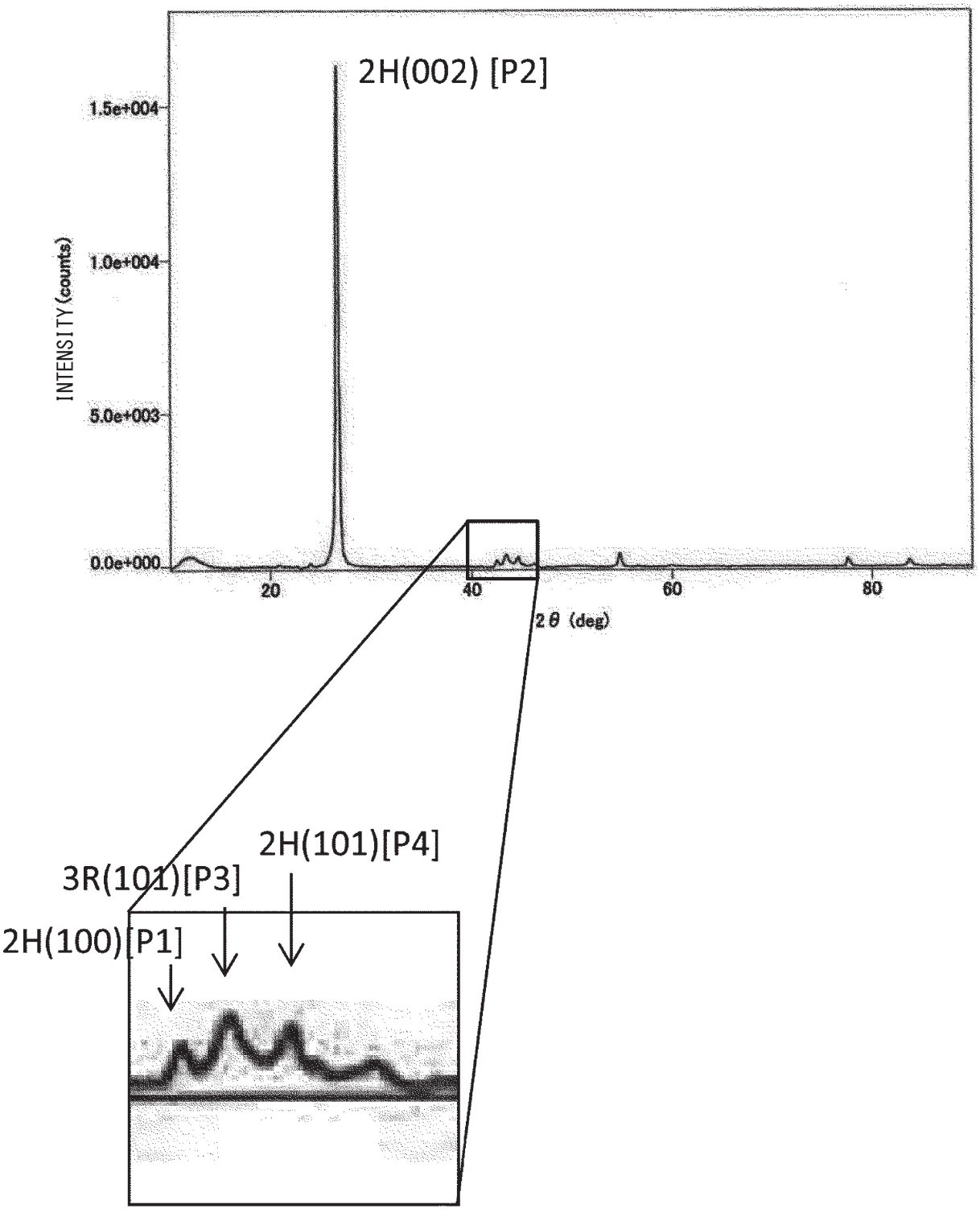

2H(002) [P2]
1.5e+004
1.0e+004
5.0e+003
0.0e+000
INTENSITY (counts)
20
40
60
80
2θ (deg)
2H(101)[P4]
3R(101)[P3]
2H(100)[P1]

Fig. 7

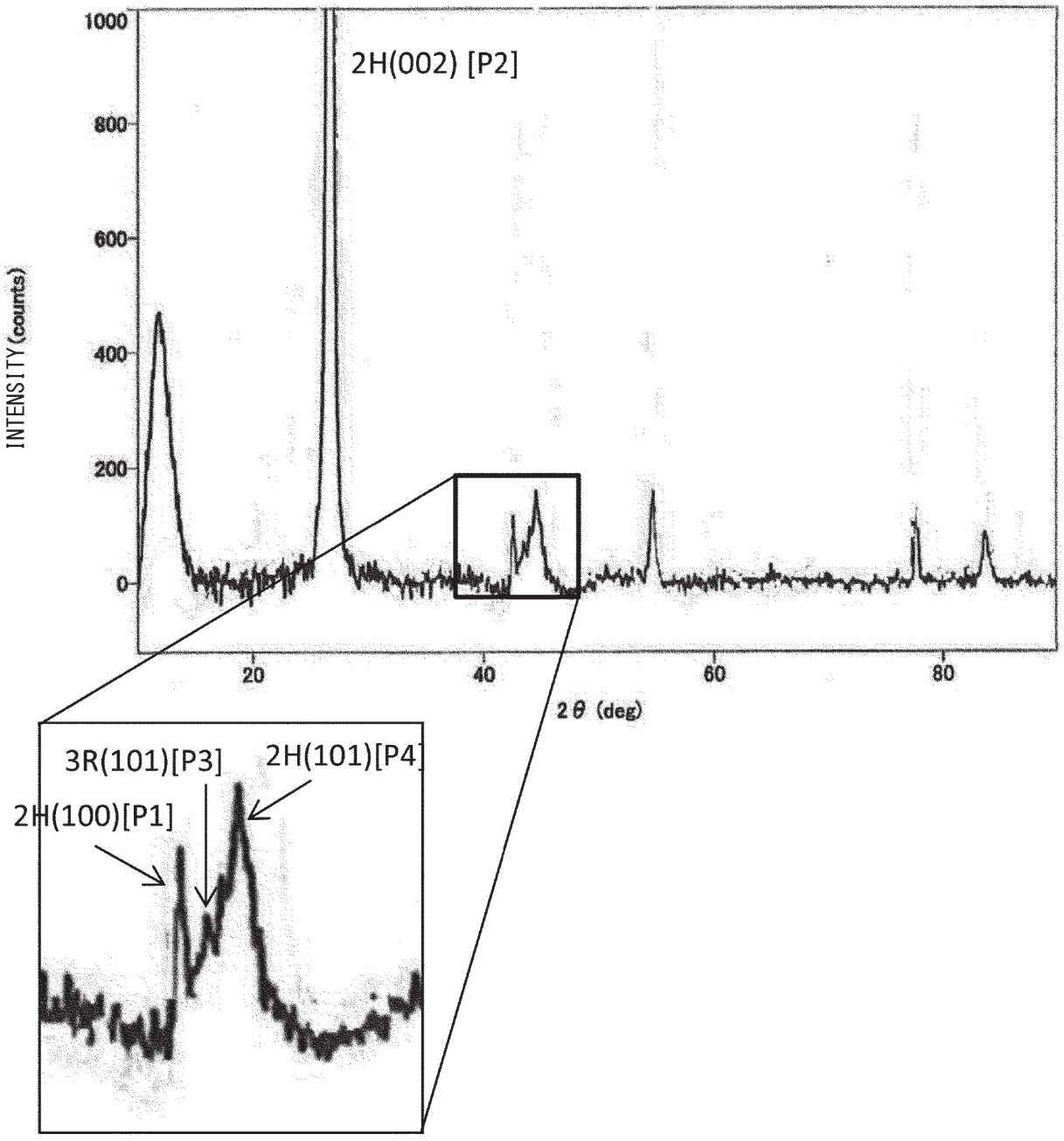

1000
800
600
400
200
0
INTENSITY(counts)
2H(002) [P2]
20
40
60
80
2θ (deg)
3R(101)[P3]
2H(101)[P4]
2H(100)[P1]

Fig. 8

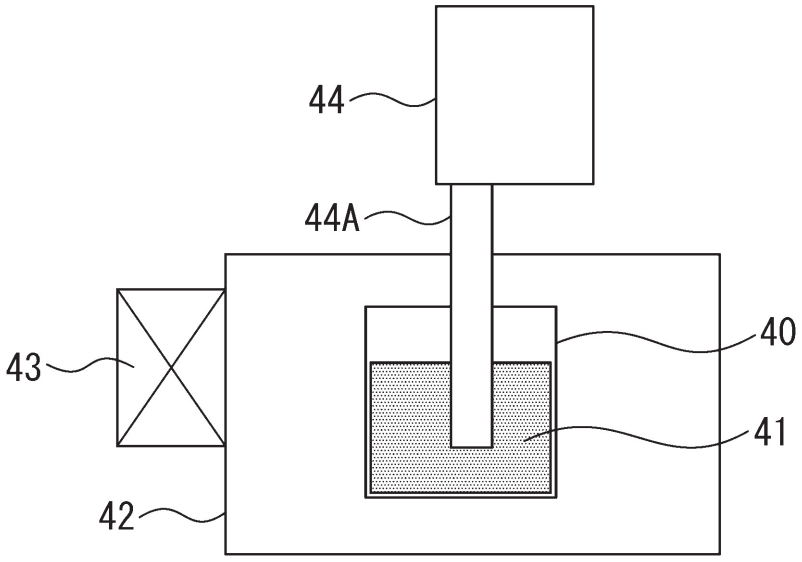
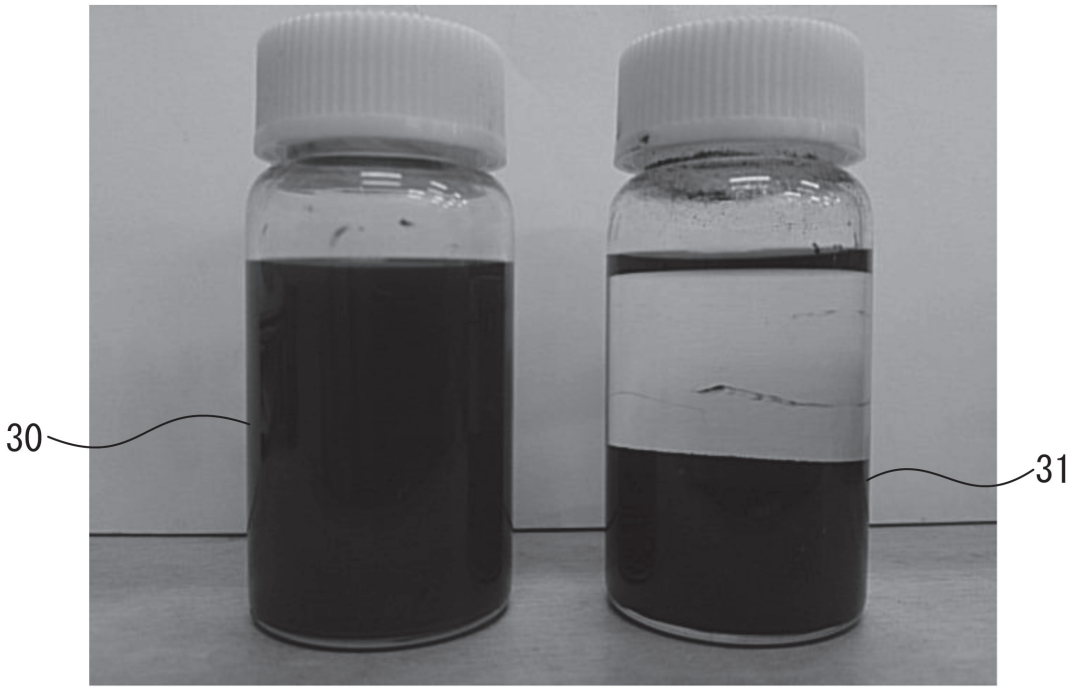


Fig. 9



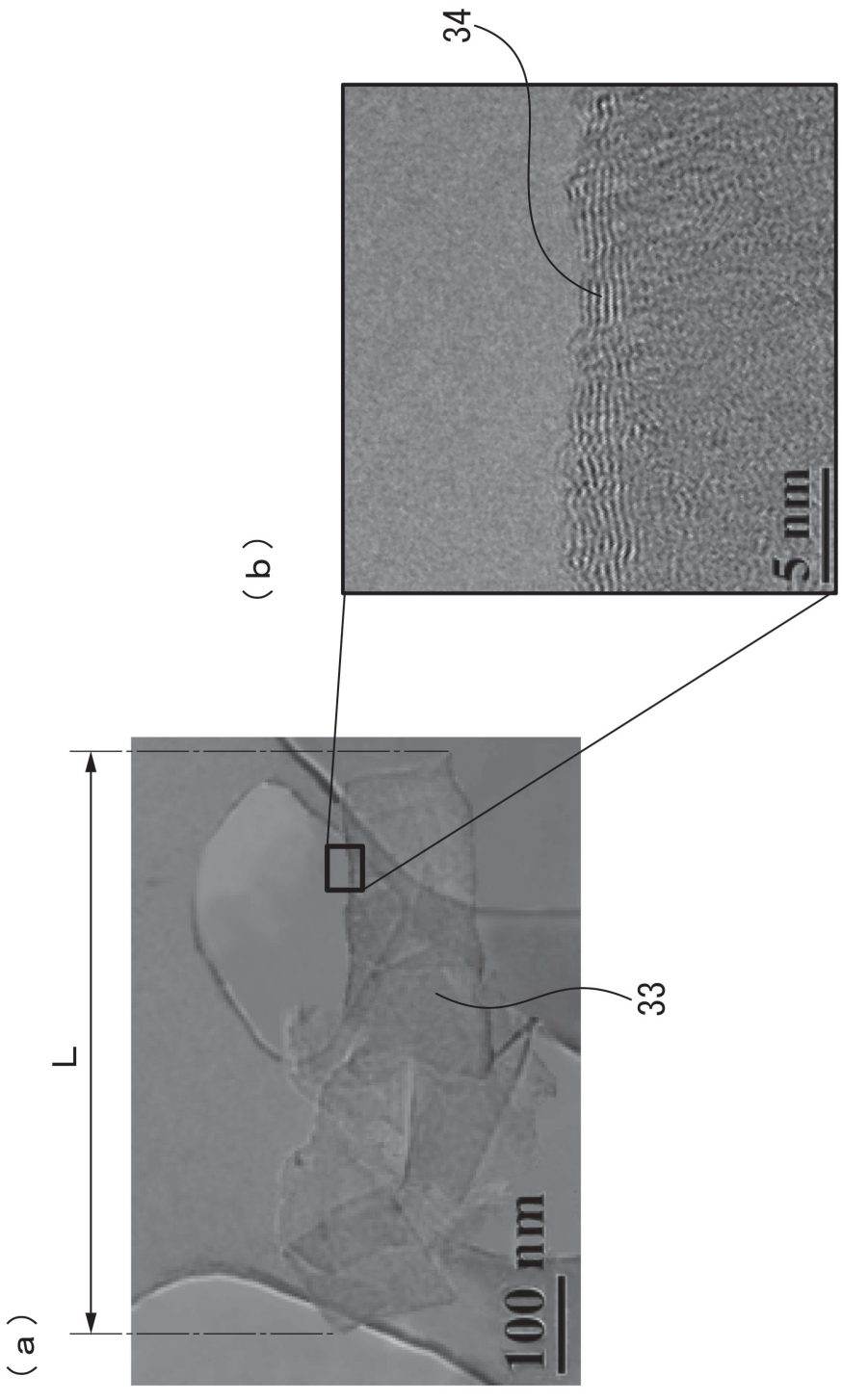
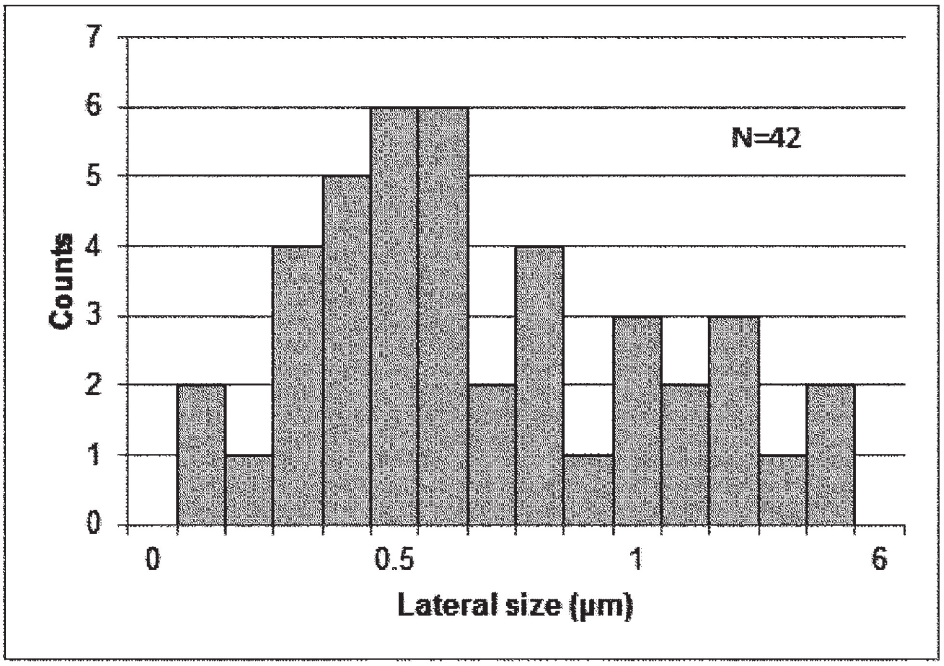


Fig. 10

Fig. 11

(a)


N=42
Counts
Lateral size (μm)
0
1
2
3
4
5
6
7
0
0.5
1
6

(b)

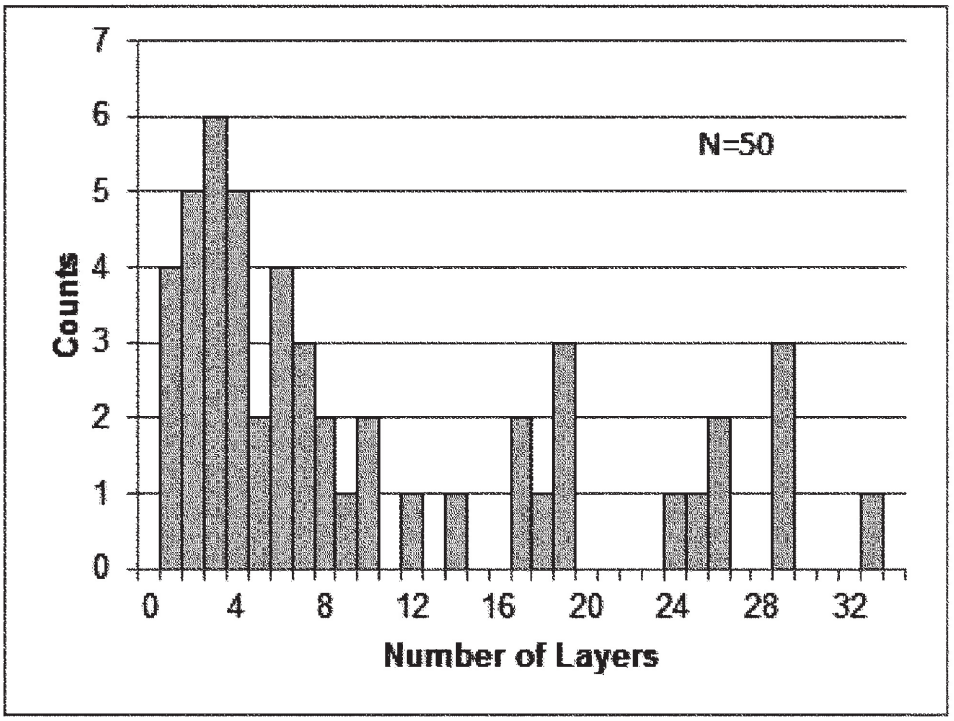
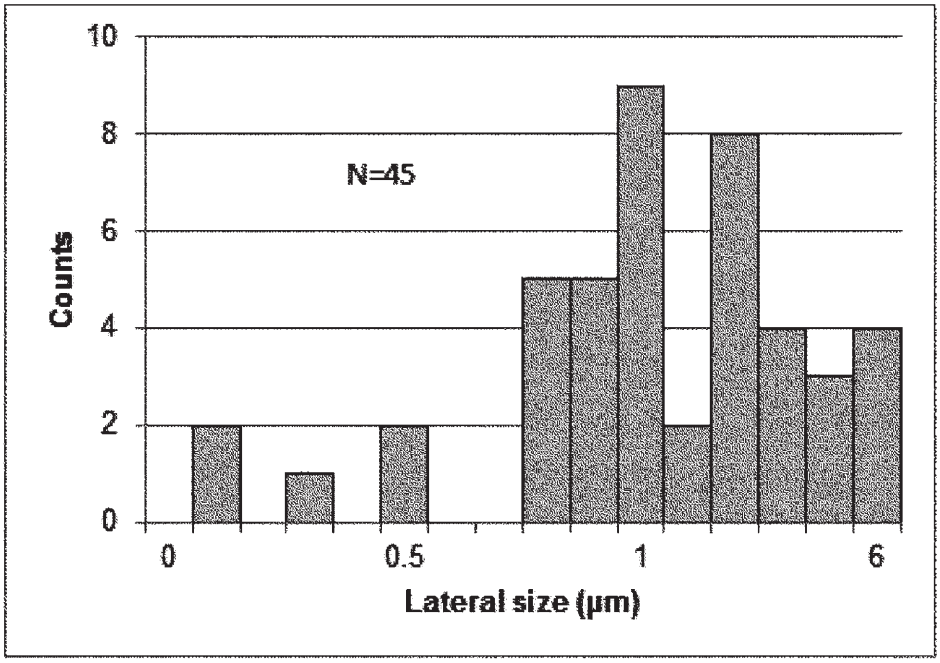

N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

Fig. 12

(a)


10
8
6
4
2
0
Counts
N=45
0
0.5
1
6
Lateral size (μm)

(b)

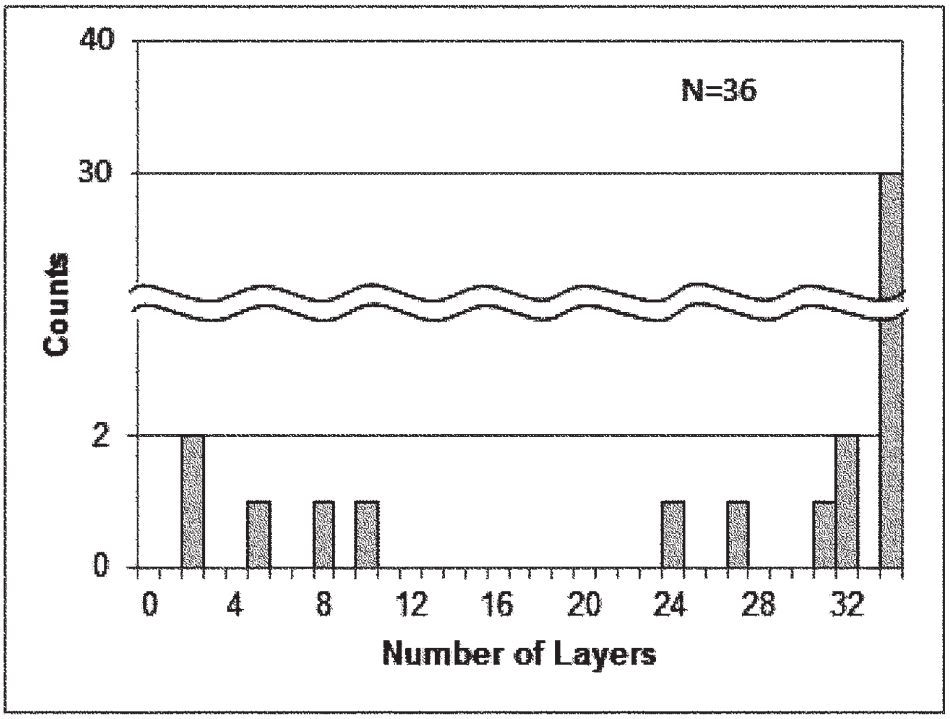
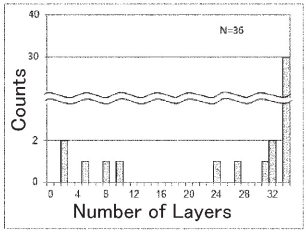
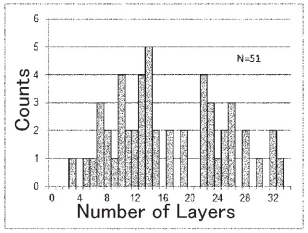
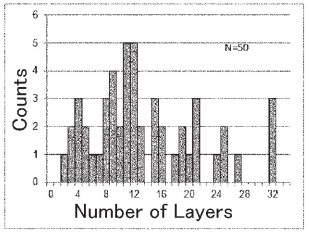

40
30
2
0
Counts
N=36
0
4
8
12
16
20
24
28
32
Number of Layers

Fig.13

SAMPLE No.	1	2	3
DISTRIBUTION OF LAYERS			
P3/(P3+P4)	23%	31%	38%
TEN LAYERS OR LESS	10%	25%	38%
P1/P2	0.008	0.016	0.016
P1	120	342	128
P2	15000	20993	8253
P3	50	321	173
P4	160	698	282

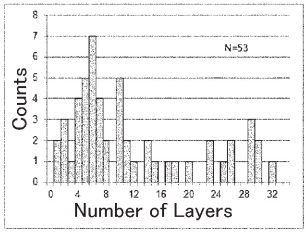
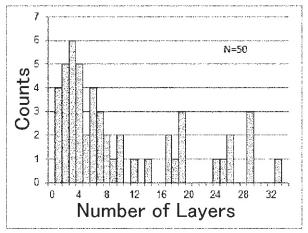
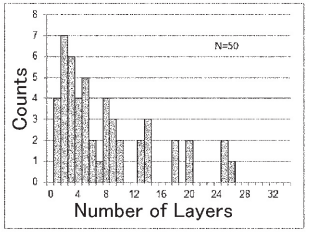
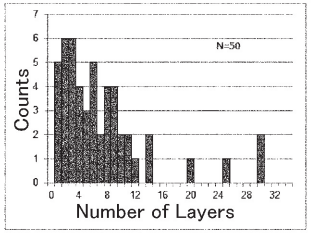
SAMPLE No.	4	5	6	7
DISTRIBUTION OF LAYERS				
P3/(P3+P4)	42%	46%	51%	58%
TEN LAYERS OR LESS	62%	68%	76%	82%
P1/P2	0.014	0.012	0.014	0.012
P1	253	162	66	151
P2	18226	13157	4675	12850
P3	320	396	170	452
P4	435	466	162	325

Fig. 14

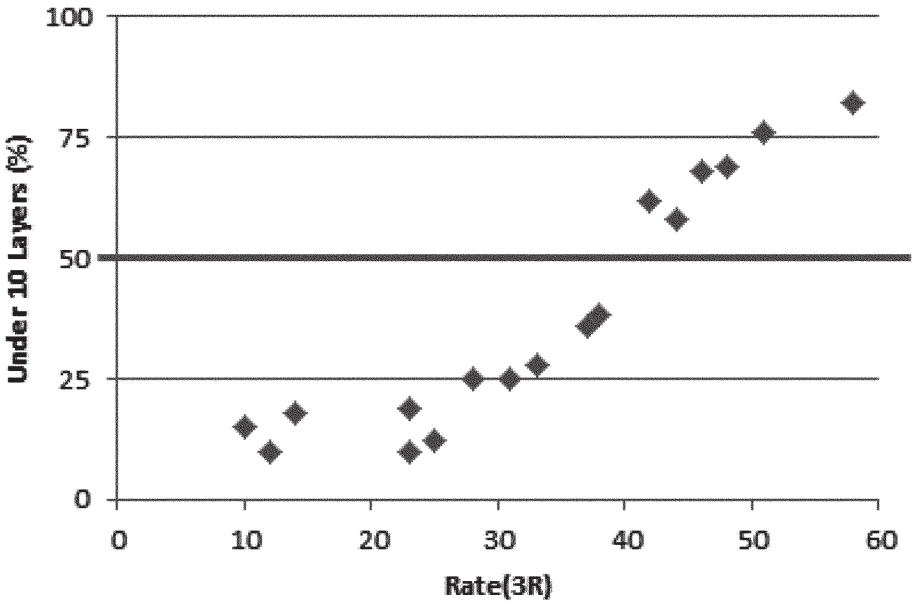
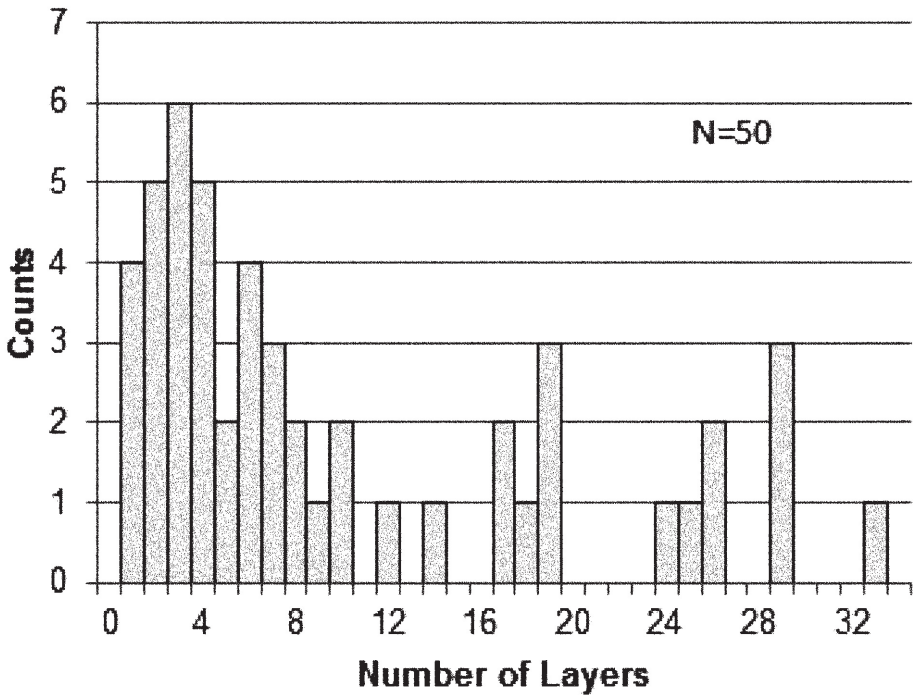


Fig. 15

（a）


N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

（b）

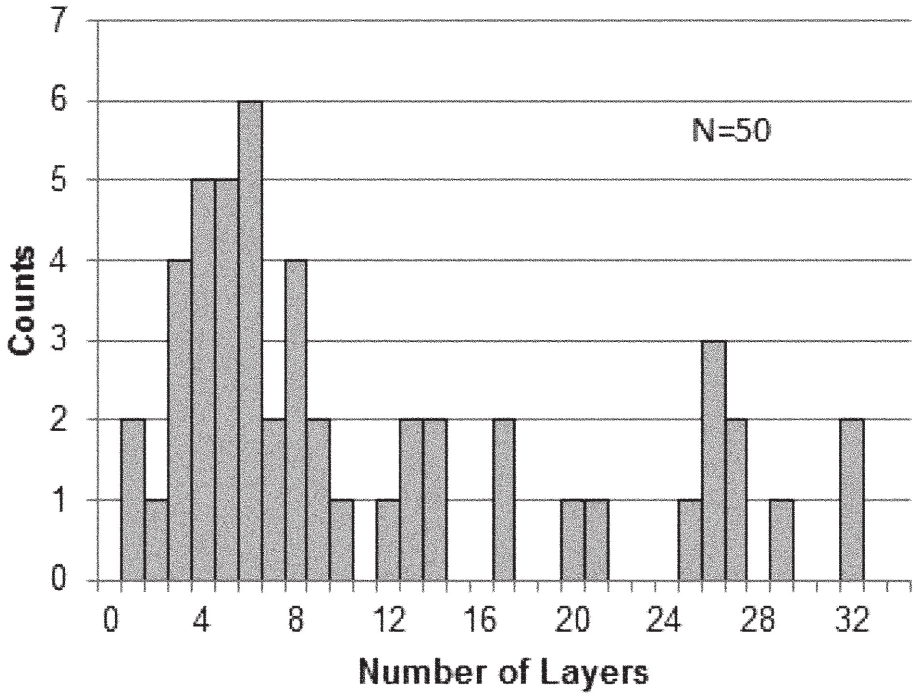

N=50
Counts
Number of Layers
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24
28
32

Fig. 16

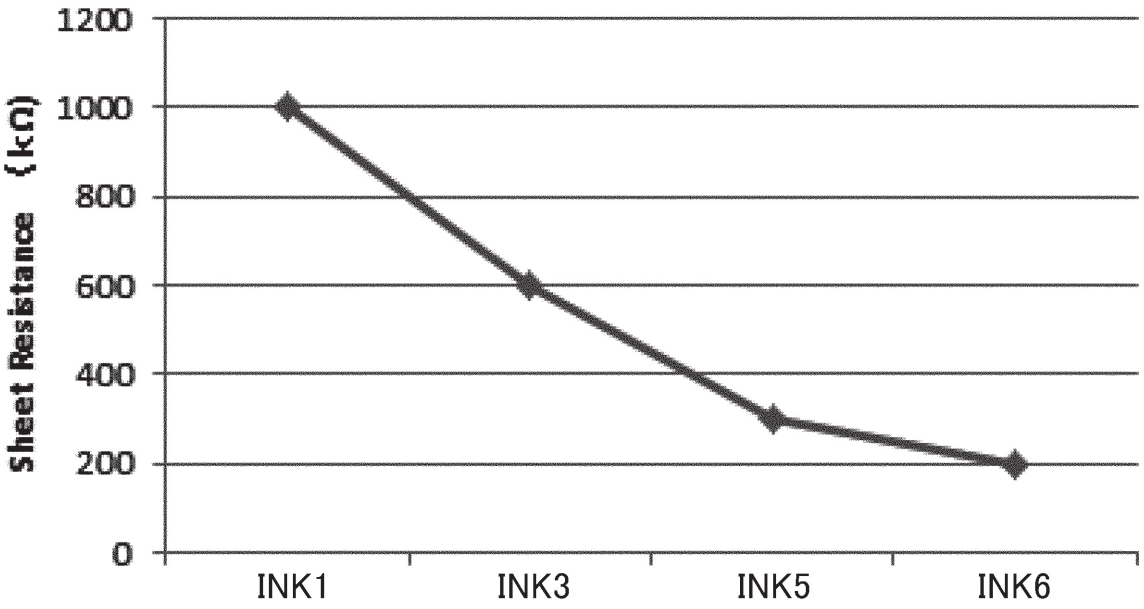

Sheet Resistance (kΩ)
1200
1000
800
600
400
200
0
INK1
INK3
INK5
INK6

Fig. 17

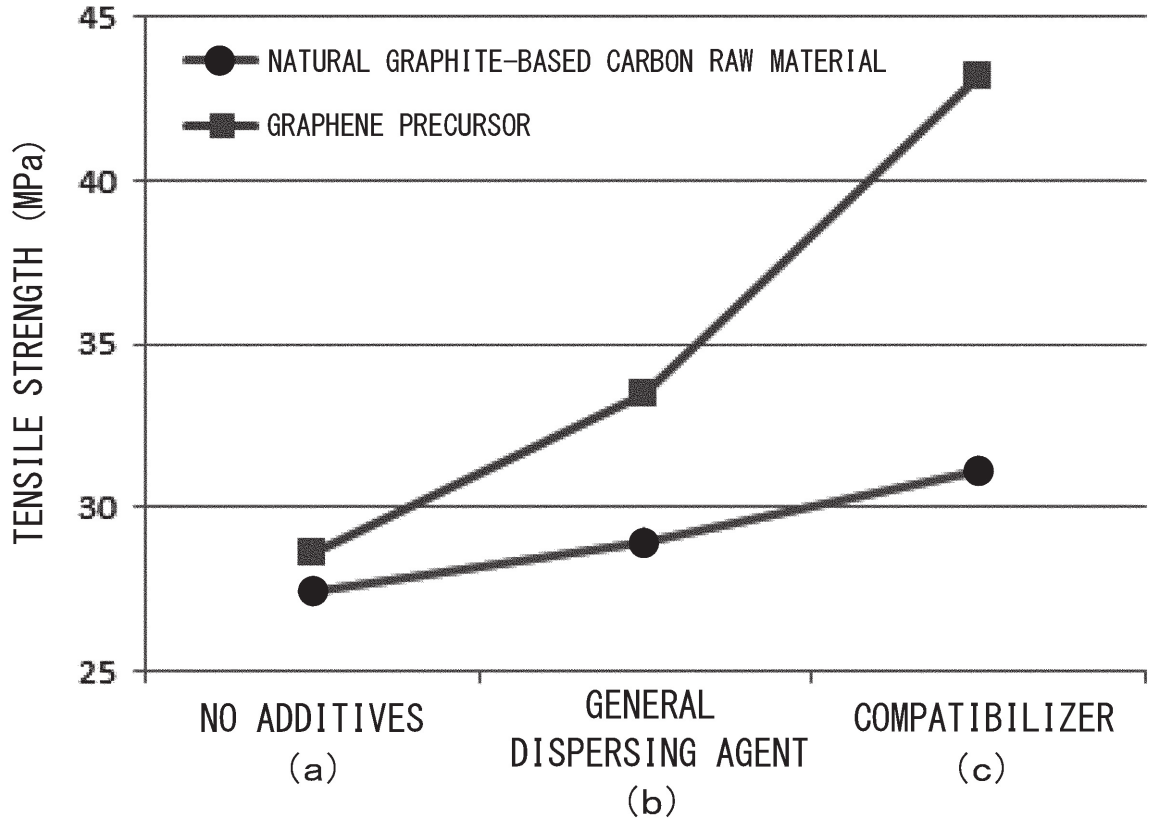

45
40
35
30
25
TENSILE STRENGTH (MPa)
NATURAL GRAPHITE-BASED CARBON RAW MATERIAL
GRAPHENE PRECURSOR
NO ADDITIVES
(a)
GENERAL
DISPERSING AGENT
(b)
COMPATIBILIZER
(c)

Fig. 18

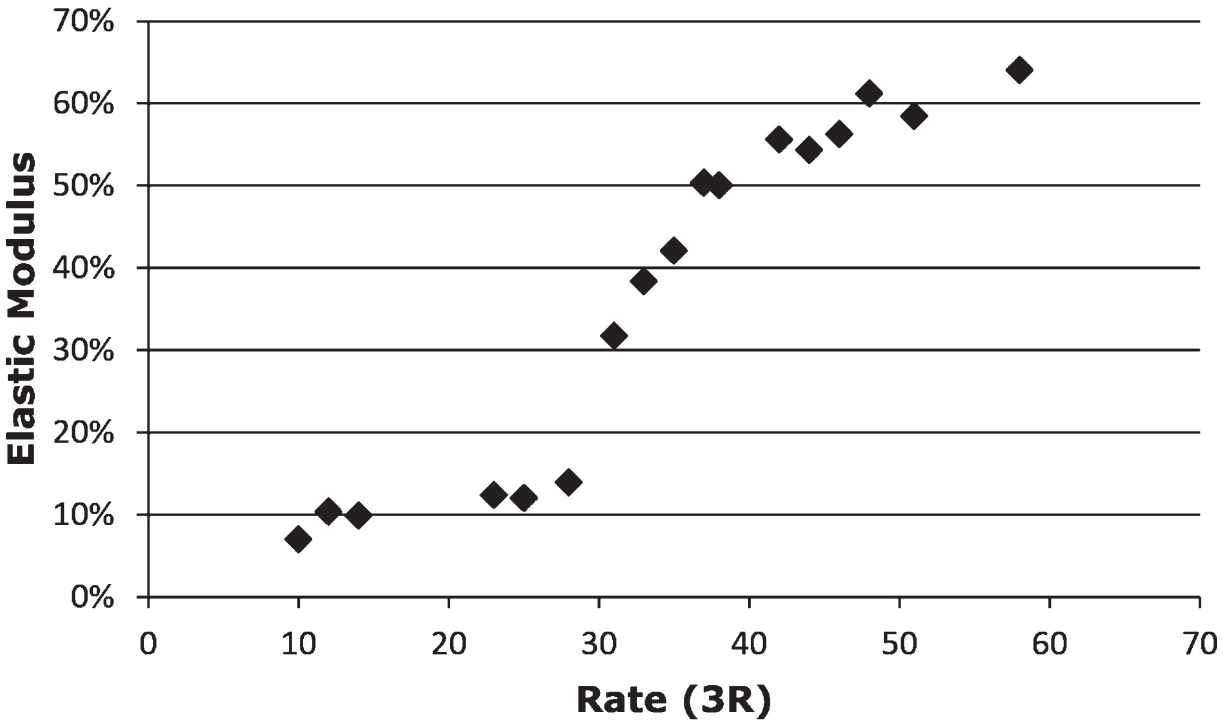
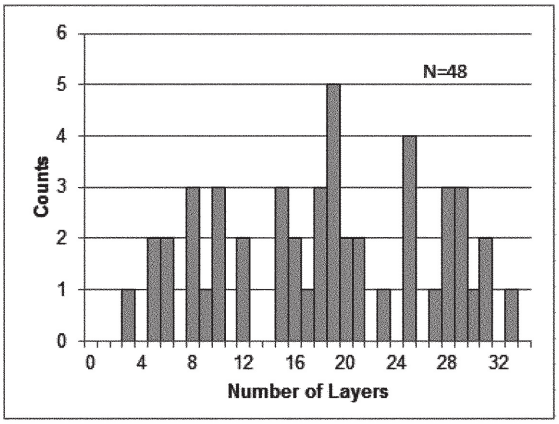

70%
60%
50%
40%
30%
20%
10%
0%
Elastic Modulus
0
10
20
30
40
50
60
70
Rate (3R)

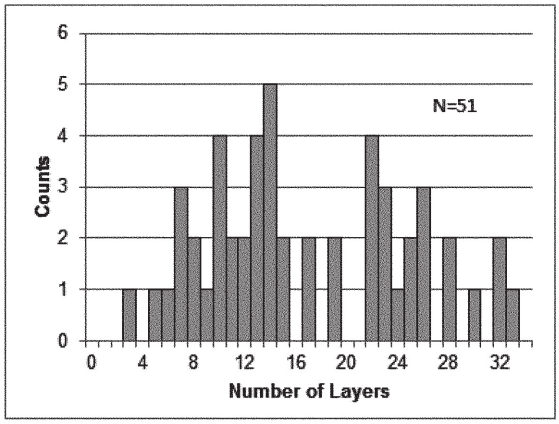
Fig. 19

(a)



P3/(P3+P4)=28%
TEN LAYERS OR LESS: 25%

(b)



P3/(P3+P4)=31%
TEN LAYERS OR LESS: 25%

Fig. 20

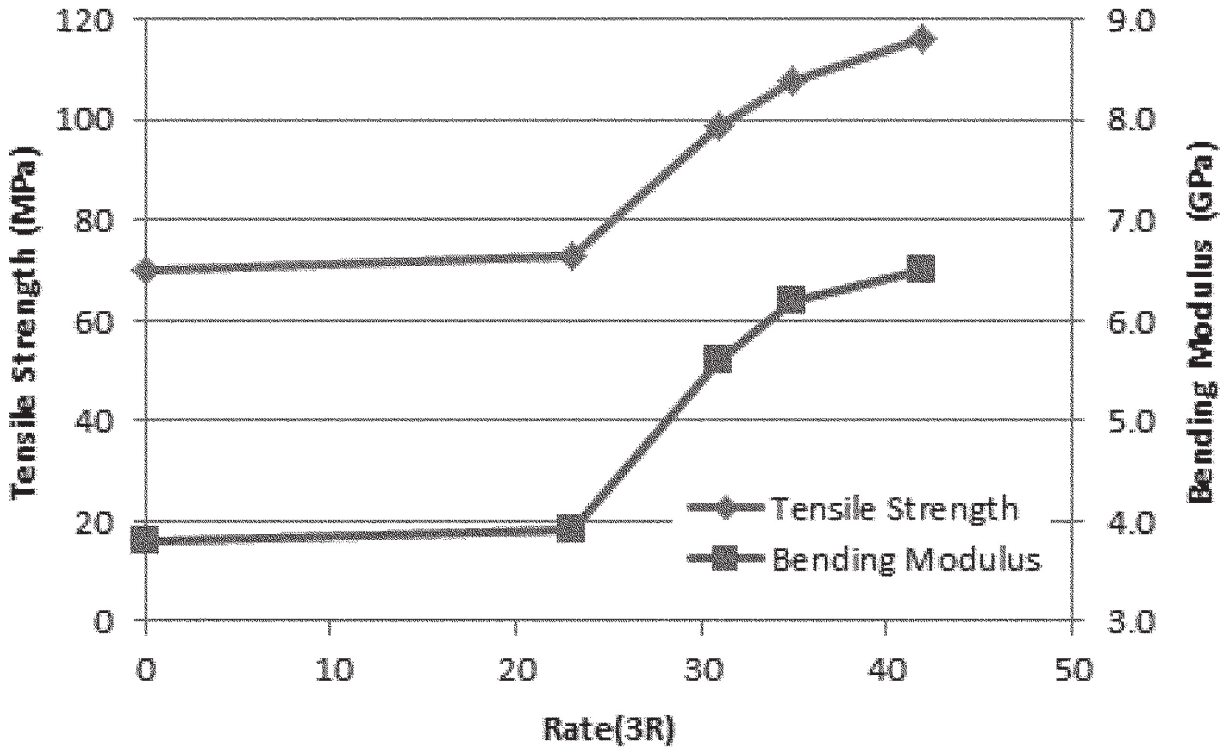

120
100
80
60
40
20
0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
0
10
20
30
40
50
Tensile Strength (MPa)
Bending Modulus (GPa)
Rate(3R)
Tensile Strength
Bending Modulus

Fig. 21

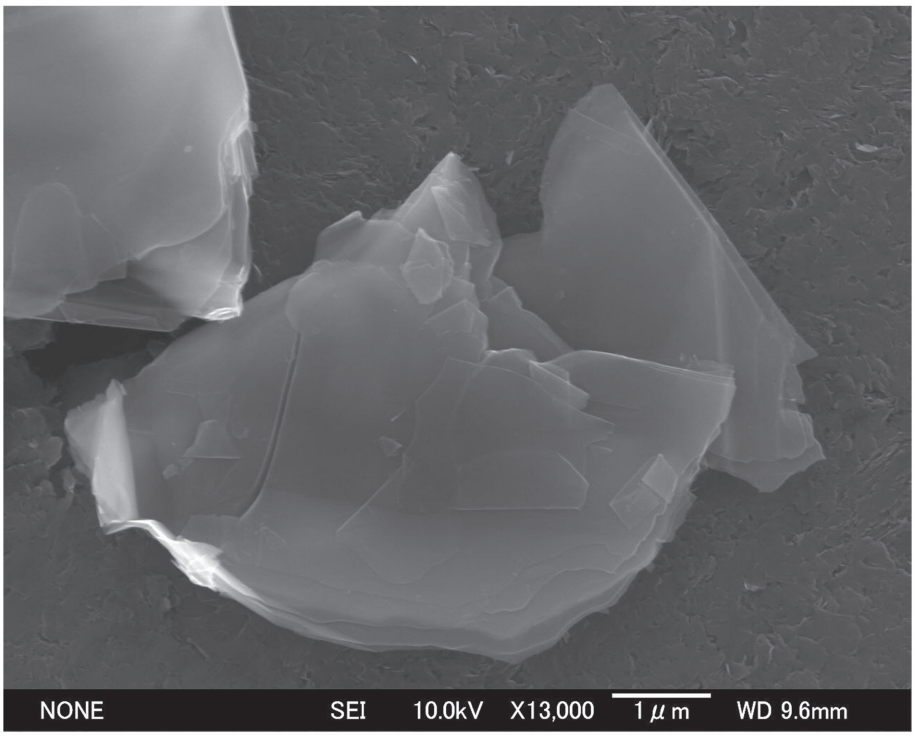


Fig. 22

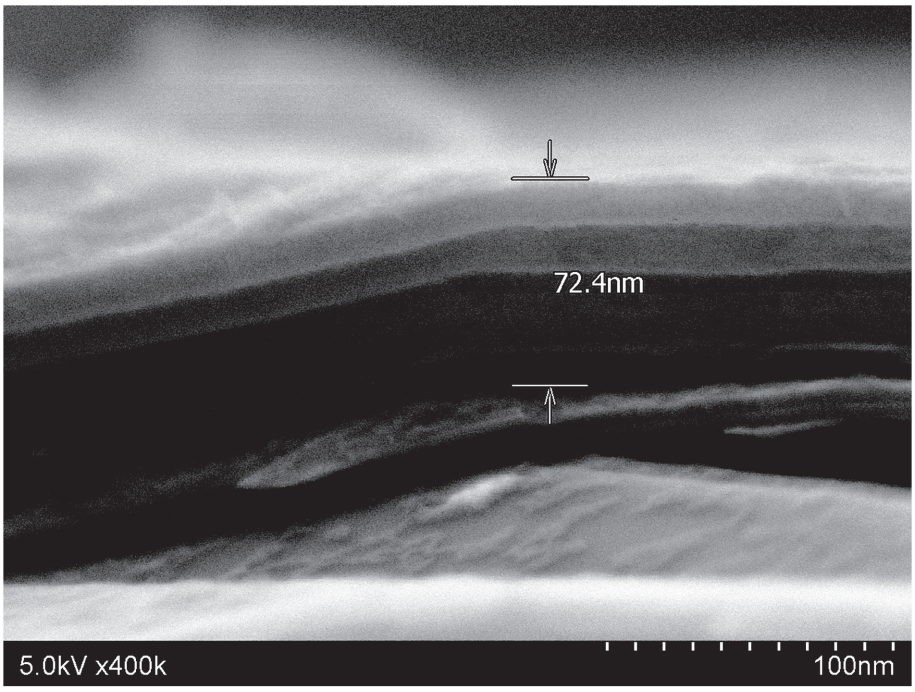


Fig. 23

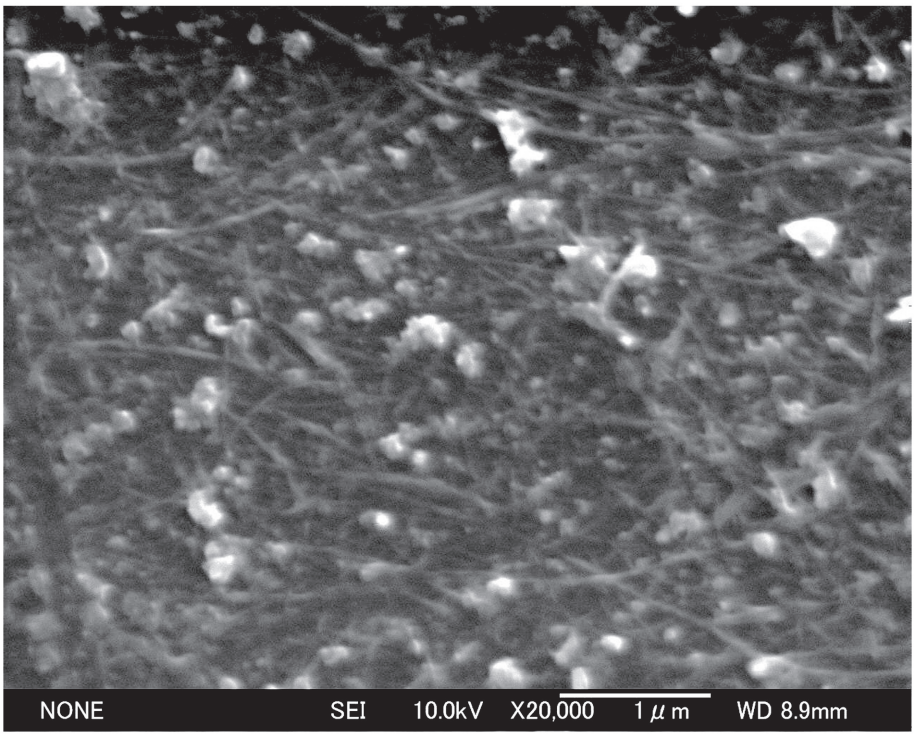


Fig. 24

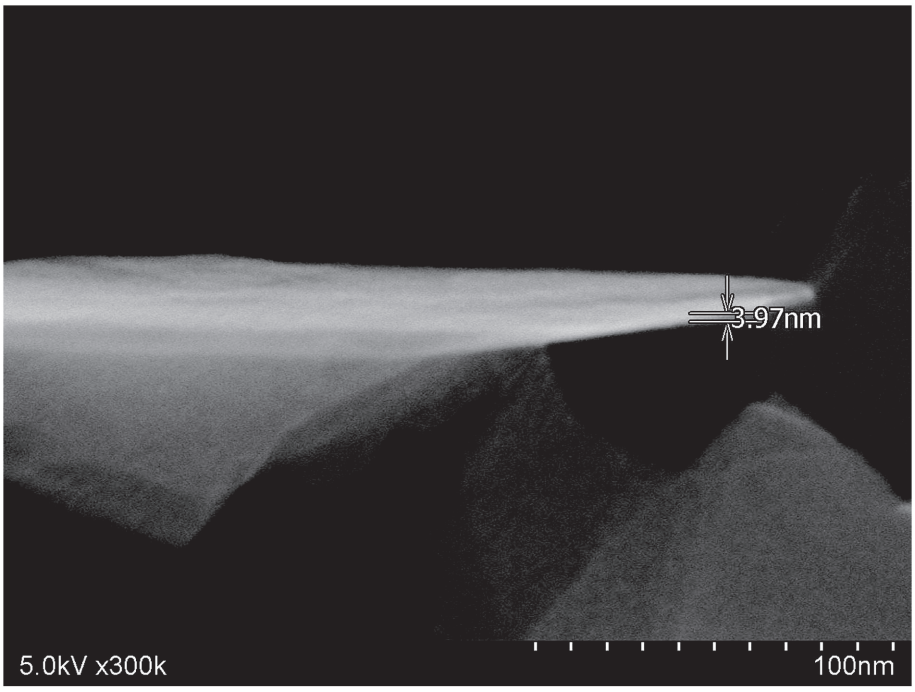


Fig. 25

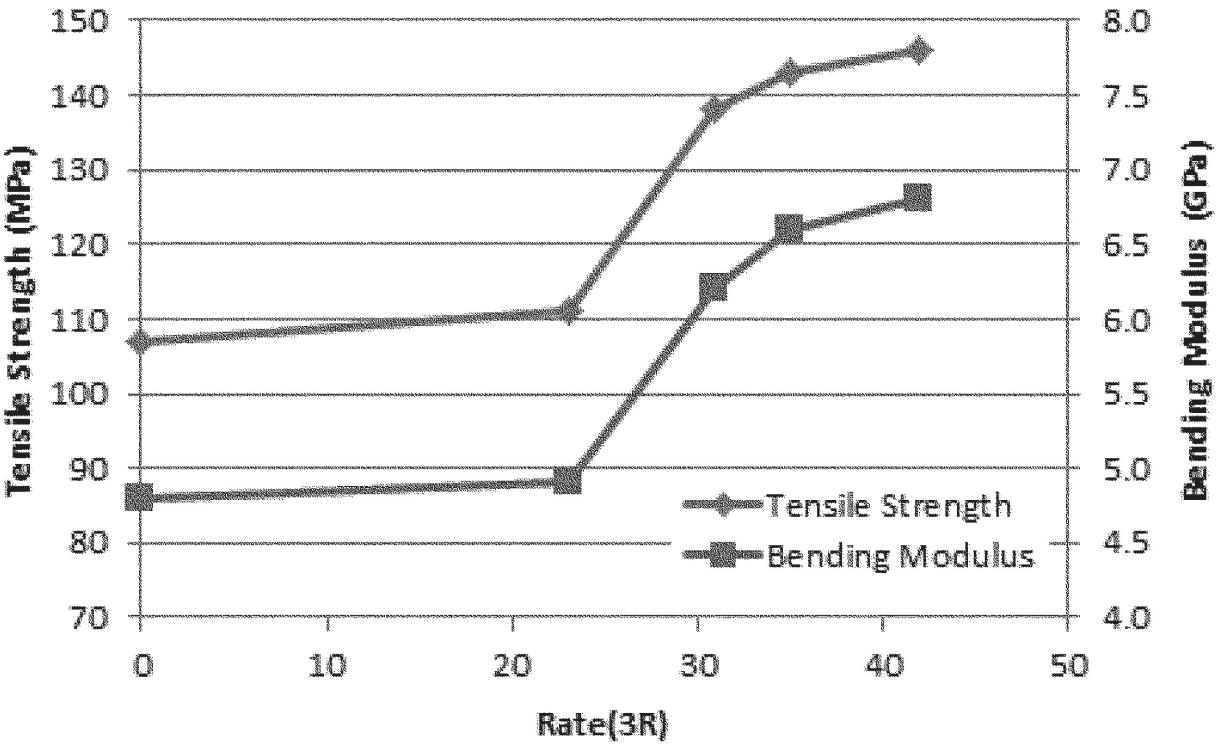

150
140
130
120
110
100
90
80
70
Tensile Strength (MPa)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Bending Modulus (GPa)
0
10
20
30
40
50
Rate(3R)
Tensile Strength
Bending Modulus

Fig. 26

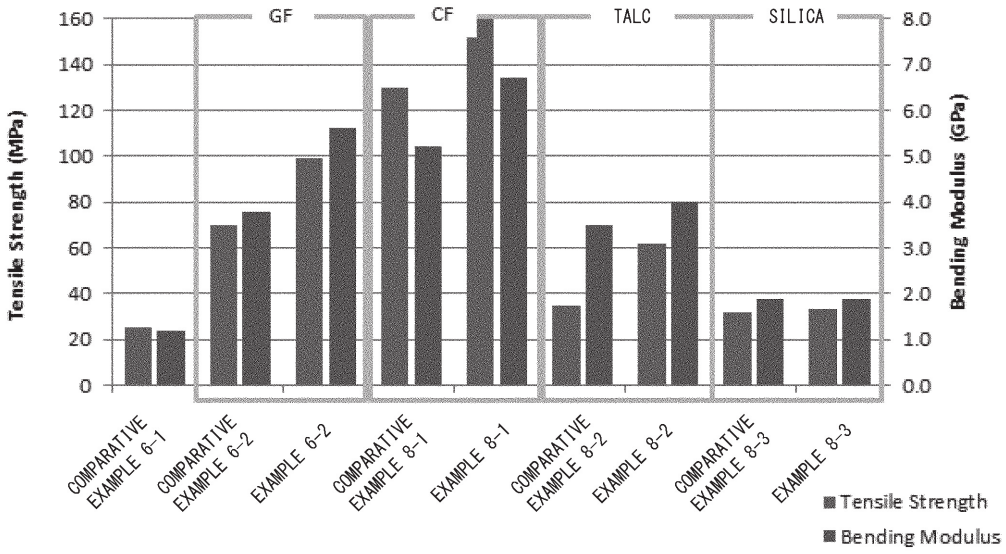

GF
CF
TALC
SILICA
Tensile Strength (MPa)
Bending Modulus (GPa)
160
140
120
100
80
60
40
20
0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
COMPARATIVE EXAMPLE 6-1
COMPARATIVE EXAMPLE 6-2
EXAMPLE 6-2
COMPARATIVE EXAMPLE 8-1
EXAMPLE 8-1
COMPARATIVE EXAMPLE 8-2
EXAMPLE 8-2
COMPARATIVE EXAMPLE 8-3
EXAMPLE 8-3
Tensile Strength
Bending Modulus

Fig. 27

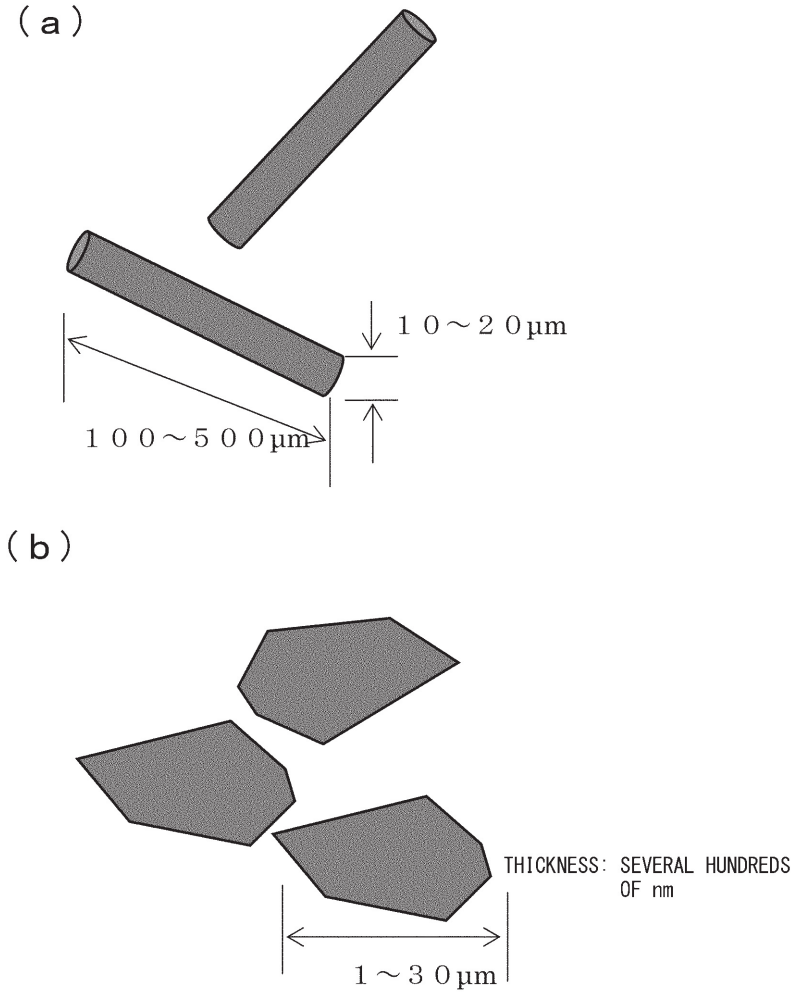
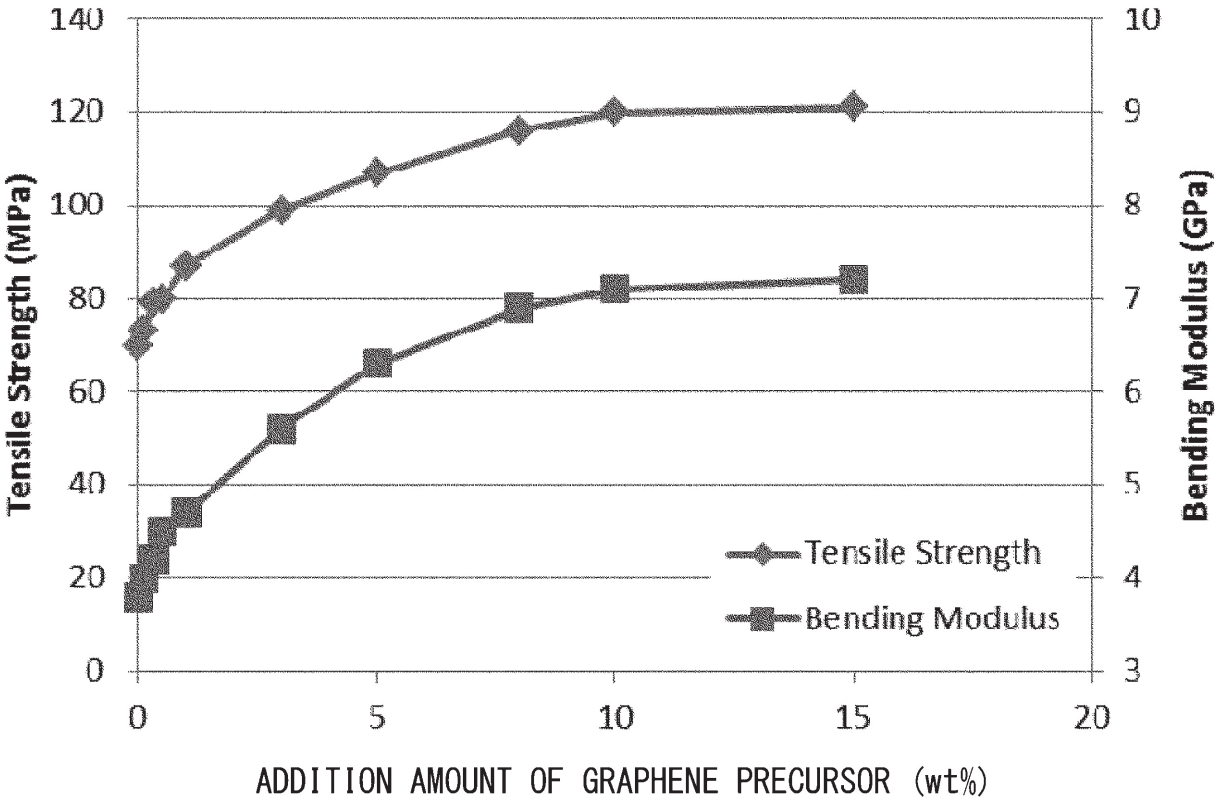

（a）
１０～２０μm
１００～５００μm
（b）
THICKNESS: SEVERAL HUNDREDS OF nm
１～３０μm
（c）
１０nm～１μm

Fig. 28


140
120
100
80
60
40
20
0
Tensile Strength (MPa)
10
9
8
7
6
5
4
3
Bending Modulus (GPa)
Tensile Strength
Bending Modulus
0
5
10
15
20
ADDITION AMOUNT OF GRAPHENE PRECURSOR (wt%)