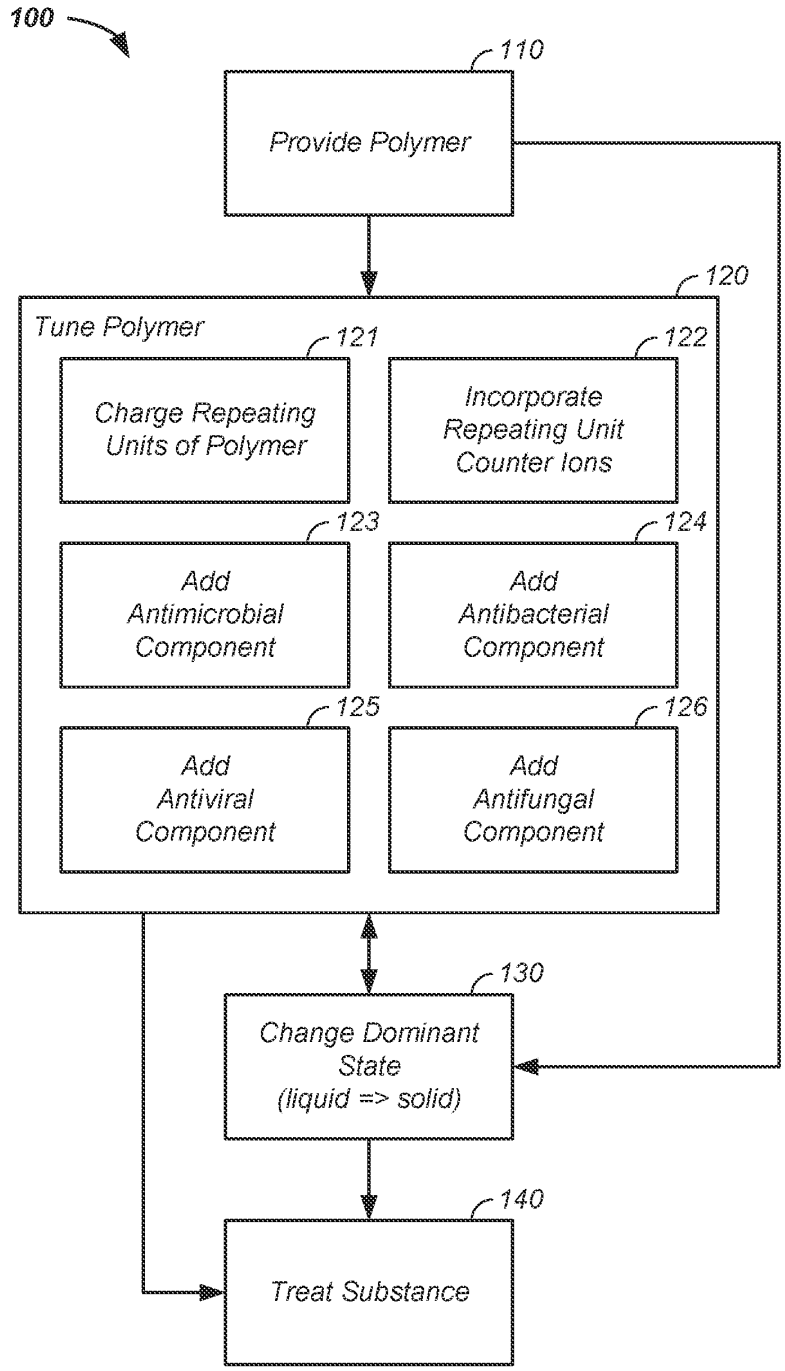

100
110
Provide Polymer
120
Tune Polymer
121
Charge Repeating Units of Polymer
122
Incorporate Repeating Unit Counter Ions
123
Add Antimicrobial Component
124
Add Antibacterial Component
125
Add Antiviral Component
126
Add Antifungal Component
130
Change Dominant State (liquid => solid)
140
Treat Substance

FIG. 1

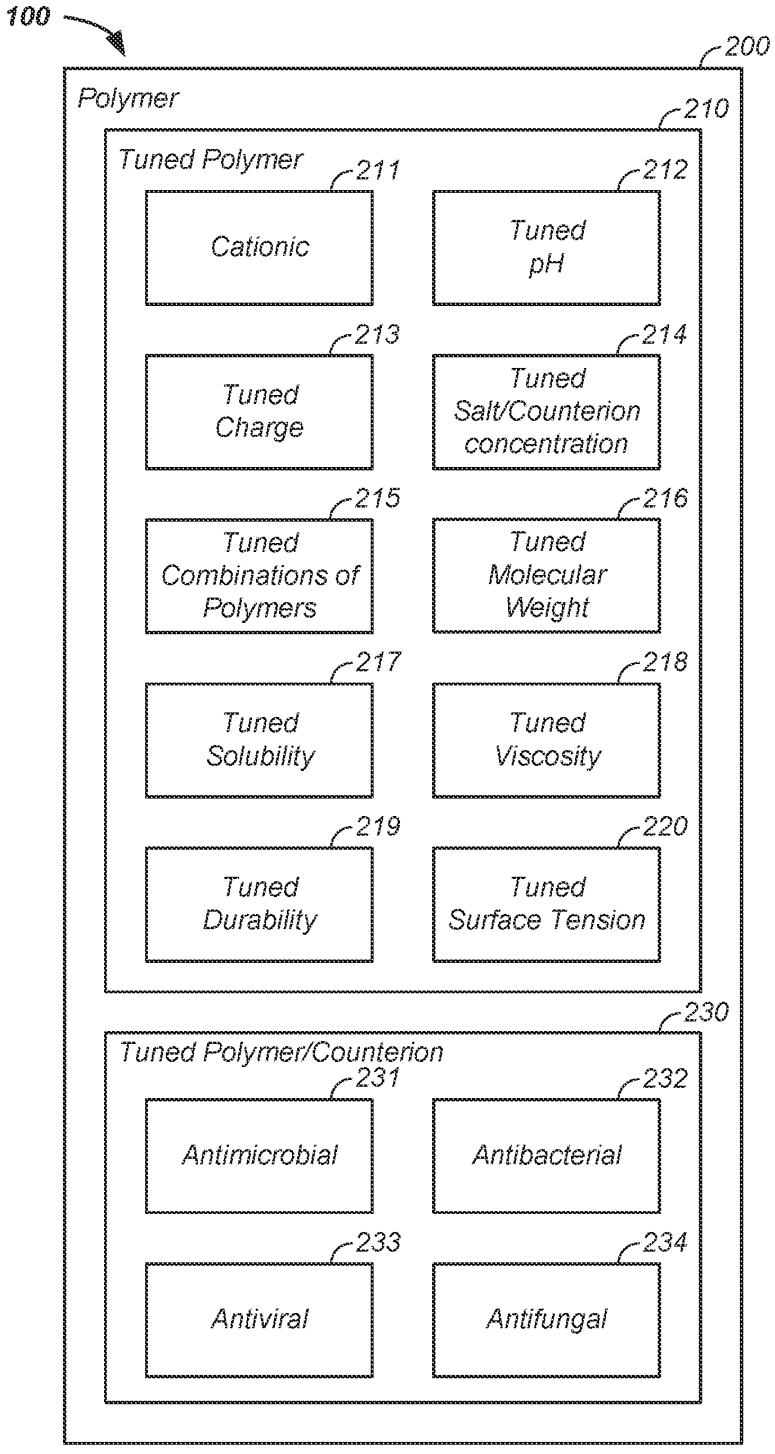

100
200
Polymer
210
Tuned Polymer
211
Cationic
212
Tuned pH
213
Tuned Charge
214
Tuned Salt/Counterion concentration
215
Tuned Combinations of Polymers
216
Tuned Molecular Weight
217
Tuned Solubility
218
Tuned Viscosity
219
Tuned Durability
220
Tuned Surface Tension
230
Tuned Polymer/Counterion
231
Antimicrobial
232
Antibacterial
233
Antiviral
234
Antifungal

FIG. 2

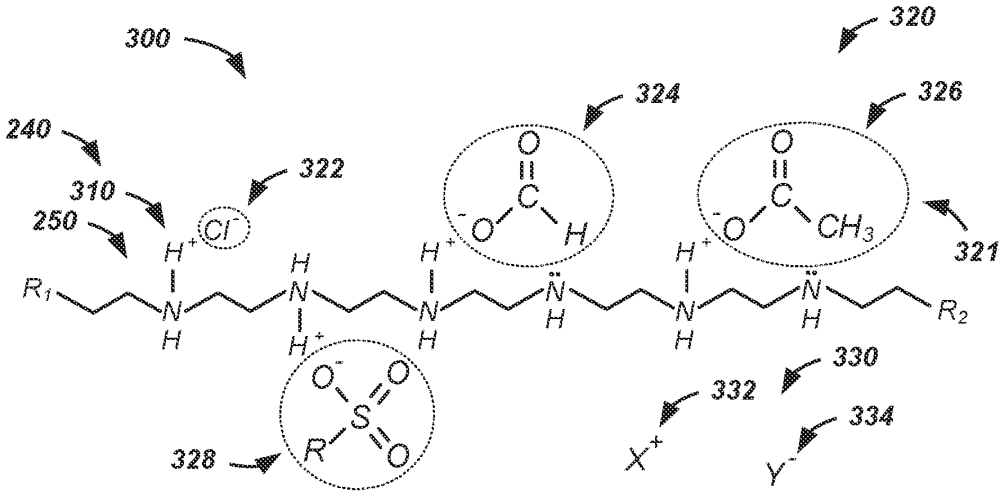

300
320
324
326
240
322
310
250
321
330
332
334
328

FIG. 3A

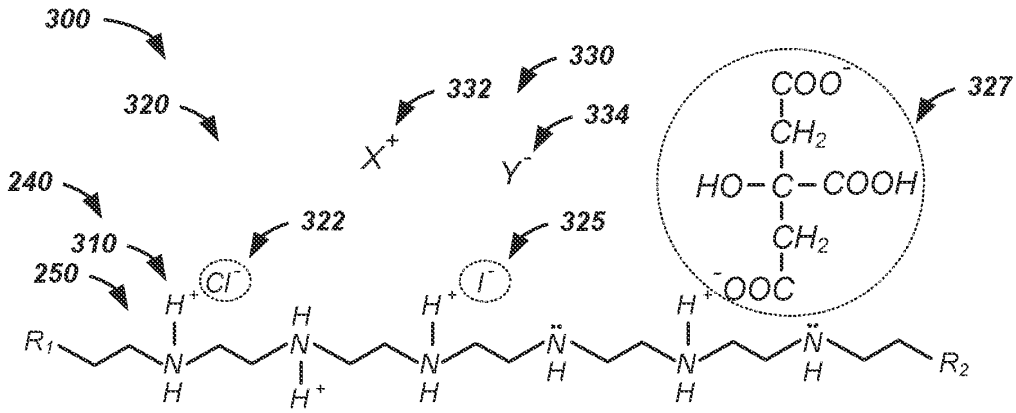

300
320
330
332
327
240
322
325
310
250

FIG. 3B

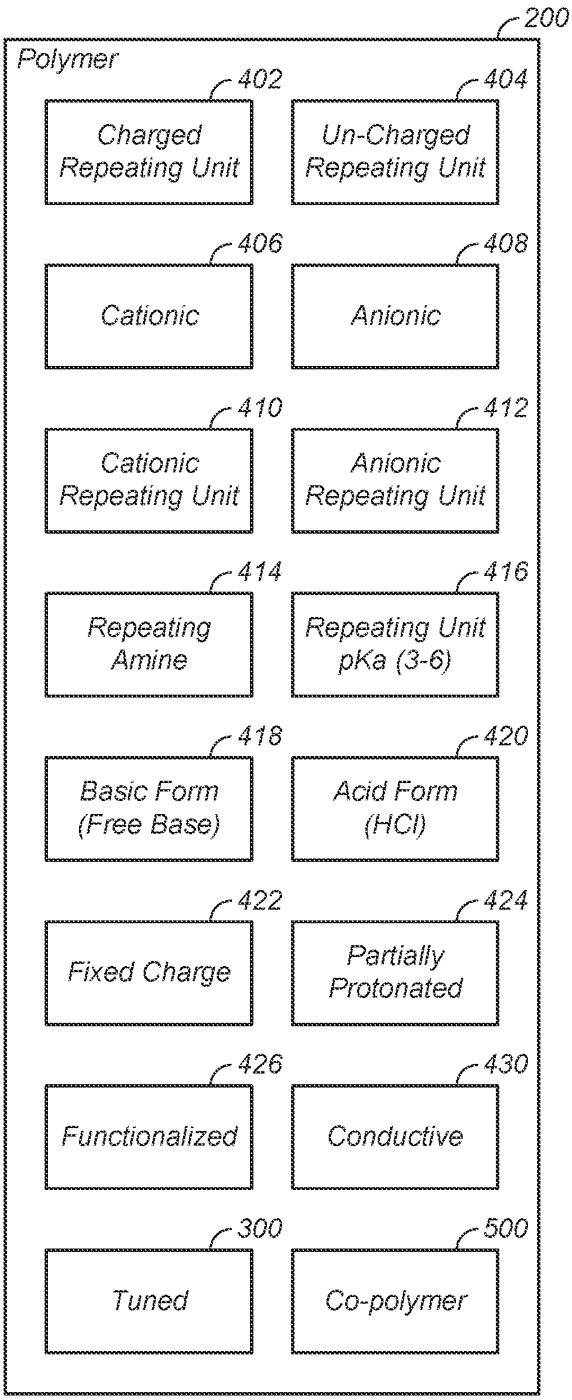

200
Polymer
402
Charged Repeating Unit
404
Un-Charged Repeating Unit
406
Cationic
408
Anionic
410
Cationic Repeating Unit
412
Anionic Repeating Unit
414
Repeating Amine
416
Repeating Unit pKa (3-6)
418
Basic Form (Free Base)
420
Acid Form (HCl)
422
Fixed Charge
424
Partially Protonated
426
Functionalized
430
Conductive
300
Tuned
500
Co-polymer

FIG. 4

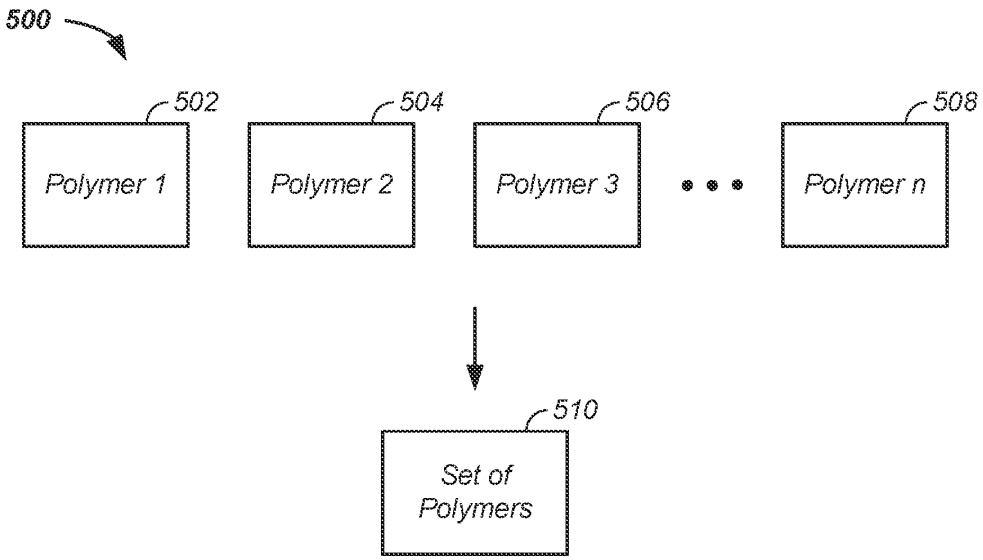

500
502
Polymer 1
504
Polymer 2
506
Polymer 3
508
Polymer n
510
Set of Polymers

FIG. 5A

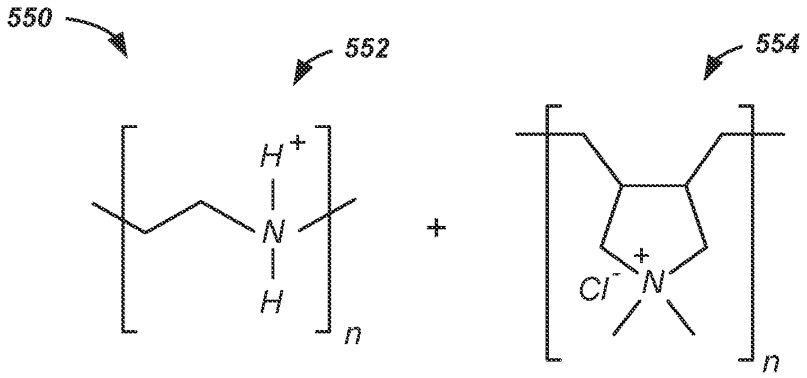


FIG. 5B

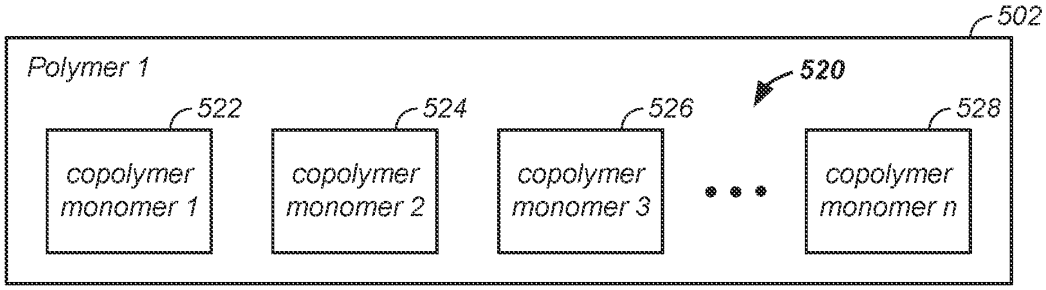

502
Polymer 1
520
522
524
526
528
copolymer monomer 1
copolymer monomer 2
copolymer monomer 3
copolymer monomer n

FIG. 5C

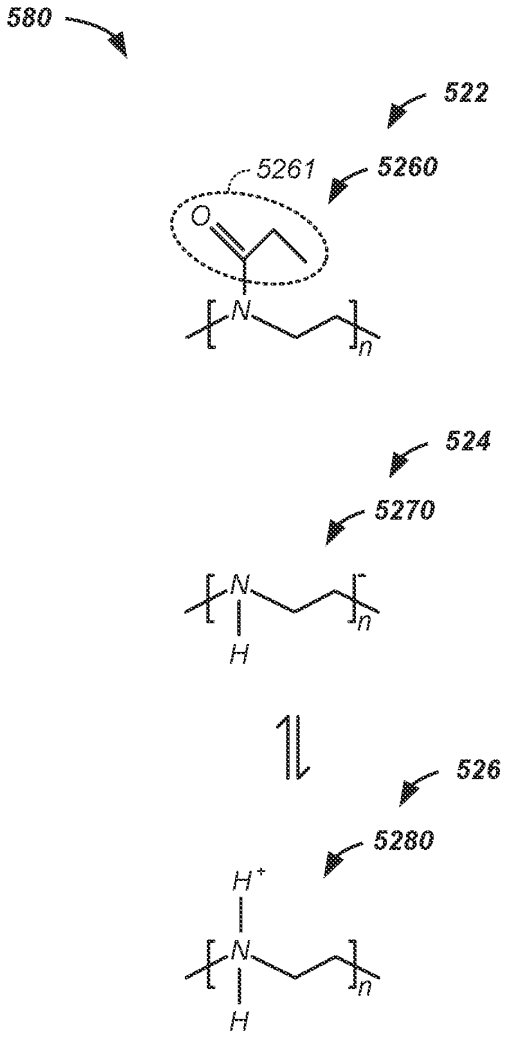


FIG. 5D

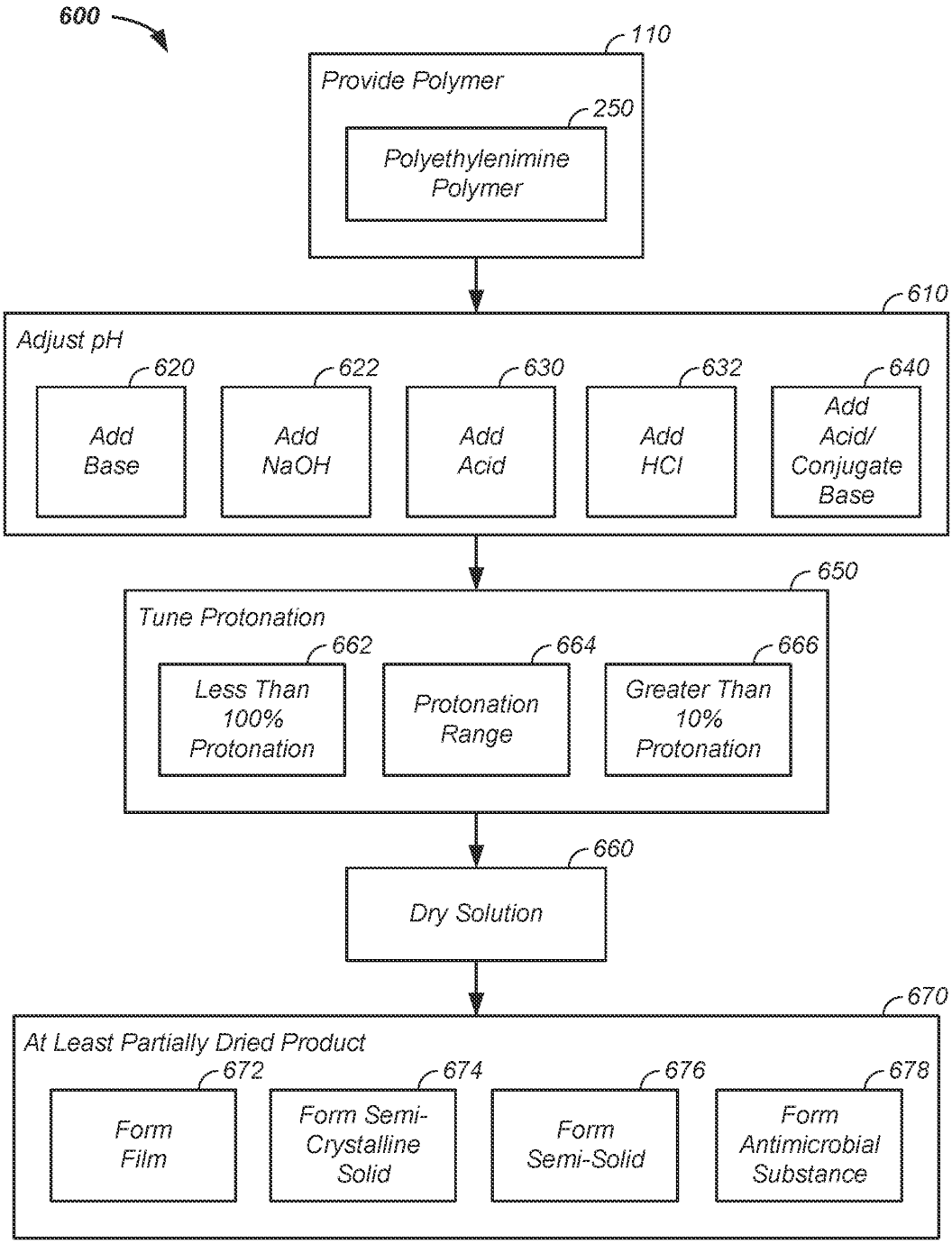

600
110
Provide Polymer
250
Polyethylenimine Polymer
610
Adjust pH
620
Add Base
622
Add NaOH
630
Add Acid
632
Add HCl
640
Add Acid/ Conjugate Base
650
Tune Protonation
662
Less Than 100% Protonation
664
Protonation Range
666
Greater Than 10% Protonation
660
Dry Solution
670
At Least Partially Dried Product
672
Form Film
674
Form Semi-Crystalline Solid
676
Form Semi-Solid
678
Form Antimicrobial Substance

FIG. 6

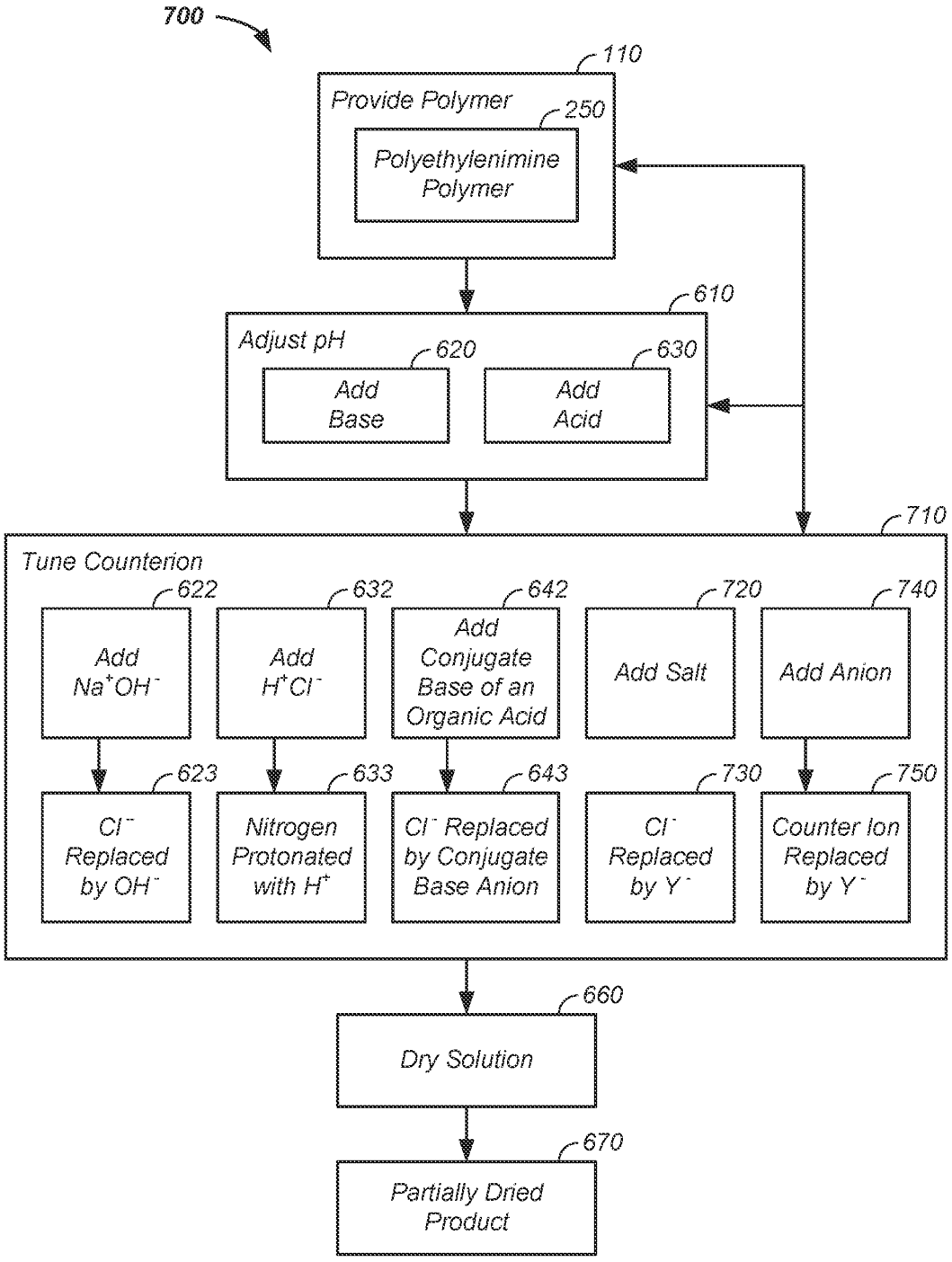

700
110
Provide Polymer
250
Polyethylenimine Polymer
610
Adjust pH
620
Add Base
630
Add Acid
710
Tune Counterion
622
Add Na^+OH^-
632
Add H^+Cl^-
642
Add Conjugate Base of an Organic Acid
720
Add Salt
740
Add Anion
623
Cl^- Replaced by OH^-
633
Nitrogen Protonated with H^+
643
Cl^- Replaced by Conjugate Base Anion
730
Cl^- Replaced by Y^-
750
Counter Ion Replaced by Y^-
660
Dry Solution
670
Partially Dried Product

FIG. 7

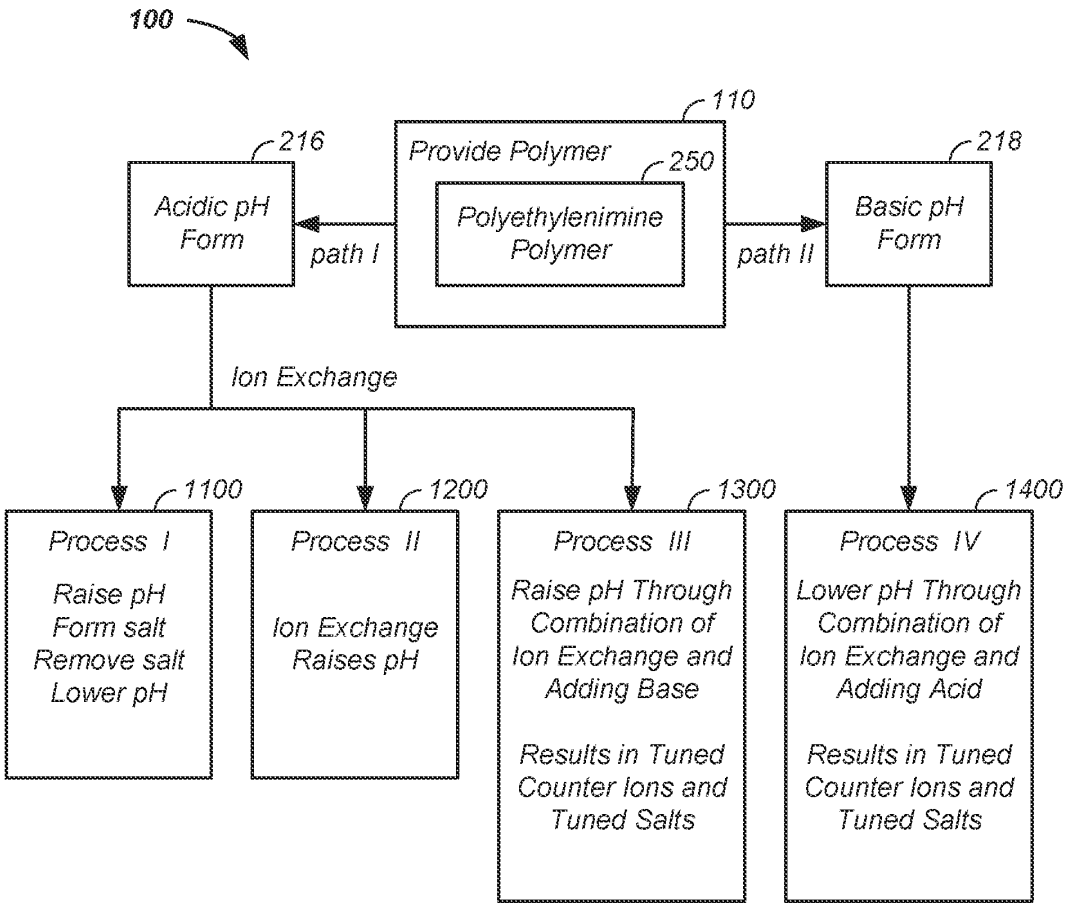

100
110
Provide Polymer
250
Polyethylenimine Polymer
216
Acidic pH Form
path I
path II
218
Basic pH Form
Ion Exchange
1100
Process I
Raise pH
Form salt
Remove salt
Lower pH
1200
Process II
Ion Exchange
Raises pH
1300
Process III
Raise pH Through Combination of Ion Exchange and Adding Base
Results in Tuned Counter Ions and Tuned Salts
1400
Process IV
Lower pH Through Combination of Ion Exchange and Adding Acid
Results in Tuned Counter Ions and Tuned Salts

FIG. 8

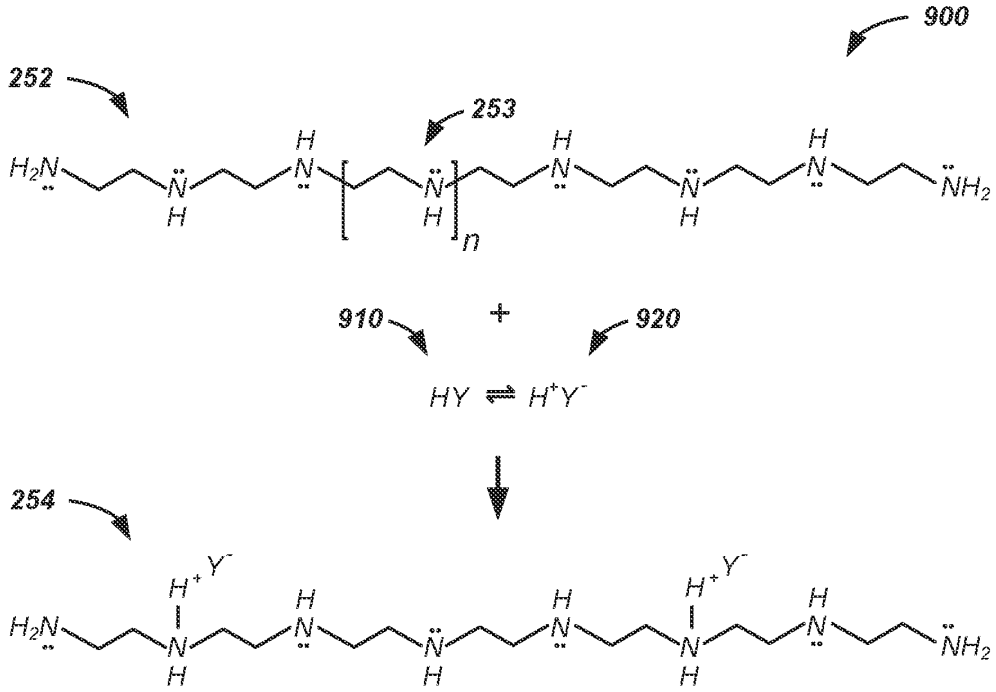


FIG. 9A

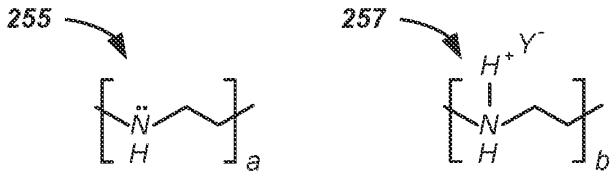


FIG. 9B

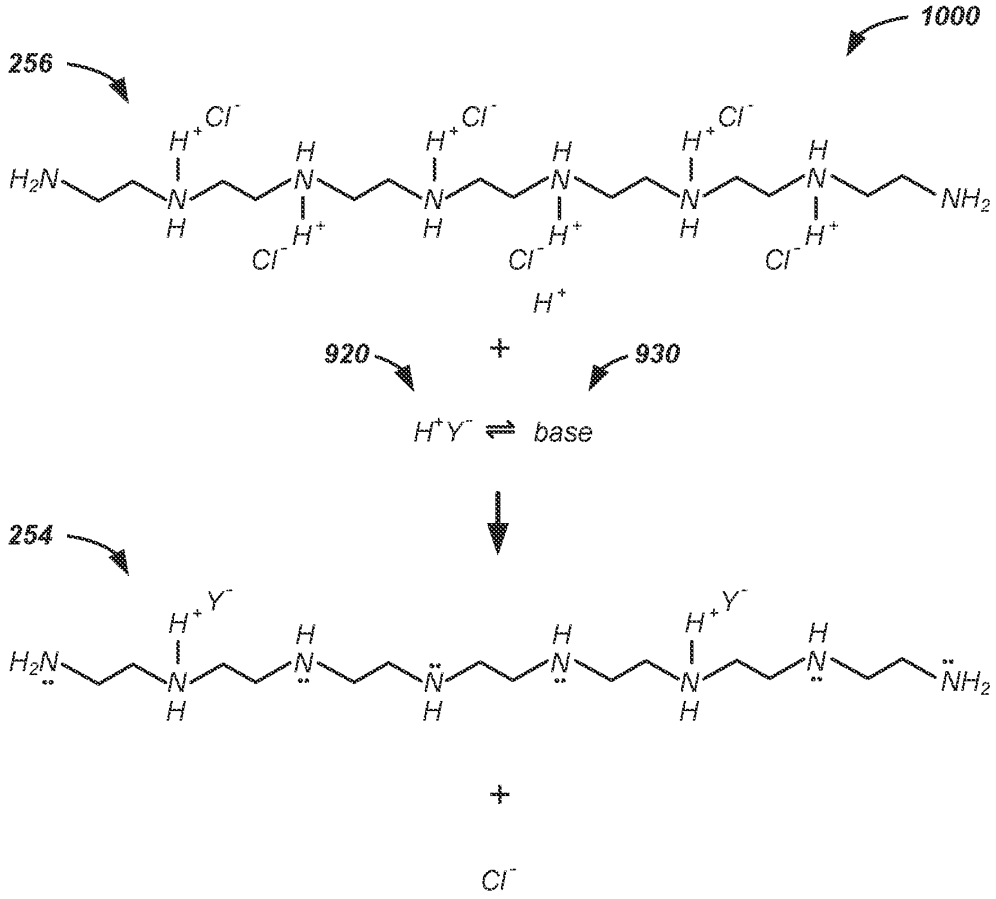


FIG. 10

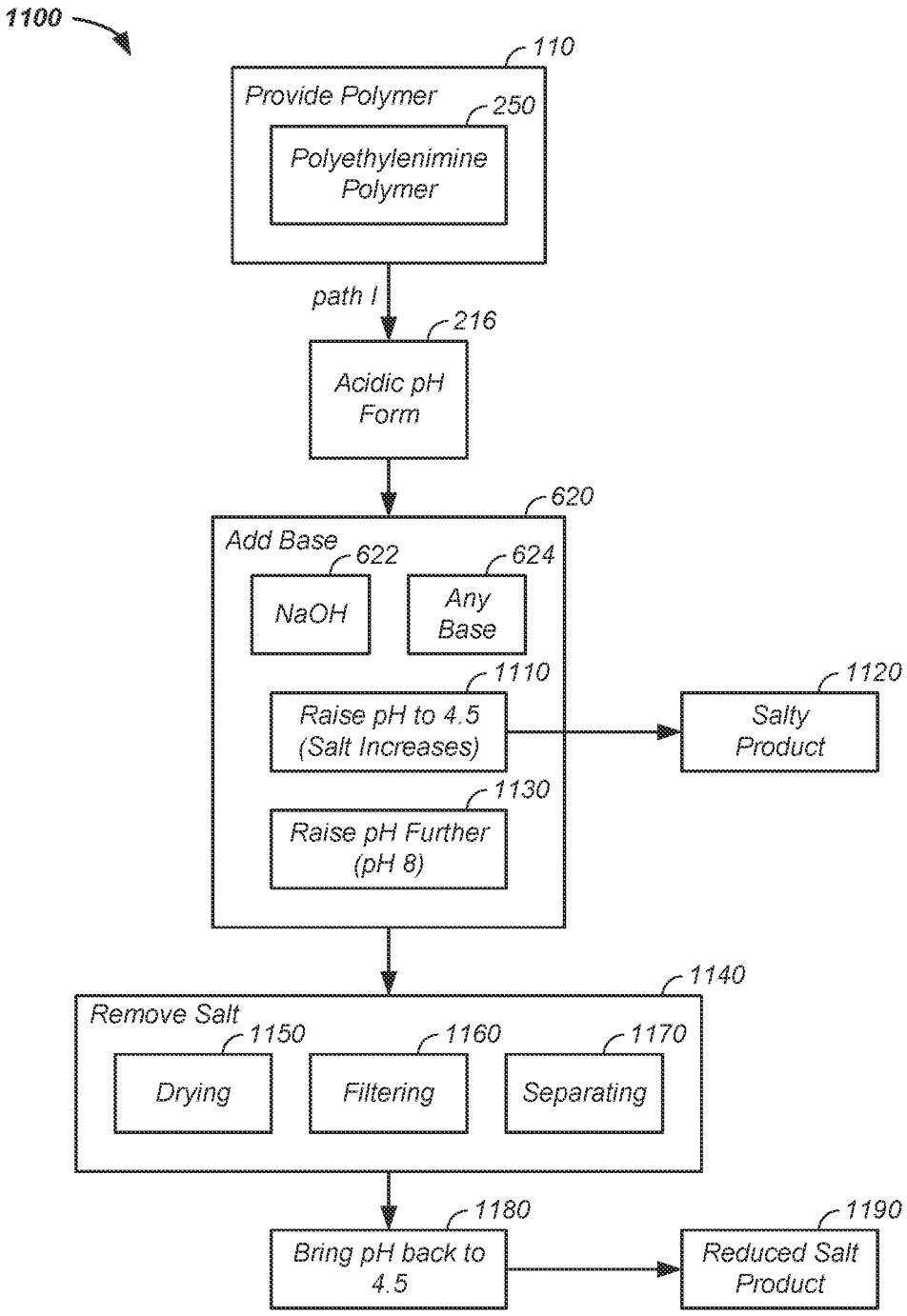

1100
110
Provide Polymer
250
Polyethylenimine Polymer
path I
216
Acidic pH Form
620
Add Base
622
NaOH
624
Any Base
1110
Raise pH to 4.5 (Salt Increases)
1120
Salty Product
1130
Raise pH Further (pH 8)
1140
Remove Salt
1150
Drying
1160
Filtering
1170
Separating
1180
Bring pH back to 4.5
1190
Reduced Salt Product

FIG. 11

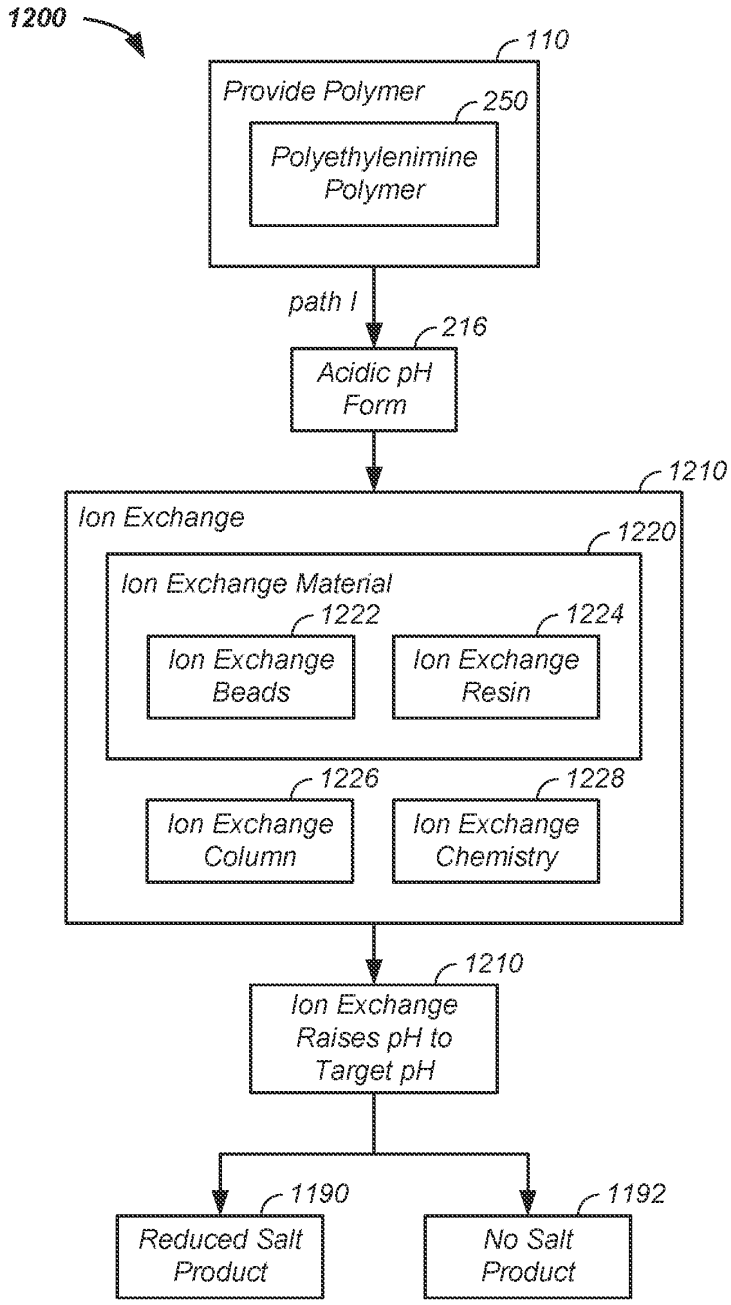

1200
110
Provide Polymer
250
Polyethylenimine Polymer
path I
216
Acidic pH Form
1210
Ion Exchange
1220
Ion Exchange Material
1222
Ion Exchange Beads
1224
Ion Exchange Resin
1226
Ion Exchange Column
1228
Ion Exchange Chemistry
1210
Ion Exchange Raises pH to Target pH
1190
Reduced Salt Product
1192
No Salt Product

FIG. 12

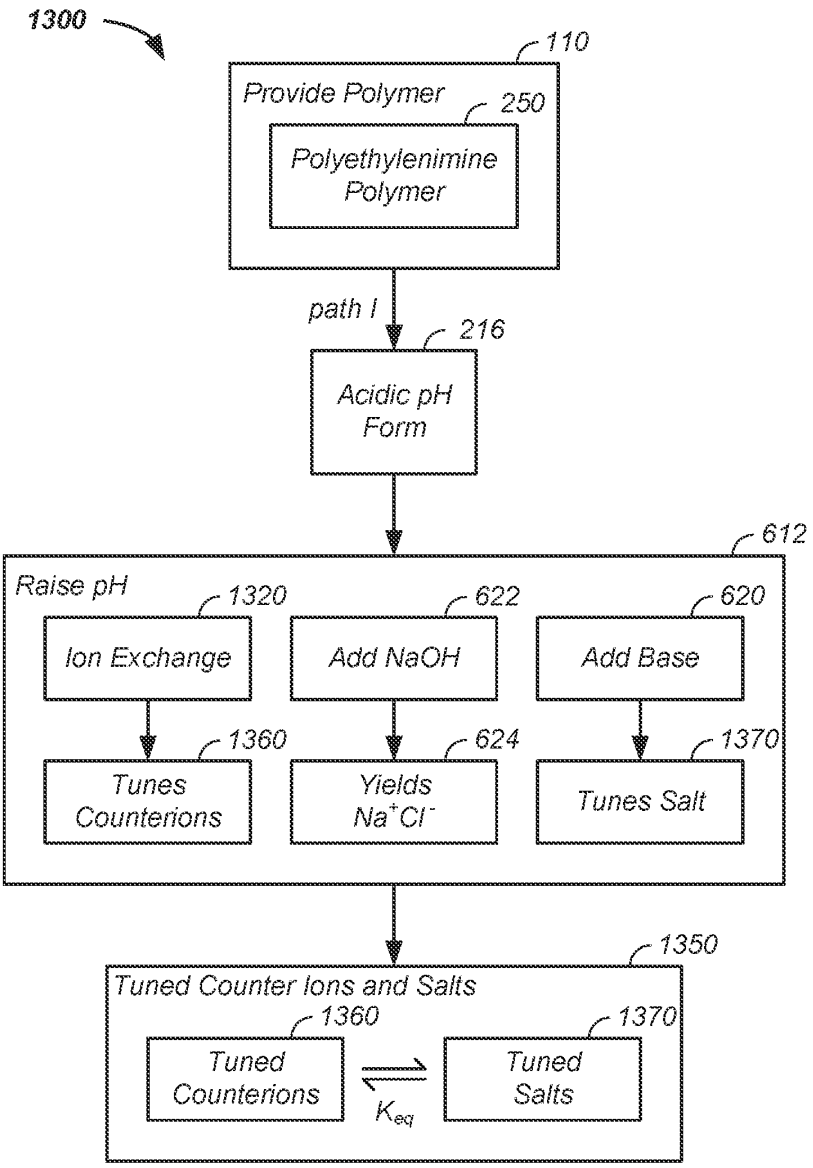

1300
110
Provide Polymer
250
Polyethylenimine Polymer
path I
216
Acidic pH Form
612
Raise pH
1320
Ion Exchange
622
Add NaOH
620
Add Base
1360
Tunes Counterions
624
Yields Na^+Cl^-
1370
Tunes Salt
1350
Tuned Counter Ions and Salts
1360
Tuned Counterions
1370
Tuned Salts
K_{eq}

FIG. 13

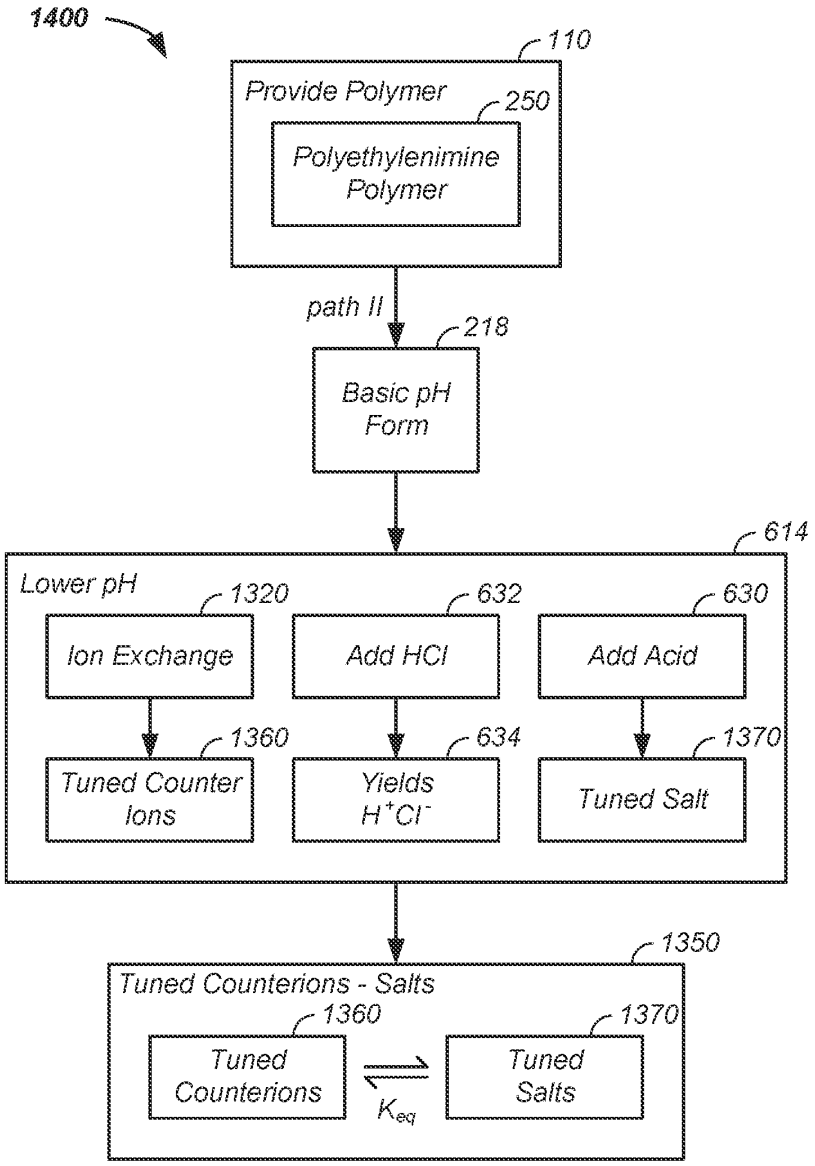

1400
110
Provide Polymer
250
Polyethylenimine Polymer
path II
218
Basic pH Form
614
Lower pH
1320
Ion Exchange
632
Add HCl
630
Add Acid
1360
Tuned Counter Ions
634
Yields H^+Cl^-
1370
Tuned Salt
1350
Tuned Counterions - Salts
1360
Tuned Counterions
1370
Tuned Salts
K_{eq}

FIG. 14

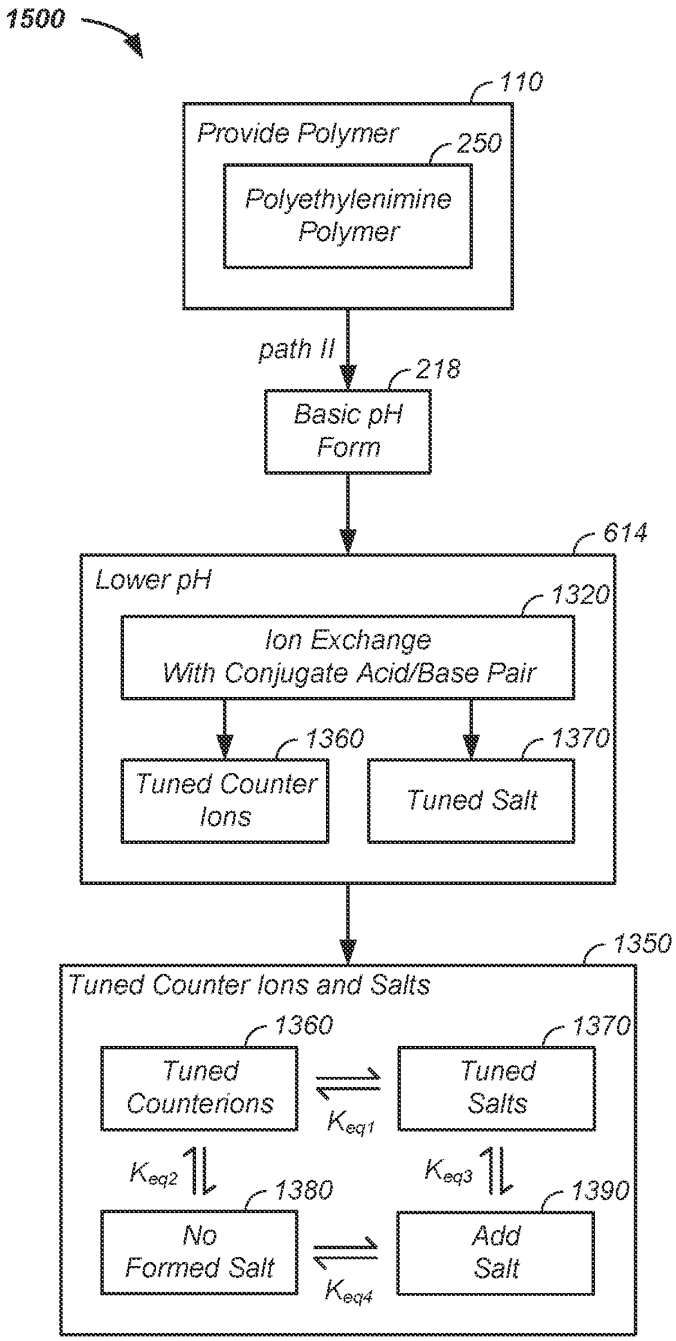

1500
110
Provide Polymer
250
Polyethylenimine Polymer
path II
218
Basic pH Form
614
Lower pH
1320
Ion Exchange With Conjugate Acid/Base Pair
1360
Tuned Counter Ions
1370
Tuned Salt
1350
Tuned Counter Ions and Salts
1360
Tuned Counterions
1370
Tuned Salts
K_{eq1}
K_{eq2}
K_{eq3}
1380
No Formed Salt
1390
Add Salt
K_{eq4}

FIG. 15

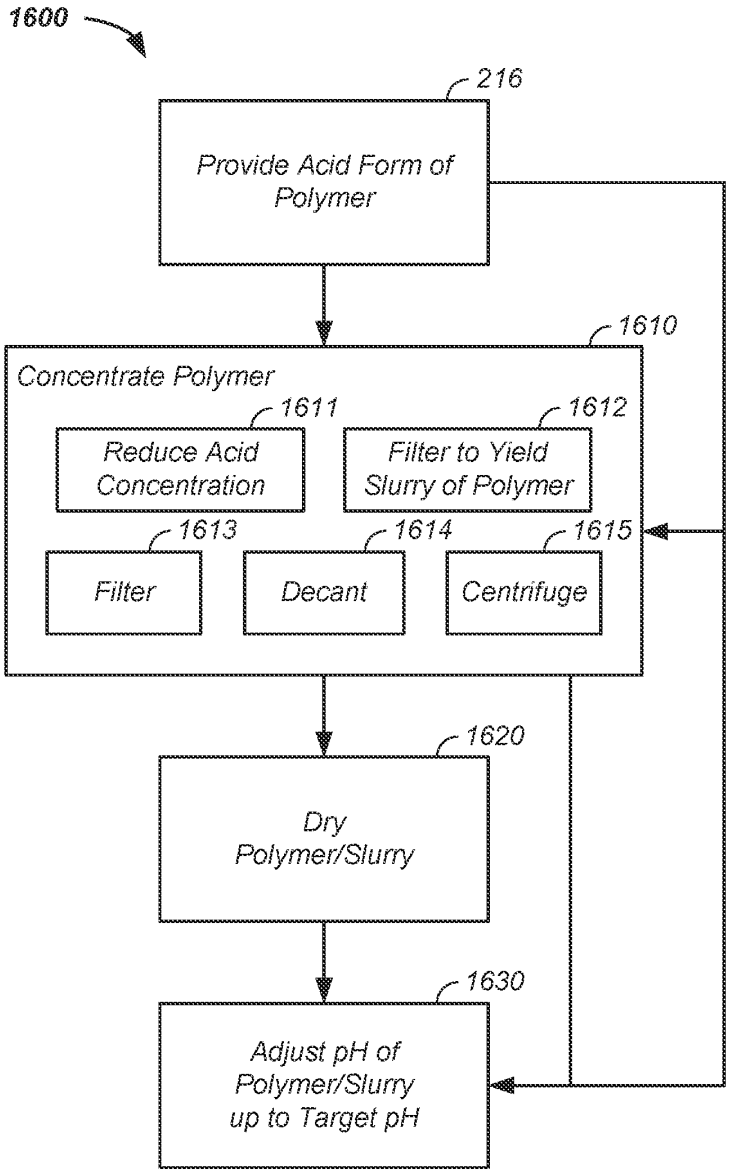

1600
216
Provide Acid Form of Polymer
1610
Concentrate Polymer
1611
Reduce Acid Concentration
1612
Filter to Yield Slurry of Polymer
1613
Filter
1614
Decant
1615
Centrifuge
1620
Dry Polymer/Slurry
1630
Adjust pH of Polymer/Slurry up to Target pH

FIG. 16

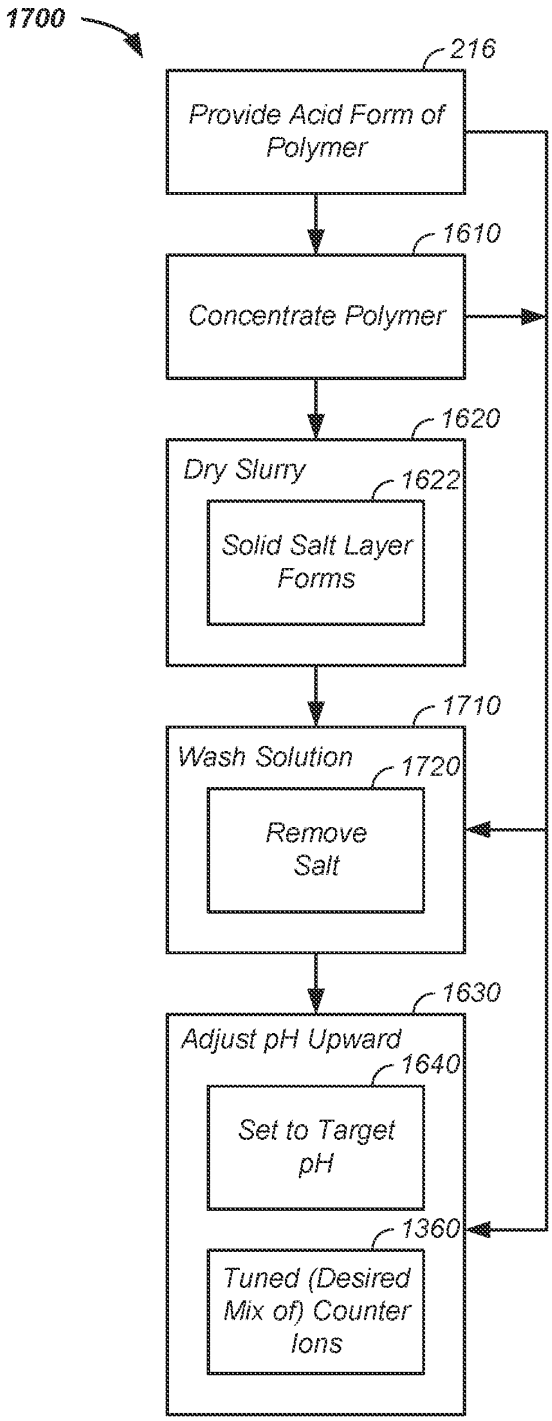

1700
216
Provide Acid Form of Polymer
1610
Concentrate Polymer
1620
Dry Slurry
1622
Solid Salt Layer Forms
1710
Wash Solution
1720
Remove Salt
1630
Adjust pH Upward
1640
Set to Target pH
1360
Tuned (Desired Mix of) Counter Ions

FIG. 17

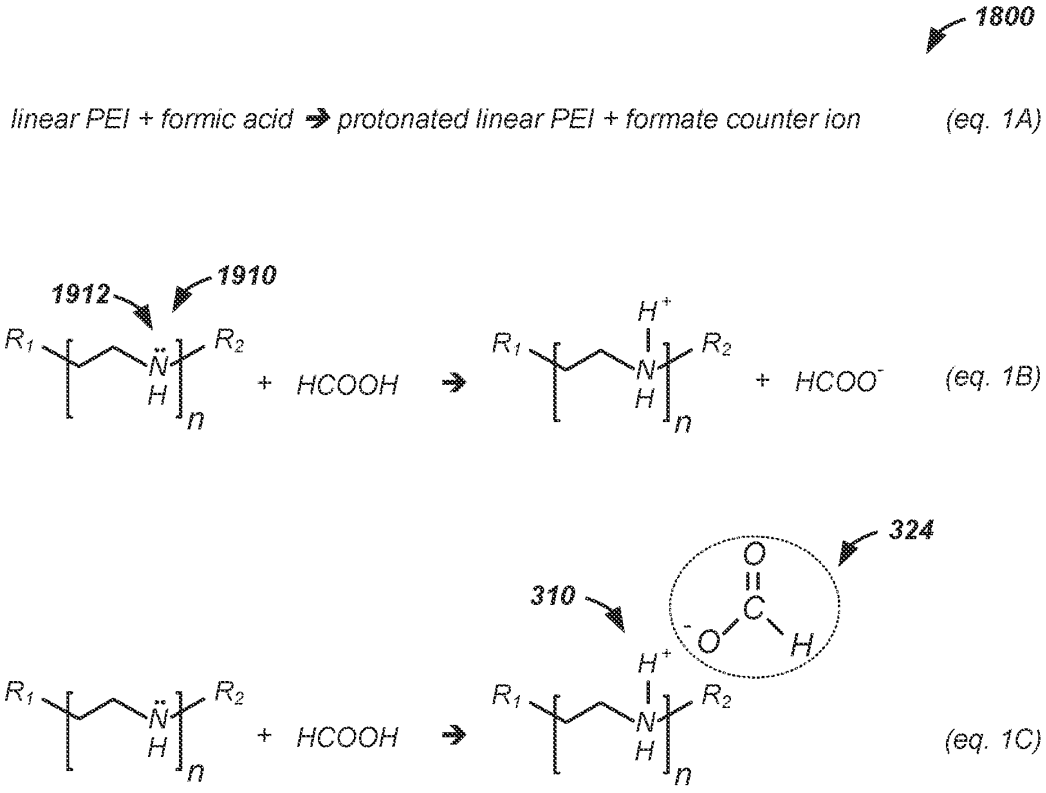

1800
linear PEI + formic acid ➔ protonated linear PEI + formate counter ion
(eq. 1A)
1912
1910
R1
R2
N
H
n
+ HCOOH
H+
+ HCOO-
(eq. 1B)
324
310
O
C
O
H
+ HCOOH
(eq. 1C)

FIG. 18

PEI + HCl + formic acid ➔ protonated PEI + chloride and formate salts/counterions

FIG. 19A

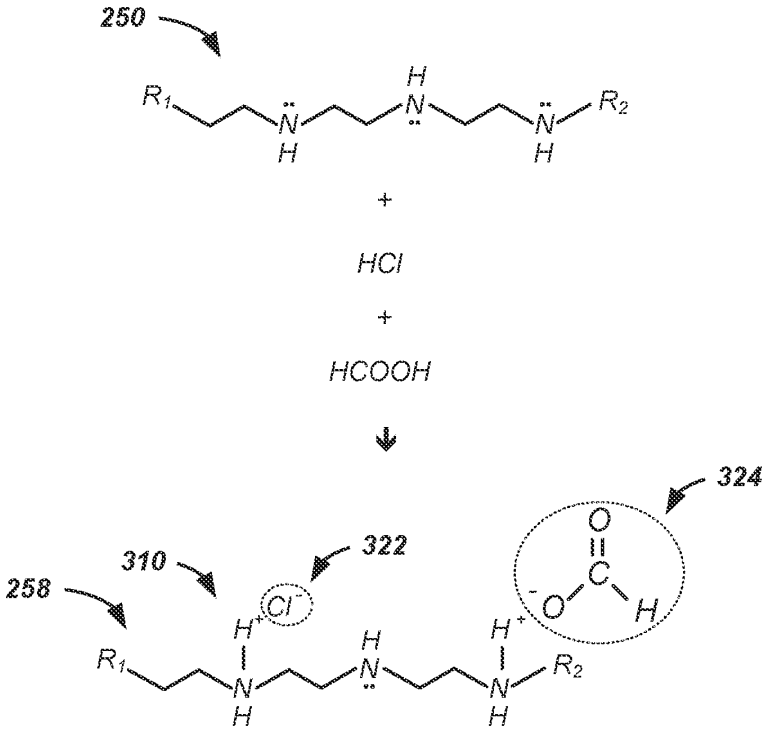


FIG. 19B

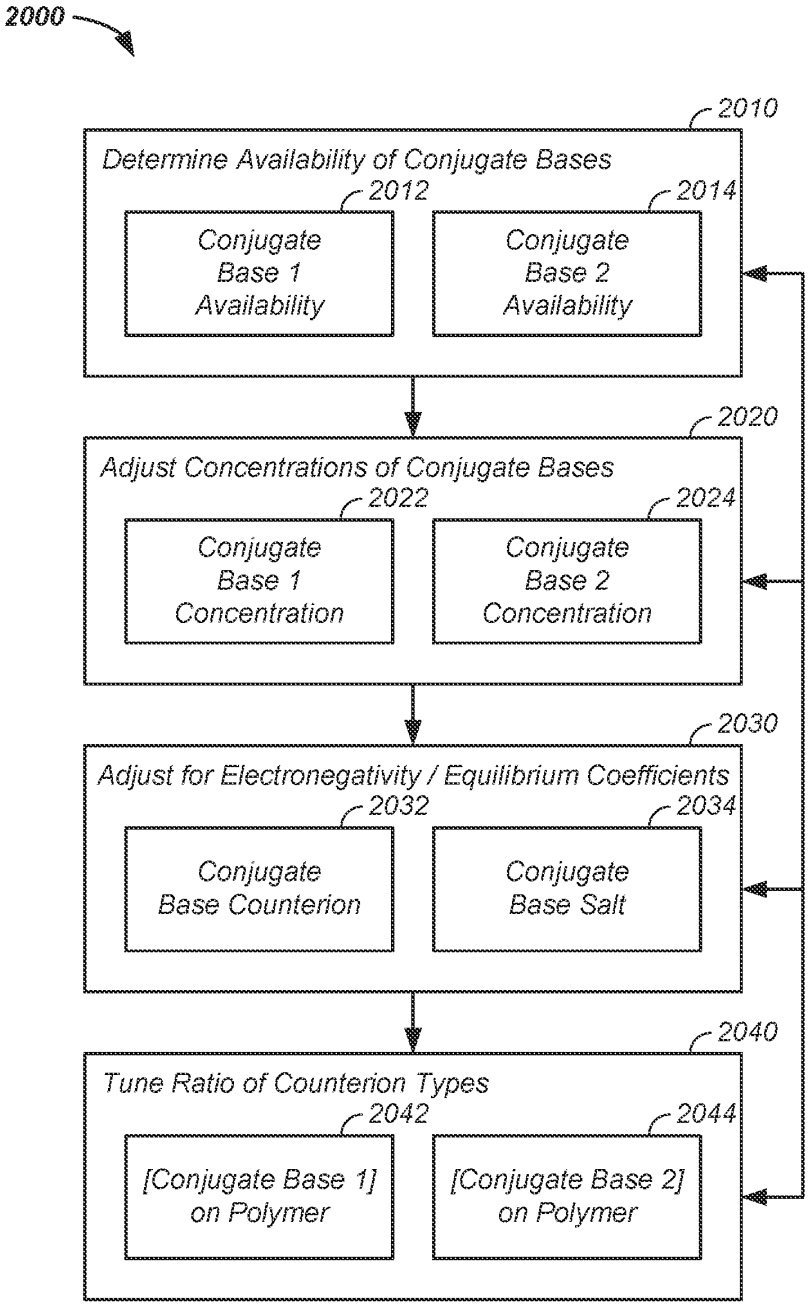

2000
2010
Determine Availability of Conjugate Bases
2012
Conjugate Base 1 Availability
2014
Conjugate Base 2 Availability
2020
Adjust Concentrations of Conjugate Bases
2022
Conjugate Base 1 Concentration
2024
Conjugate Base 2 Concentration
2030
Adjust for Electronegativity / Equilibrium Coefficients
2032
Conjugate Base Counterion
2034
Conjugate Base Salt
2040
Tune Ratio of Counterion Types
2042
[Conjugate Base 1] on Polymer
2044
[Conjugate Base 2] on Polymer

FIG. 20

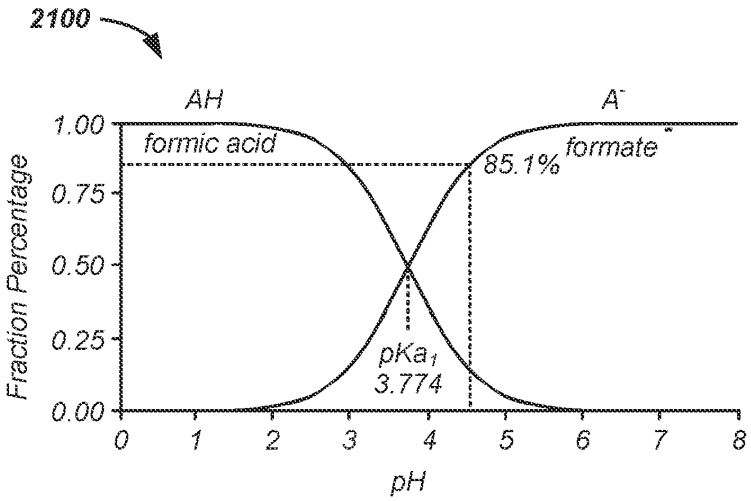

2100
AH
formic acid
A-
formate-
85.1%
1.00
0.75
0.50
0.25
0.00
Fraction Percentage
pKa1
3.774
0
1
2
3
4
5
6
7
8
pH

FIG. 21

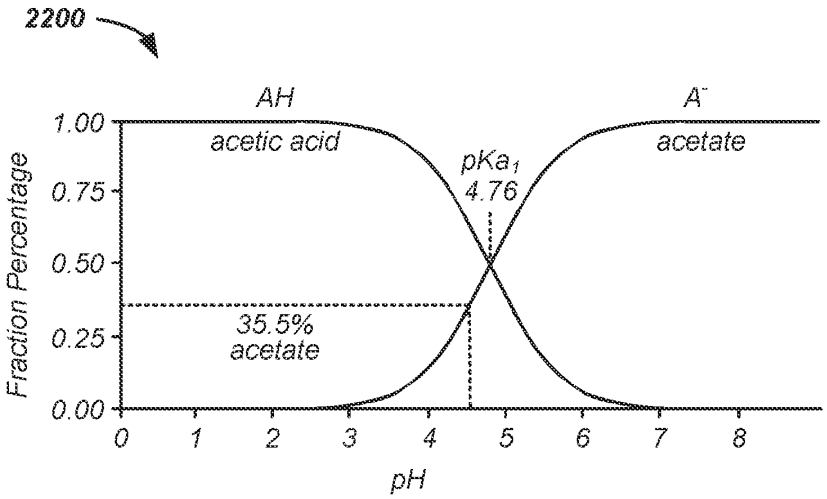

2200
AH
acetic acid
A⁻
acetate
pKa1
4.76
35.5%
acetate
Fraction Percentage
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
6
7
8
pH

FIG. 22

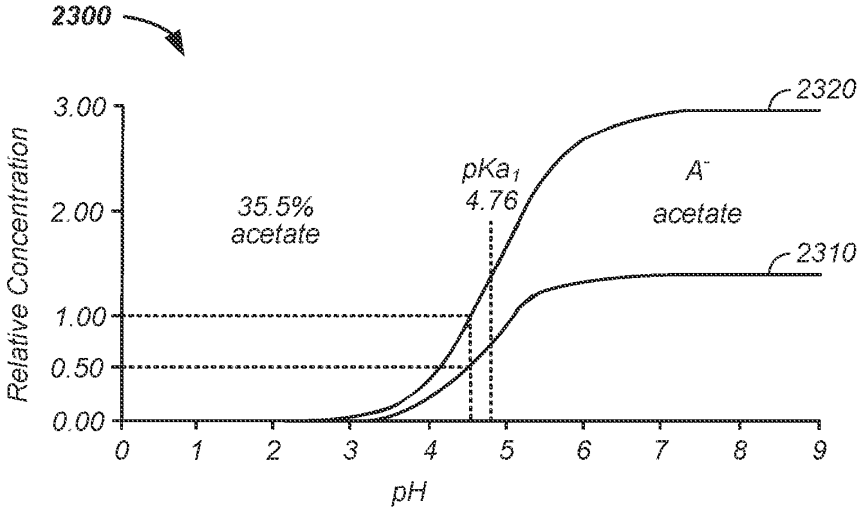

2300
3.00
2.00
1.00
0.50
0.00
Relative Concentration
35.5%
acetate
pKa1
4.76
A-
acetate
2320
2310
0
1
2
3
4
5
6
7
8
9
pH

FIG. 23

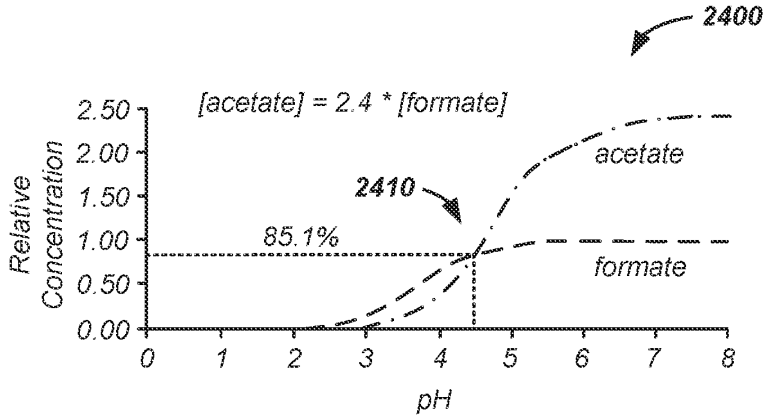

2400
[acetate] = 2.4 * [formate]
2.50
2.00
1.50
1.00
0.50
0.00
Relative Concentration
2410
85.1%
acetate
formate
0
1
2
3
4
5
6
7
8
pH

FIG. 24

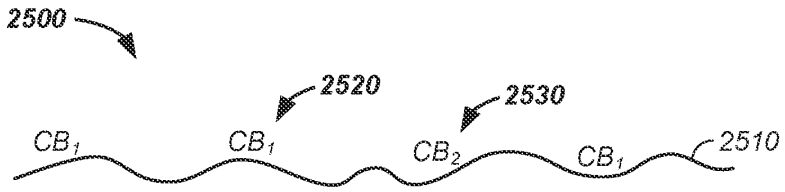


FIG. 25A

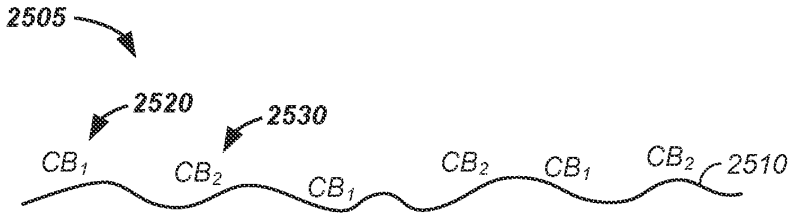


FIG. 25B

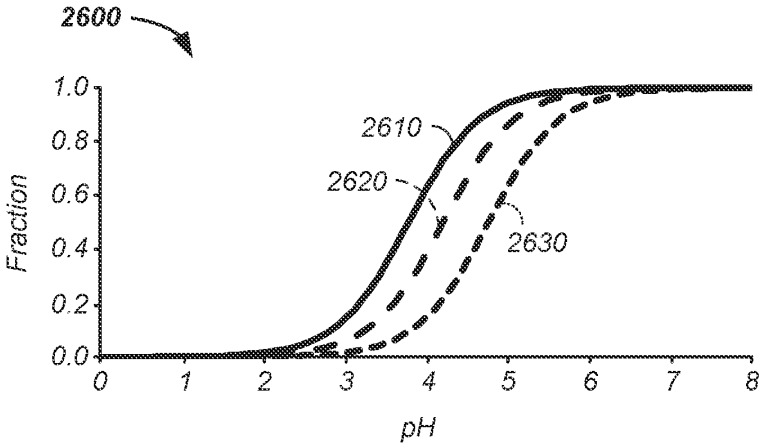


FIG. 26

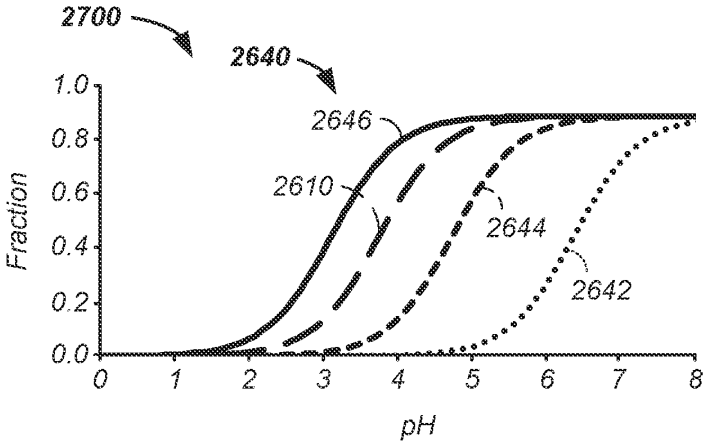

2700
2640
2646
2610
2644
2642
1.0
0.8
0.6
0.4
0.2
0.0
Fraction
0
1
2
3
4
5
6
7
8
pH

FIG. 27

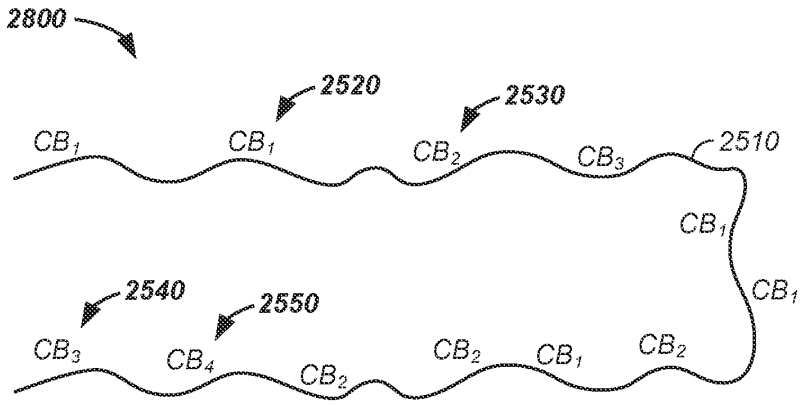

2800
2520
2530
CB1
CB1
CB2
CB3
2510
CB1
CB1
2540
2550
CB3
CB4
CB2
CB2
CB1
CB2

FIG. 28

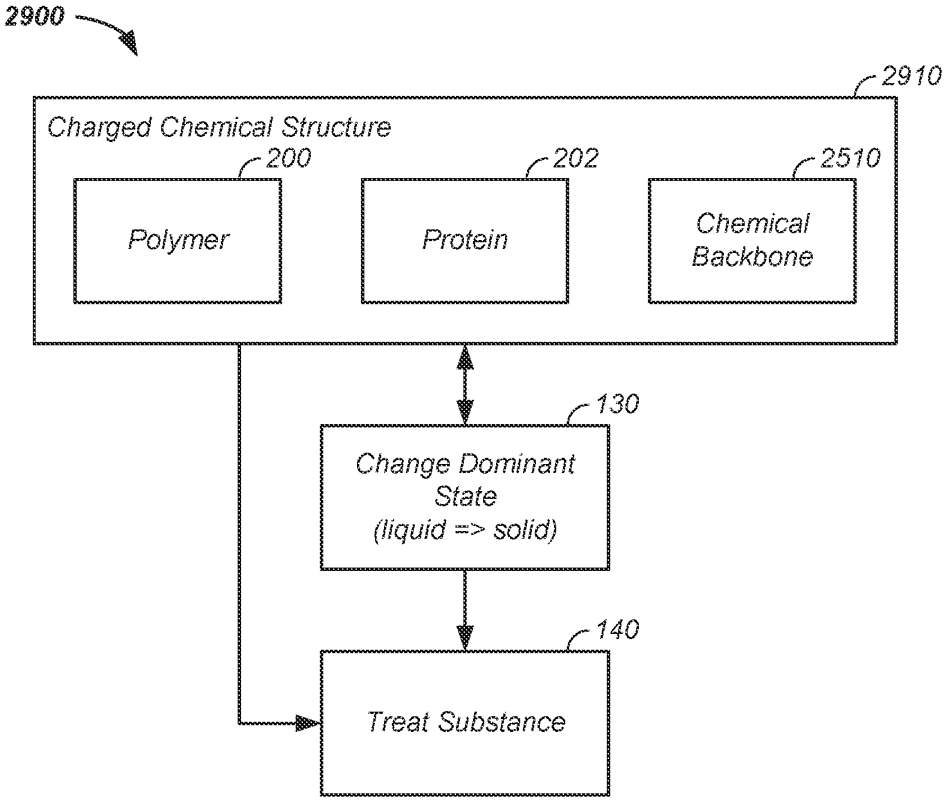

2900
2910
Charged Chemical Structure
200
Polymer
202
Protein
2510
Chemical Backbone
130
Change Dominant State (liquid => solid)
140
Treat Substance

FIG. 29

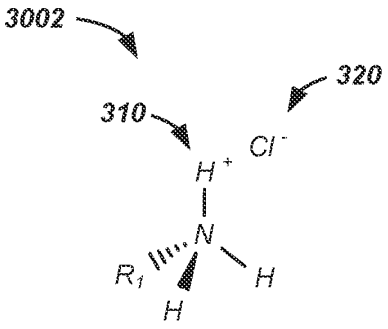


FIG. 30A

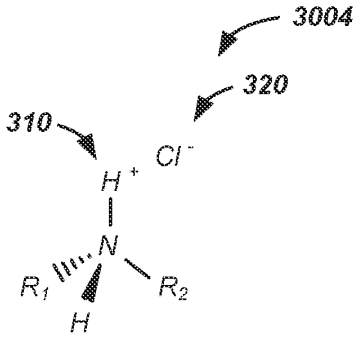


FIG. 30B

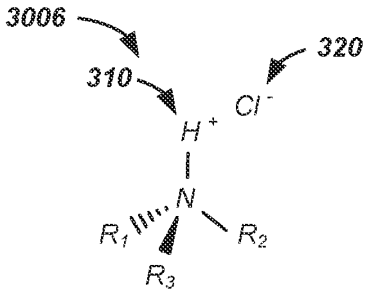


FIG. 30C

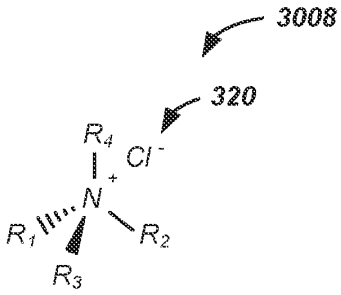


FIG. 30D

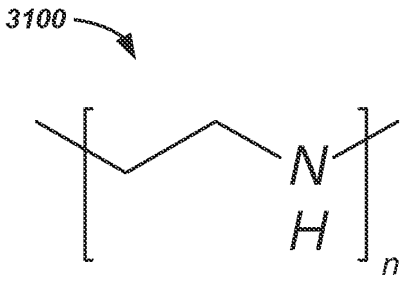


FIG. 31A

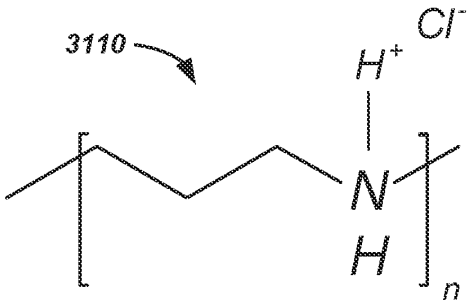


FIG. 31C

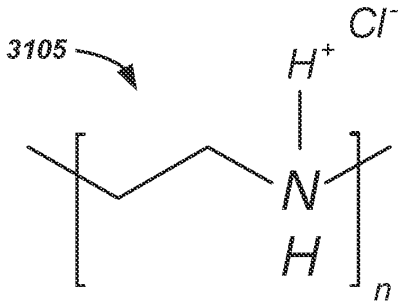


FIG. 31B

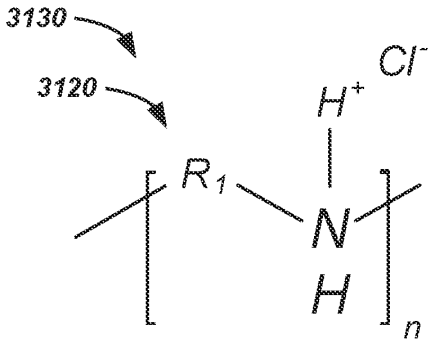


FIG. 31D

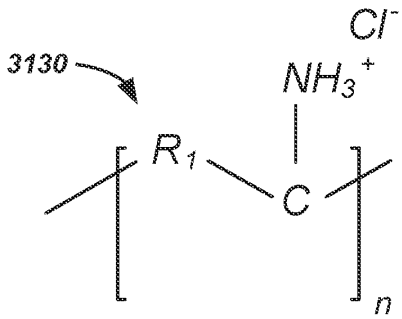


FIG. 31E

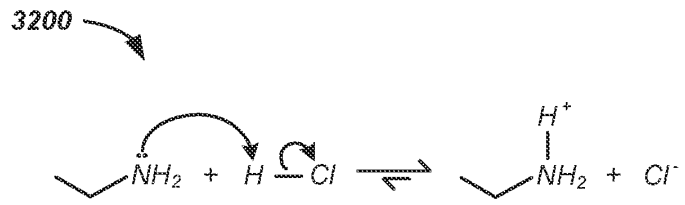


FIG. 32

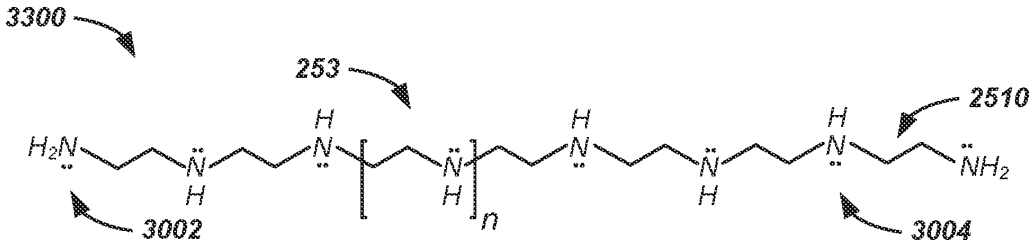


FIG. 33A

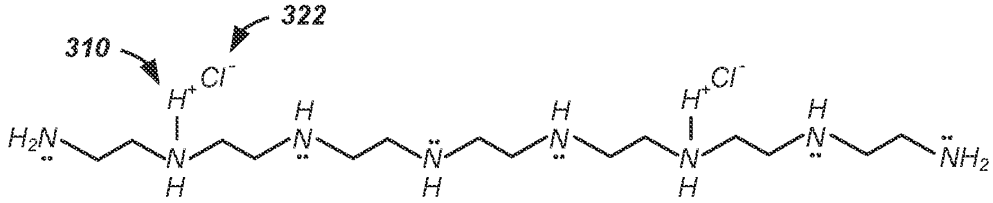


FIG. 33B

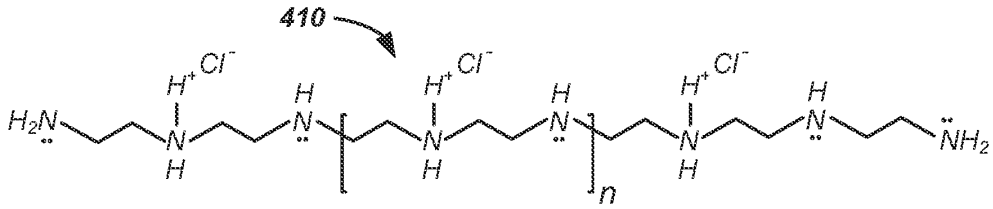


FIG. 33C

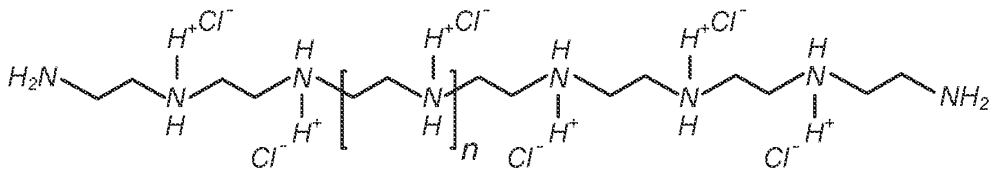


FIG. 33D

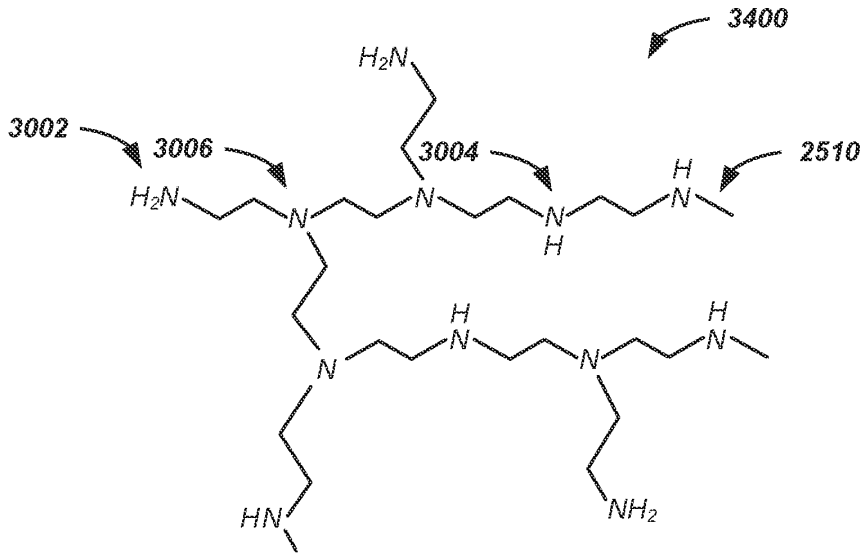


FIG. 34A

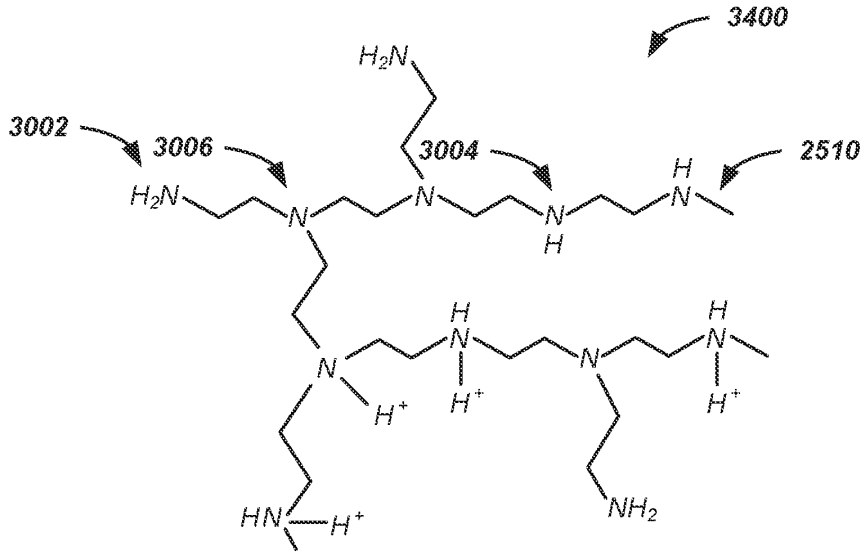


FIG. 34B

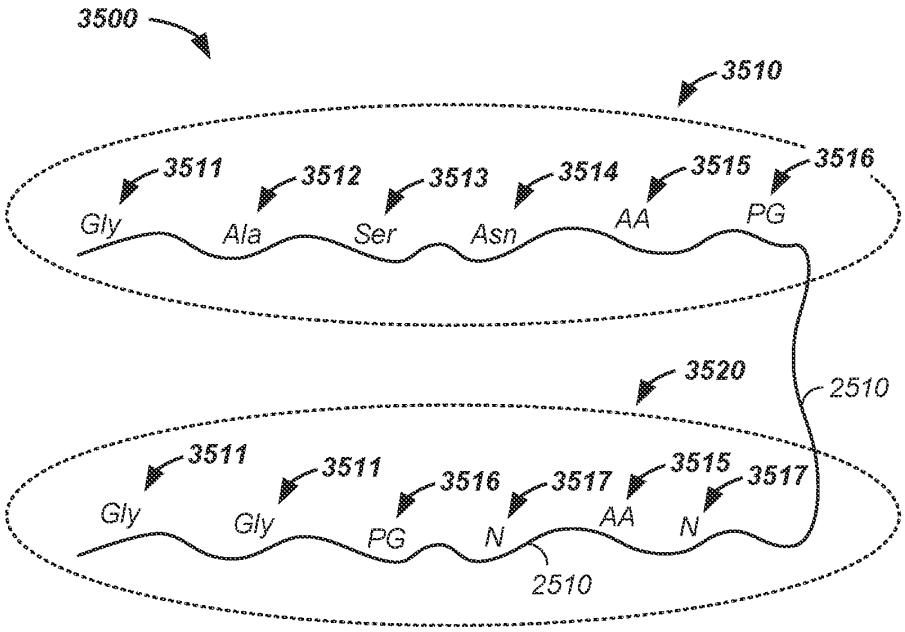

3500
3510
3511
3512
3513
3514
3515
3516
Gly
Ala
Ser
Asn
AA
PG
3520
2510
3511
3511
3516
3517
3515
3517
Gly
Gly
PG
N
AA
N
2510

FIG. 35

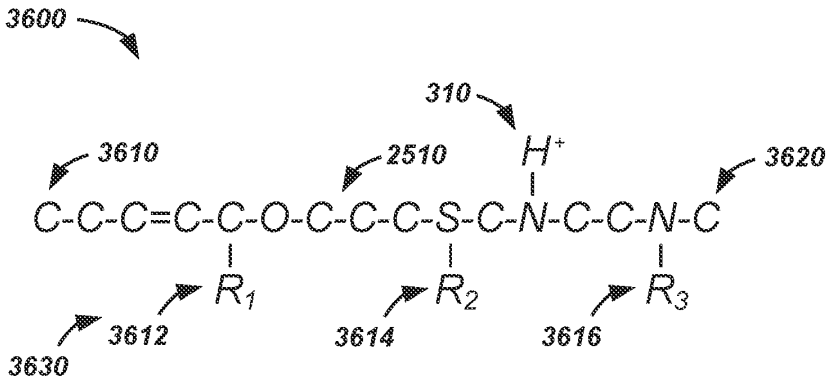

3600
310
3610
2510
3620
C-C-C=C-C-O-C-C-C-S-C-N-C-C-N-C
H+
R1
R2
R3
3612
3614
3616
3630

FIG. 36

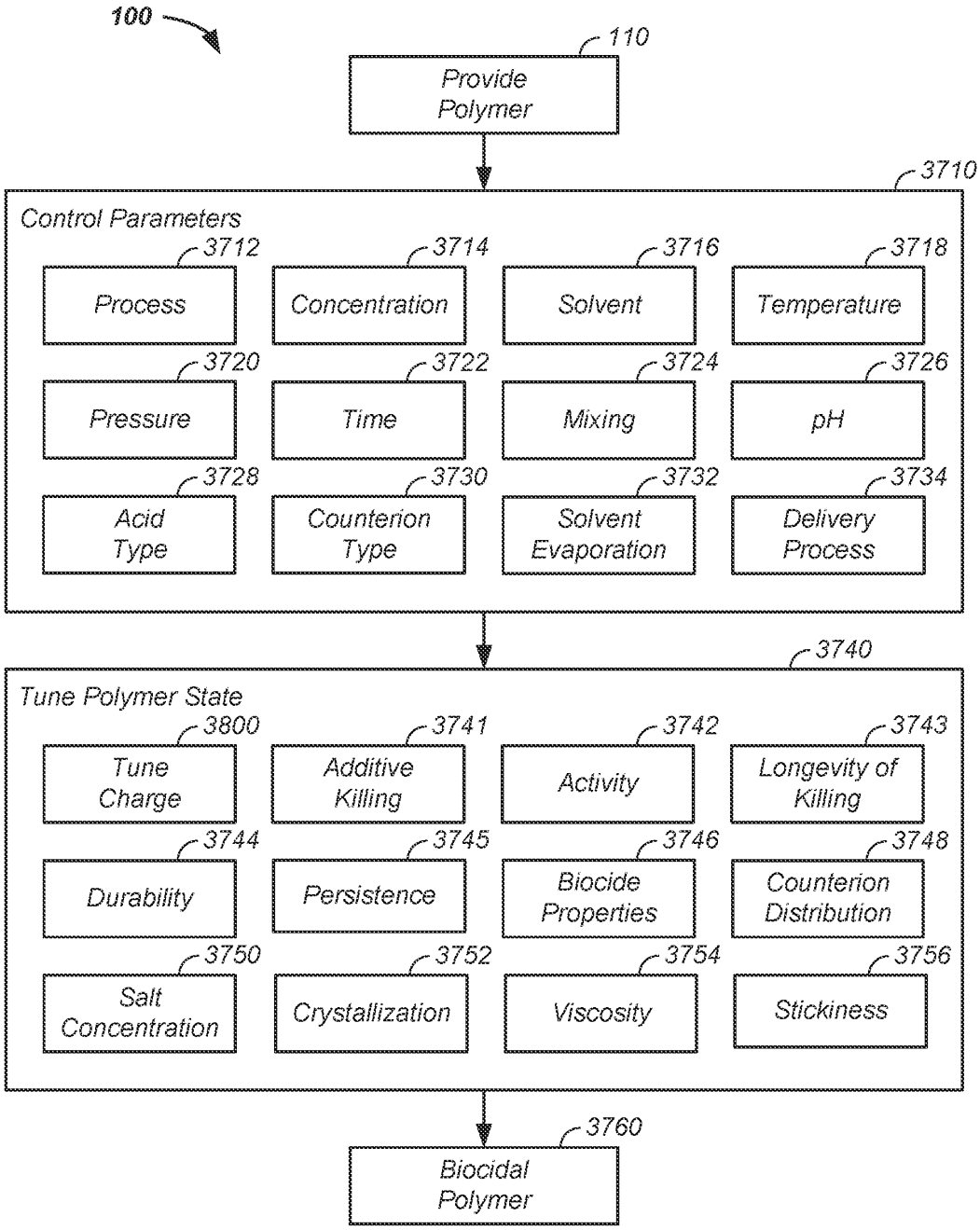

100
110
Provide Polymer
3710
Control Parameters
3712
Process
3714
Concentration
3716
Solvent
3718
Temperature
3720
Pressure
3722
Time
3724
Mixing
3726
pH
3728
Acid Type
3730
Counterion Type
3732
Solvent Evaporation
3734
Delivery Process
3740
Tune Polymer State
3800
Tune Charge
3741
Additive Killing
3742
Activity
3743
Longevity of Killing
3744
Durability
3745
Persistence
3746
Biocide Properties
3748
Counterion Distribution
3750
Salt Concentration
3752
Crystallization
3754
Viscosity
3756
Stickiness
3760
Biocidal Polymer

FIG. 37

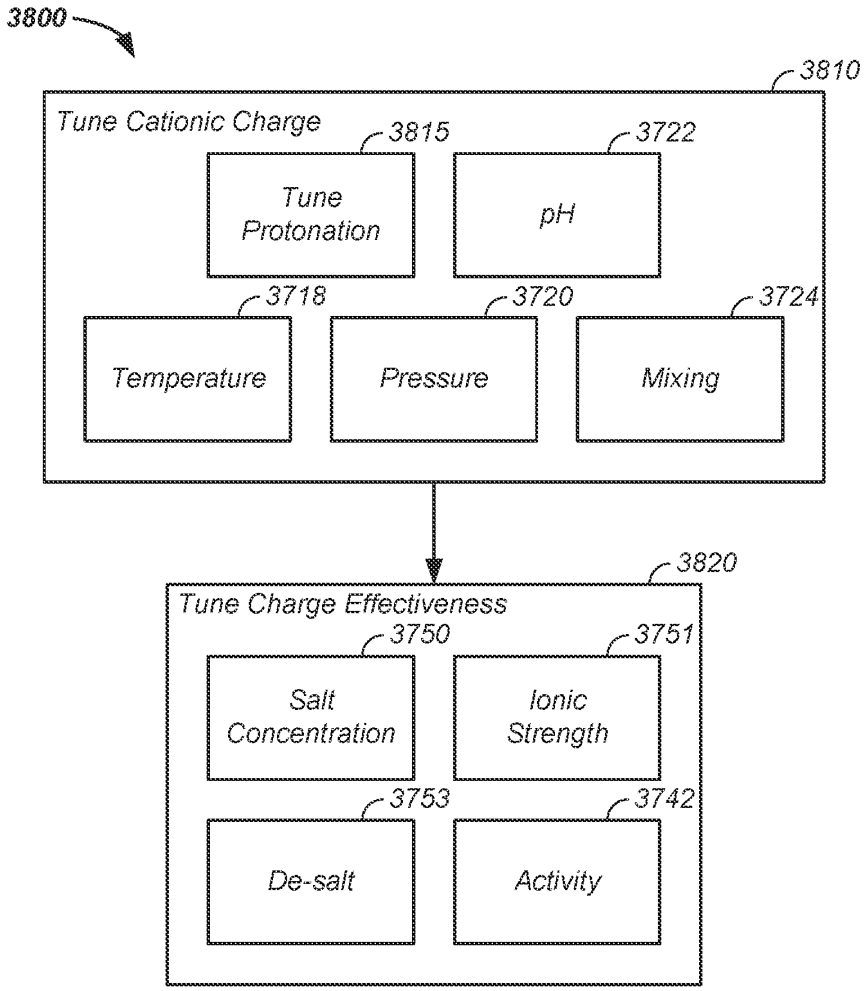

3800
3810
Tune Cationic Charge
3815
Tune Protonation
3722
pH
3718
Temperature
3720
Pressure
3724
Mixing
3820
Tune Charge Effectiveness
3750
Salt Concentration
3751
Ionic Strength
3753
De-salt
3742
Activity

FIG. 38

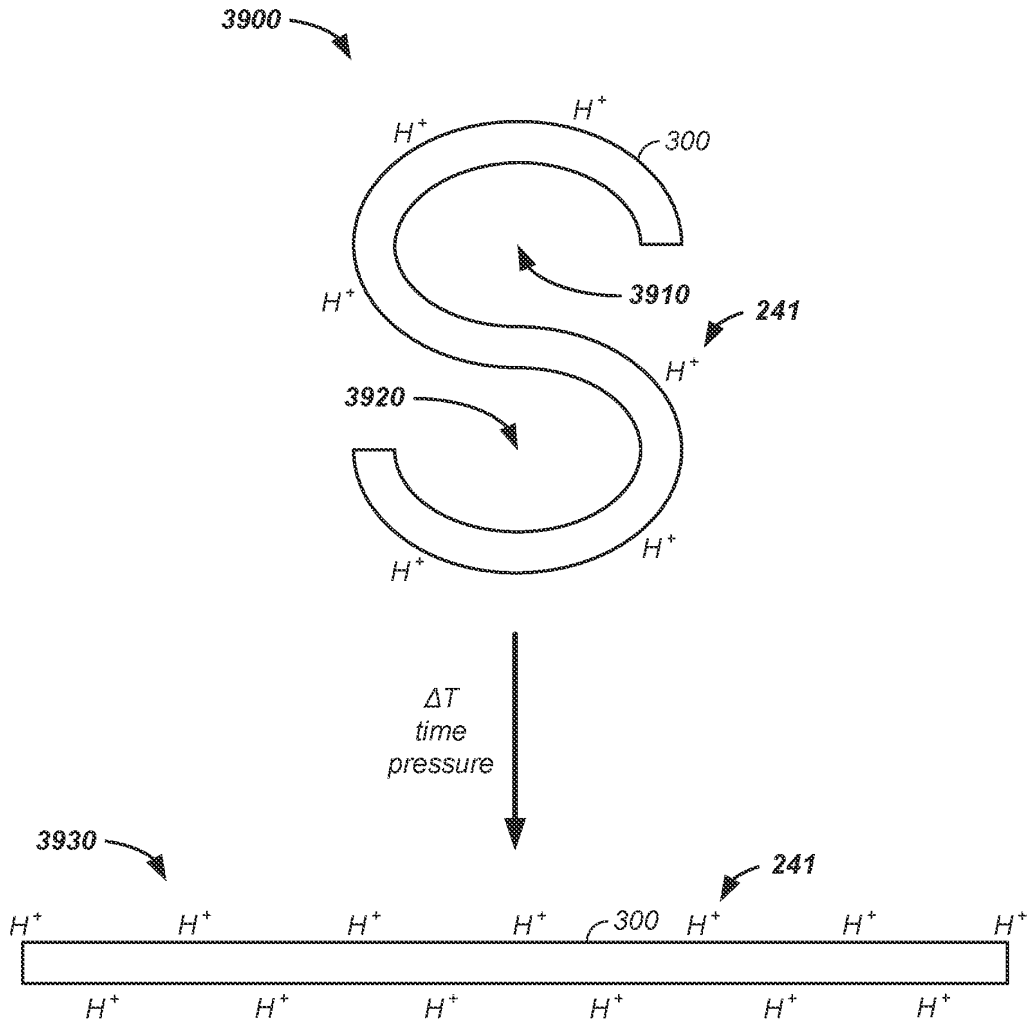

3900
H+
H+
300
H+
3910
241
H+
3920
H+
H+
ΔT
time
pressure
3930
241
H+
H+
H+
H+
300
H+
H+
H+
H+
H+
H+
H+
H+
H+
H+
H+
H+

FIG. 39

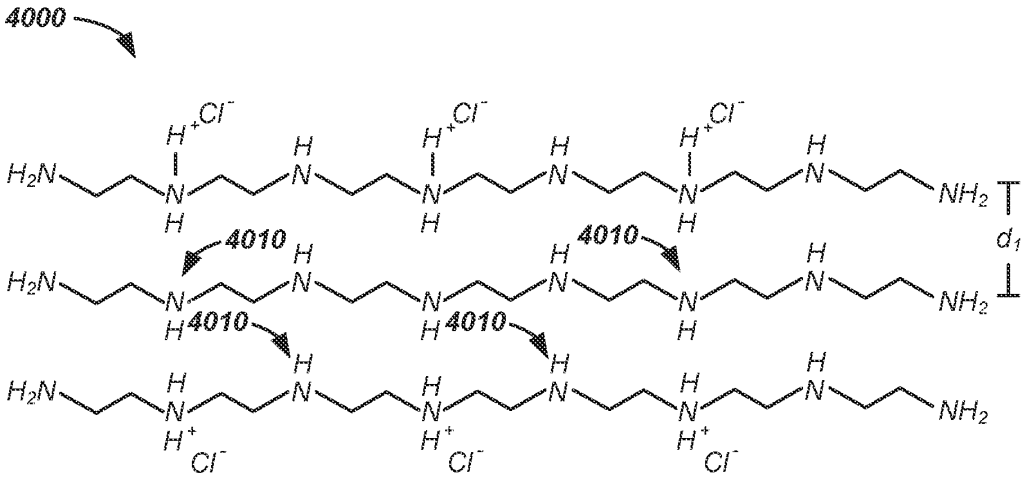


FIG. 40A

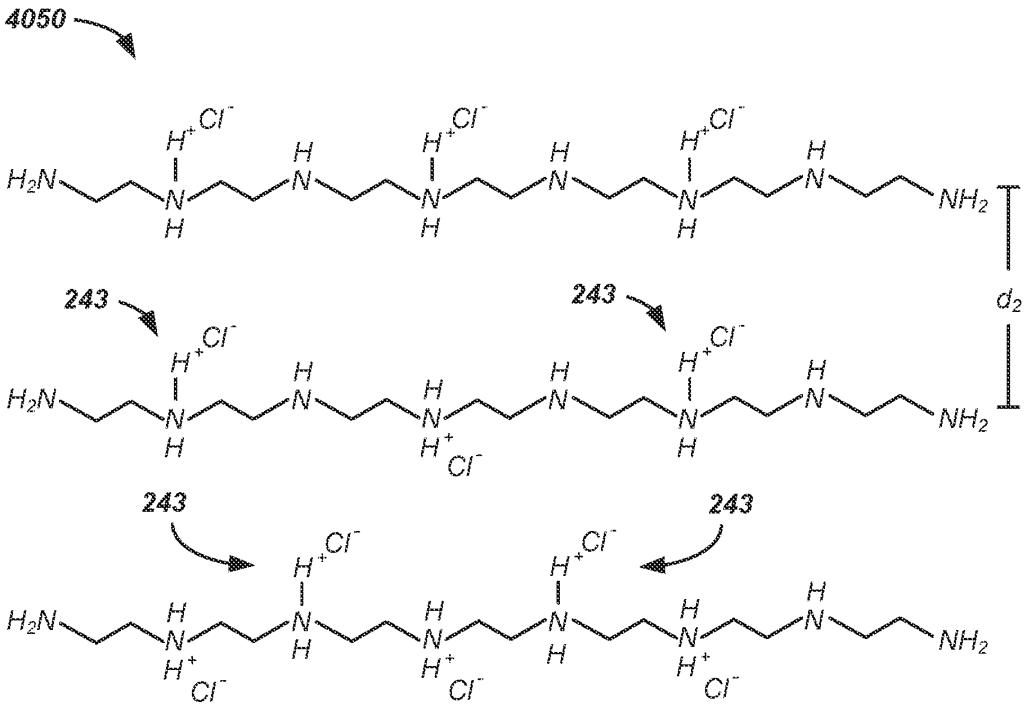


FIG. 40B

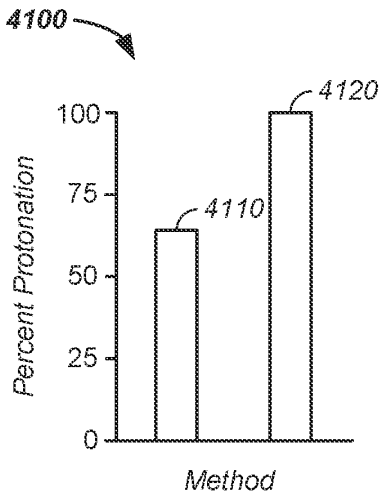


FIG. 41

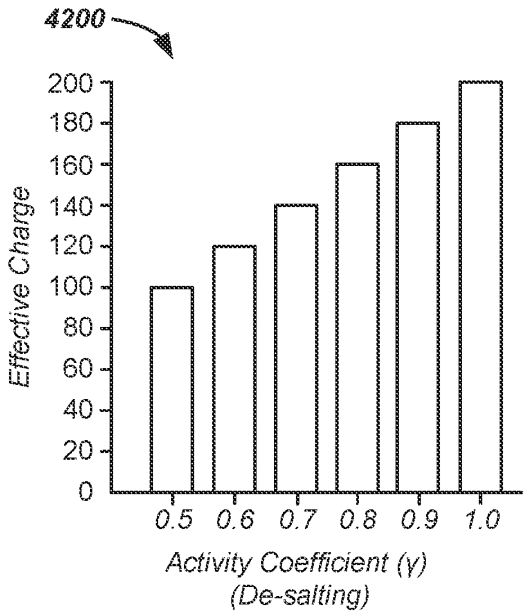

4200
200
180
160
140
120
100
80
60
40
20
0
Effective Charge
0.5
0.6
0.7
0.8
0.9
1.0
Activity Coefficient (γ)
(De-salting)

FIG. 42

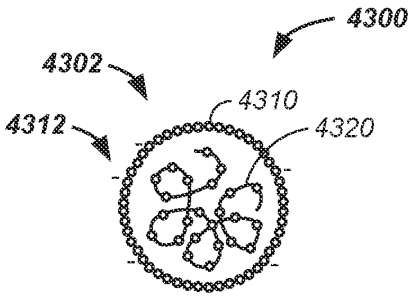


FIG. 43A

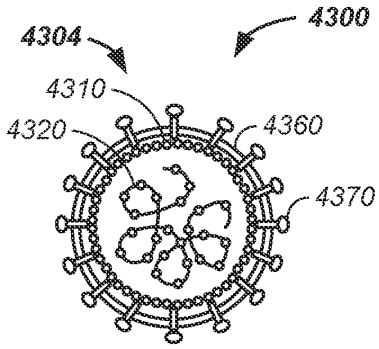


FIG. 43B

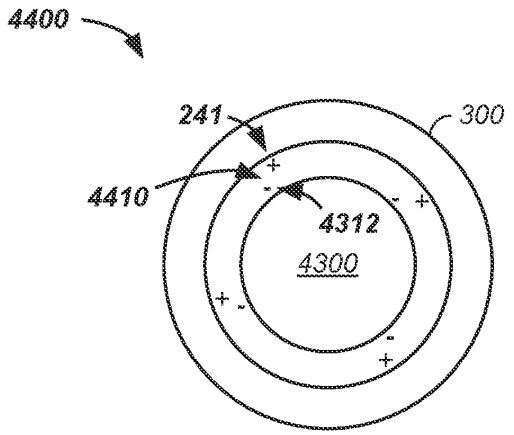


FIG. 44A

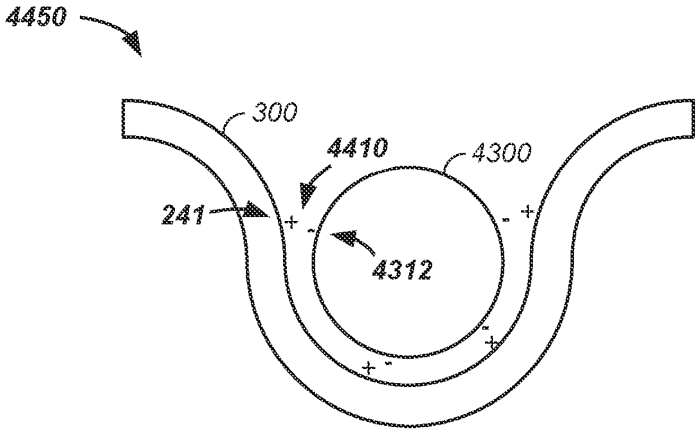


FIG. 44B

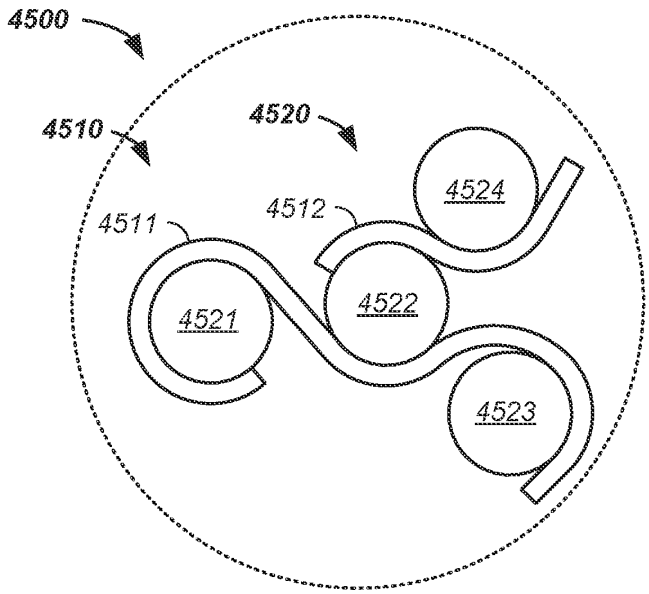


FIG. 45

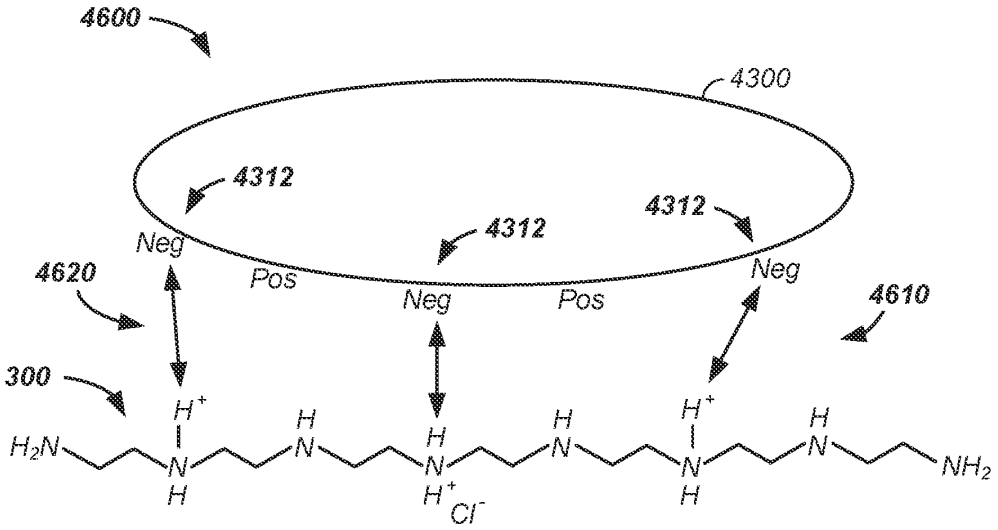


FIG. 46A

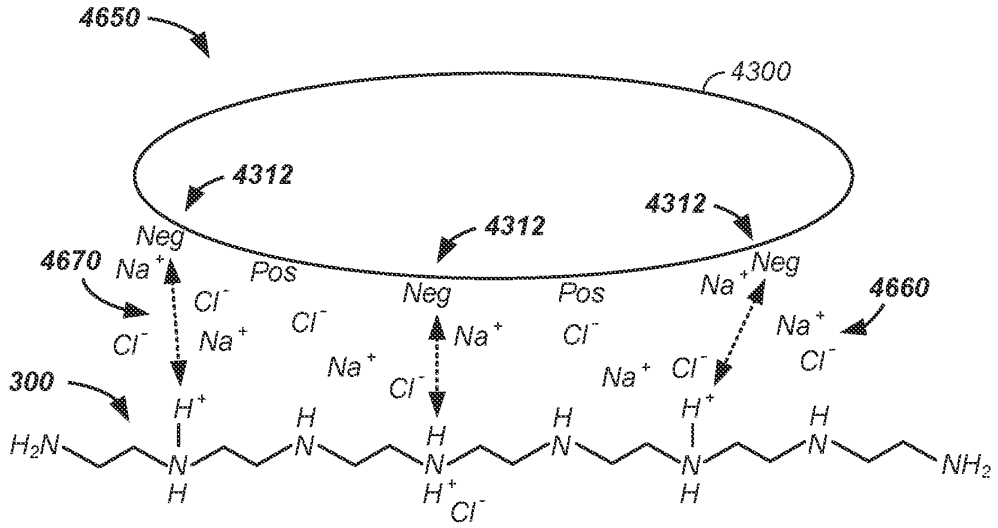


FIG. 46B

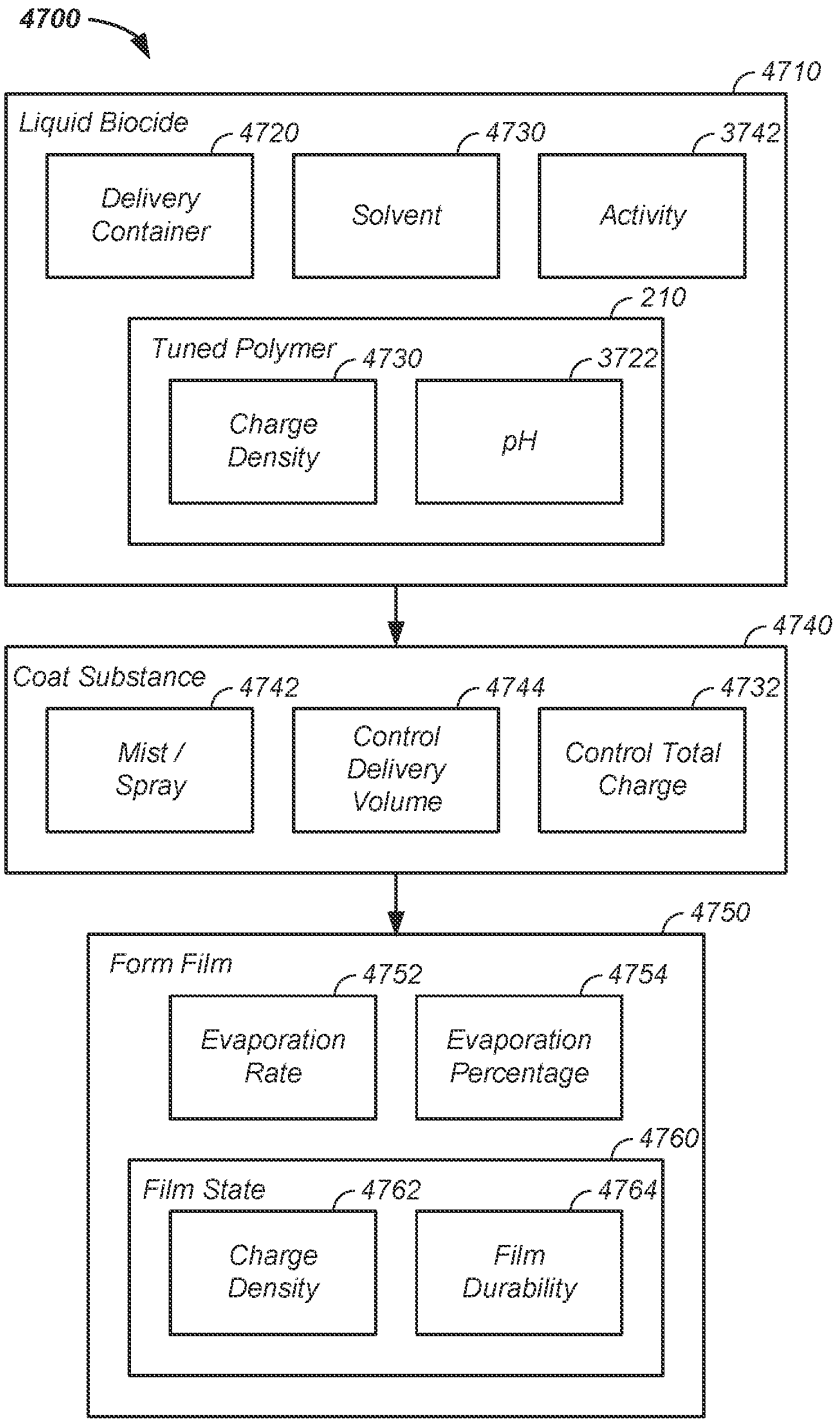

4700
4710
Liquid Biocide
4720
4730
3742
Delivery Container
Solvent
Activity
210
Tuned Polymer
4730
3722
Charge Density
pH
4740
Coat Substance
4742
4744
4732
Mist / Spray
Control Delivery Volume
Control Total Charge
4750
Form Film
4752
4754
Evaporation Rate
Evaporation Percentage
4760
Film State
4762
4764
Charge Density
Film Durability

FIG. 47

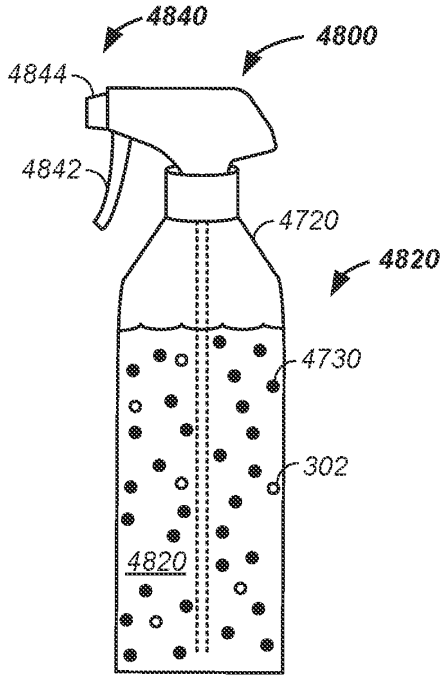


FIG. 48A

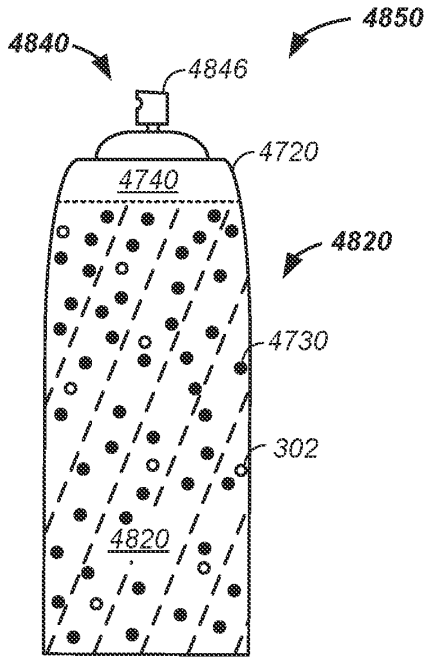


FIG. 48B

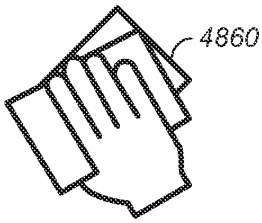


FIG. 48C

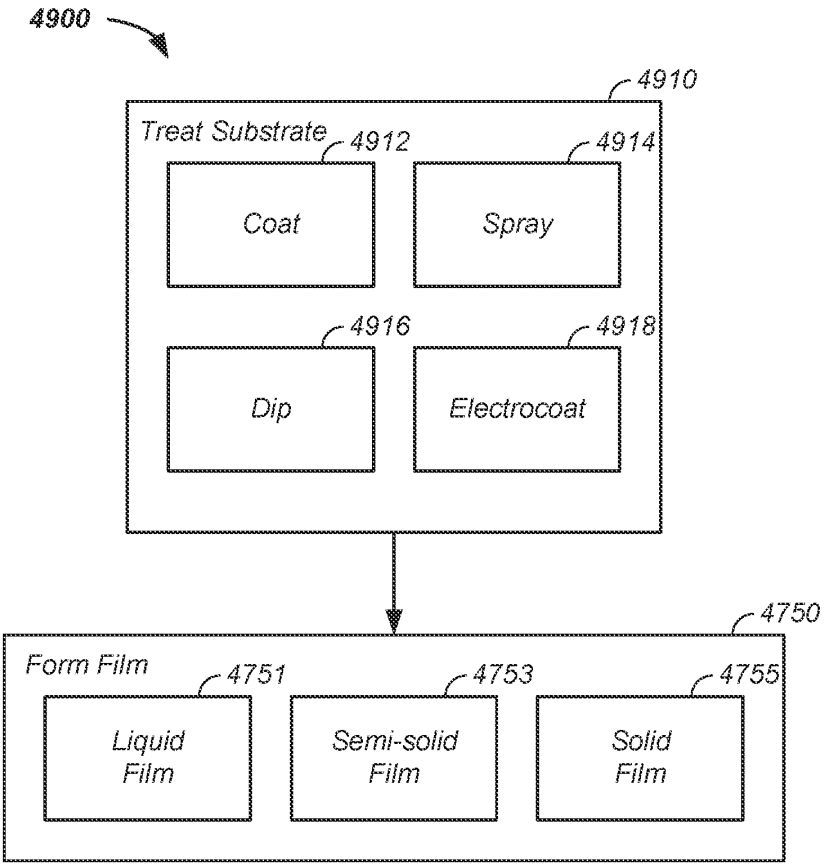

4900
4910
Treat Substrate
4912
4914
Coat
Spray
4916
4918
Dip
Electrocoat
4750
Form Film
4751
4753
4755
Liquid Film
Semi-solid Film
Solid Film

FIG. 49

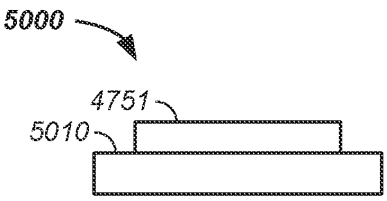


FIG. 50A

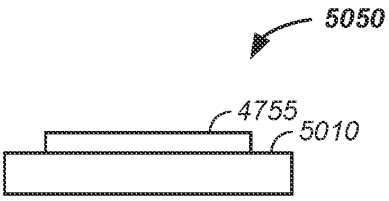


FIG. 50B

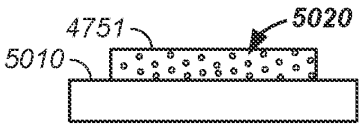


FIG. 50C

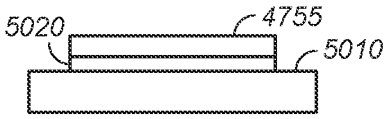


FIG. 50D

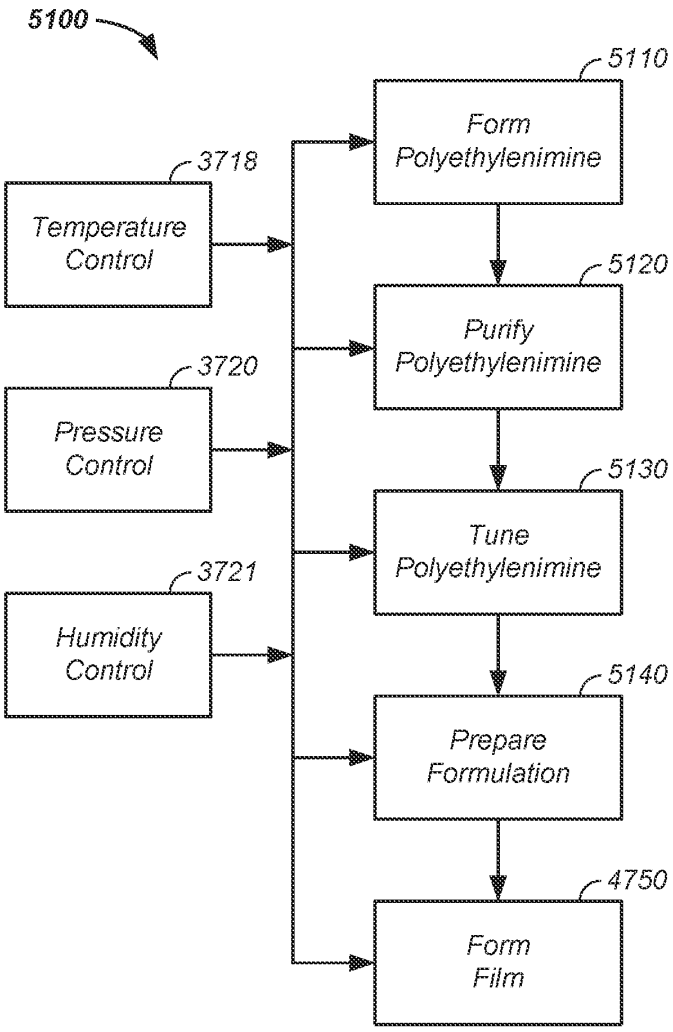

5100
5110
Form Polyethylenimine
3718
Temperature Control
5120
Purify Polyethylenimine
3720
Pressure Control
5130
Tune Polyethylenimine
3721
Humidity Control
5140
Prepare Formulation
4750
Form Film

FIG. 51

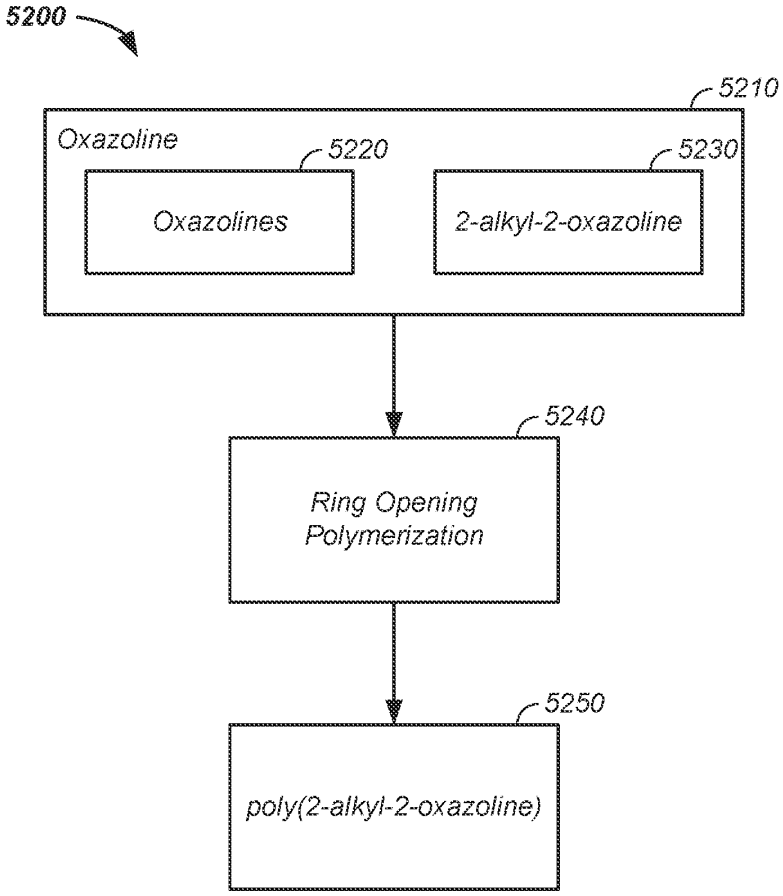

5200
5210
Oxazoline
5220
Oxazolines
5230
2-alkyl-2-oxazoline
5240
Ring Opening Polymerization
5250
poly(2-alkyl-2-oxazoline)

FIG. 52

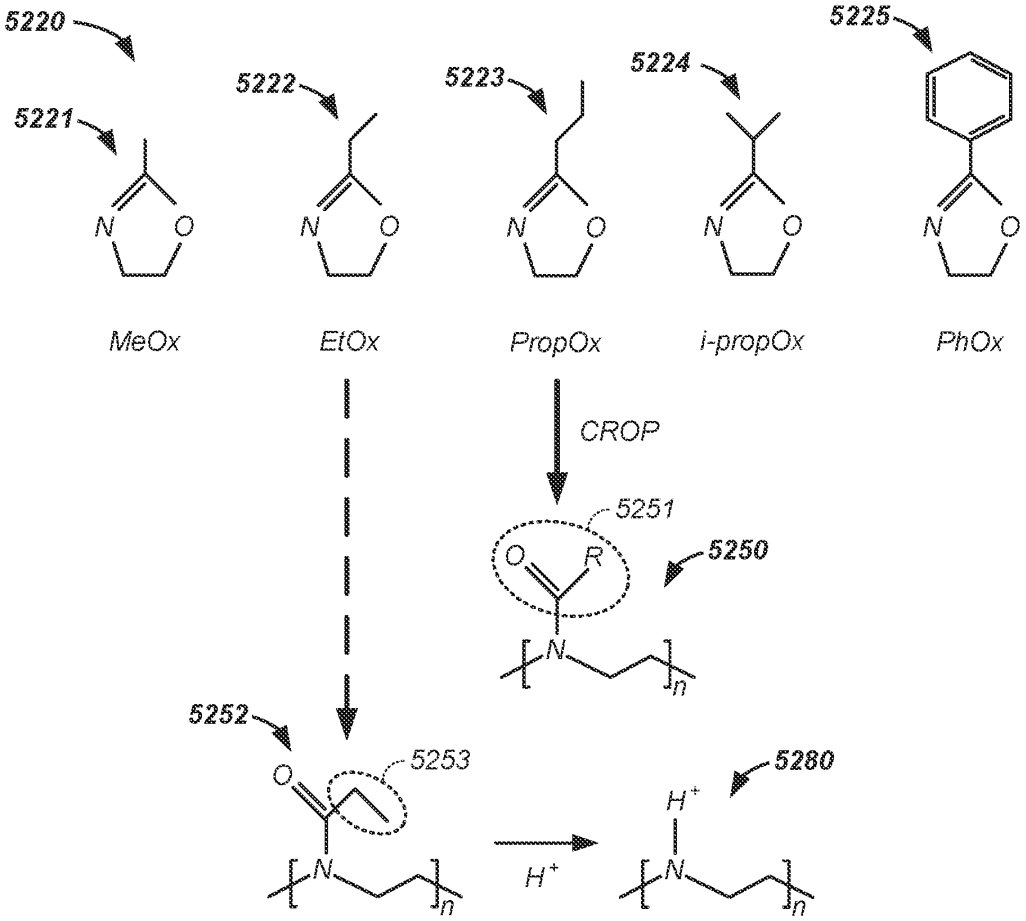


FIG. 53A

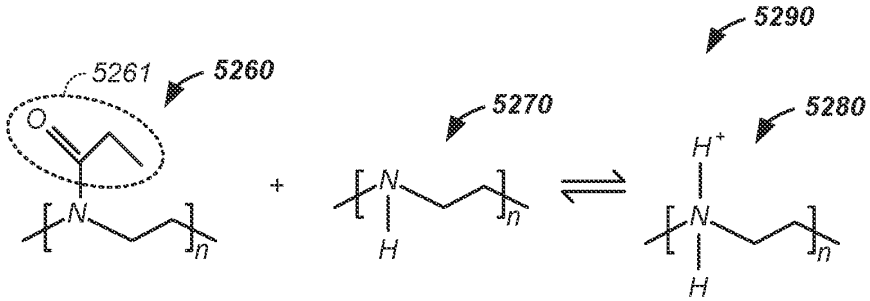


FIG. 53B

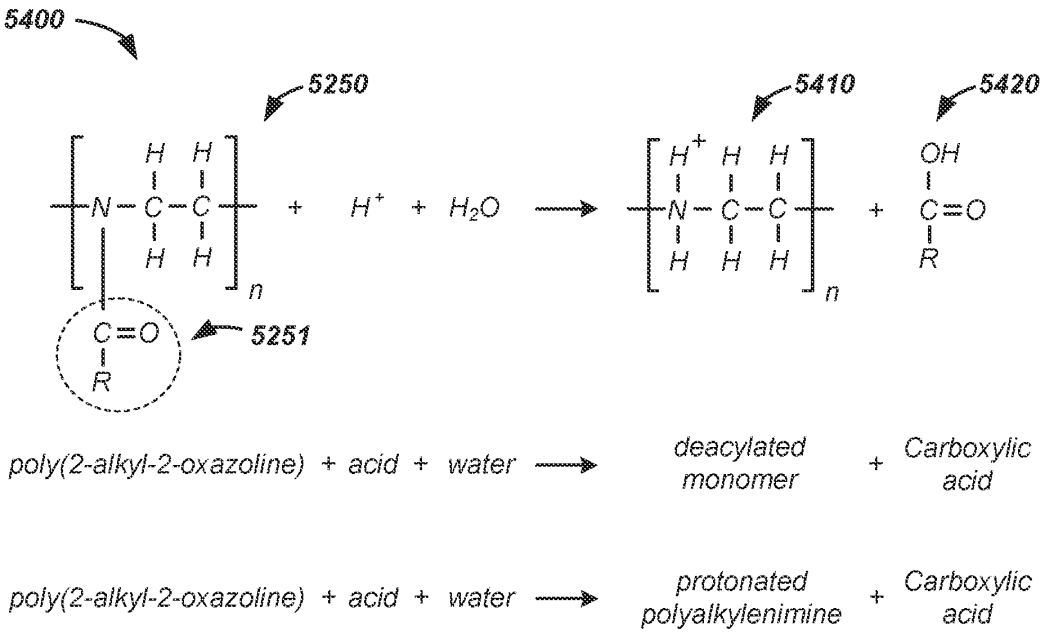


FIG. 54A

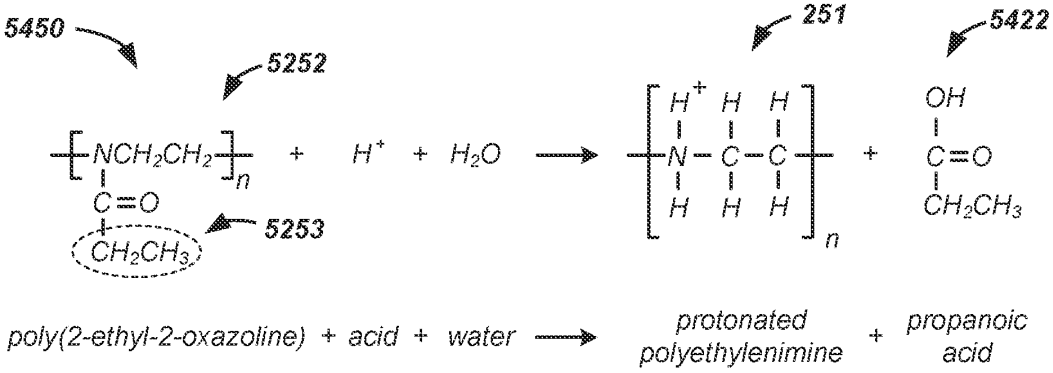


FIG. 54B

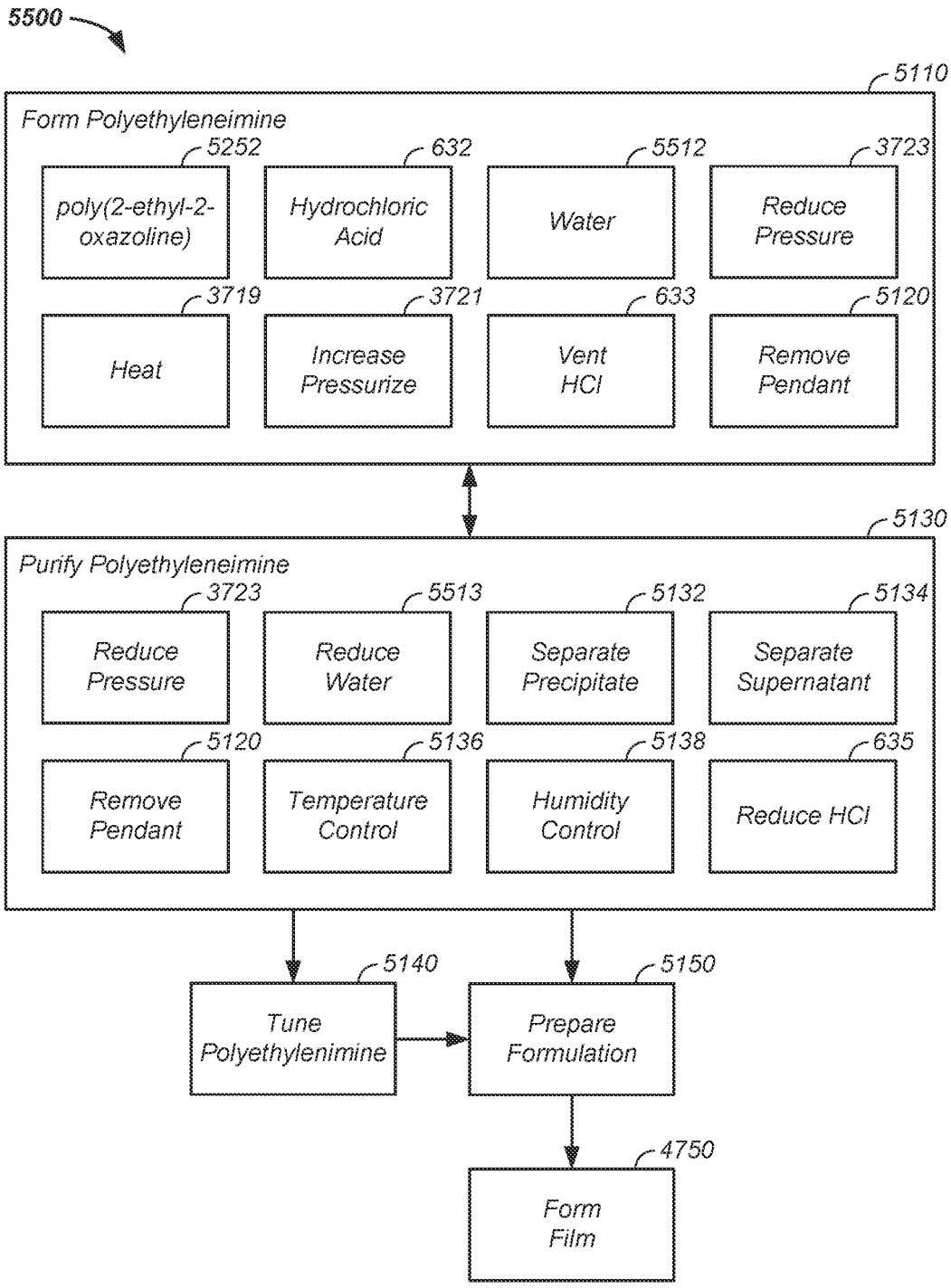

5500
5110
Form Polyethyleneimine
5252
poly(2-ethyl-2-oxazoline)
632
Hydrochloric Acid
5512
Water
3723
Reduce Pressure
3719
Heat
3721
Increase Pressurize
633
Vent HCl
5120
Remove Pendant
5130
Purify Polyethyleneimine
3723
Reduce Pressure
5513
Reduce Water
5132
Separate Precipitate
5134
Separate Supernatant
5120
Remove Pendant
5136
Temperature Control
5138
Humidity Control
635
Reduce HCl
5140
Tune Polyethylenimine
5150
Prepare Formulation
4750
Form Film

FIG. 55

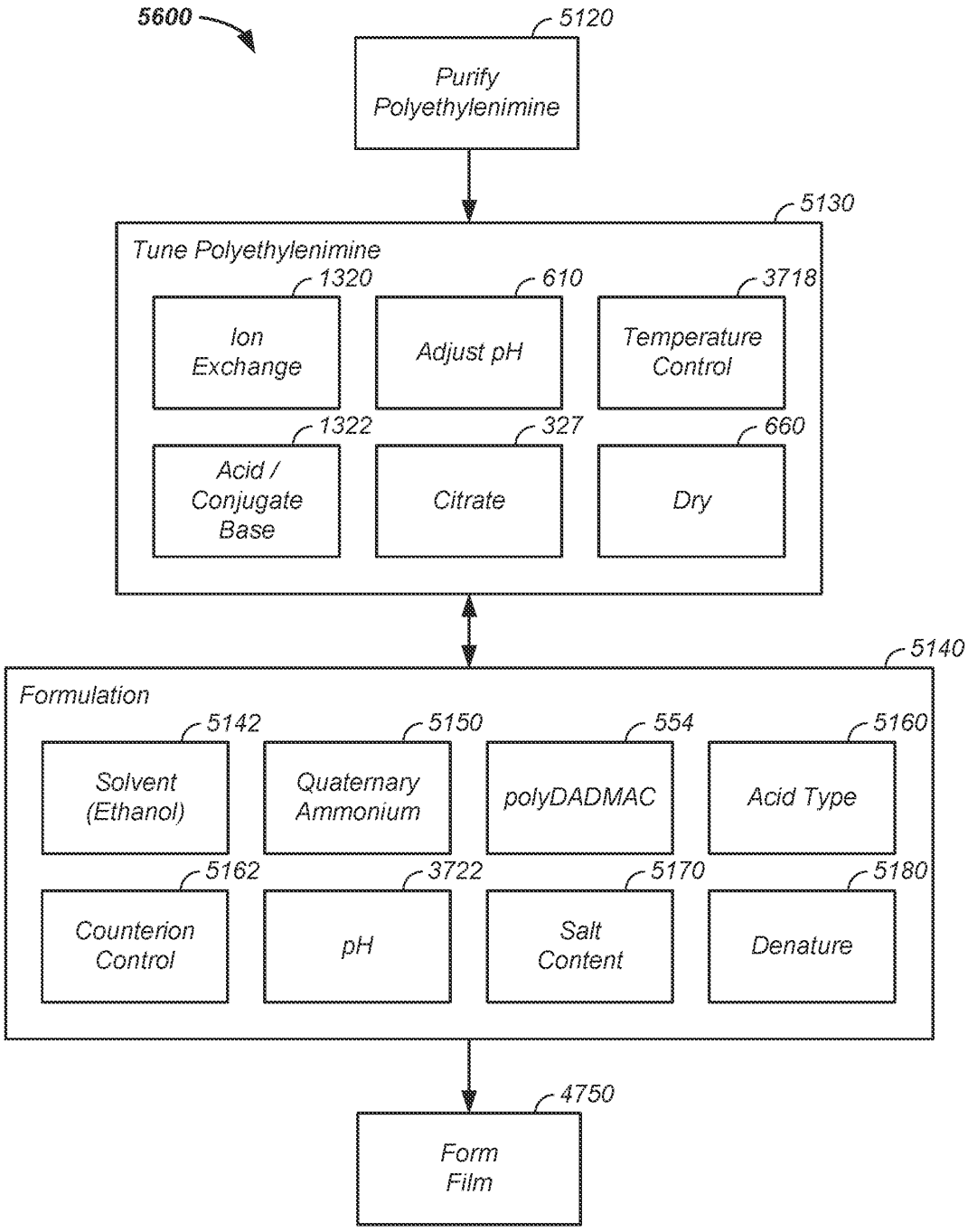

5600
5120
Purify Polyethylenimine
5130
Tune Polyethylenimine
1320
Ion Exchange
610
Adjust pH
3718
Temperature Control
1322
Acid / Conjugate Base
327
Citrate
660
Dry
5140
Formulation
5142
Solvent (Ethanol)
5150
Quaternary Ammonium
554
polyDADMAC
5160
Acid Type
5162
Counterion Control
3722
pH
5170
Salt Content
5180
Denature
4750
Form Film

FIG. 56

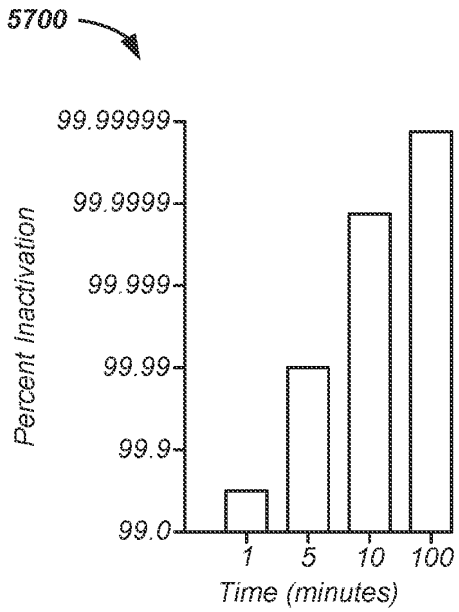

5700
99.99999
99.9999
99.999
99.99
99.9
99.0
Percent Inactivation
1
5
10
100
Time (minutes)

FIG. 57

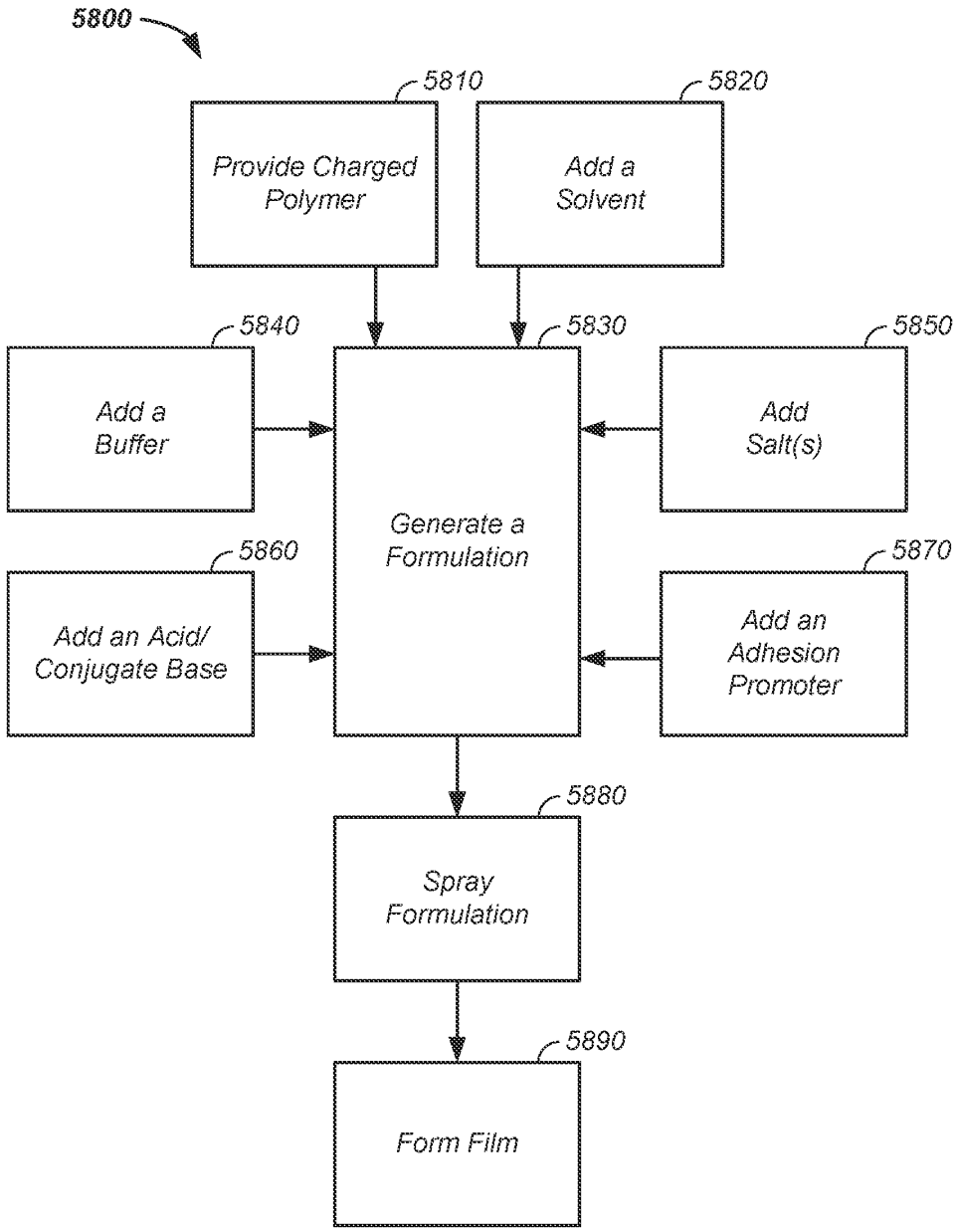

5800
5810
Provide Charged Polymer
5820
Add a Solvent
5840
Add a Buffer
5830
Generate a Formulation
5850
Add Salt(s)
5860
Add an Acid/ Conjugate Base
5870
Add an Adhesion Promoter
5880
Spray Formulation
5890
Form Film

FIG. 58

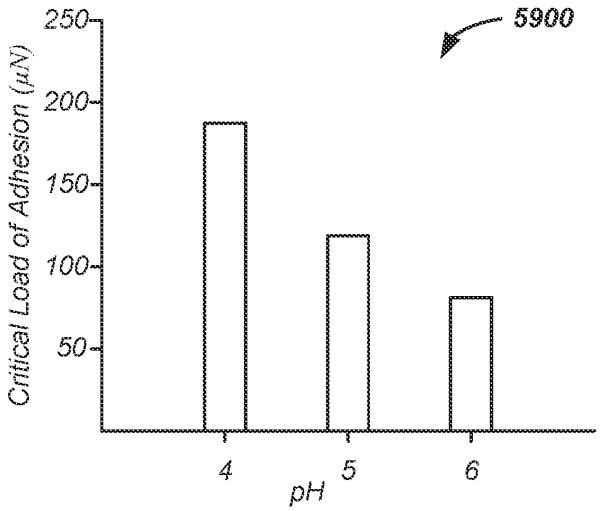


FIG. 59