FIG. 1

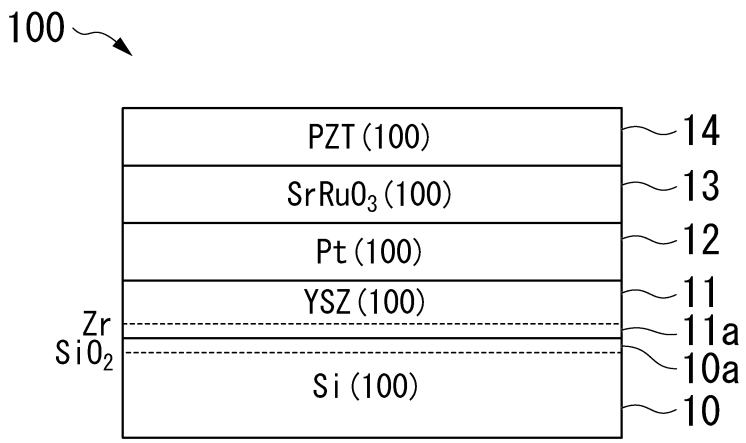

100
PZT (100)
$SrRuO_3$ (100)
Pt (100)
YSZ (100)
Zr
SiO_2
Si (100)
14
13
12
11
11a
10a
10

FIG. 2

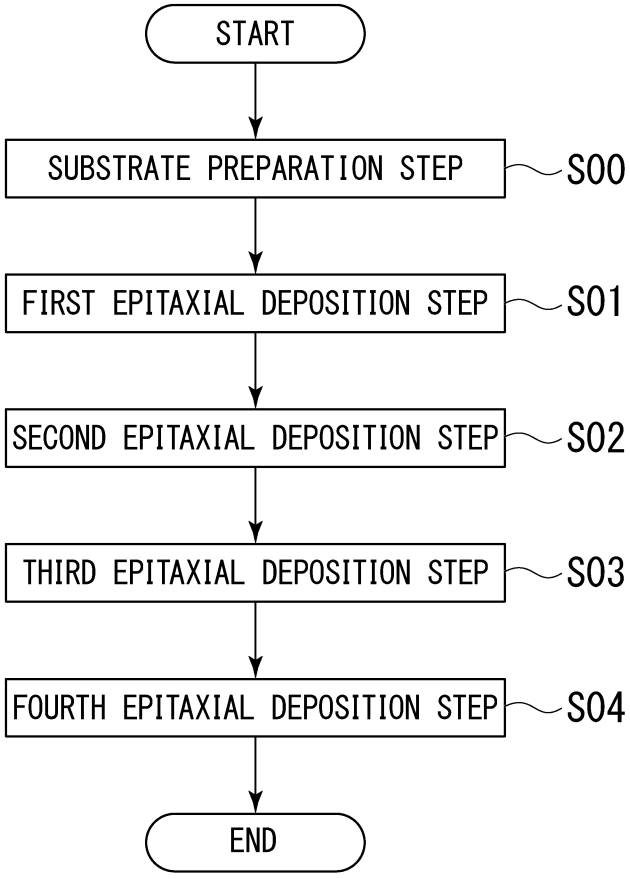

START
SUBSTRATE PREPARATION STEP
S00
FIRST EPITAXIAL DEPOSITION STEP
S01
SECOND EPITAXIAL DEPOSITION STEP
S02
THIRD EPITAXIAL DEPOSITION STEP
S03
FOURTH EPITAXIAL DEPOSITION STEP
S04
END

FIG. 3

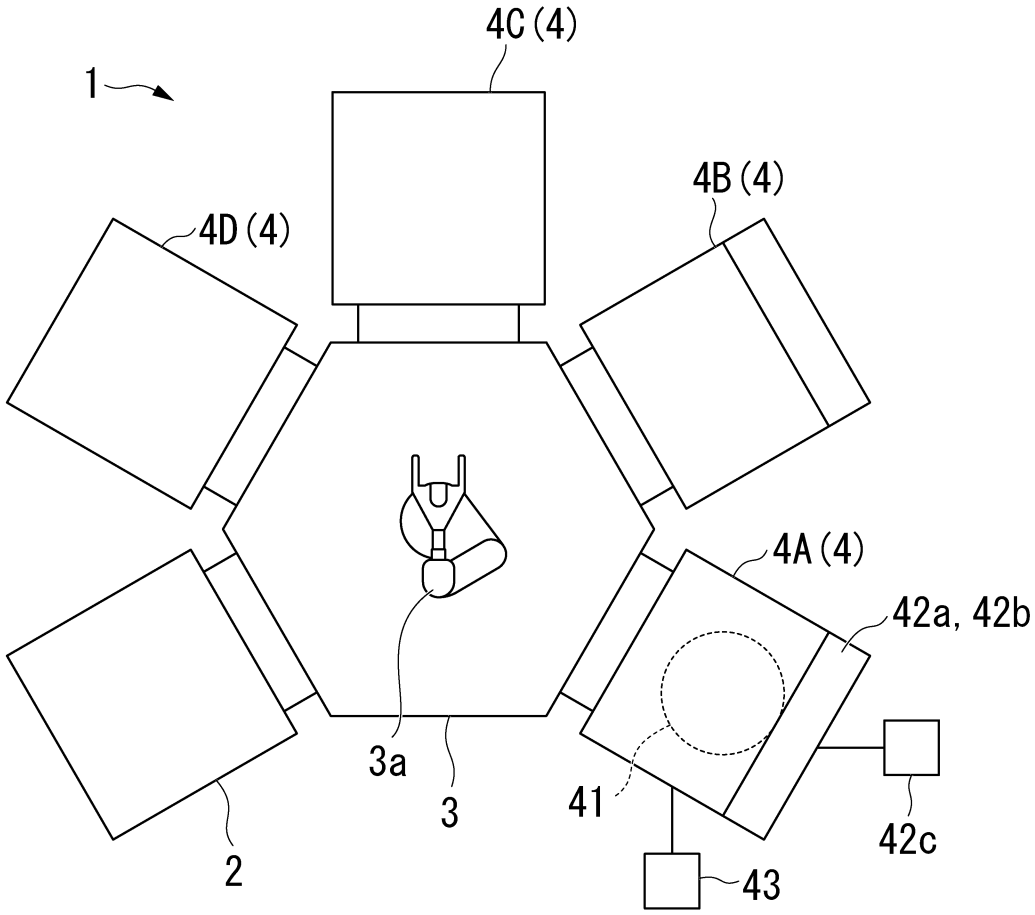


FIG. 4A

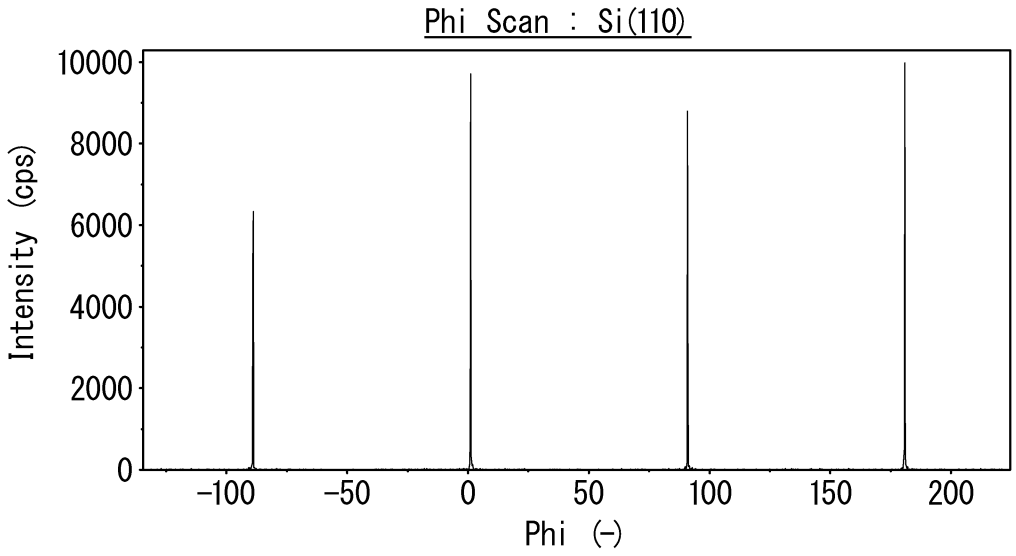


FIG. 4B

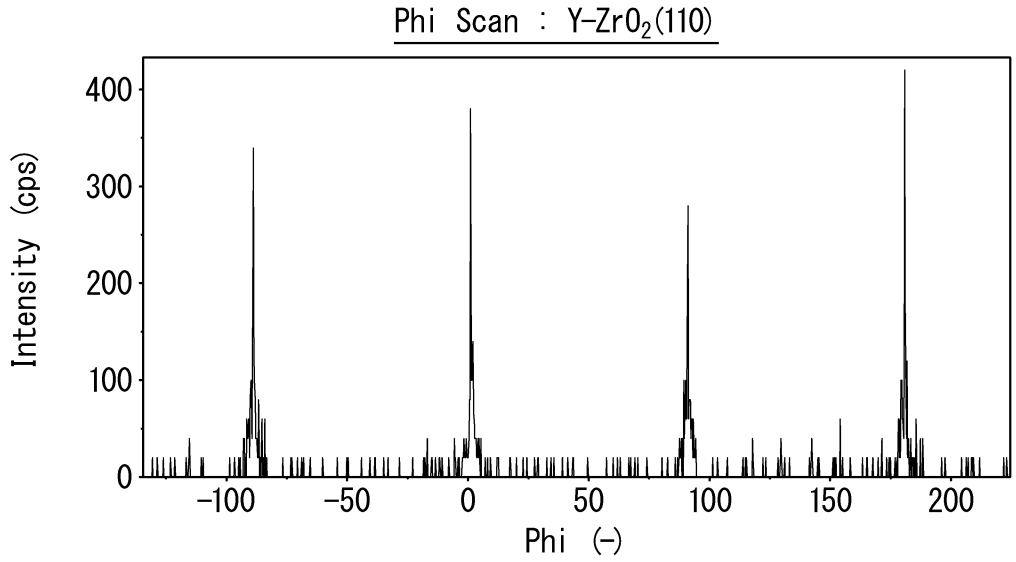


FIG. 4C

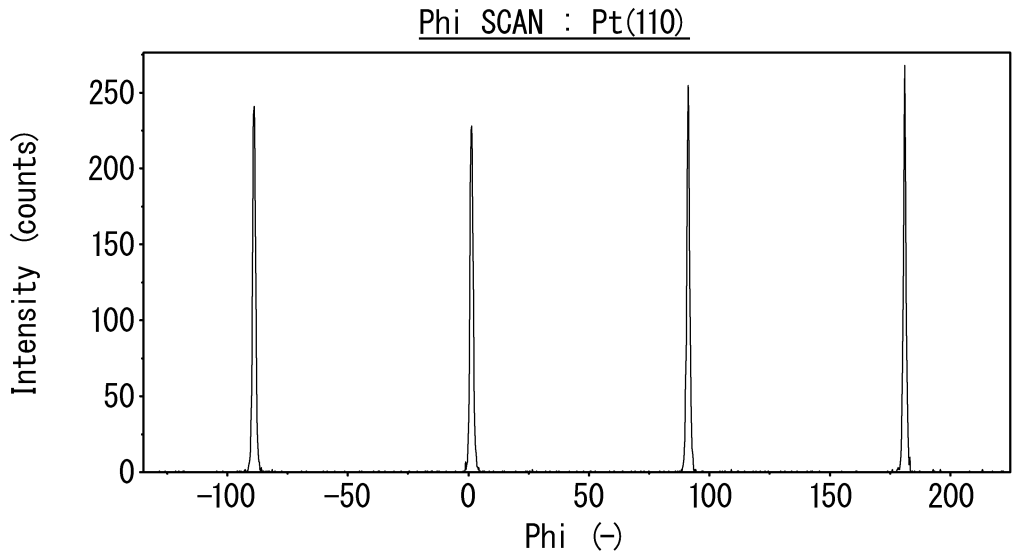


FIG. 5A

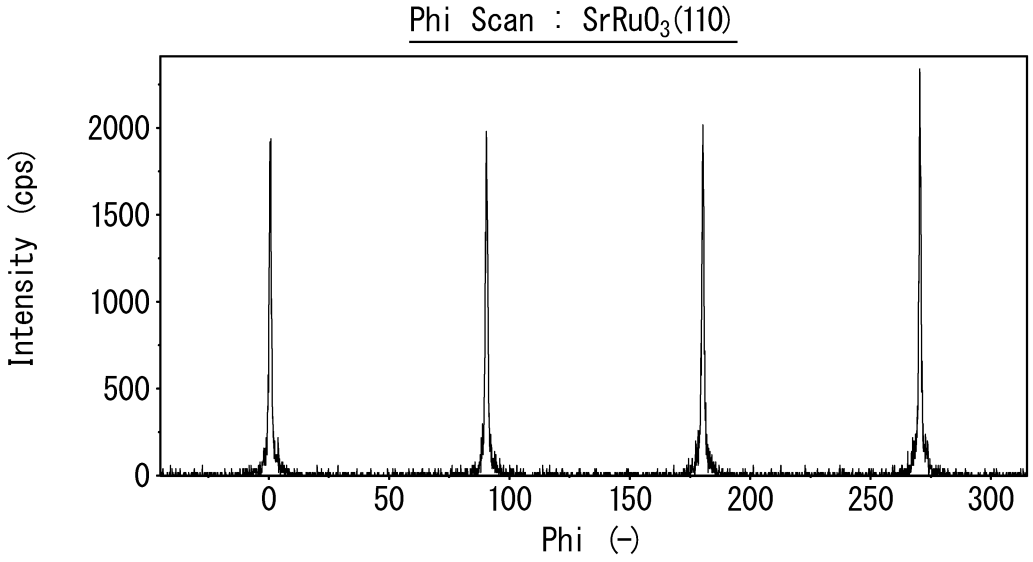


FIG. 5B

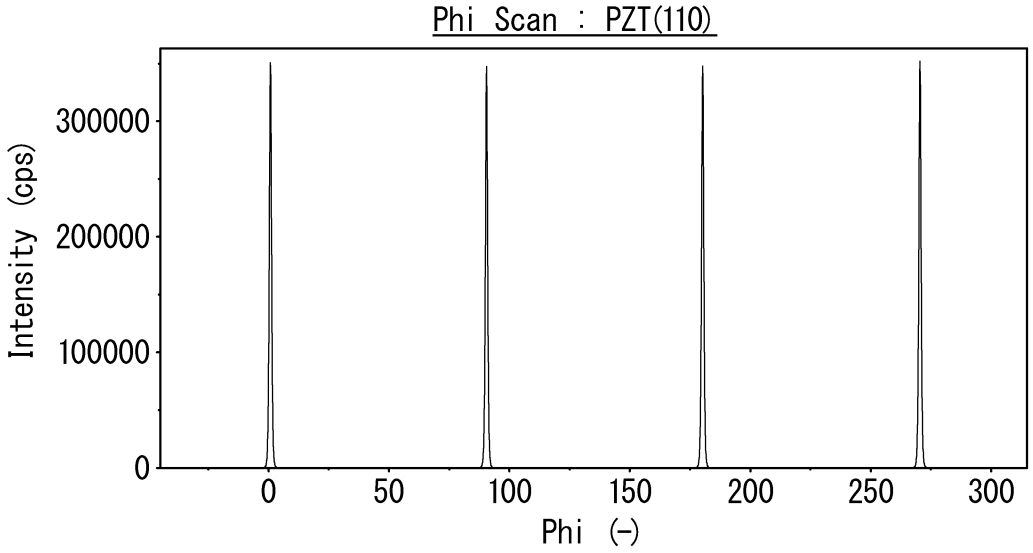


FIG. 5C

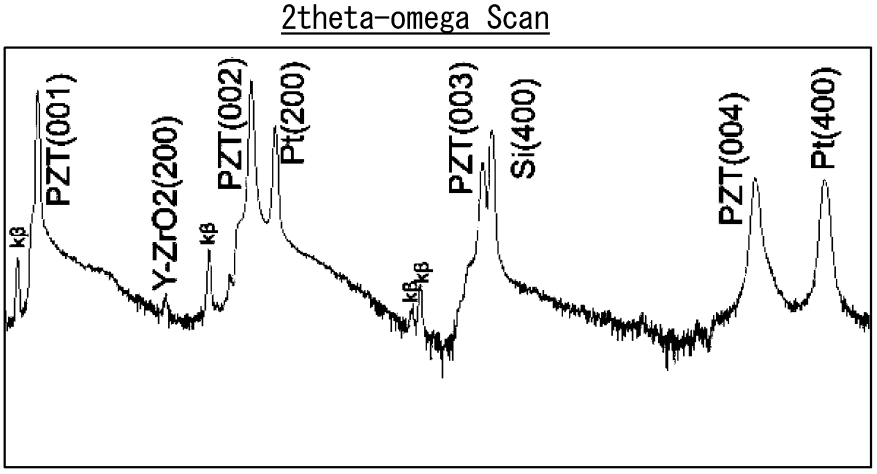


FIG. 6

YSZ FILM THICKNESS 200 TO 500 nm

Etching	Seed layer	600℃	650℃	700℃
YES	NO	×YSZ (111) LARGE	△YSZ (111) SMALL	◎YSZ (111) NONE
NO	NO	×YSZ (111) LARGE	◎YSZ (111) NONE	◎YSZ (111) NONE
NO	YES		◎YSZ (111) NONE	

FIG. 7

YSZ FILM THICKNESS 60 nm OR LESS

Etching	Seed layer	600℃	650℃	700℃
NO	NO		×YSZ (111) LARGE	△YSZ (111) SMALL
NO	YES	×YSZ (111) LARGE	◎YSZ (111) NONE	◎YSZ (111) NONE

FIG. 8

Pt DEPOSITION TEMPERATURE	YSZ FILM THICKNESS					
	20nm	25nm	30nm	40nm	50nm	60nm
400℃	111		111&200	111&200		
500℃	111	200	200	200	200	111
600℃	111	200	200	200	200	111

FIG. 9

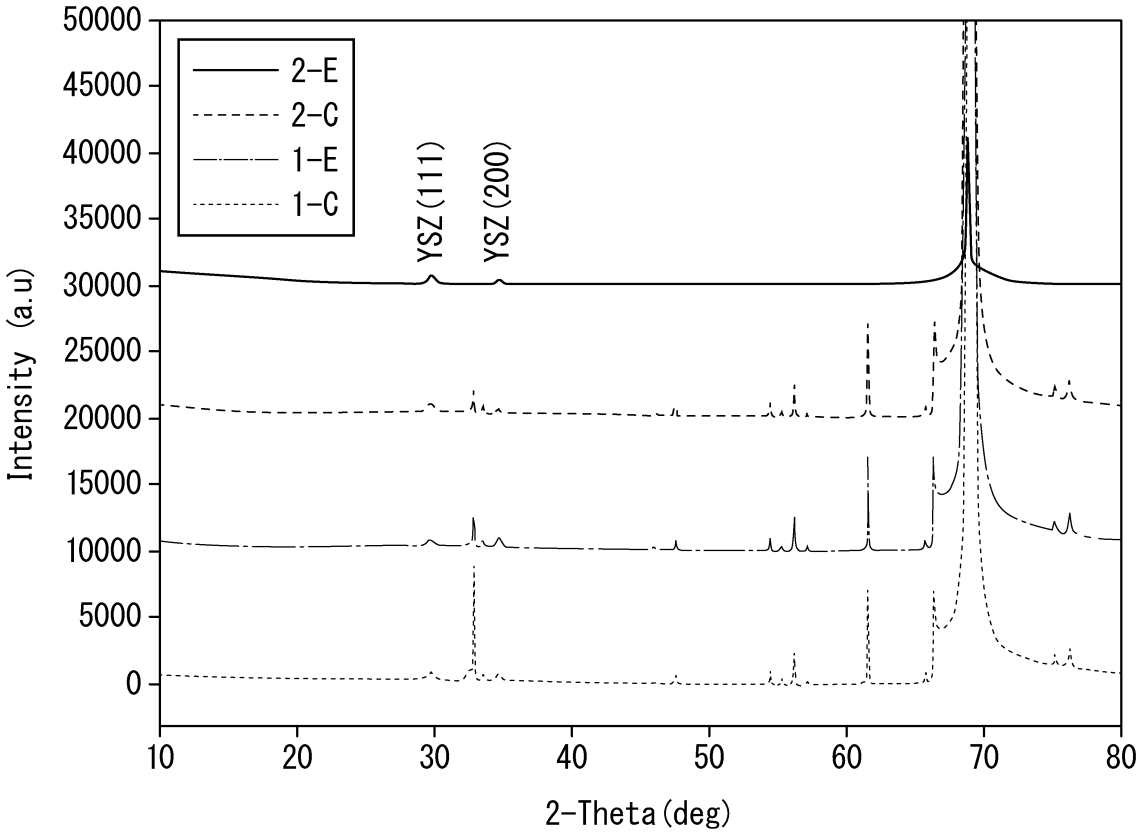

2-E
2-C
1-E
1-C
YSZ (111)
YSZ (200)
Intensity (a.u)
2-Theta (deg)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10
20
30
40
50
60
70
80

FIG. 10

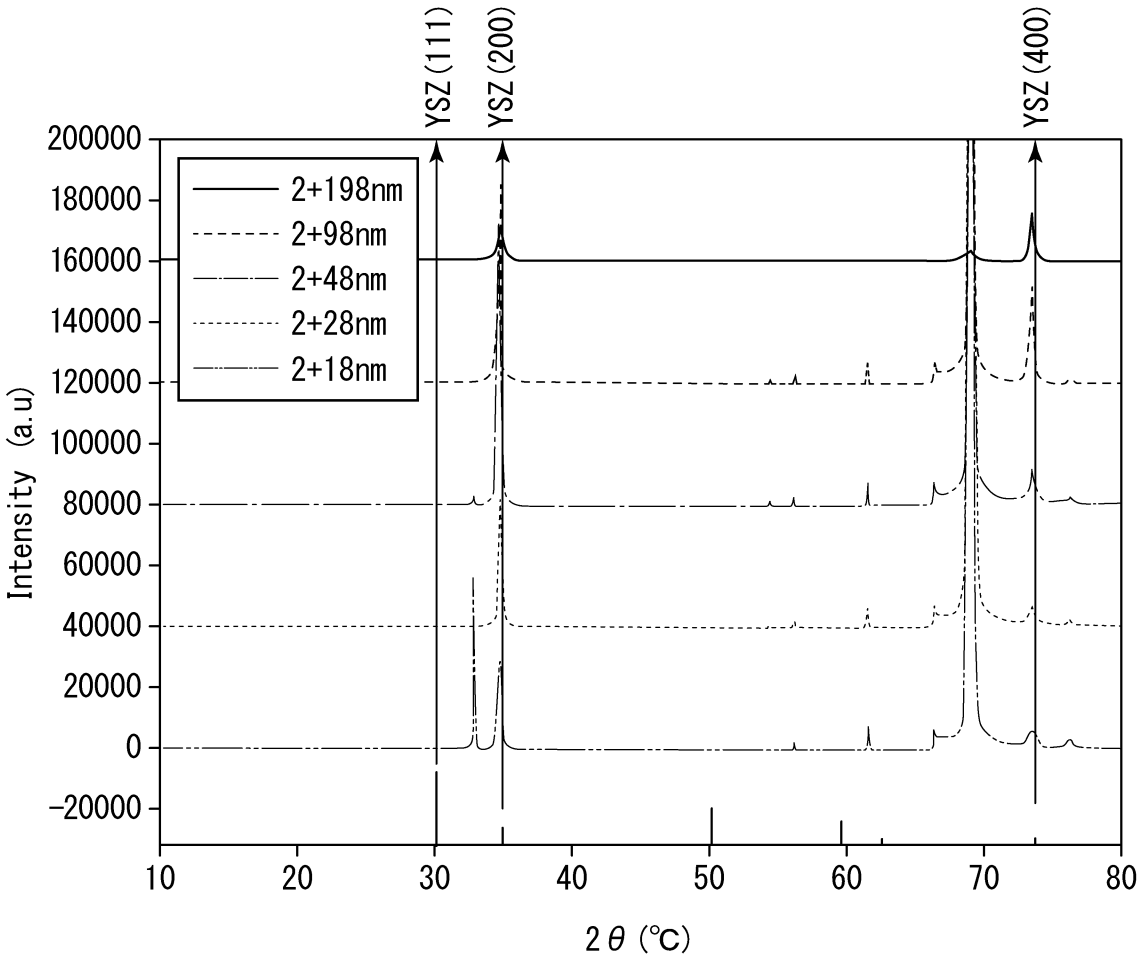

YSZ (111)
YSZ (200)
YSZ (400)
2+198nm
2+98nm
2+48nm
2+28nm
2+18nm
Intensity (a.u)
2θ (℃)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
-20000
10
20
30
40
50
60
70
80

FIG. 11

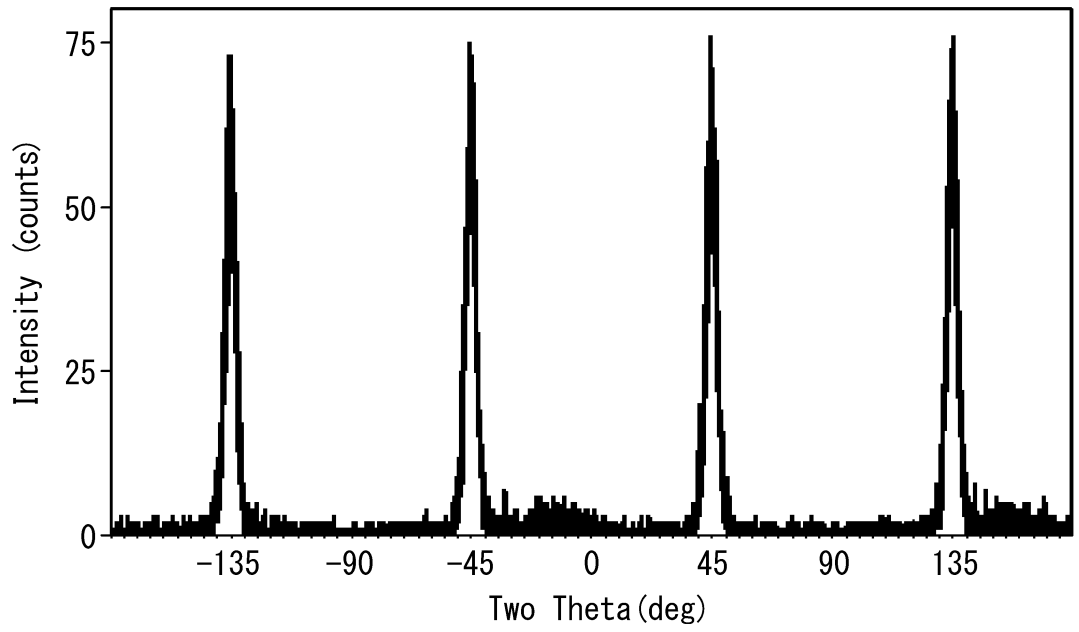

75
50
25
0
Intensity (counts)
-135
-90
-45
0
45
90
135
Two Theta(deg)

FIG. 12

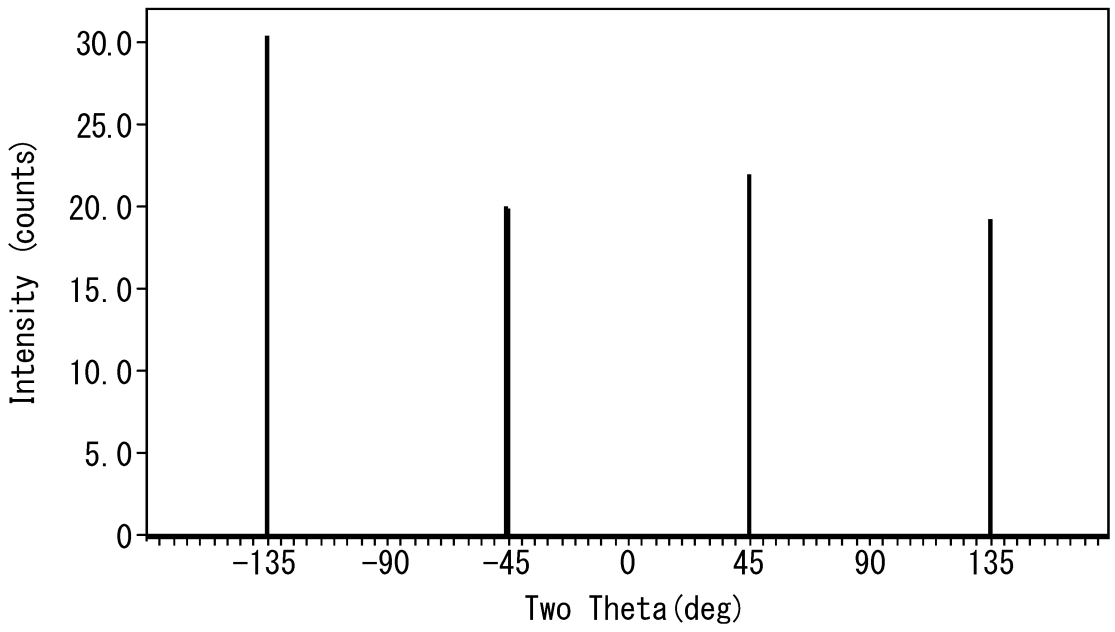

30.0
25.0
20.0
15.0
10.0
5.0
0
Intensity (counts)
-135
-90
-45
0
45
90
135
Two Theta(deg)

FIG. 13

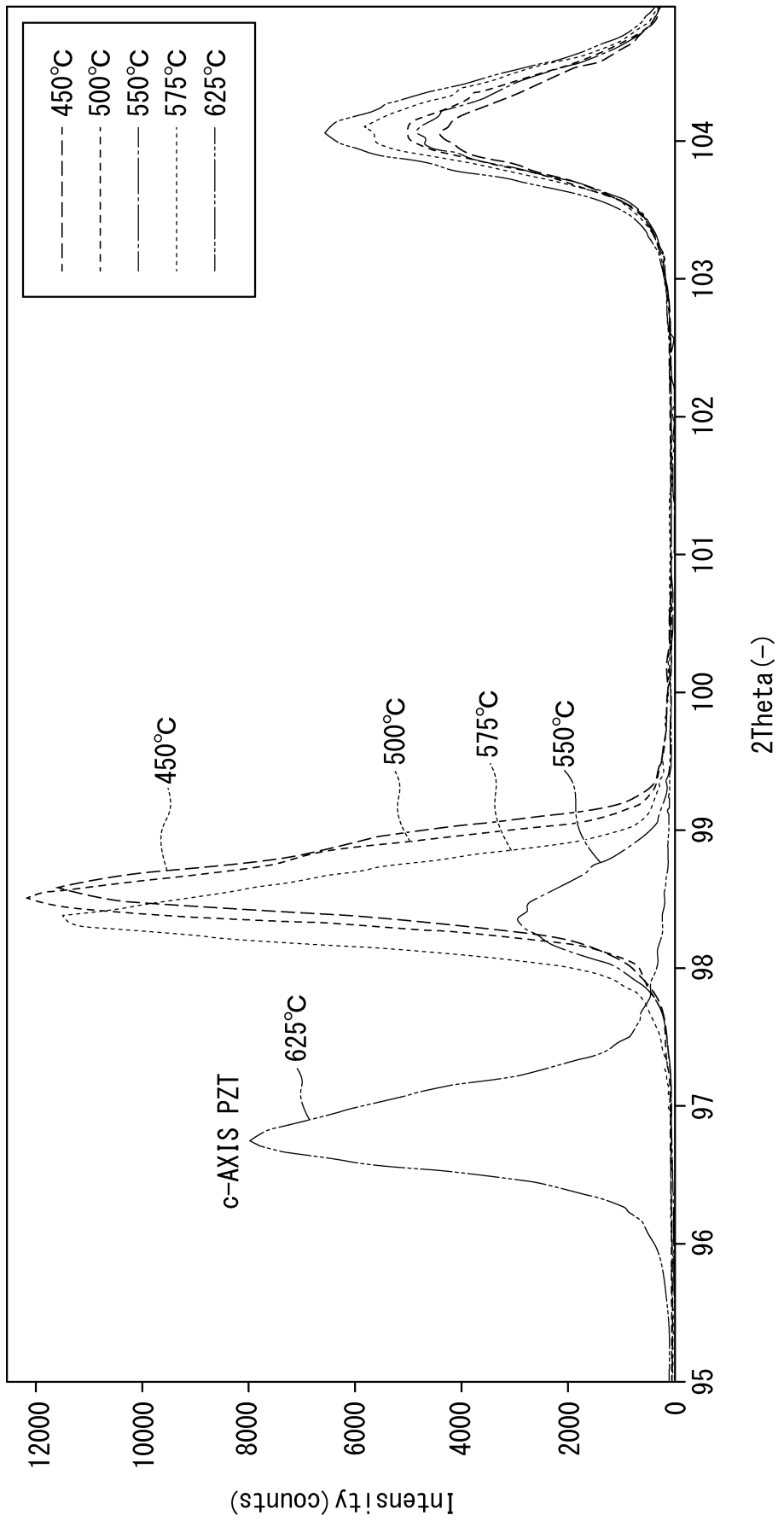

450°C
500°C
550°C
575°C
625°C
a-AXIS PZT
c-AXIS PZT
Intensity (counts)
2Theta (-)
0
2000
4000
6000
8000
10000
12000
95
96
97
98
99
100
101
102
103
104

FIG. 14

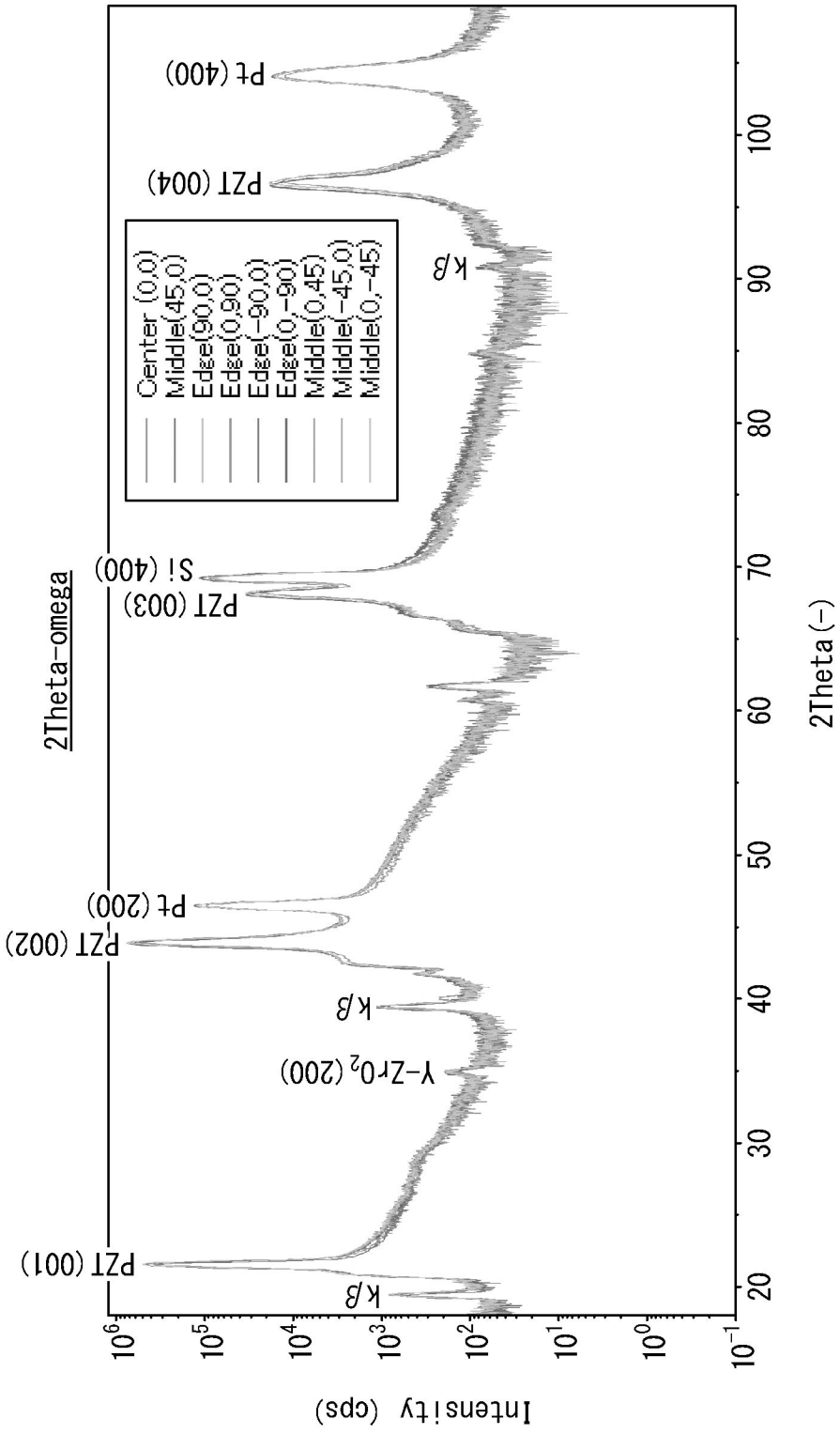

2Theta-omega
Intensity (cps)
2Theta (-)
Center (0,0)
Middle(45,0)
Edge(90,0)
Edge(0,90)
Edge(-90,0)
Edge(0,-90)
Middle(0,45)
Middle(-45,0)
Middle(0,-45)
PZT (001)
kβ
Y-ZrO2 (200)
kβ
PZT (002)
Pt (200)
PZT (003)
Si (400)
kβ
PZT (004)
Pt (400)

FIG. 15

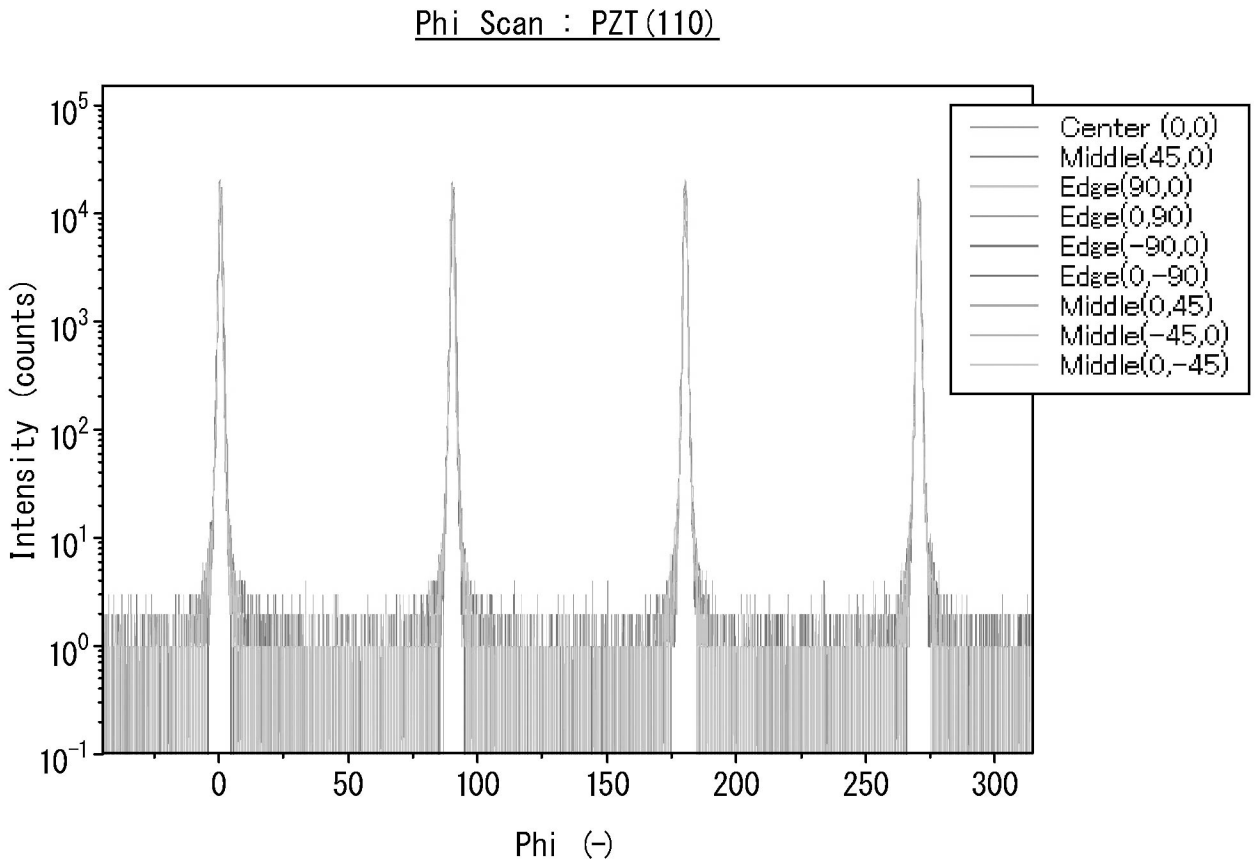

Phi Scan : PZT(110)
Intensity (counts)
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
50
100
150
200
250
300
Phi (-)
Center (0,0)
Middle(45,0)
Edge(90,0)
Edge(0,90)
Edge(-90,0)
Edge(0,-90)
Middle(0,45)
Middle(-45,0)
Middle(0,-45)

FIG. 16

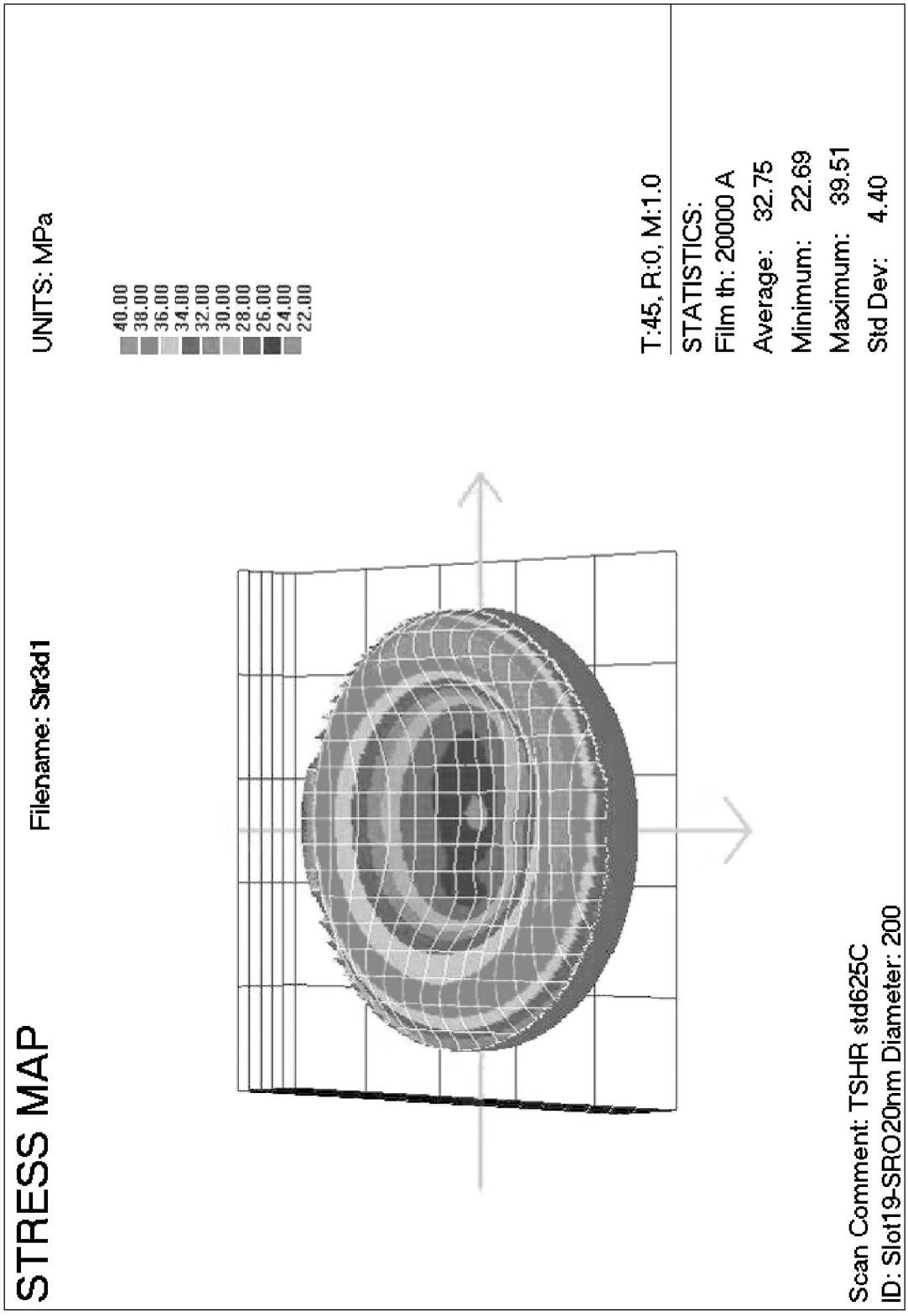

STRESS MAP
Filename: Str3d1
UNITS: MPa
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
T:45, R:0, M:1.0
STATISTICS:
Film th: 20000 A
Average: 32.75
Minimum: 22.69
Maximum: 39.51
Std Dev: 4.40
Scan Comment: TSHR std625C
ID: Slot19-SRO20nm Diameter: 200

FIG. 17

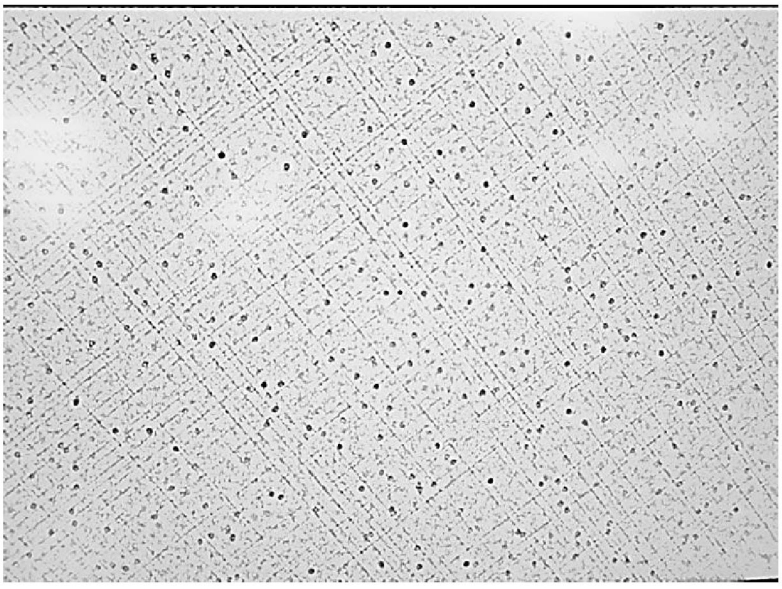


FIG. 18

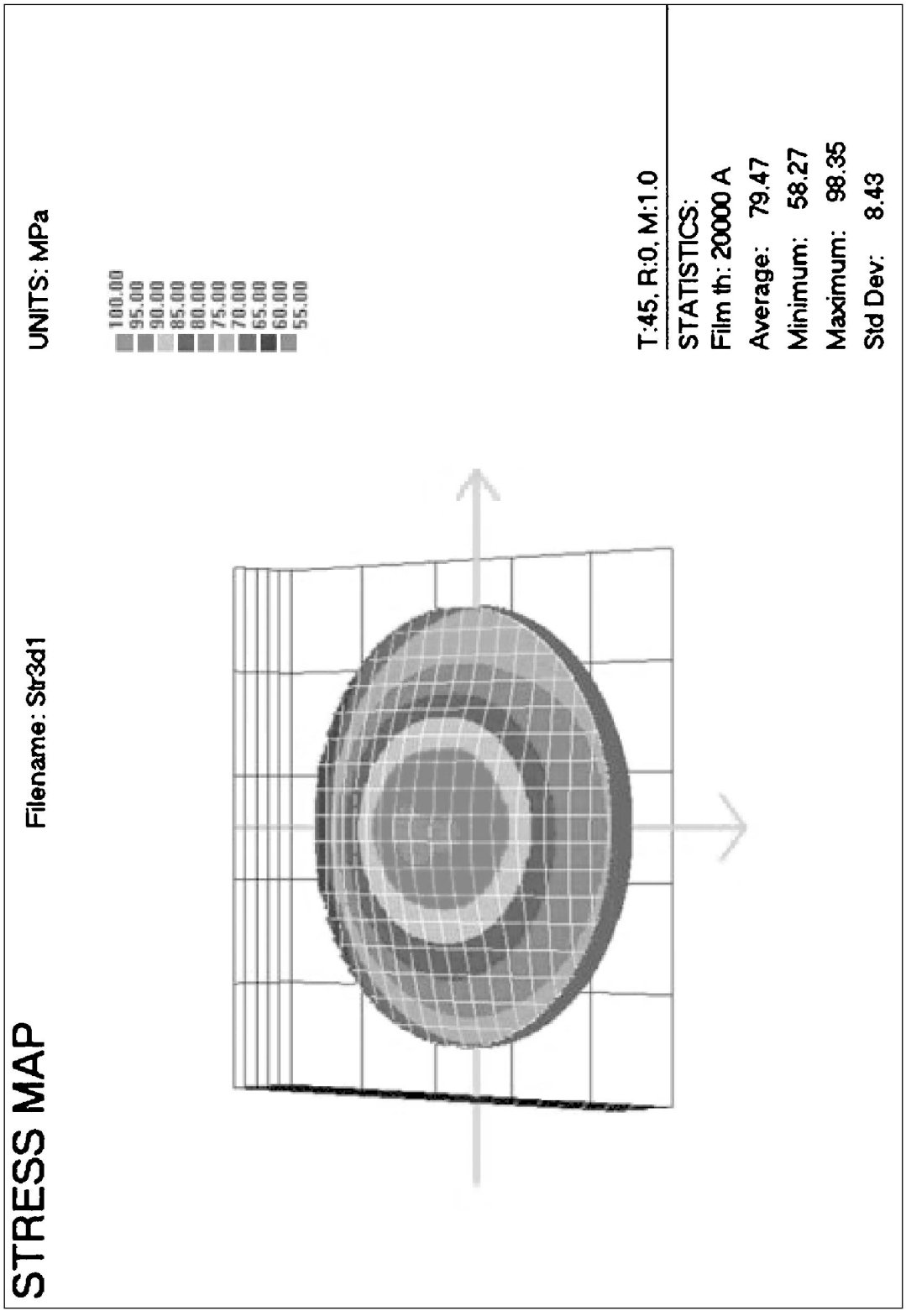

STRESS MAP
Filename: Str3d1
UNITS: MPa
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
T:45, R:0, M:1.0
STATISTICS:
Film th: 20000 A
Average: 79.47
Minimum: 58.27
Maximum: 98.35
Std Dev: 8.43

FIG. 19

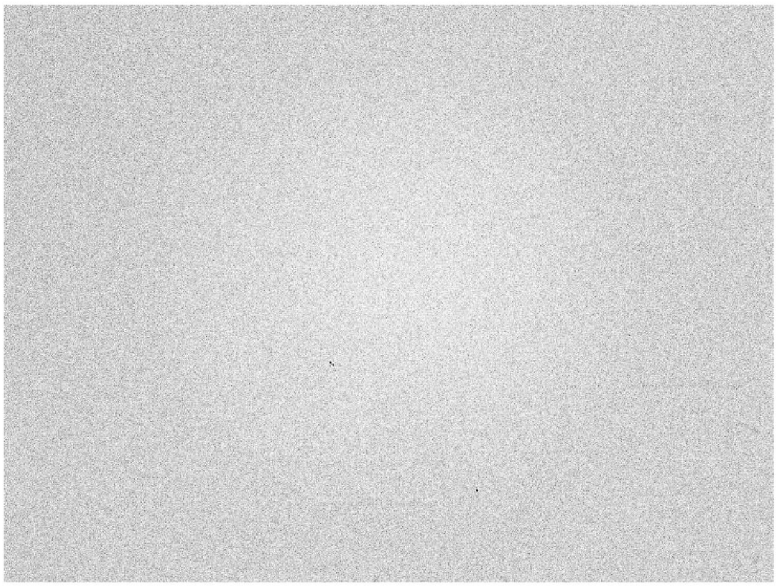


FIG. 20

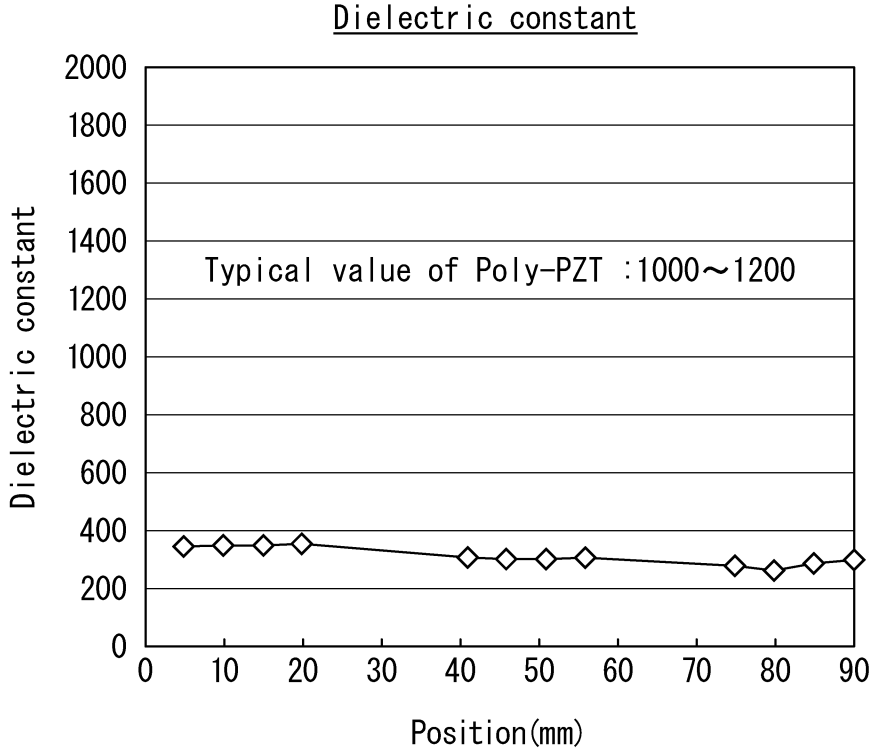

Dielectric constant
Dielectric constant
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Typical value of Poly-PZT :1000～1200
0
10
20
30
40
50
60
70
80
90
Position(mm)

FIG. 21

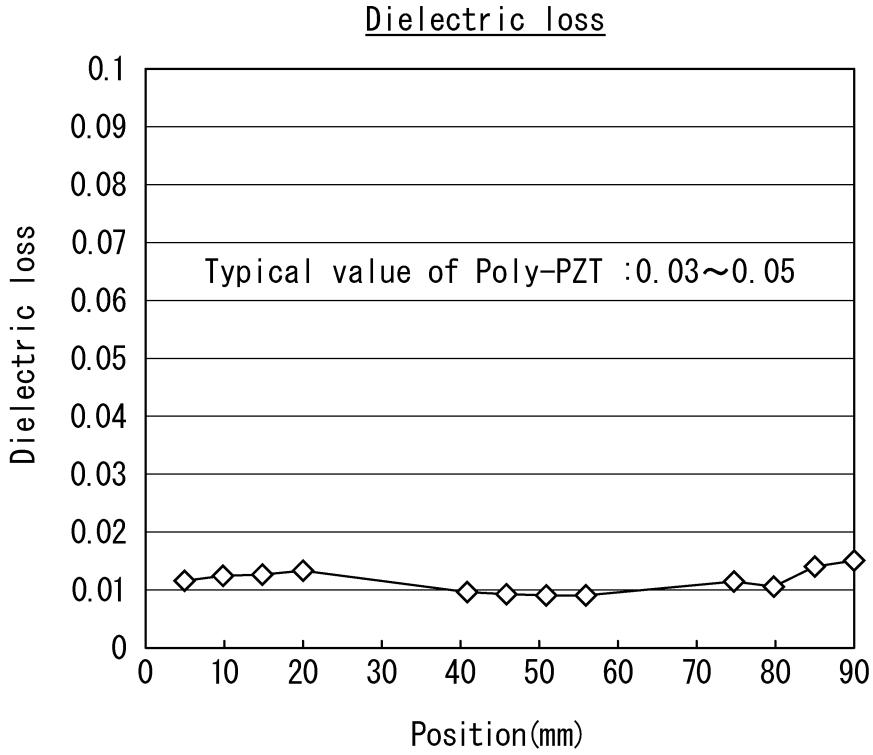

Dielectric loss
Dielectric loss
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Typical value of Poly-PZT :0.03～0.05
0
10
20
30
40
50
60
70
80
90
Position(mm)

FIG. 22

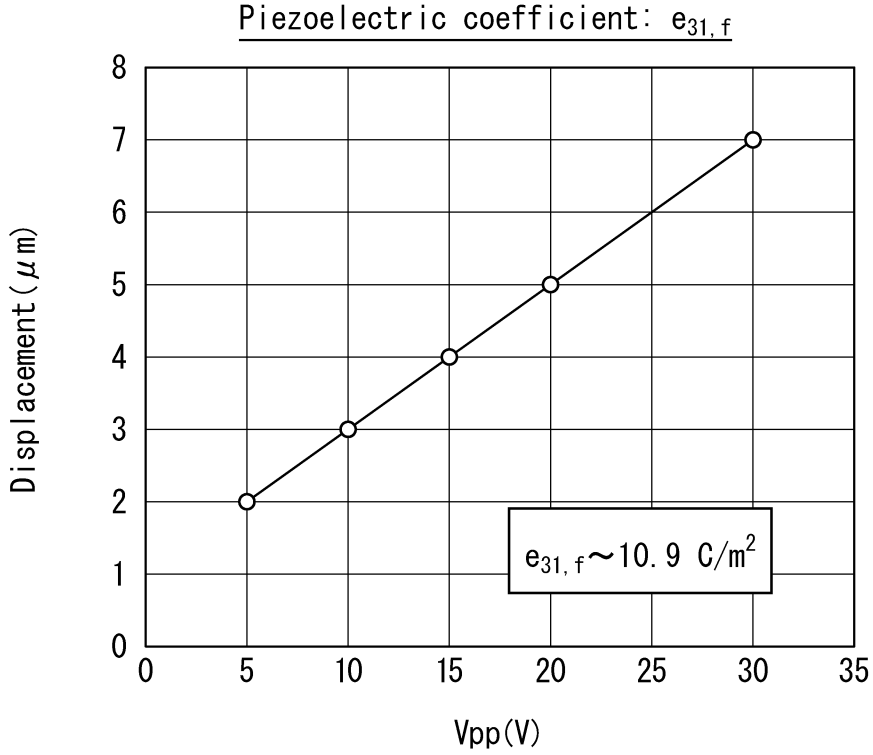

Piezoelectric coefficient: $e_{31,f}$
Displacement(μm)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30
35
Vpp(V)
$e_{31,f}$～10.9 C/m^2

FIG. 23

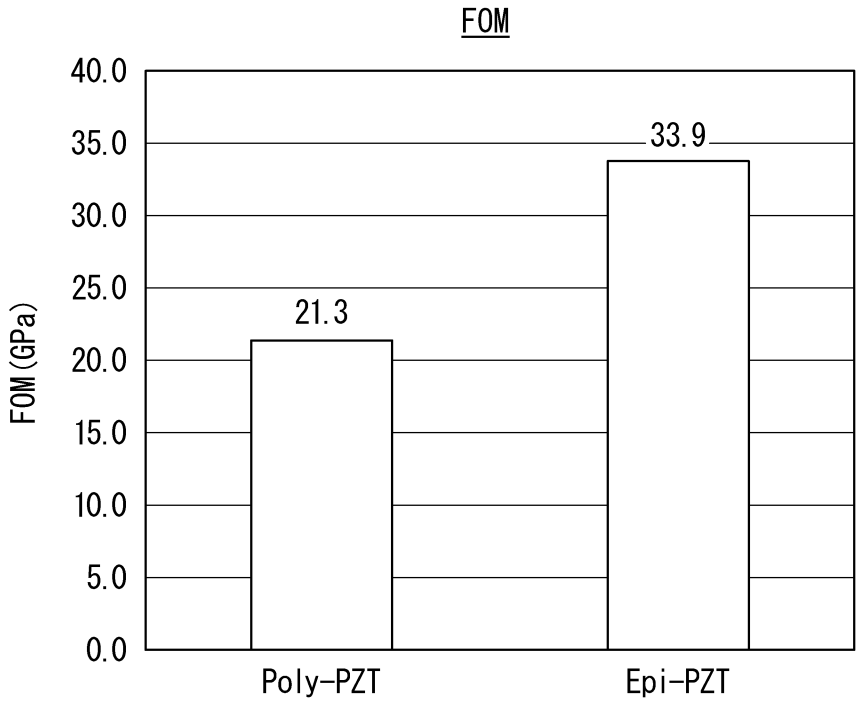

FOM
FOM(GPa)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21.3
33.9
Poly-PZT
Epi-PZT

FIG. 24

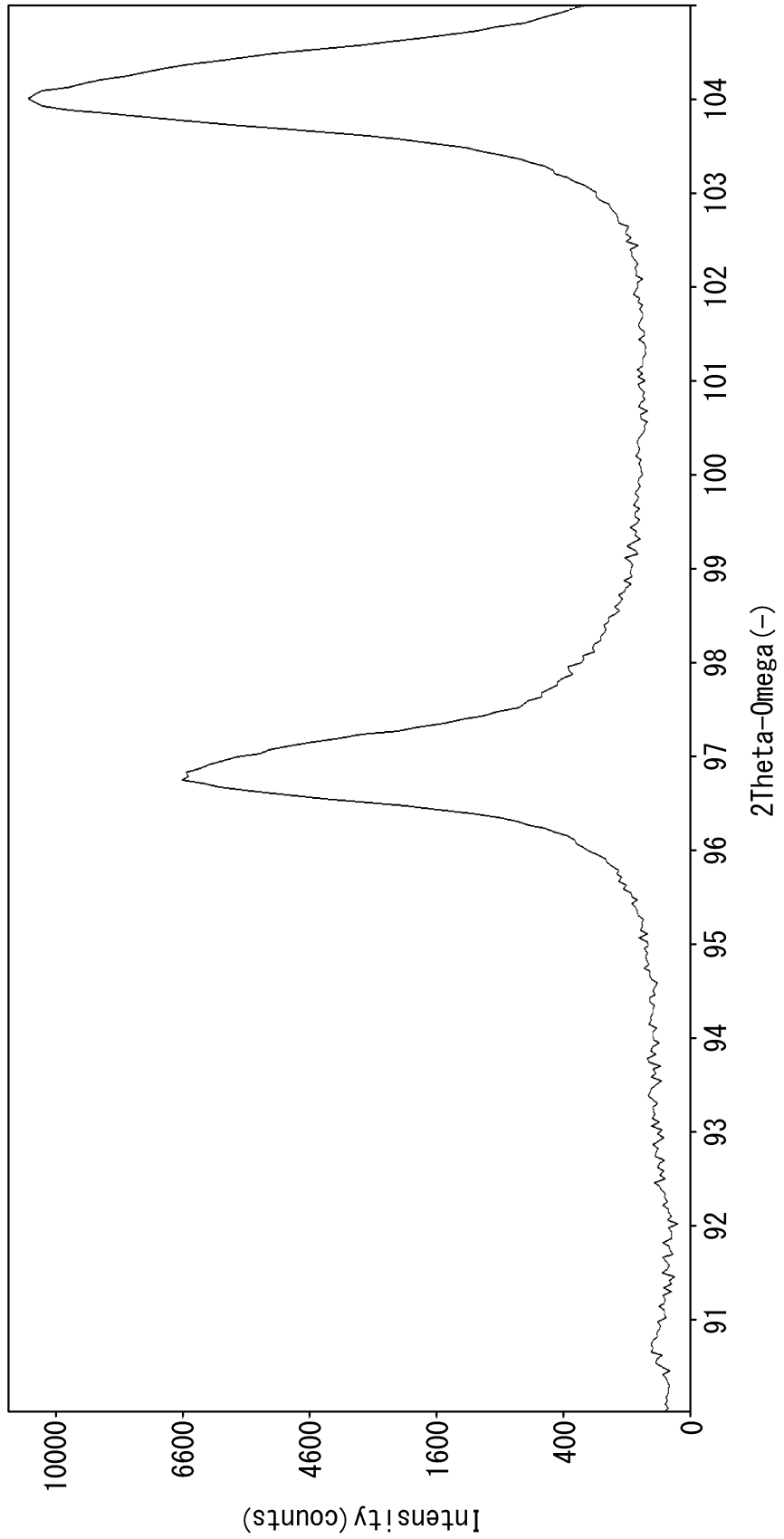

PZT/LaNiO3/Pt/YSZ/Si
625℃:96.800°
Intensity (counts)
10000
6600
4600
1600
400
0
91
92
93
94
95
96
97
98
99
100
101
102
103
104
2Theta-Omega (-)

FIG. 25

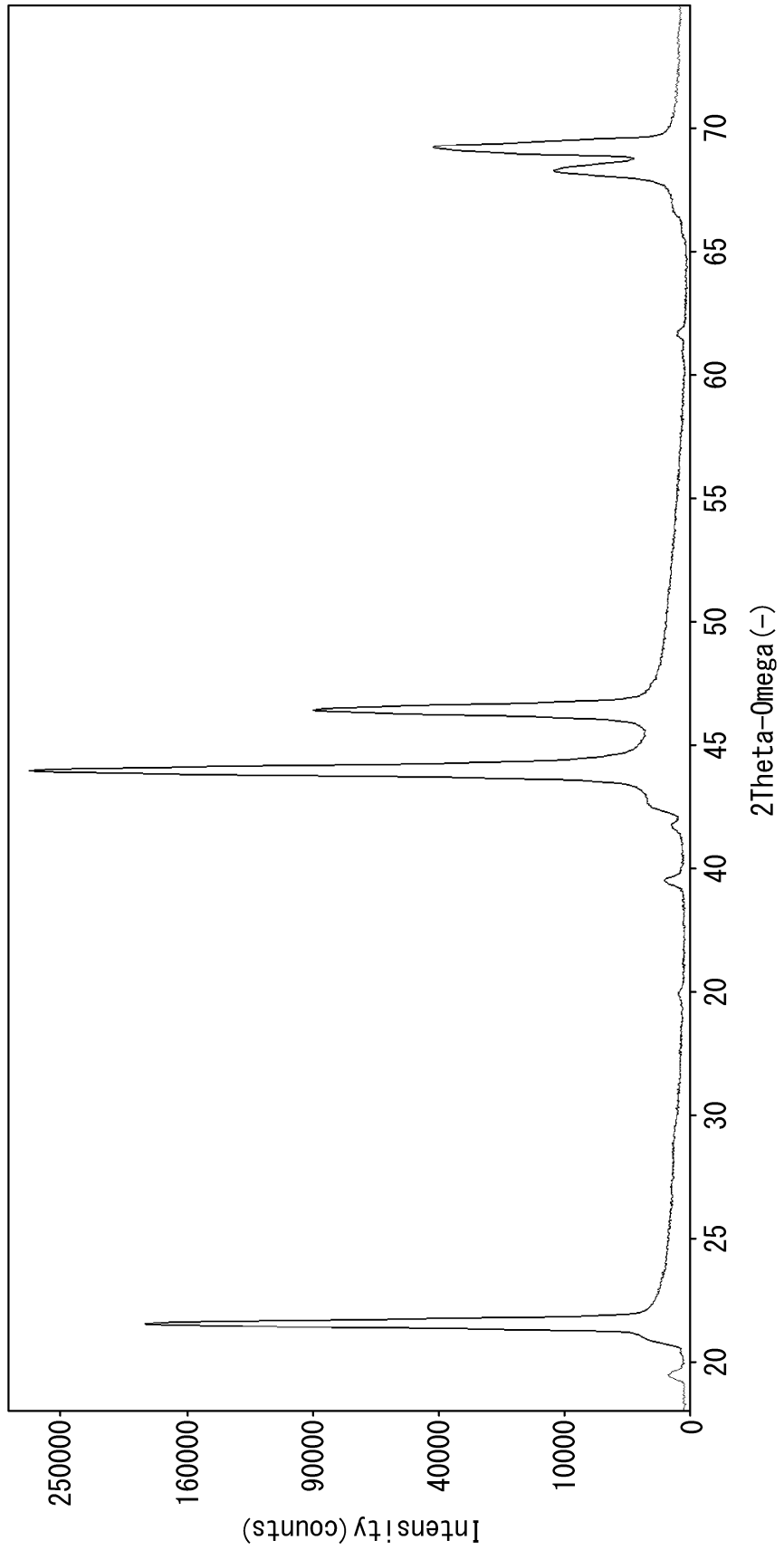

PZT/LaNiO3/Pt/YSZ/Si
2theta-omega
Intensity (counts)
250000
160000
90000
40000
10000
0
20
25
30
40
45
50
55
60
65
70
2Theta-Omega (-)

FIG. 26

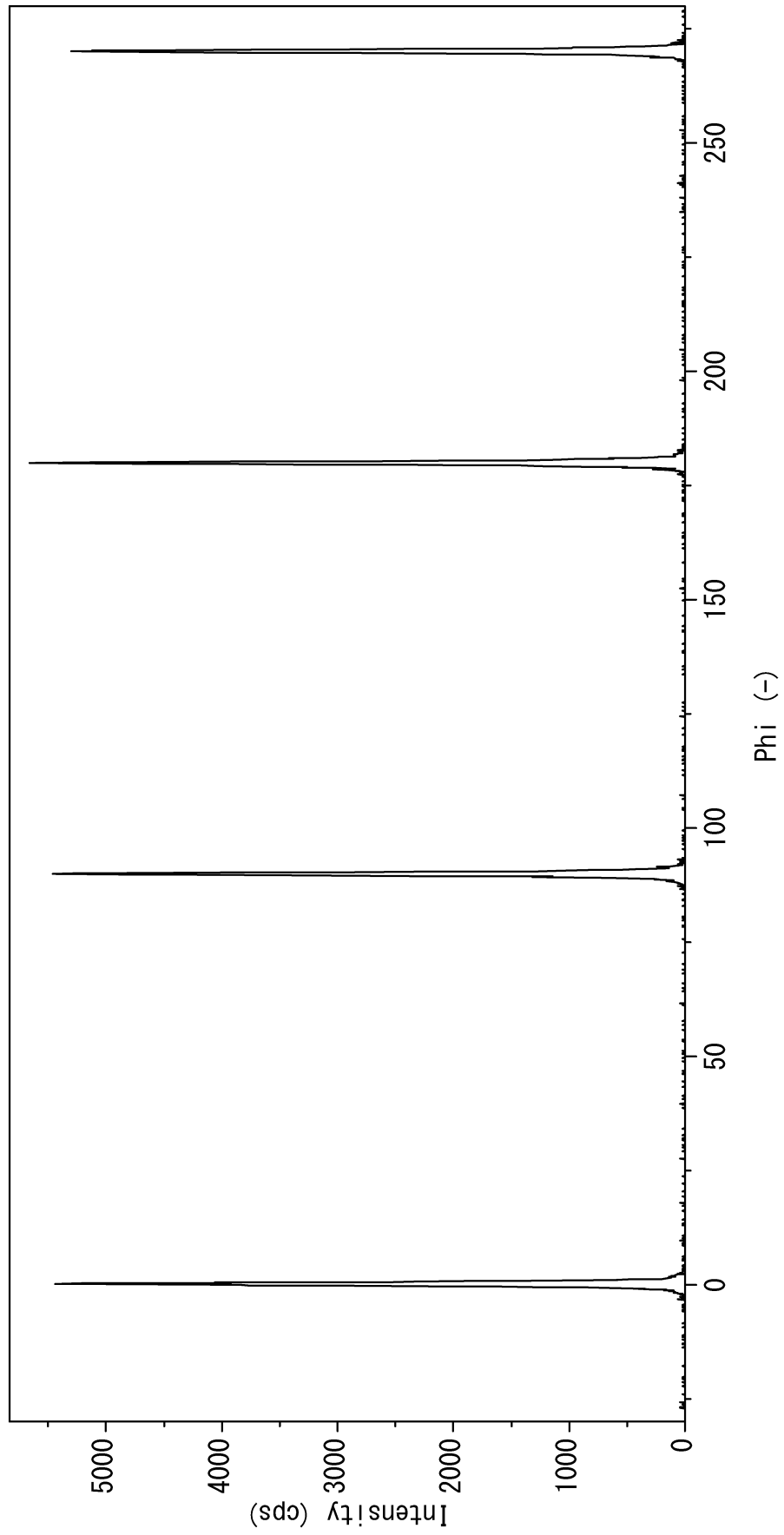
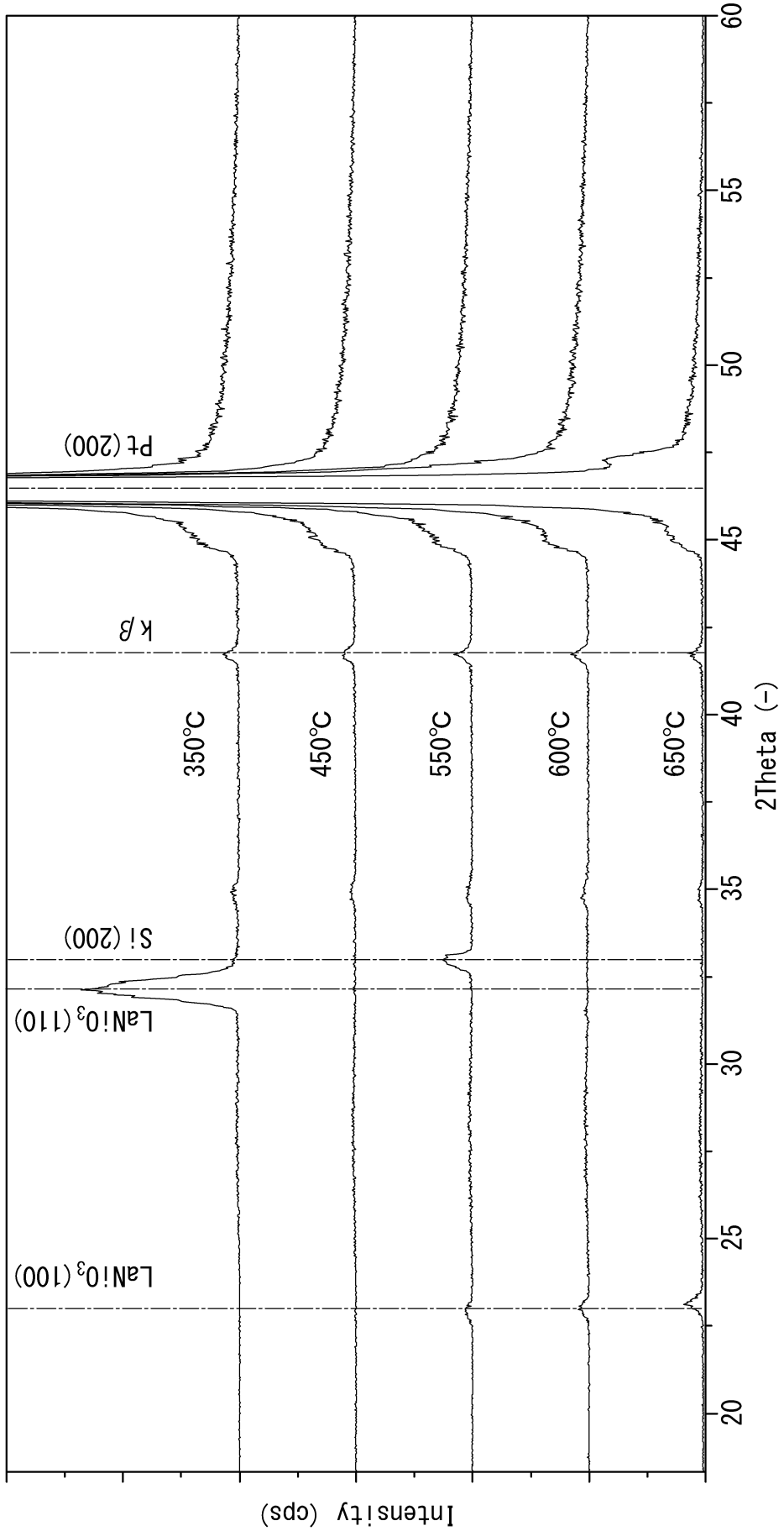

Intensity (cps)
0
1000
2000
3000
4000
5000
0
50
100
150
200
250
Phi (-)

FIG. 27


Intensity (cps)
2Theta (-)
20
25
30
35
40
45
50
55
60
LaNiO3 (100)
LaNiO3 (110)
Si (200)
kβ
Pt (200)
350°C
450°C
550°C
600°C
650°C