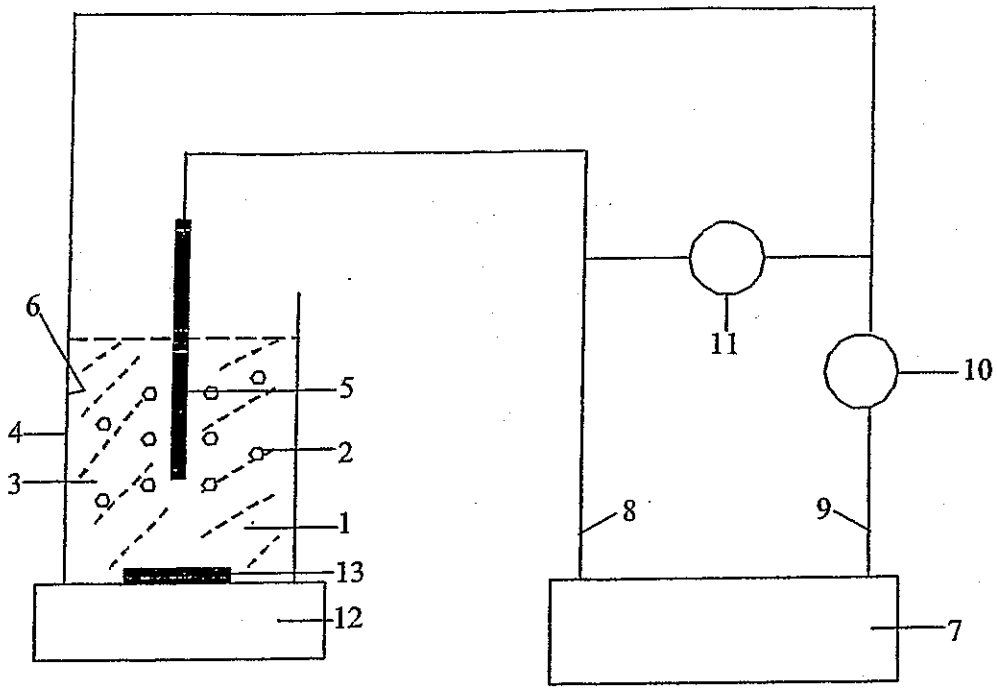


Fig. 1

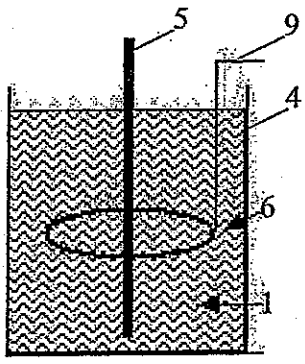


Fig. 2

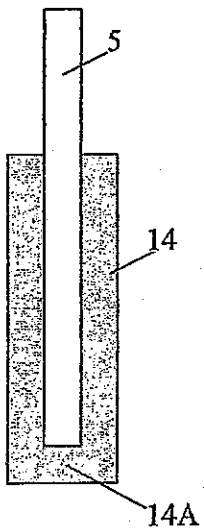


Fig. 3

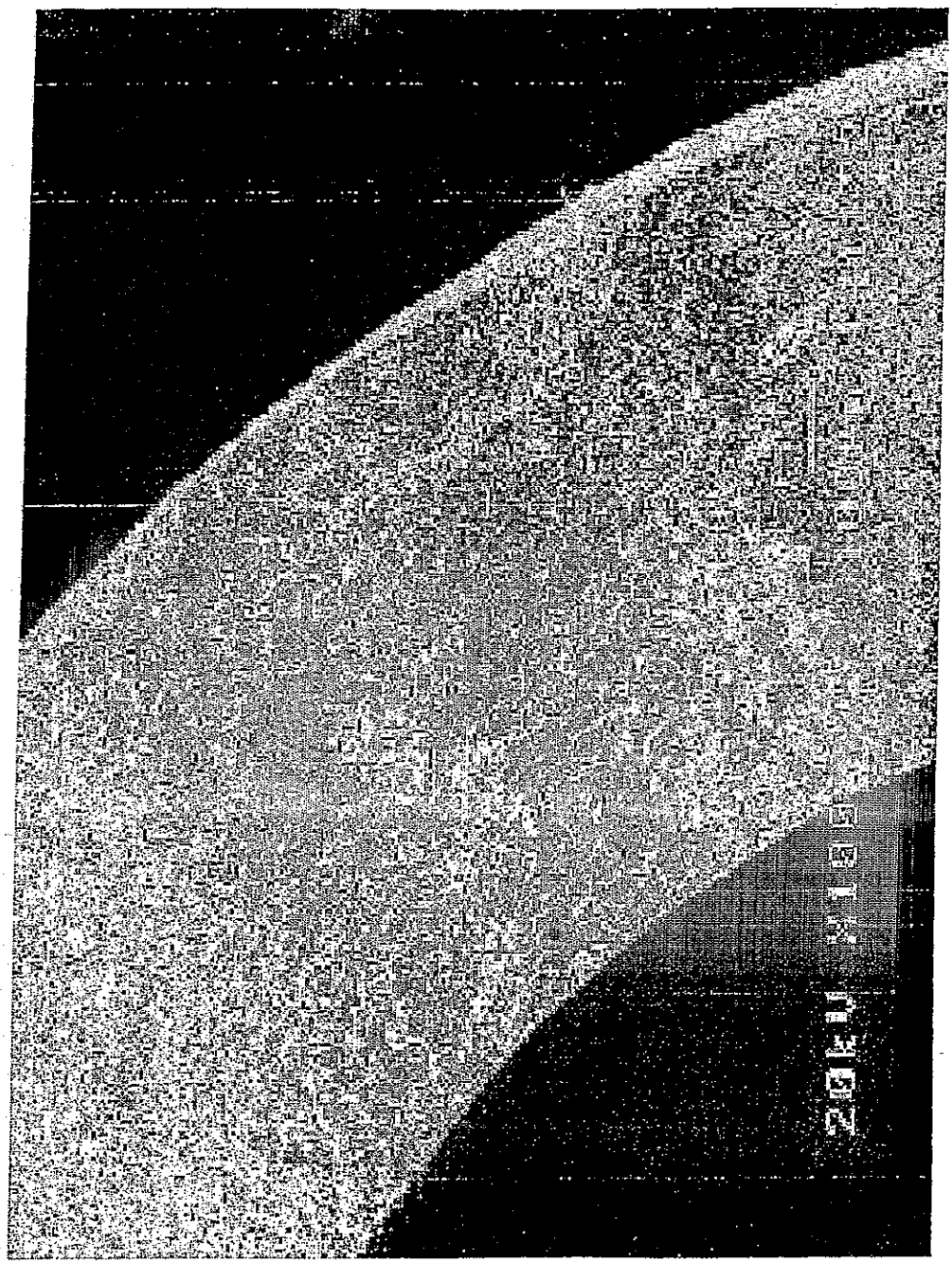


Fig. 4

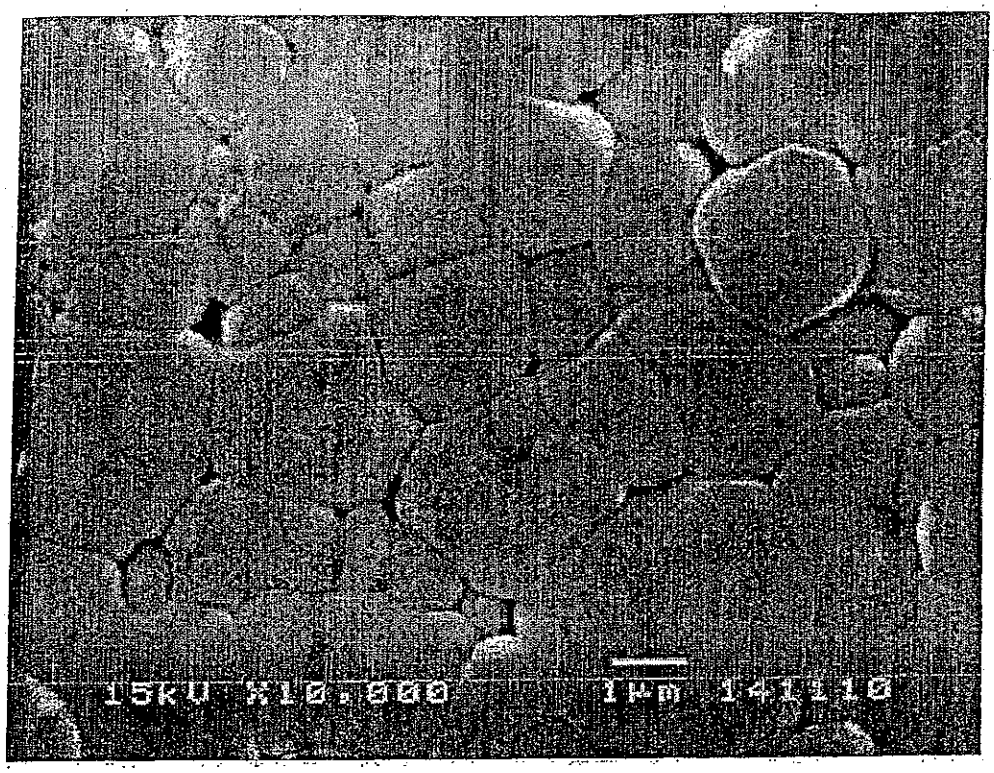


Fig. 5

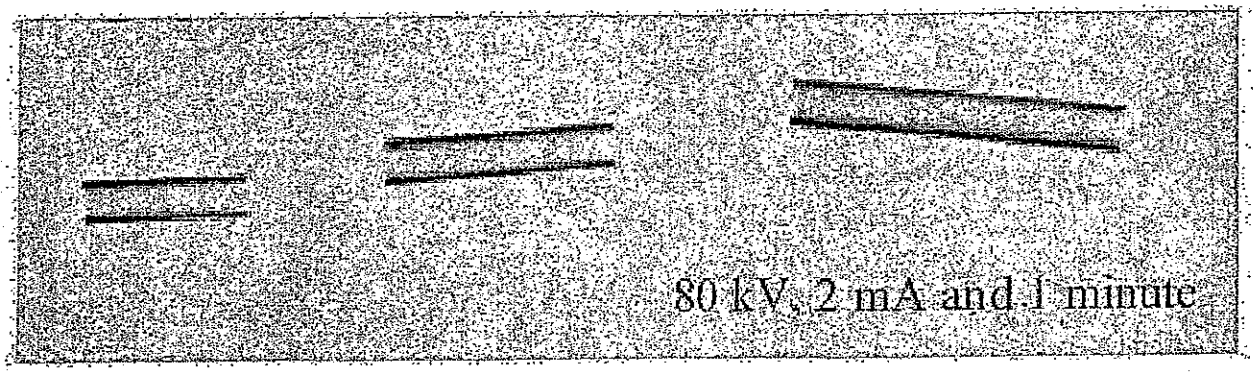


Fig. 6

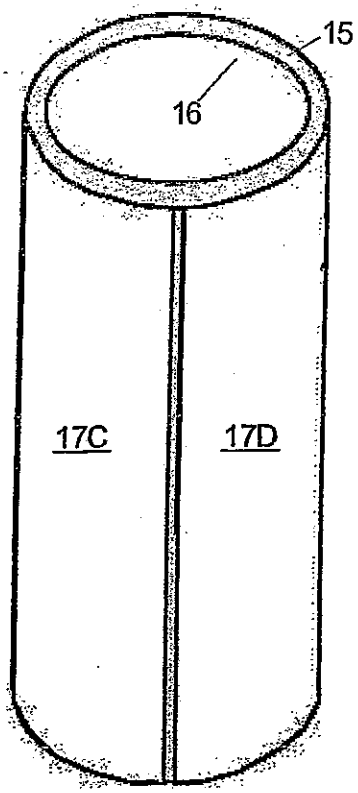


Fig. 7A

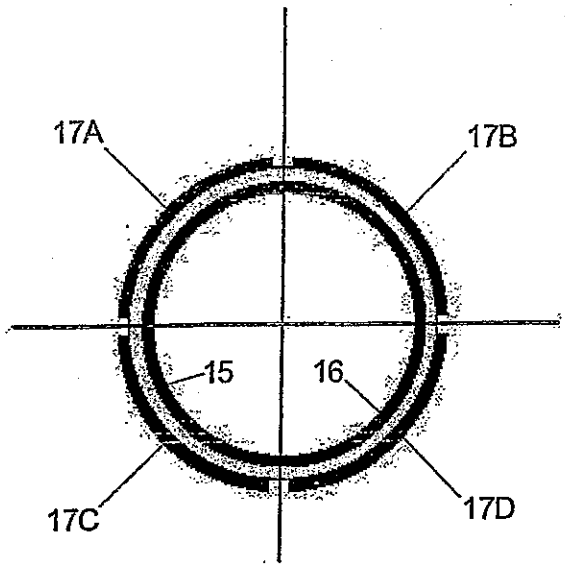


Fig. 7B

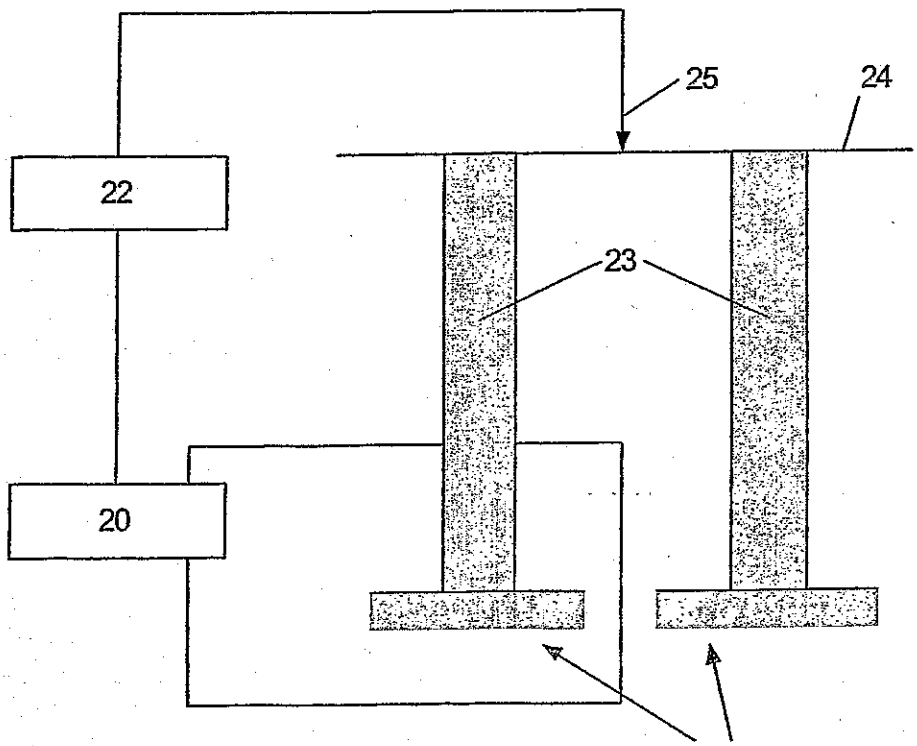


Fig. 8

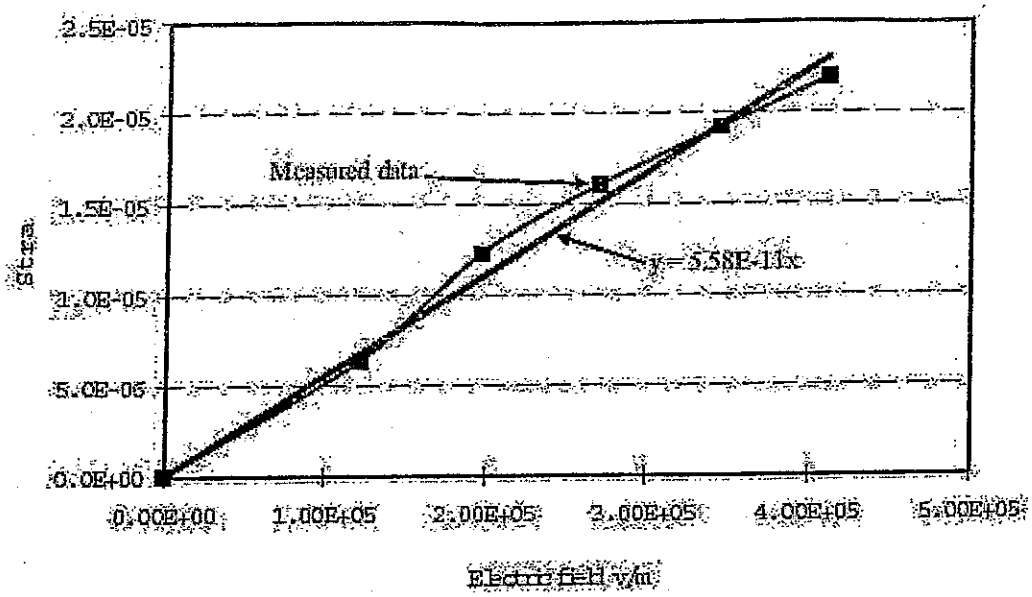


Fig. 9

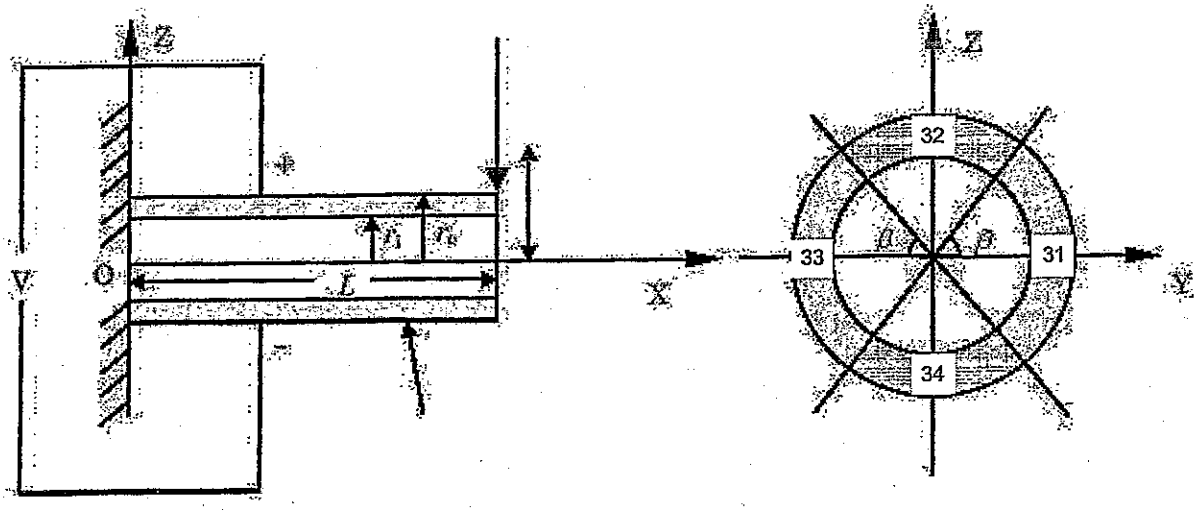


Fig. 10A

Fig. 10B

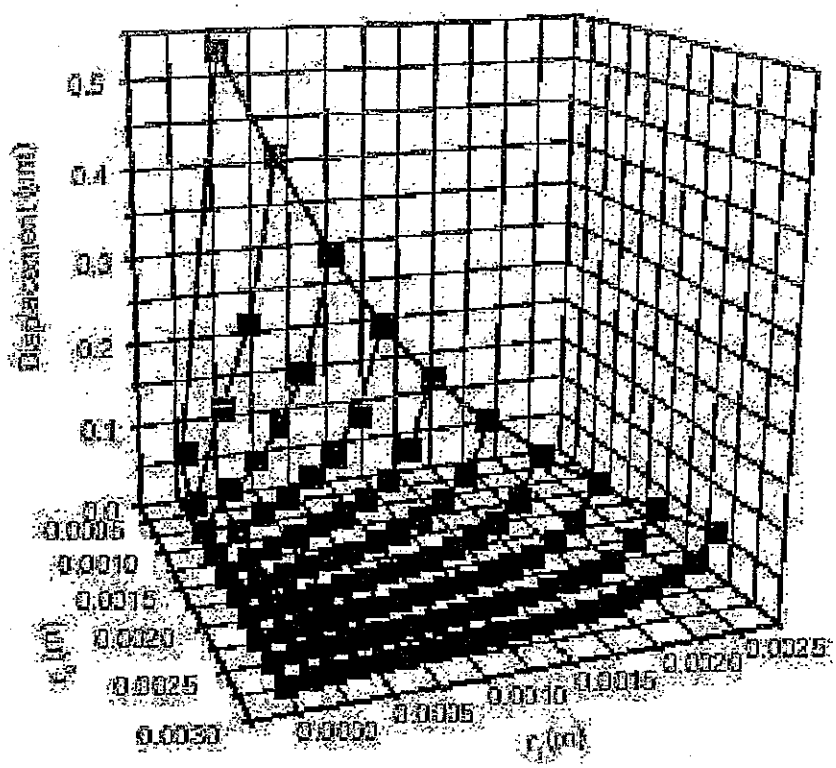

0.5
0.4
0.3
0.2
0.1
0.0
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025

Fig. 11

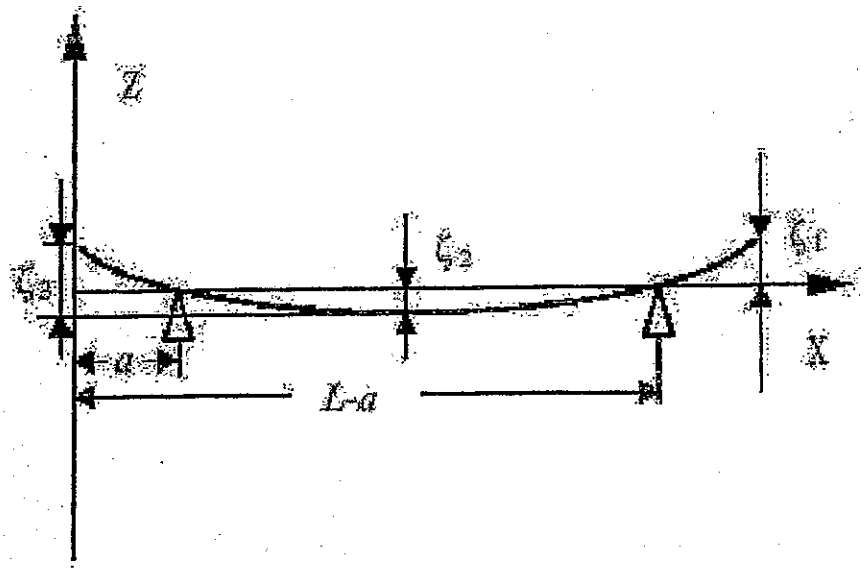

Z
X
a
L-a

Fig. 12

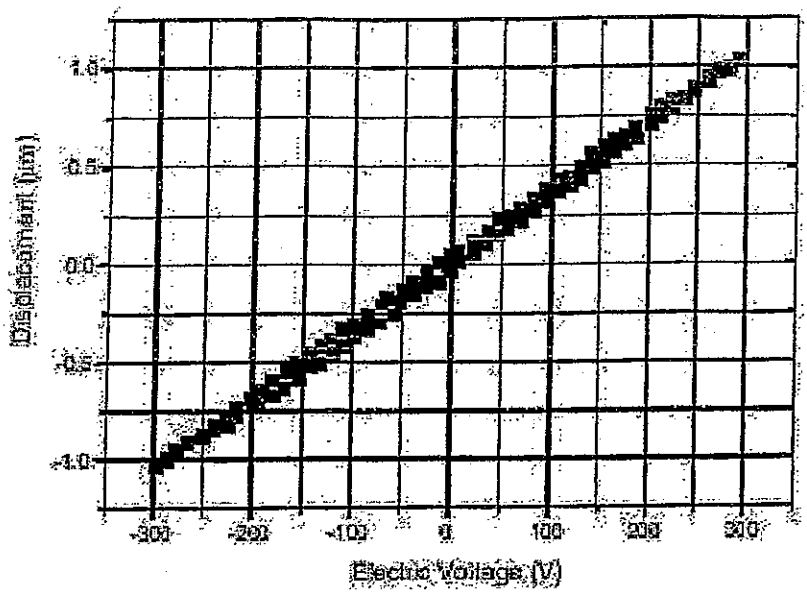

Displacement (μm)
1.0
0.5
0.0
-0.5
-1.0
-300
-200
-100
0
100
200
300
Electric Voltage (V)

Fig. 13

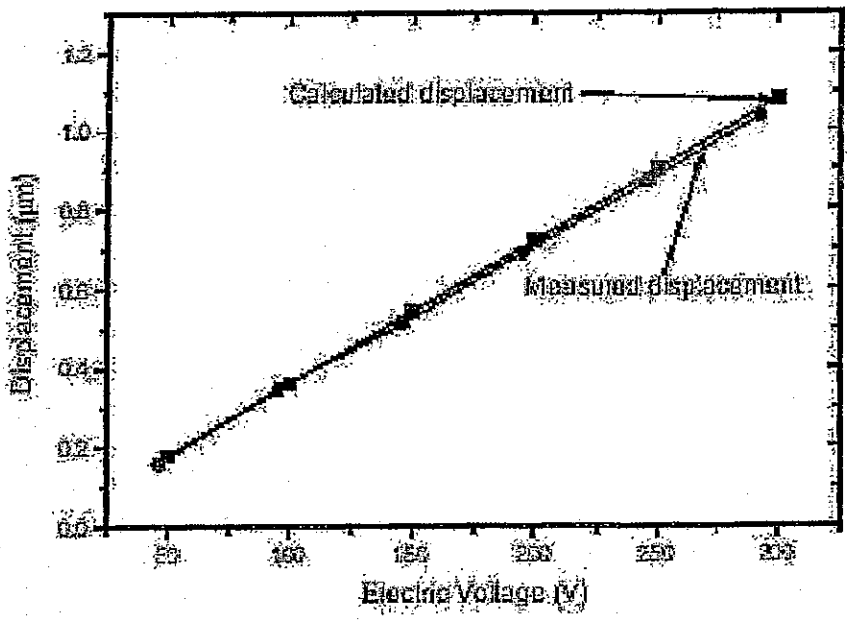

Calculated displacement
Measured displacement
Displacement (μm)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
50
100
150
200
250
300
Electric Voltage (V)

Fig. 14

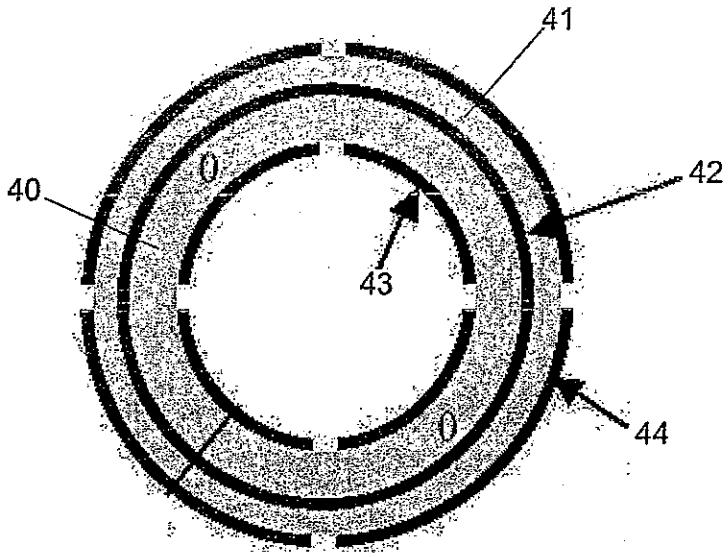


Fig. 15

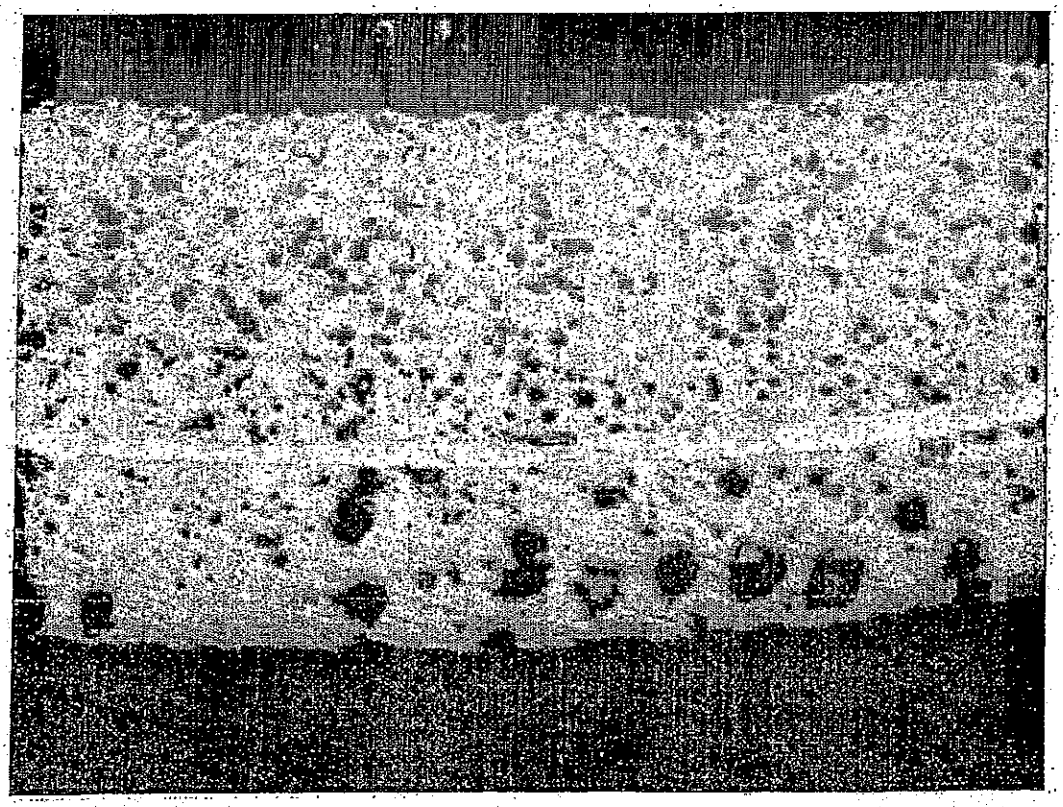


Fig. 16

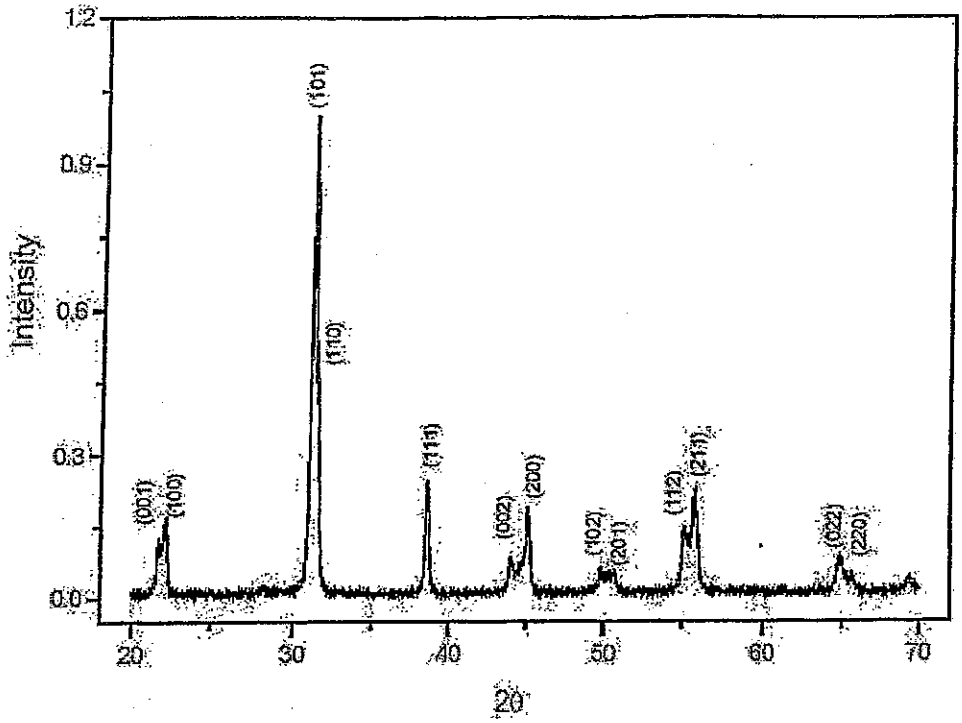

Intensity
1.2
0.9
0.6
0.3
0.0
20
30
40
50
60
70
2θ
(001)
(100)
(101)
(110)
(111)
(002)
(200)
(102)
(201)
(112)
(211)
(022)
(220)

Fig. 17



Fig. 18

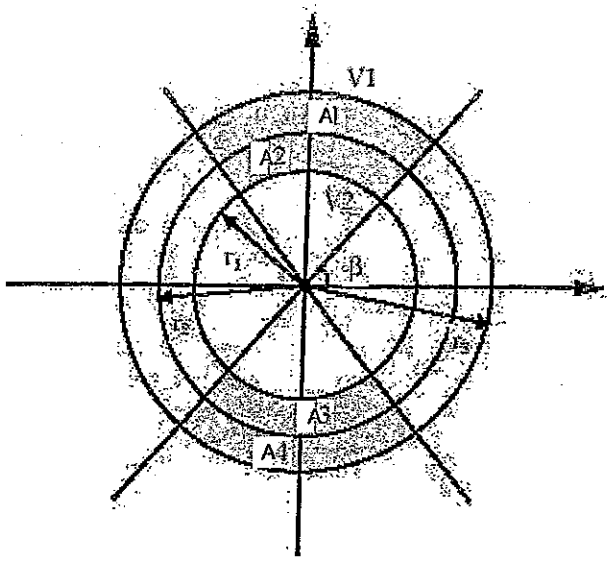

V1
A1
A2
A3
A4
β

Fig. 19

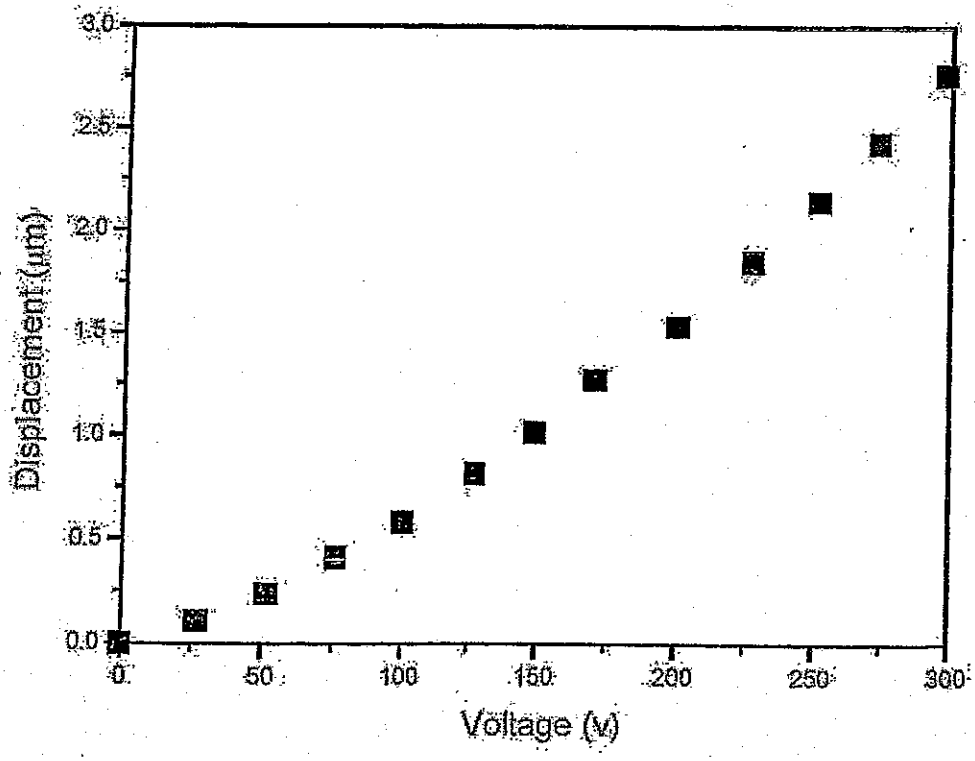

Displacement (μm)
Voltage (v)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
250
300

Fig. 20

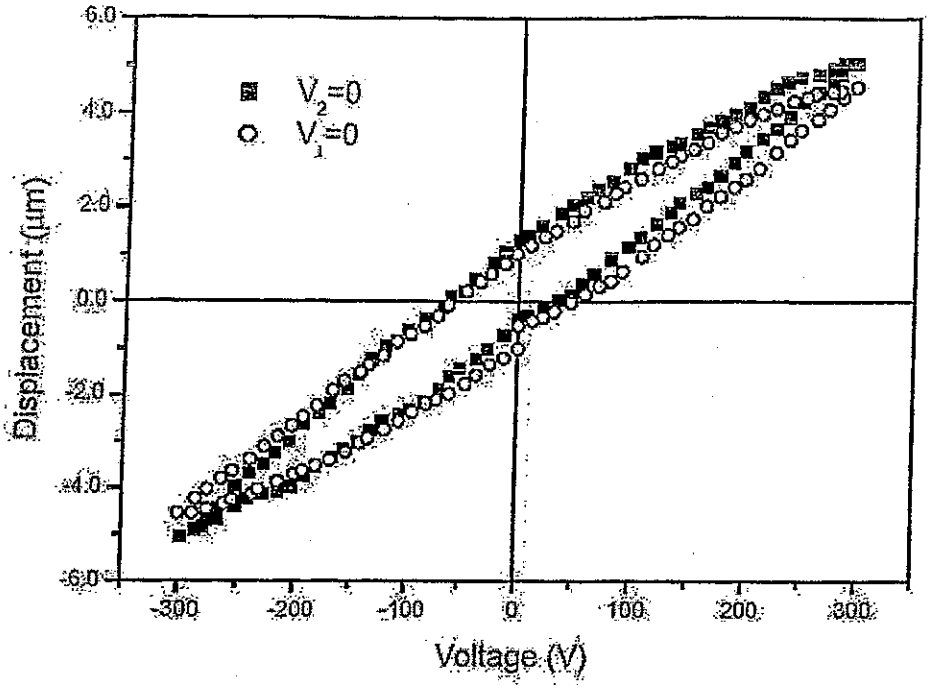

6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
Displacement (μm)
V2=0
V1=0
-300
-200
-100
0
100
200
300
Voltage (V)

Fig. 21

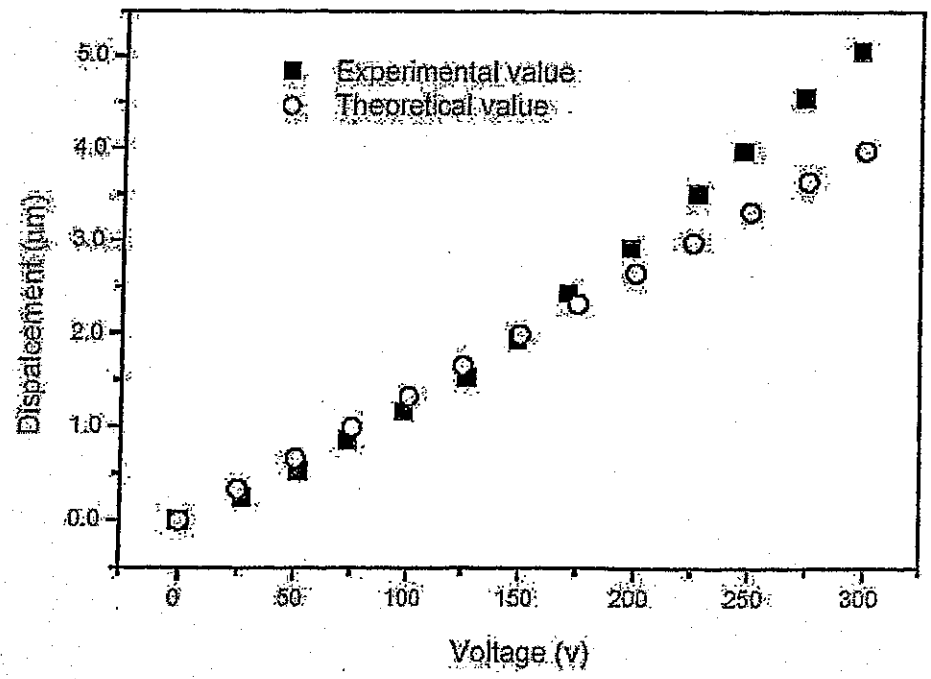

5.0
4.0
3.0
2.0
1.0
0.0
Displacement (μm)
Experimental value
Theoretical value
0
50
100
150
200
250
300
Voltage (v)

Fig. 22

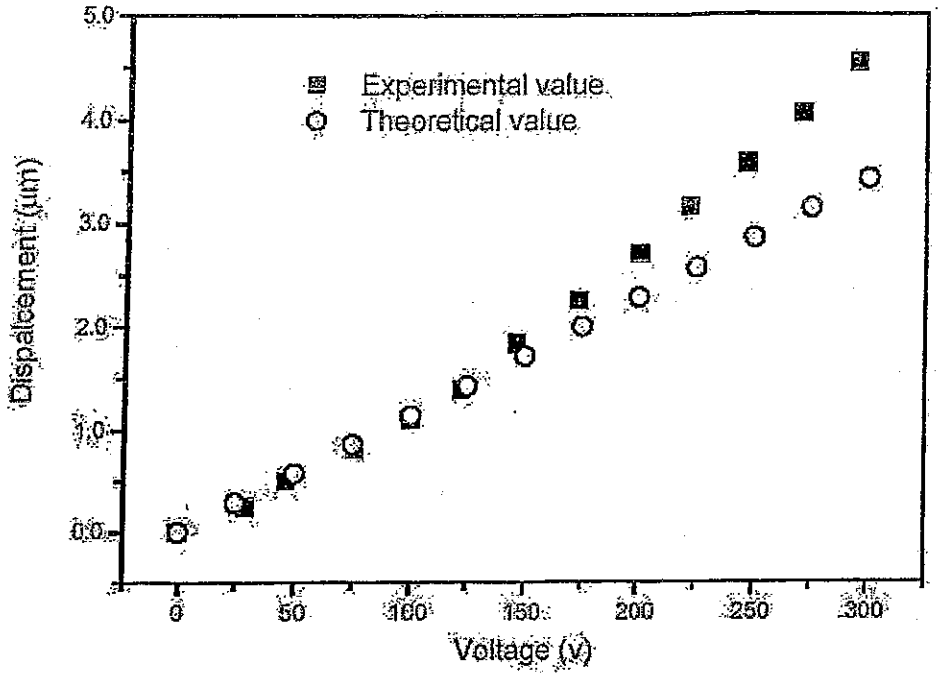

Experimental value
Theoretical value
Displacement (μm)
Voltage (v)
0.0
1.0
2.0
3.0
4.0
5.0
0
50
100
150
200
250
300

Fig. 23

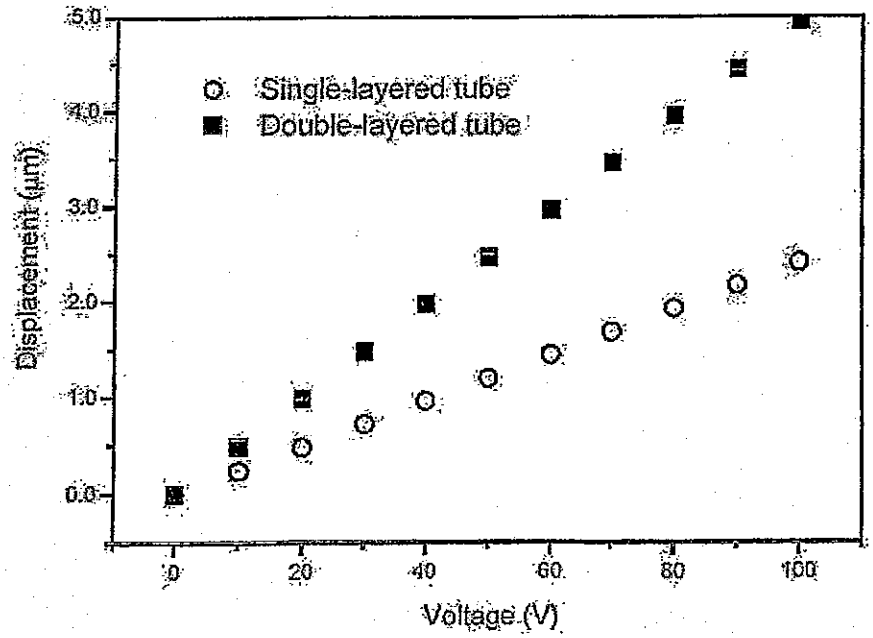

Single-layered tube
Double-layered tube
Displacement (μm)
Voltage (V)
0.0
1.0
2.0
3.0
4.0
5.0
0
20
40
60
80
100

Fig. 24

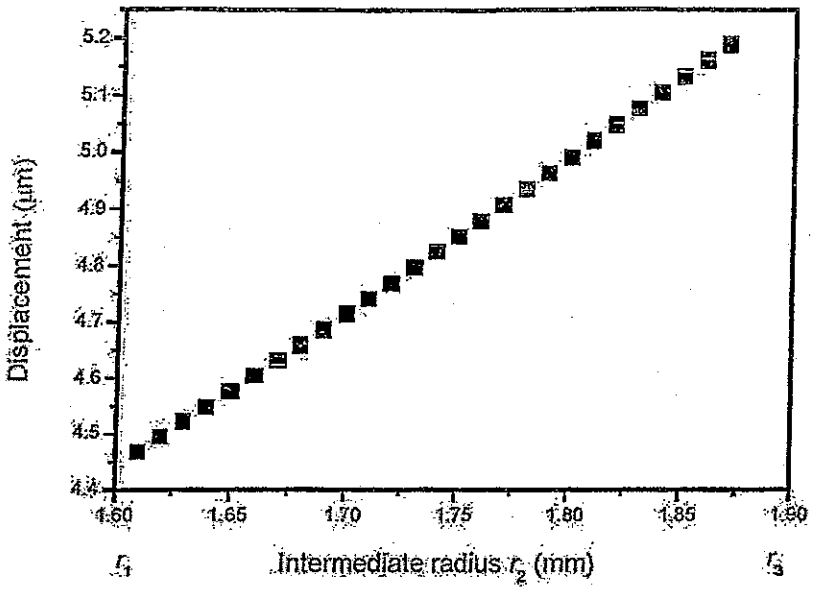

Displacement (μm)
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
1.60
1.65
1.70
1.75
1.80
1.85
1.90
Intermediate radius r_2 (mm)
r_1
r_3

Fig. 25