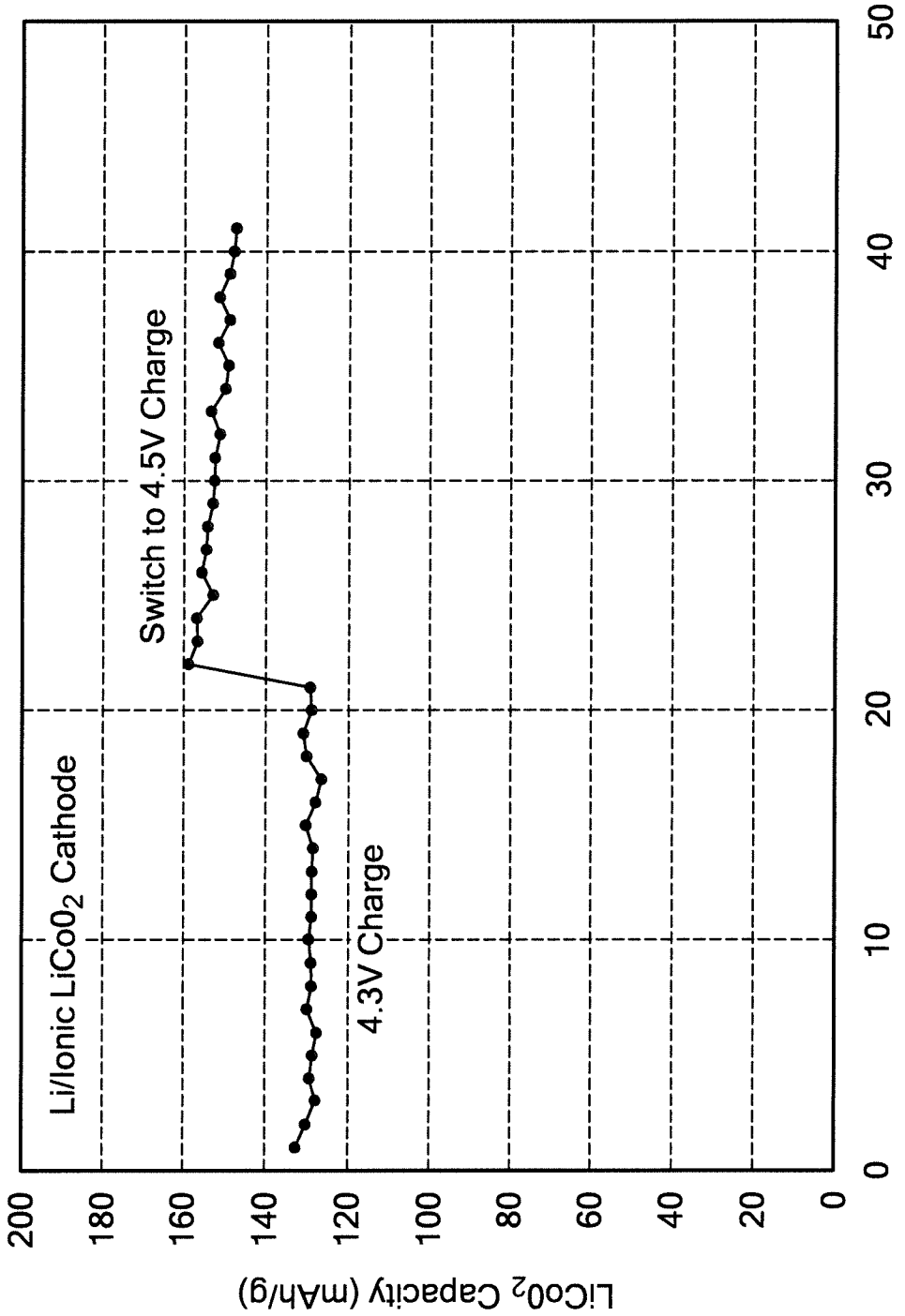

Li/Ionic $LiCoO_2$ Cathode
Switch to 4.5V Charge
4.3V Charge
$LiCoO_2$ Capacity (mAh/g)
Cycle Number
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50

FIG. 1

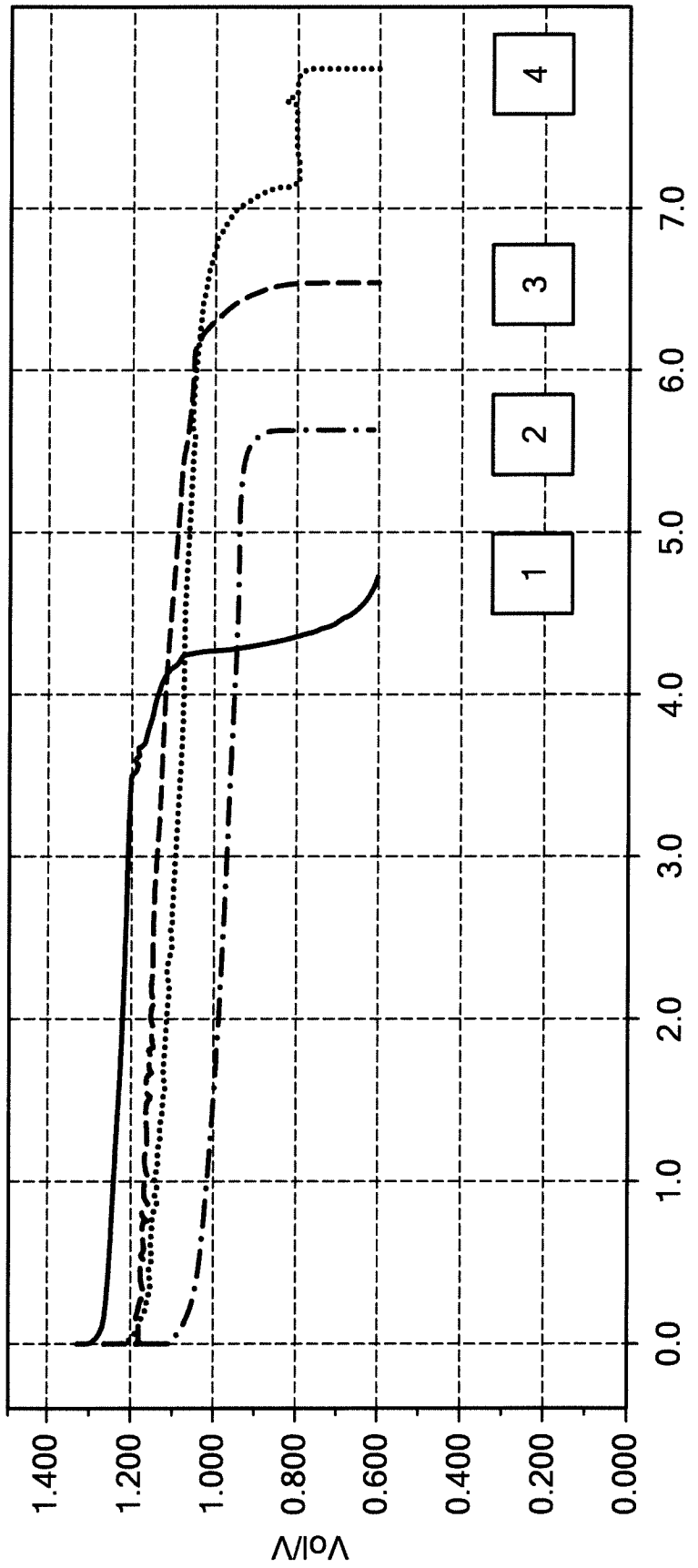

1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Vol/V
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Cap/mAh
1
2
3
4

FIG. 2

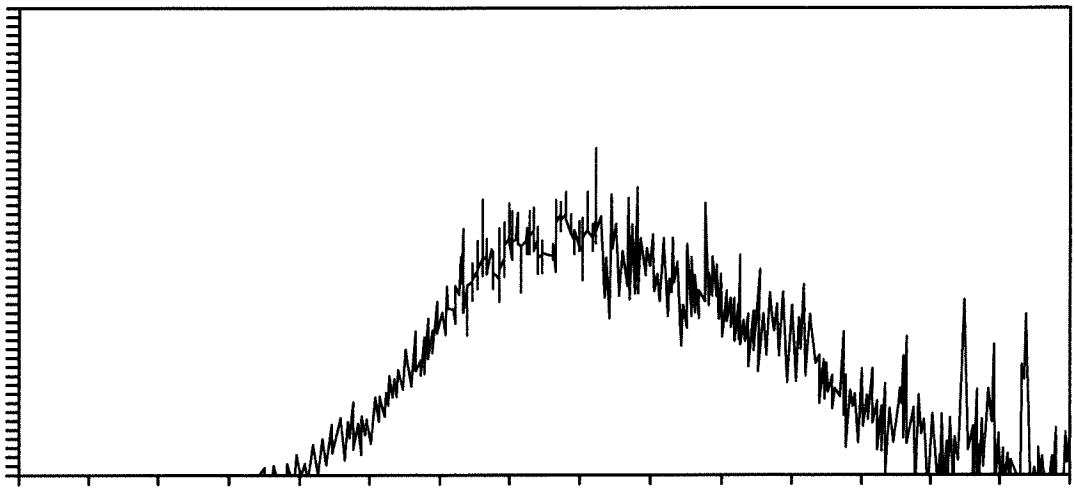


FIG. 3A

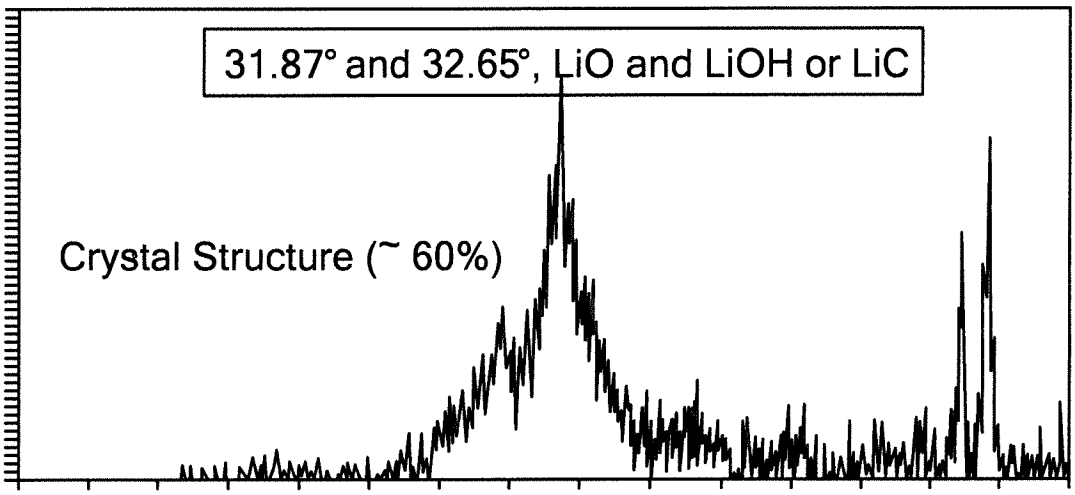


FIG. 3B

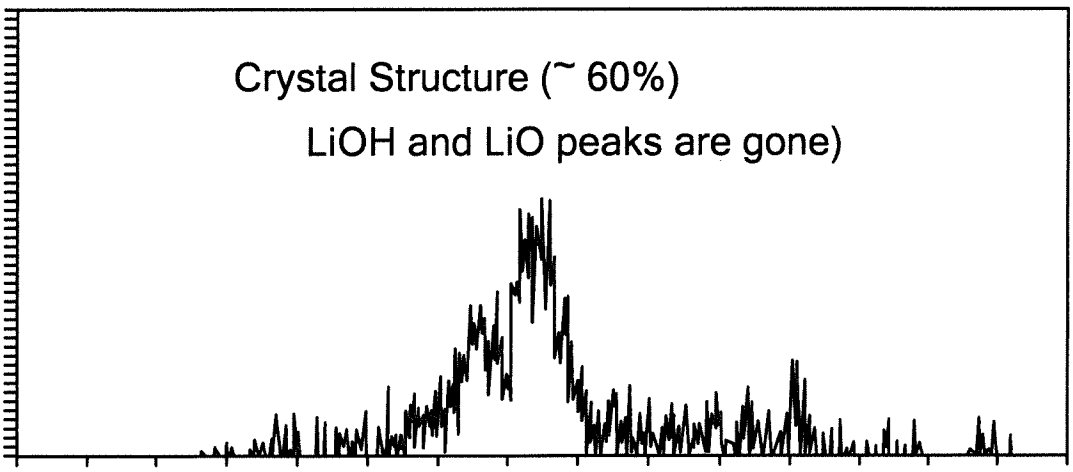


FIG. 3C

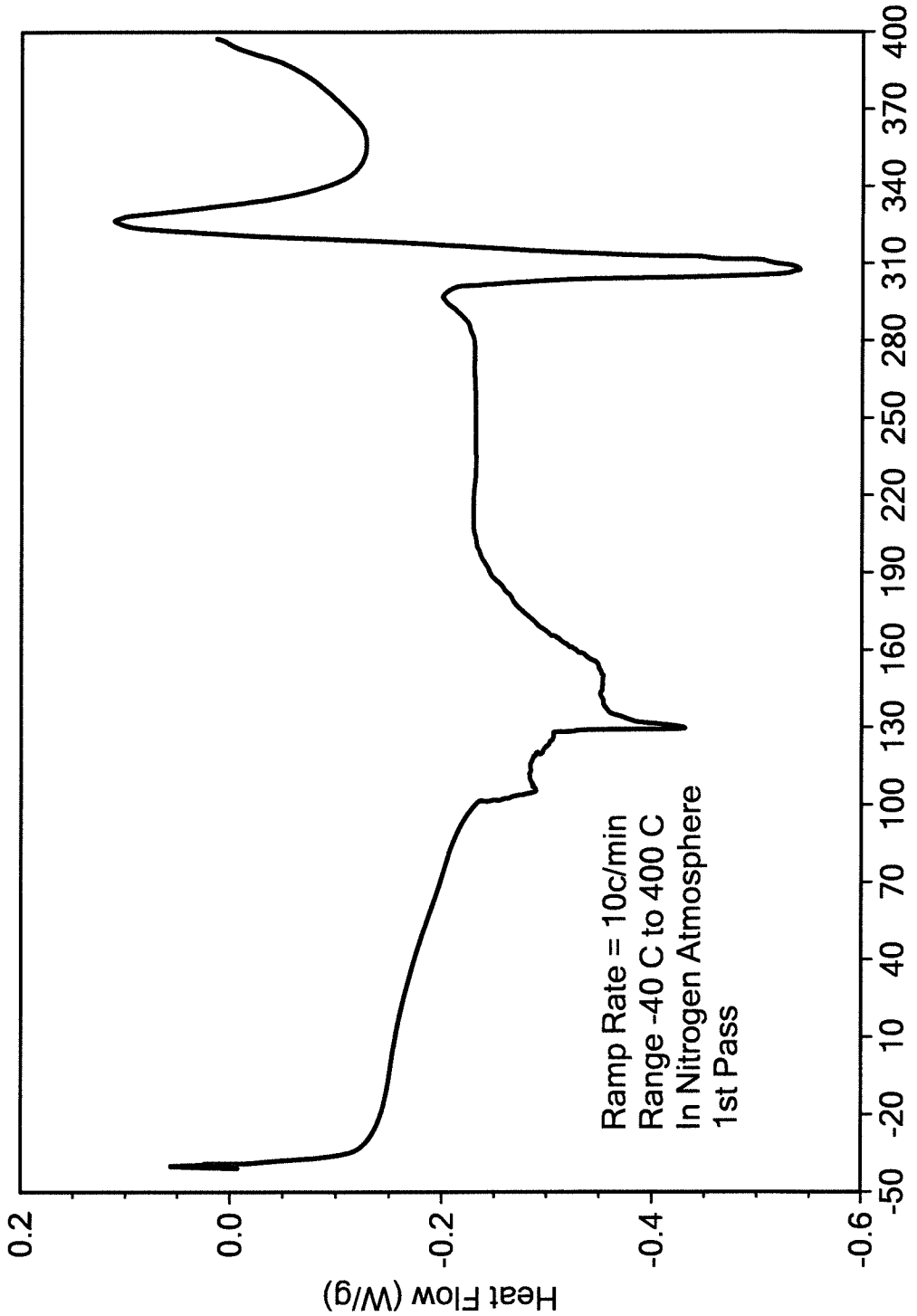

Heat Flow (W/g)
0.2
0.0
-0.2
-0.4
-0.6
Temperature (°C)
-50
-20
10
40
70
100
130
160
190
220
250
280
310
340
370
400
Ramp Rate = 10c/min
Range -40 C to 400 C
In Nitrogen Atmosphere
1st Pass

FIG. 4

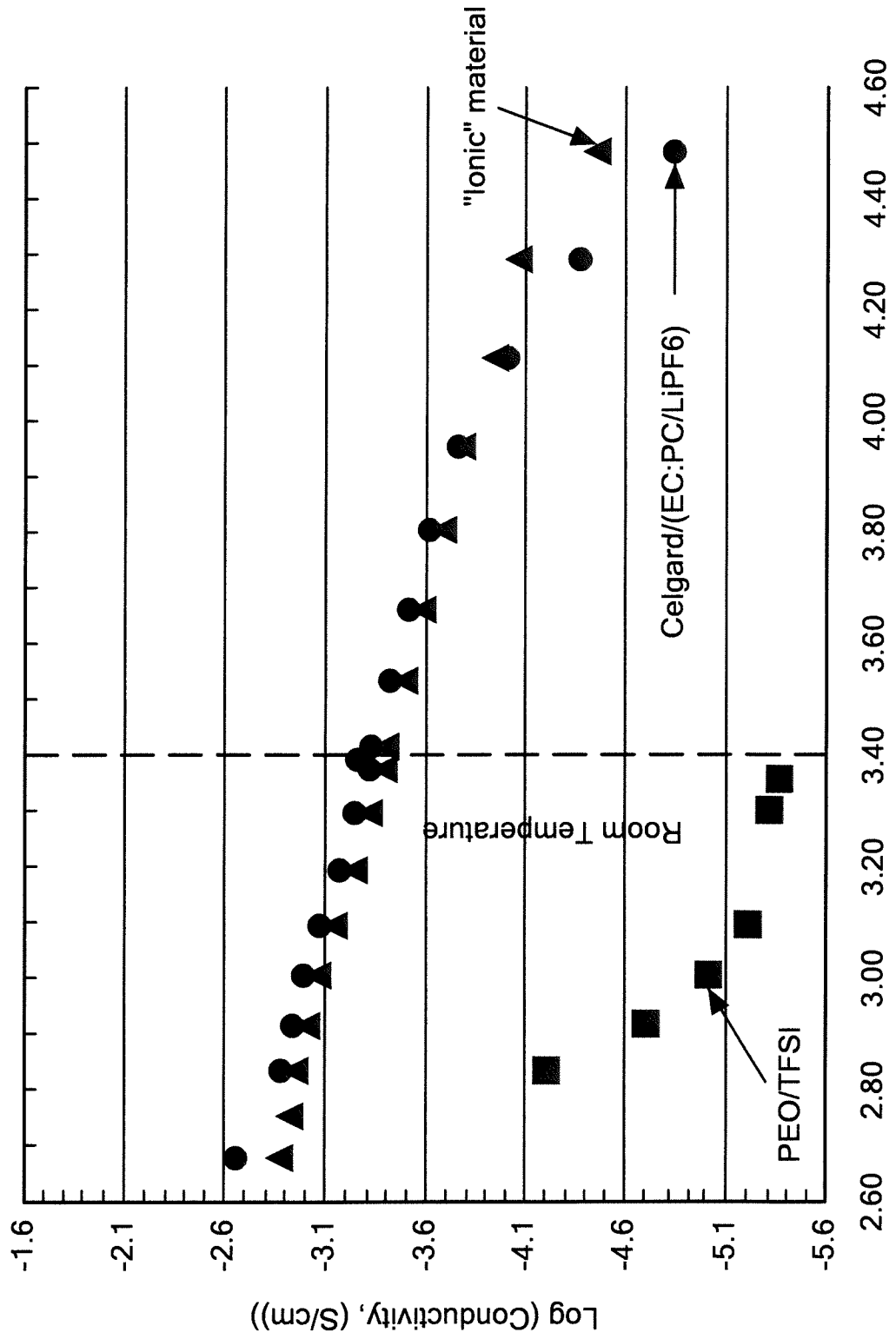

Log (Conductivity, (S/cm))
-1.6
-2.1
-2.6
-3.1
-3.6
-4.1
-4.6
-5.1
-5.6
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
1000/T (K)
Room Temperature
"Ionic" material
Celgard/(EC:PC/LiPF6)
PEO/TFSI

FIG. 5

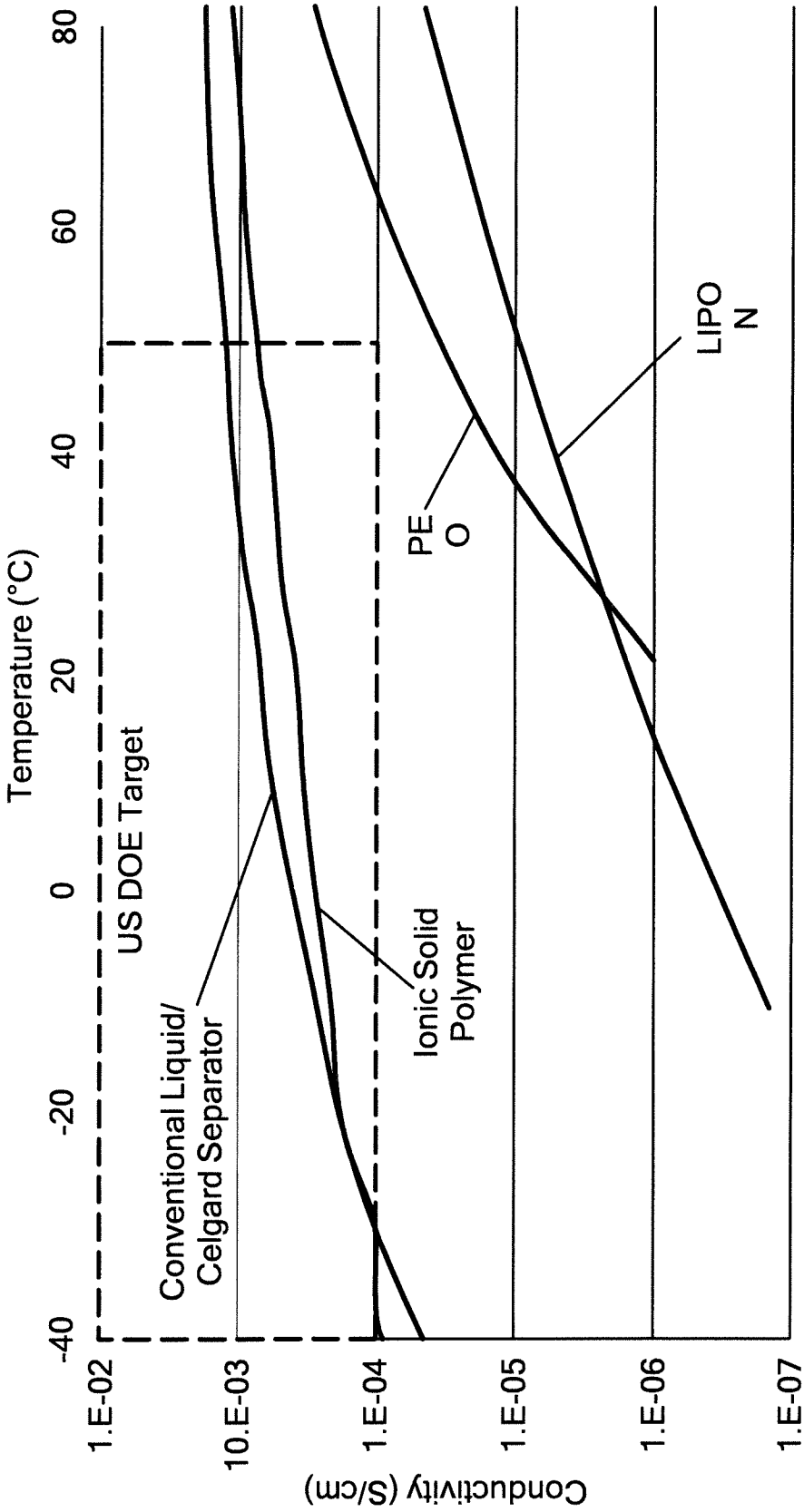

Temperature (°C)
-40
-20
0
20
40
60
80
Conductivity (S/cm)
1.E-02
10.E-03
1.E-04
1.E-05
1.E-06
1.E-07
US DOE Target
Conventional Liquid/
Celgard Separator
Ionic Solid
Polymer
PE
O
LIPO
N

FIG. 6

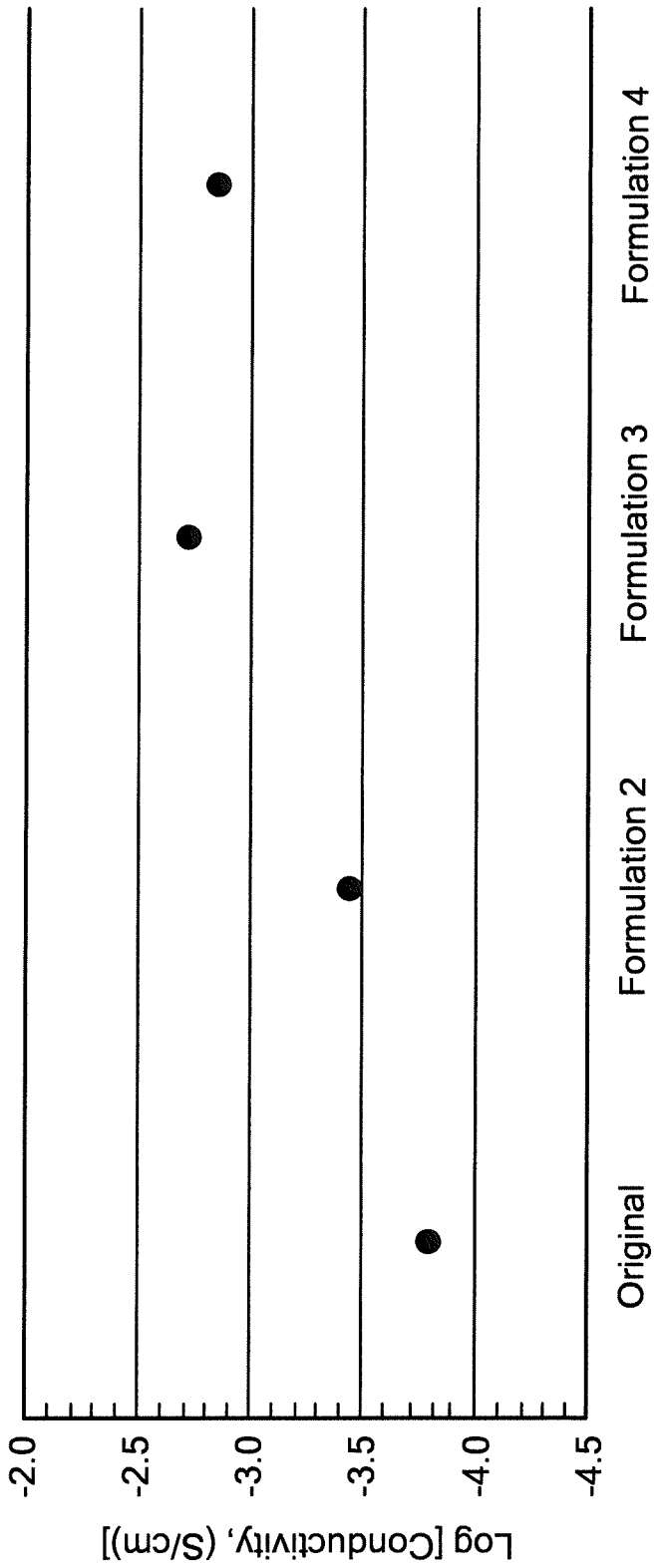

Log [Conductivity, (S/cm)]
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
Original
Formulation 2
Formulation 3
Formulation 4

FIG. 7

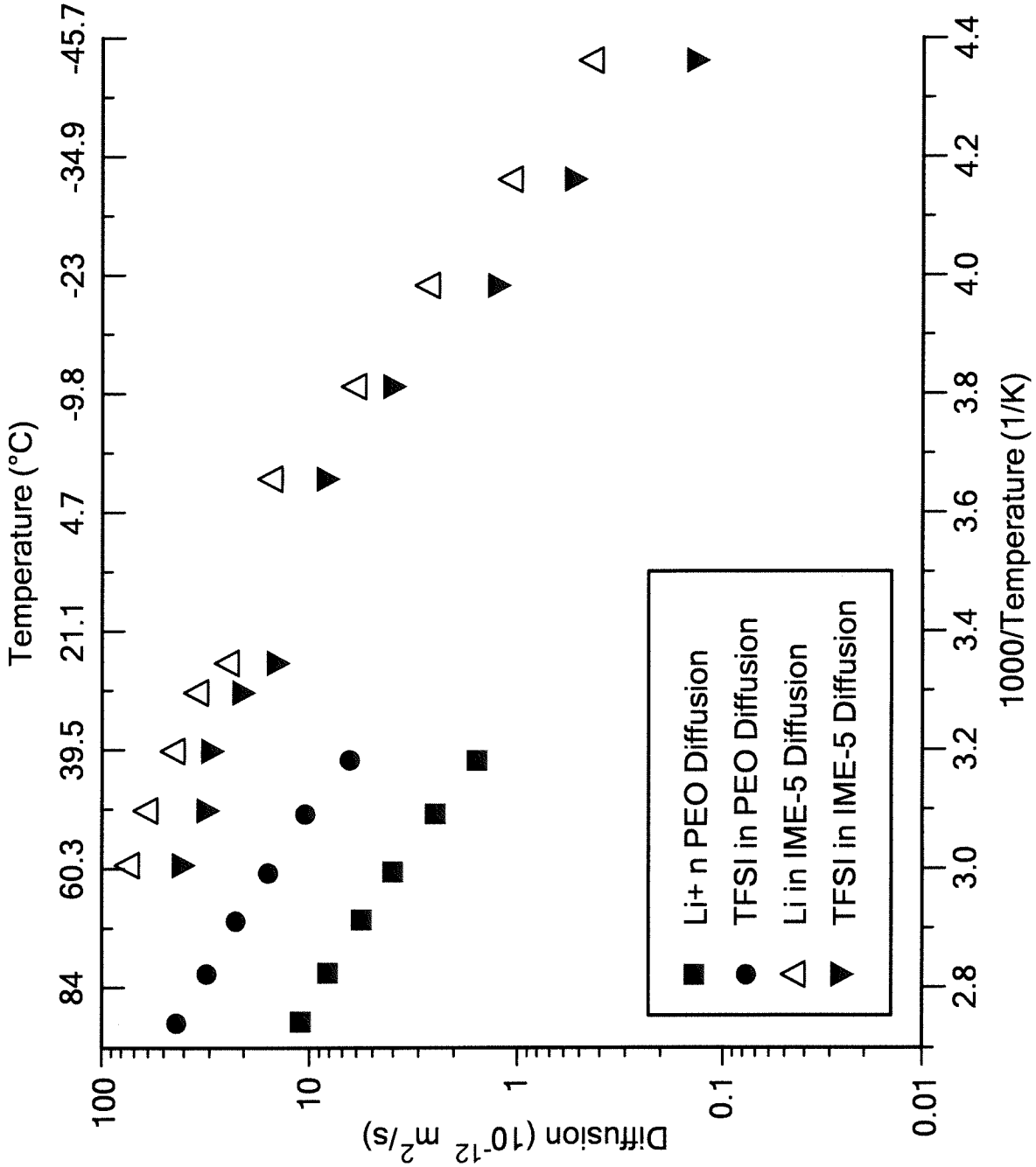

Temperature (°C)
84
60.3
39.5
21.1
4.7
-9.8
-23
-34.9
-45.7
100
10
1
0.1
0.01
Diffusion (10-12 m2/s)
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
1000/Temperature (1/K)
Li+ n PEO Diffusion
TFSI in PEO Diffusion
Li in IME-5 Diffusion
TFSI in IME-5 Diffusion

FIG. 8

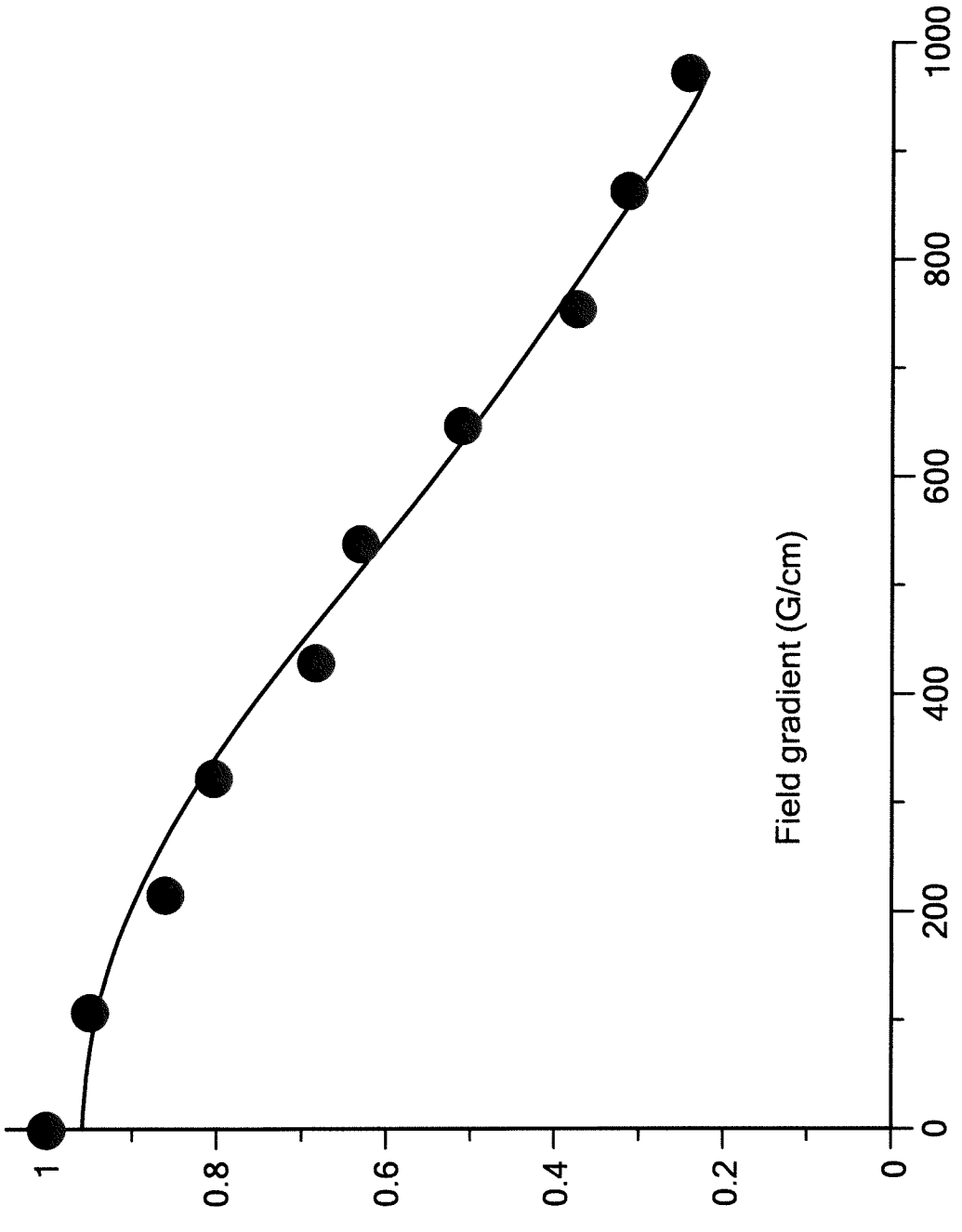


FIG. 9

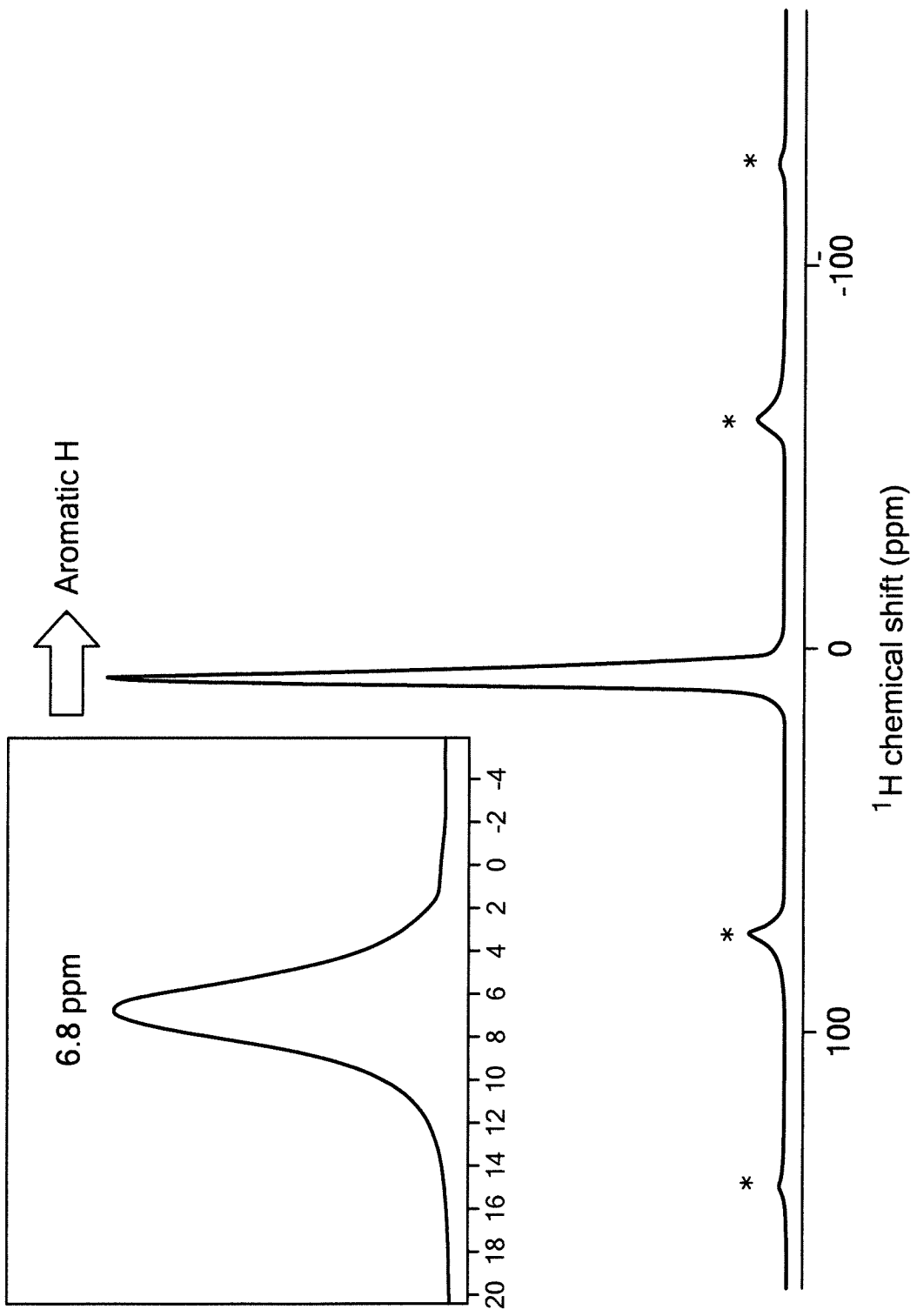

Aromatic H
6.8 ppm
20 18 16 14 12 10 8 6 4 2 0 -2 -4
100
0
-100
^{1}H chemical shift (ppm)

FIG. 10

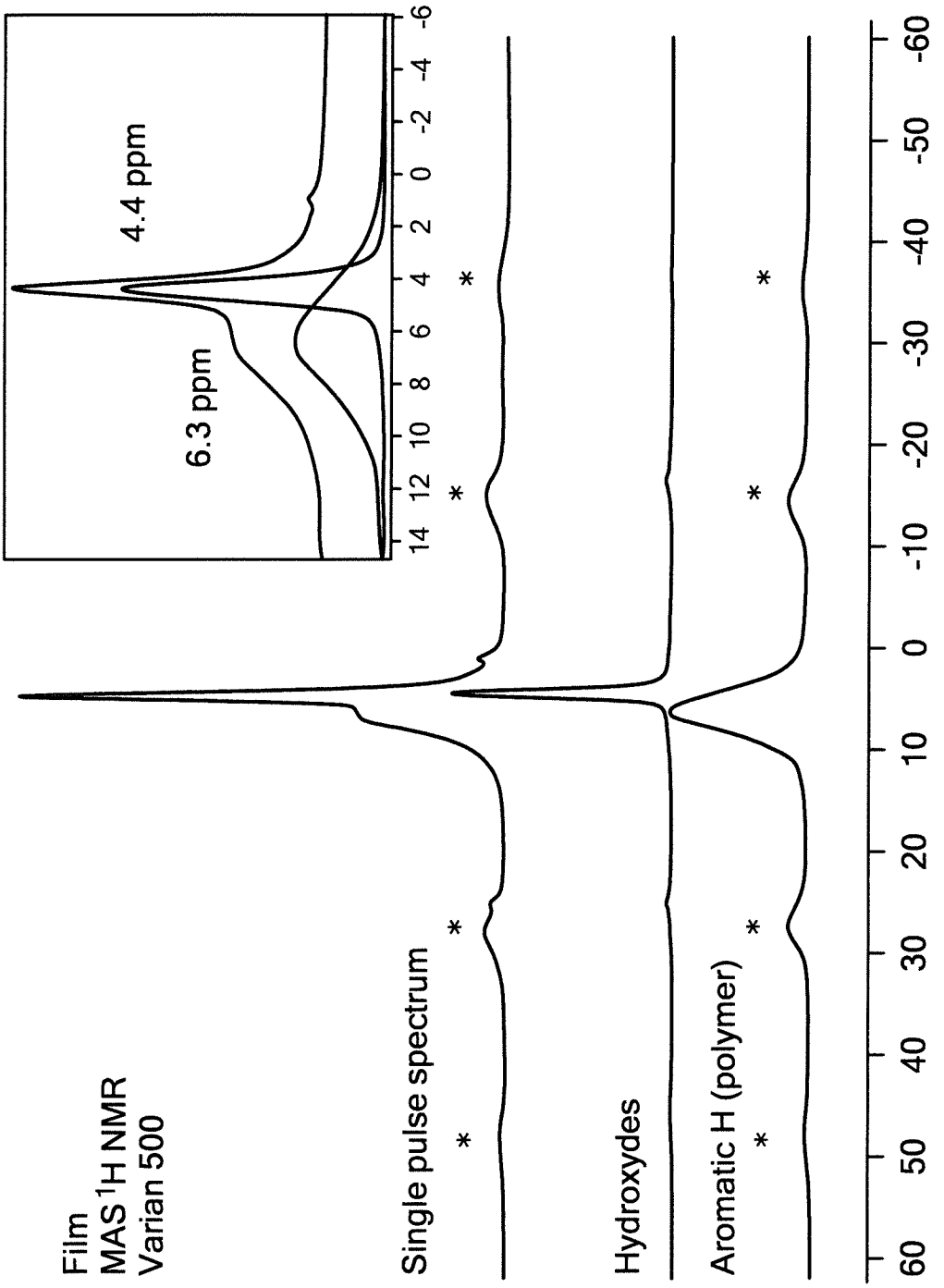

Film
MAS ^{1}H NMR
Varian 500
Single pulse spectrum
Hydroxydes
Aromatic H (polymer)
4.4 ppm
6.3 ppm
14 12 10 8 6 4 2 0 -2 -4 -6
60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60
^{1}H chemical shift (ppm)

FIG. 11

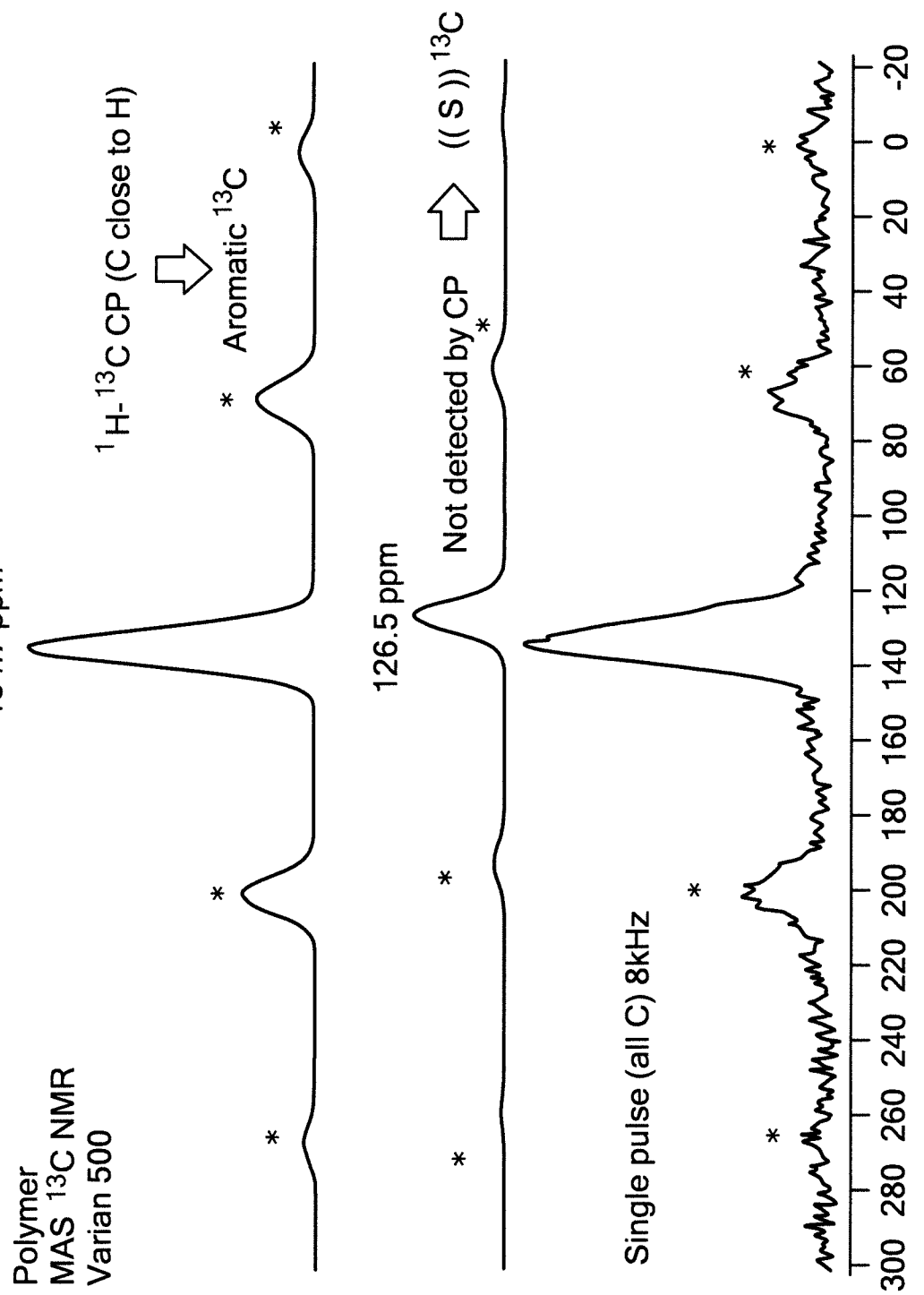

Polymer
MAS ^{13}C NMR
Varian 500
134.7 ppm
^{1}H-^{13}C CP (C close to H)
Aromatic ^{13}C
126.5 ppm
Not detected by CP
((S))^{13}C
Single pulse (all C) 8kHz
300 280 260 240 220 200 180 160 140 120 100 80 60 40 20 0 -20
^{13} C chemical shift (ppm)

FIG. 12

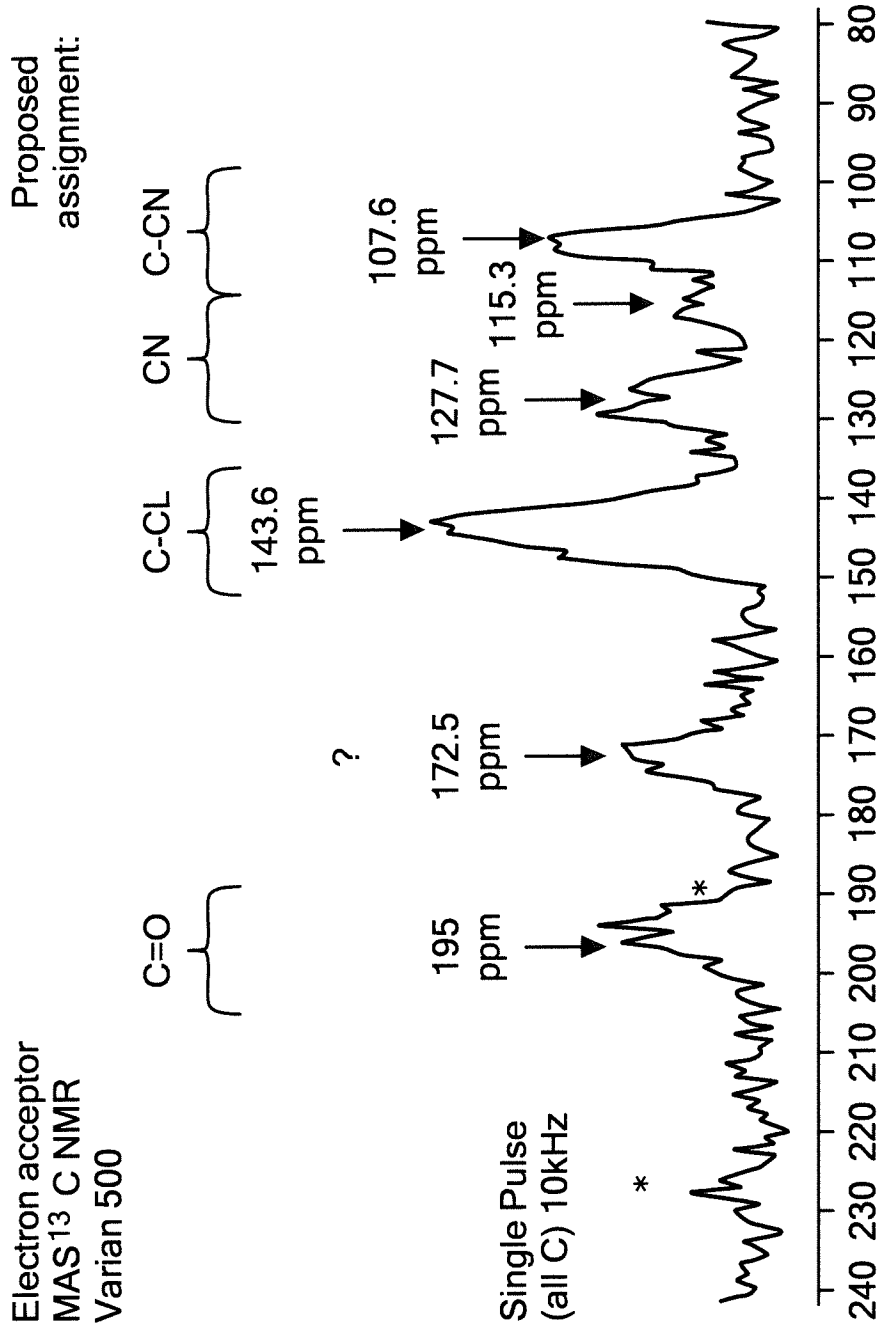

Electron acceptor
MAS13 C NMR
Varian 500
Single Pulse
(all C) 10kHz
Proposed
assignment:
C=O
C-CL
CN
C-CN
195
ppm
172.5
ppm
?
143.6
ppm
127.7
ppm
115.3
ppm
107.6
ppm
*
*
*
240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80
13C chemical shift (ppm)

FIG. 13

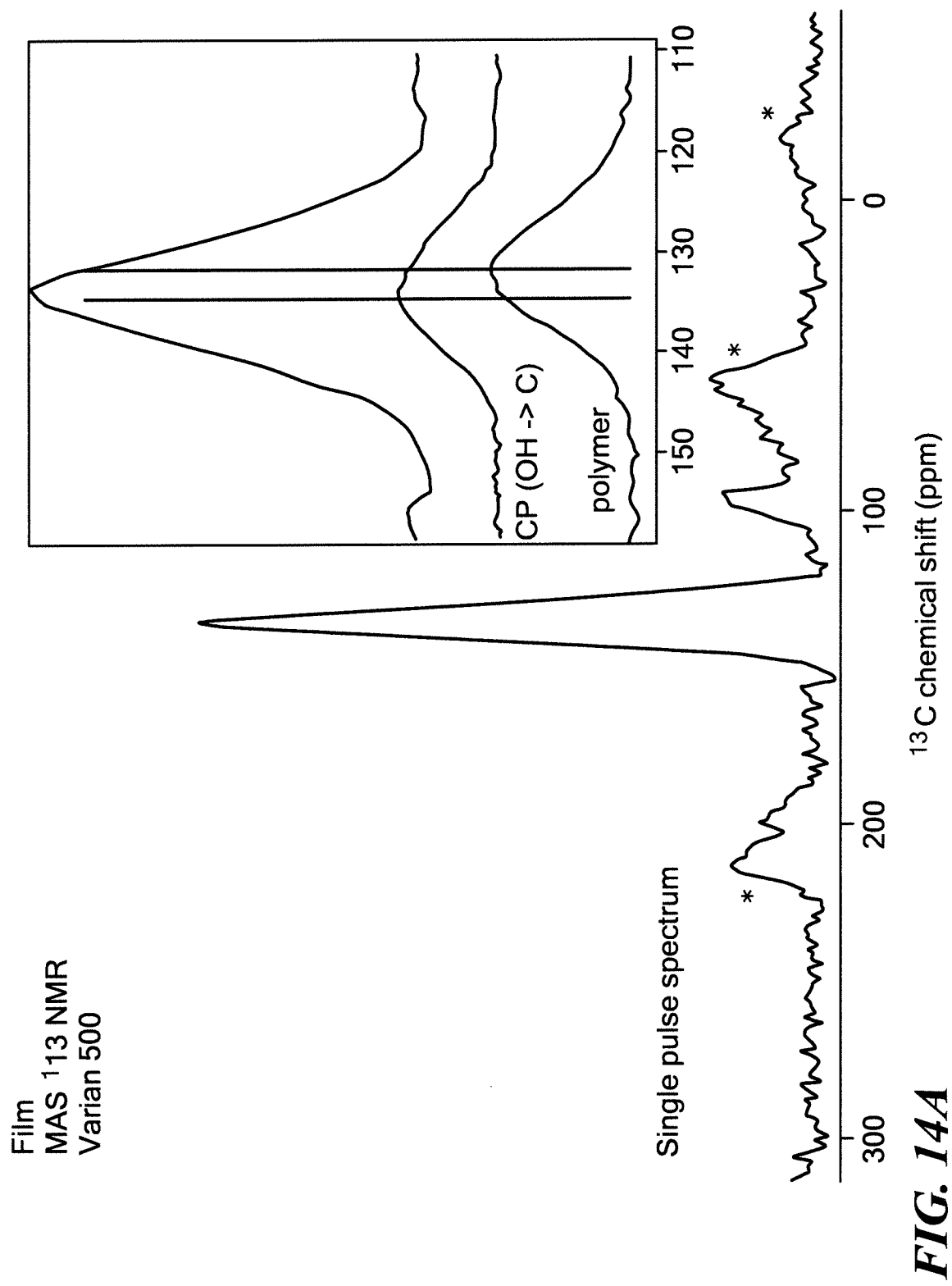

Film
MAS 113 NMR
Varian 500
Single pulse spectrum
CP (OH -> C)
polymer
*
*
*
300
200
100
0
150
140
130
120
110
13C chemical shift (ppm)

FIG. 14A

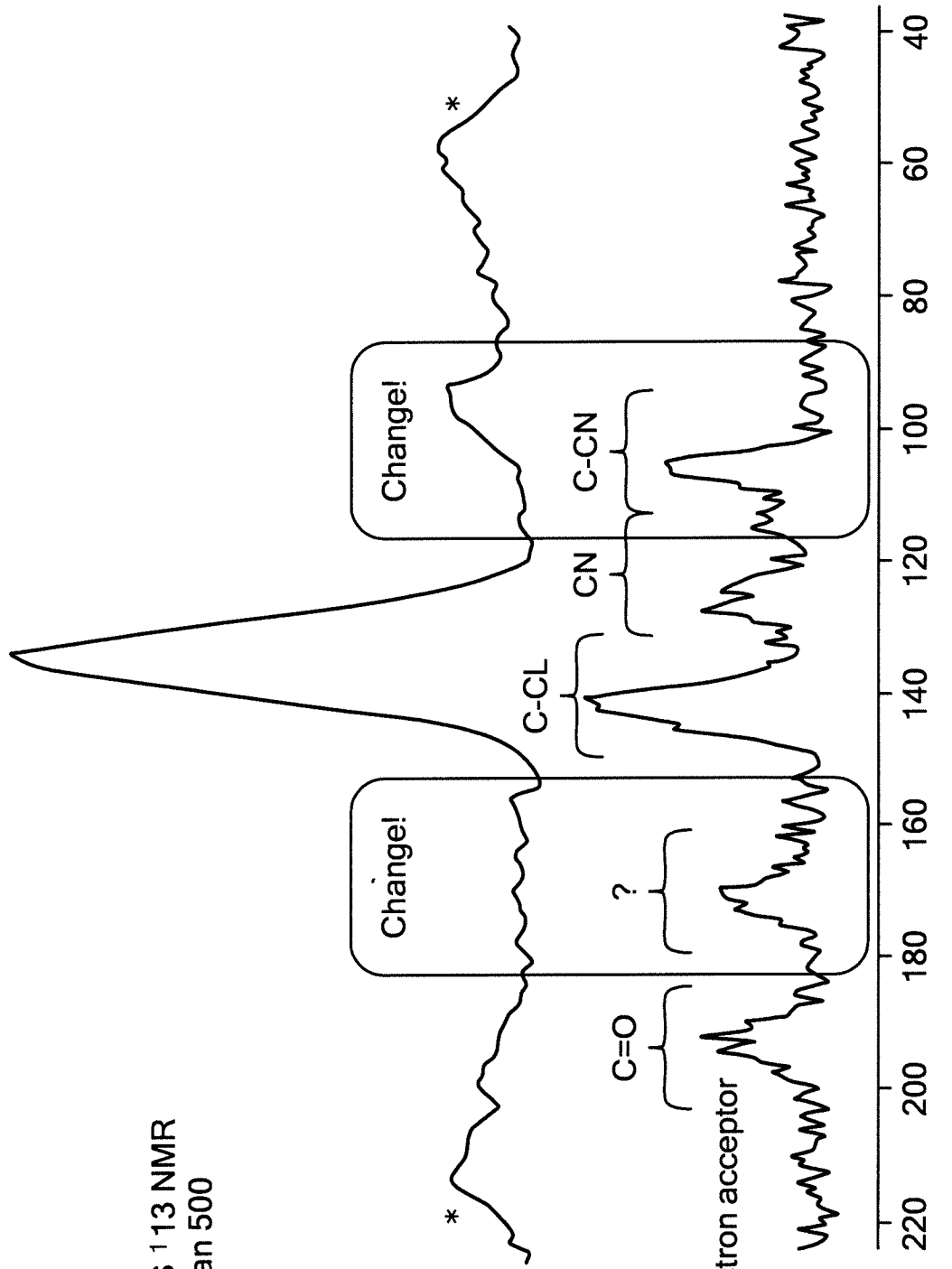

Film
MAS 113 NMR
Varian 500
Film
Change!
Change!
C-CL
CN
C-CN
C=O
?
Electron acceptor
220
200
180
160
140
120
100
80
60
40
13C chemical shift (ppm)

FIG. 14B

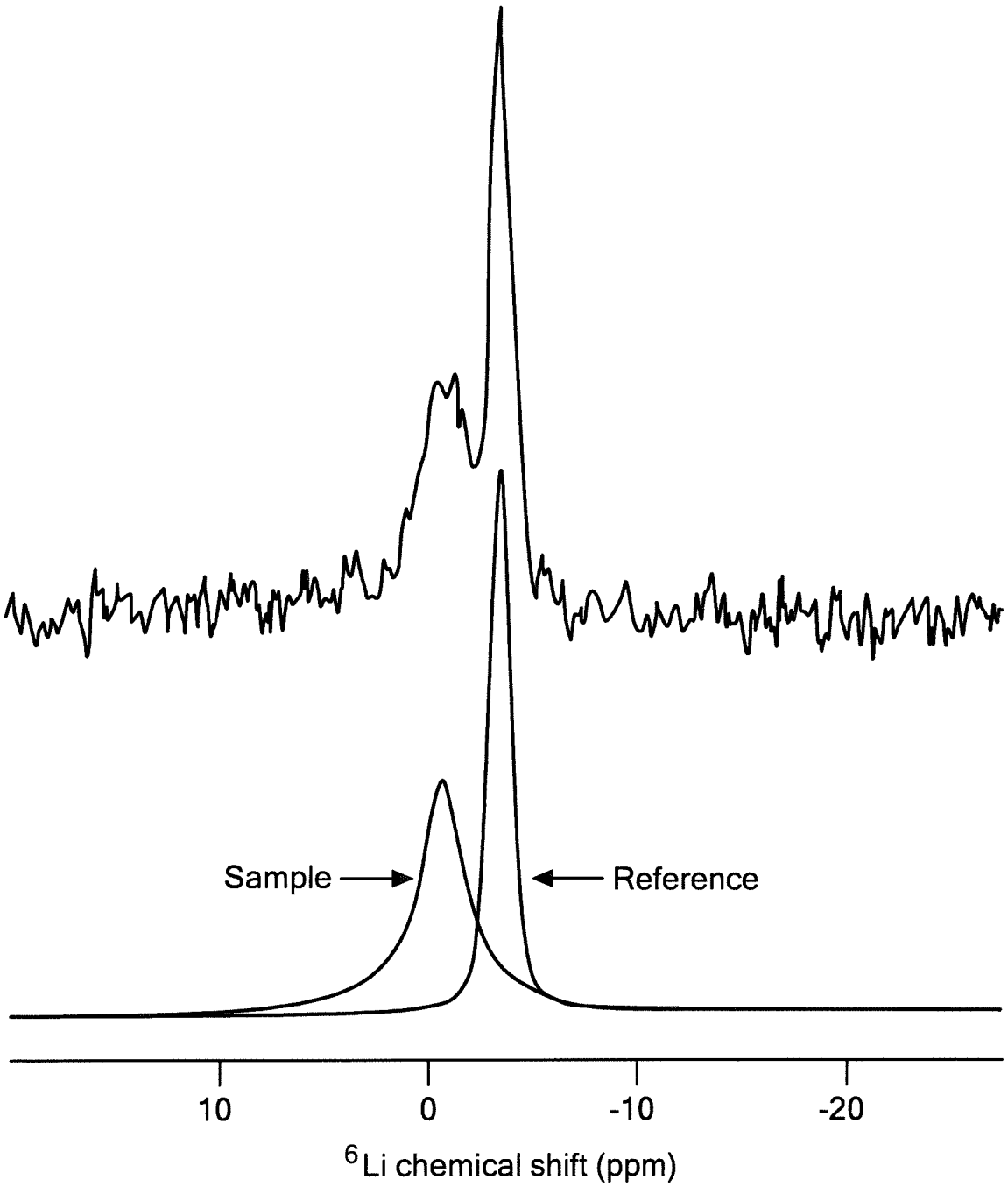


FIG. 15

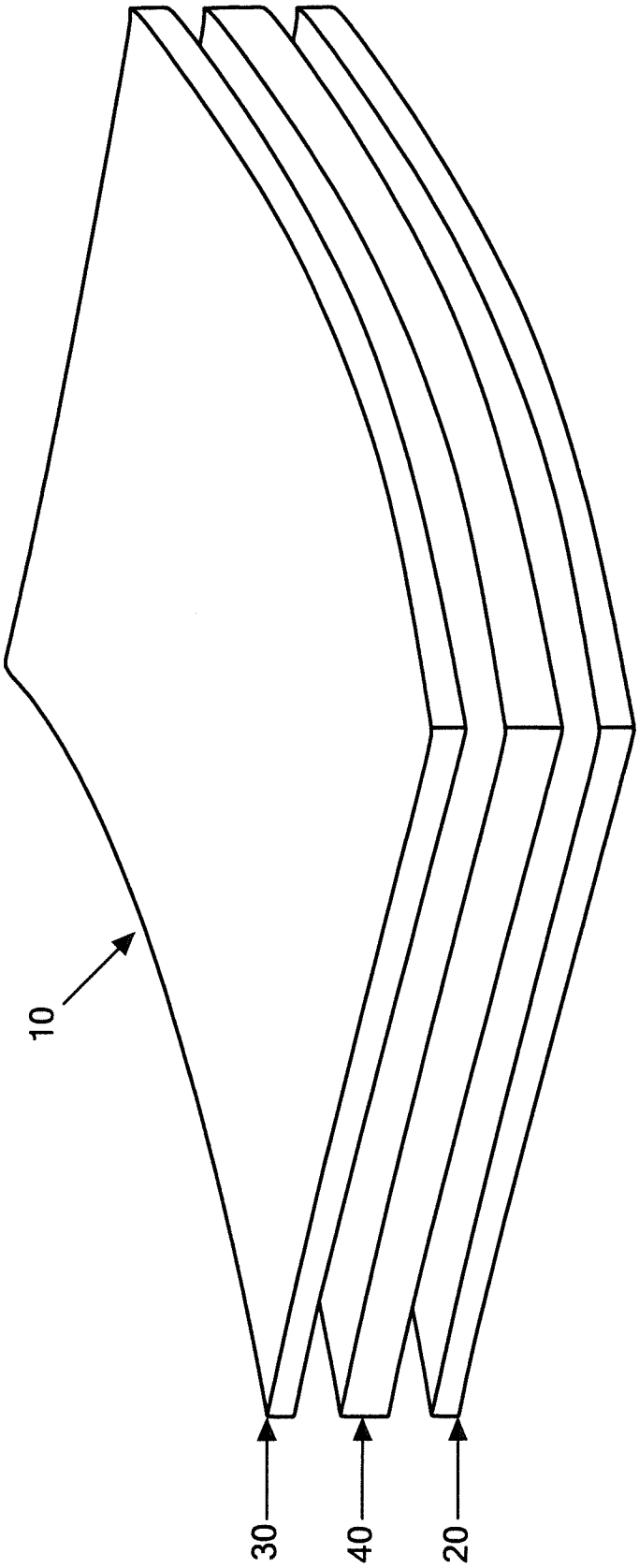


FIG. 16

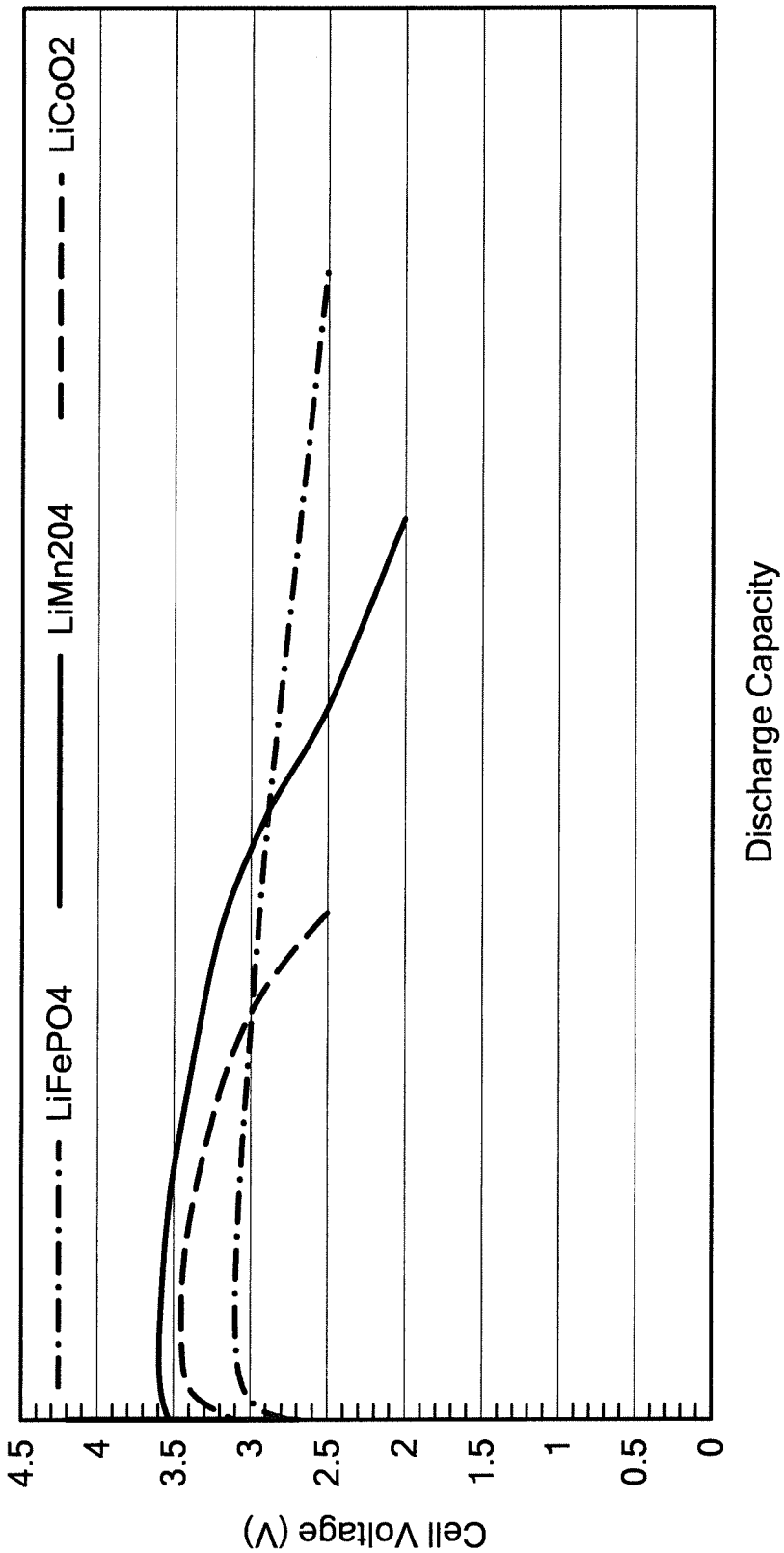

LiFePO4
LiMn2O4
LiCoO2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Cell Voltage (V)
Discharge Capacity

FIG. 17

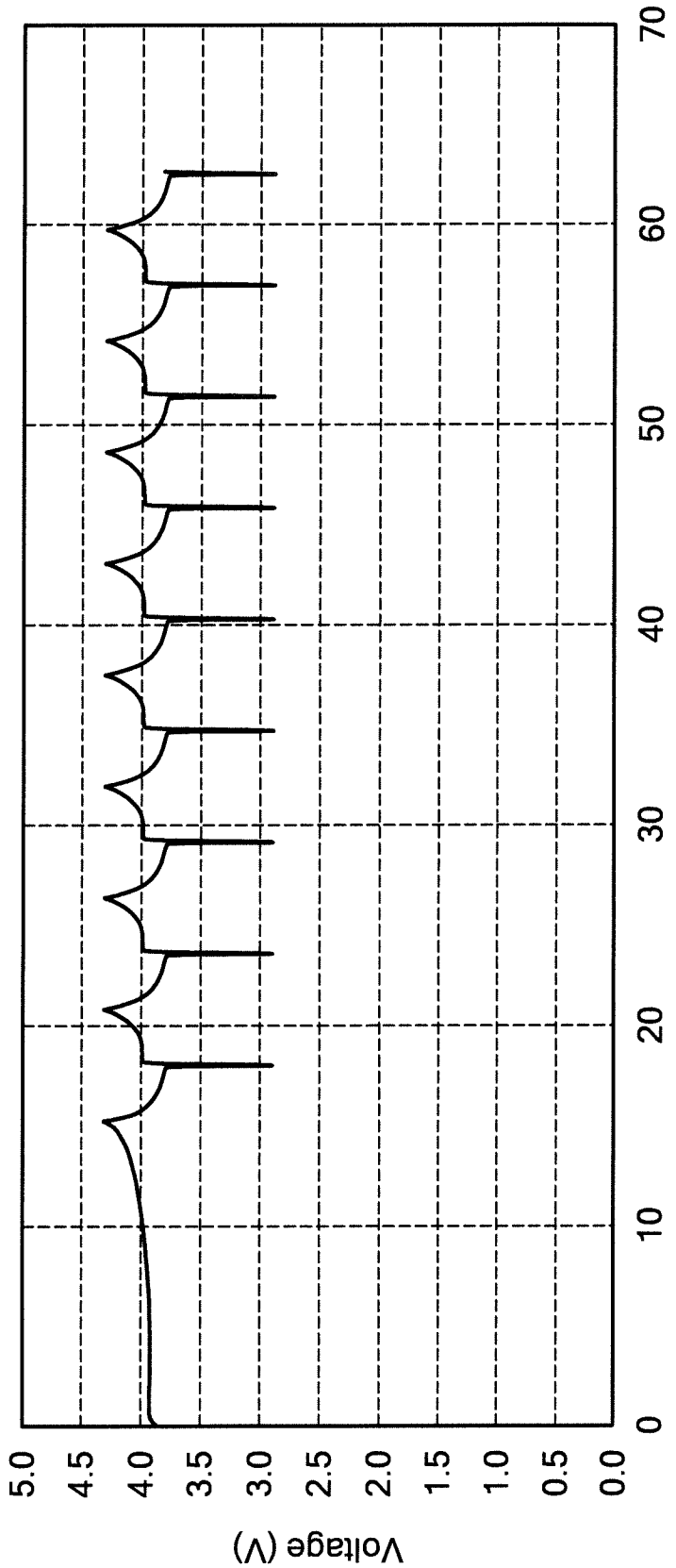

Voltage (V)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Time (h)

FIG. 18

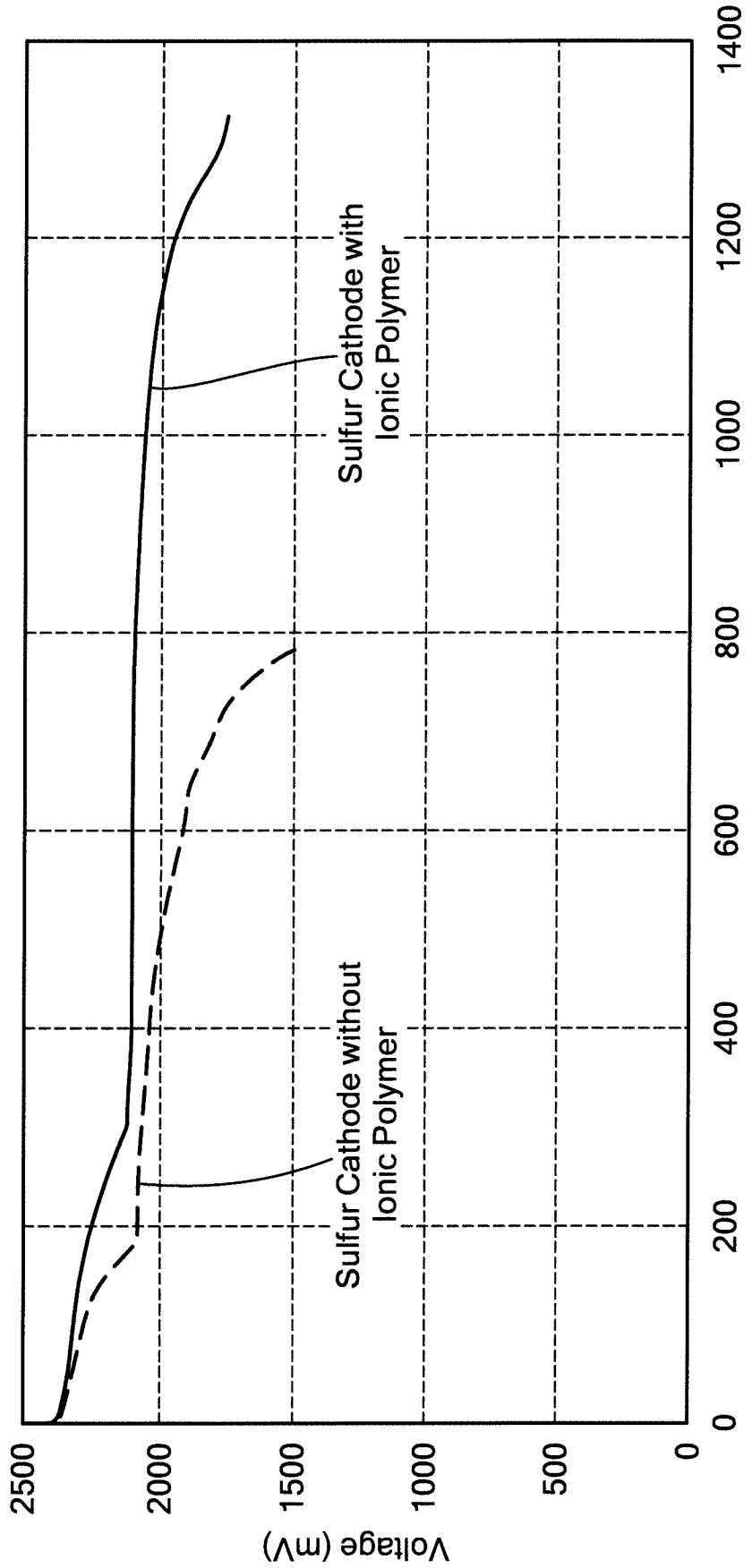

Voltage (mV)
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
Sulfur Capacity (mAh/g)
Sulfur Cathode with Ionic Polymer
Sulfur Cathode without Ionic Polymer

FIG. 19