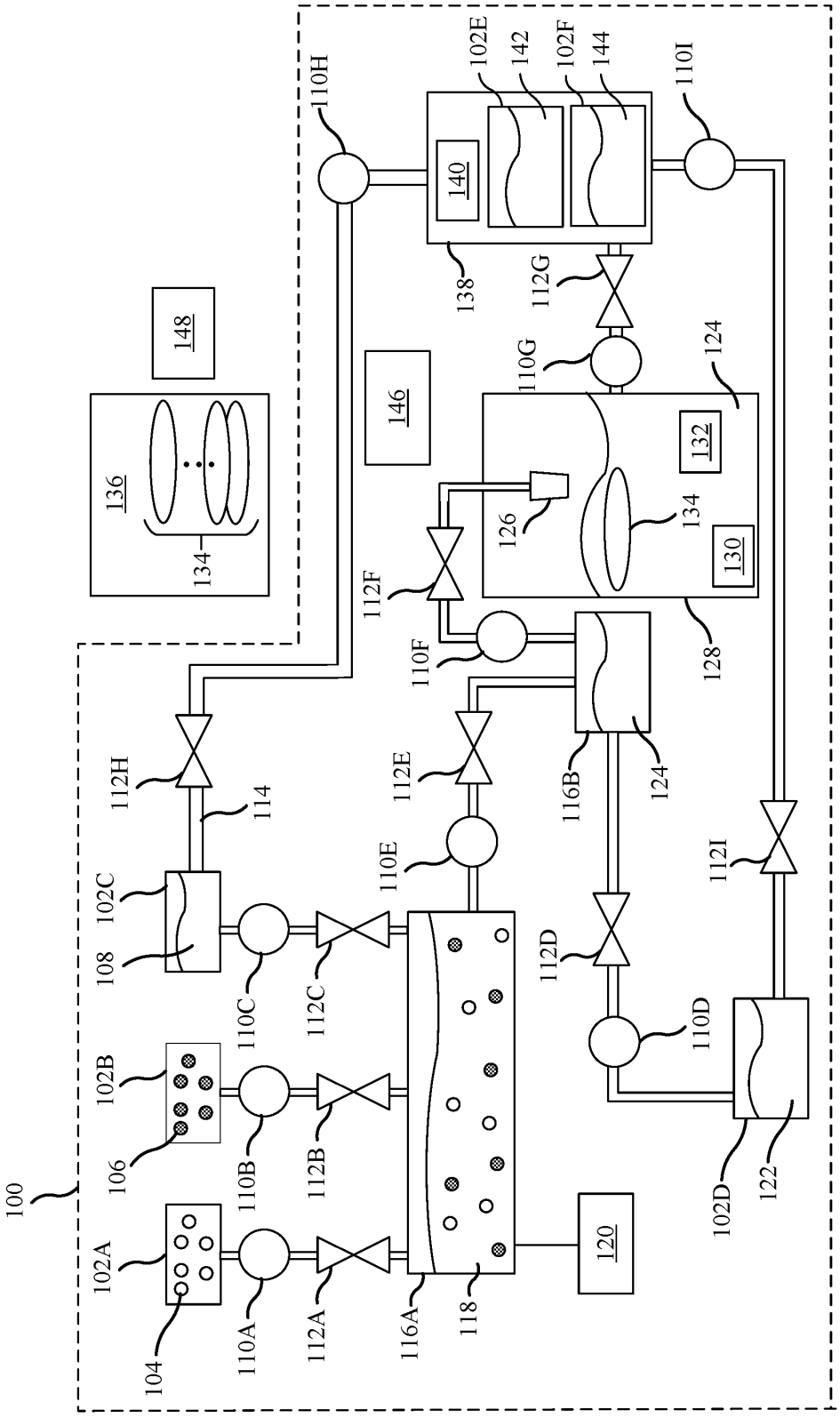

100
102A
102B
102C
102D
102E
102F
104
106
108
110A
110B
110C
110D
110E
110F
110G
110H
110I
112A
112B
112C
112D
112E
112F
112G
112H
112I
114
116A
116B
118
120
122
124
126
128
130
132
134
136
138
140
142
144
146
148

Figure 1

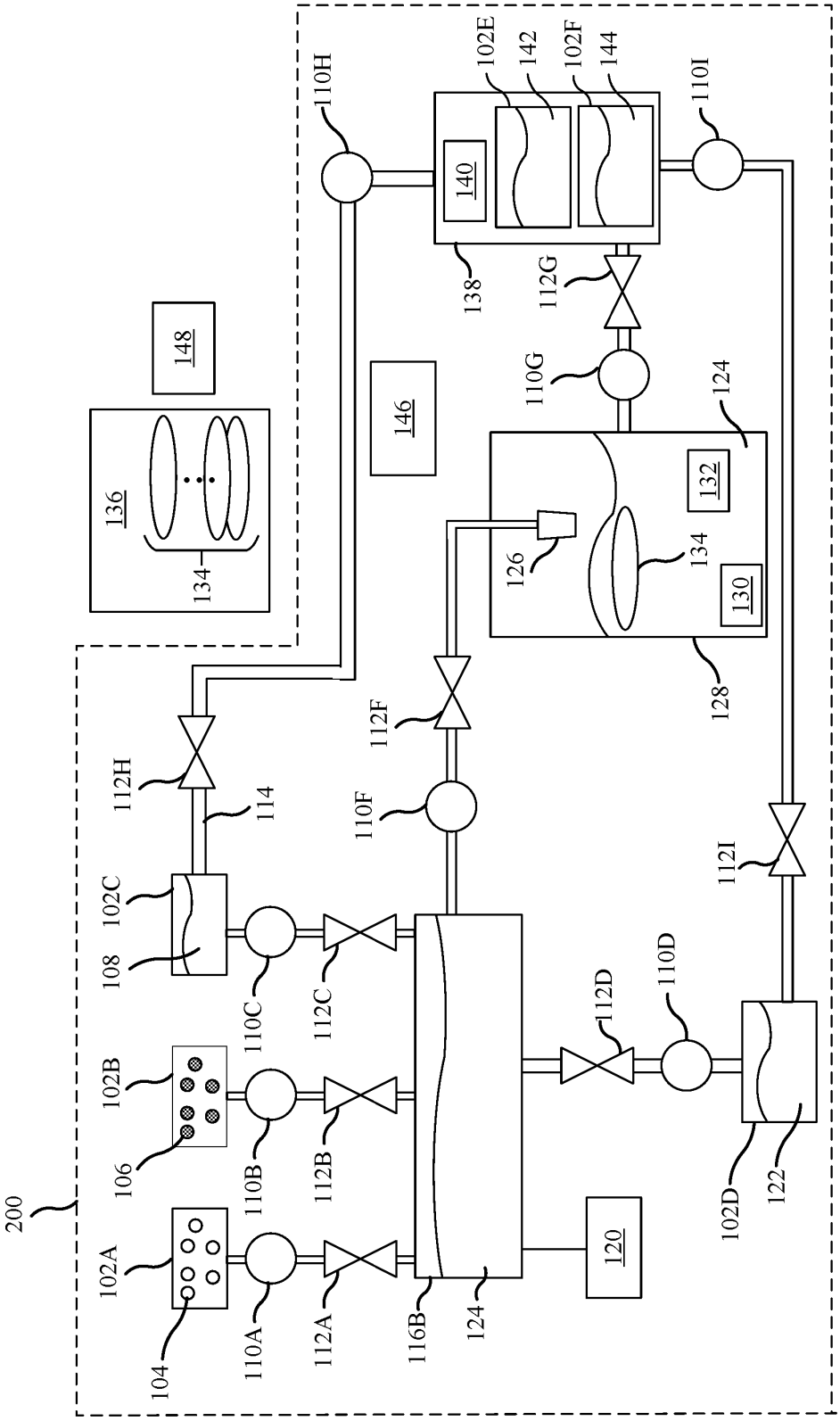

200
102A
104
110A
112A
116B
124
102B
106
110B
112B
102C
108
110C
112C
114
112H
110H
102E
142
102F
144
110I
140
138
112G
110G
124
132
126
134
130
128
112F
110F
112I
146
148
136
134
120
112D
110D
102D
122

Figure 2

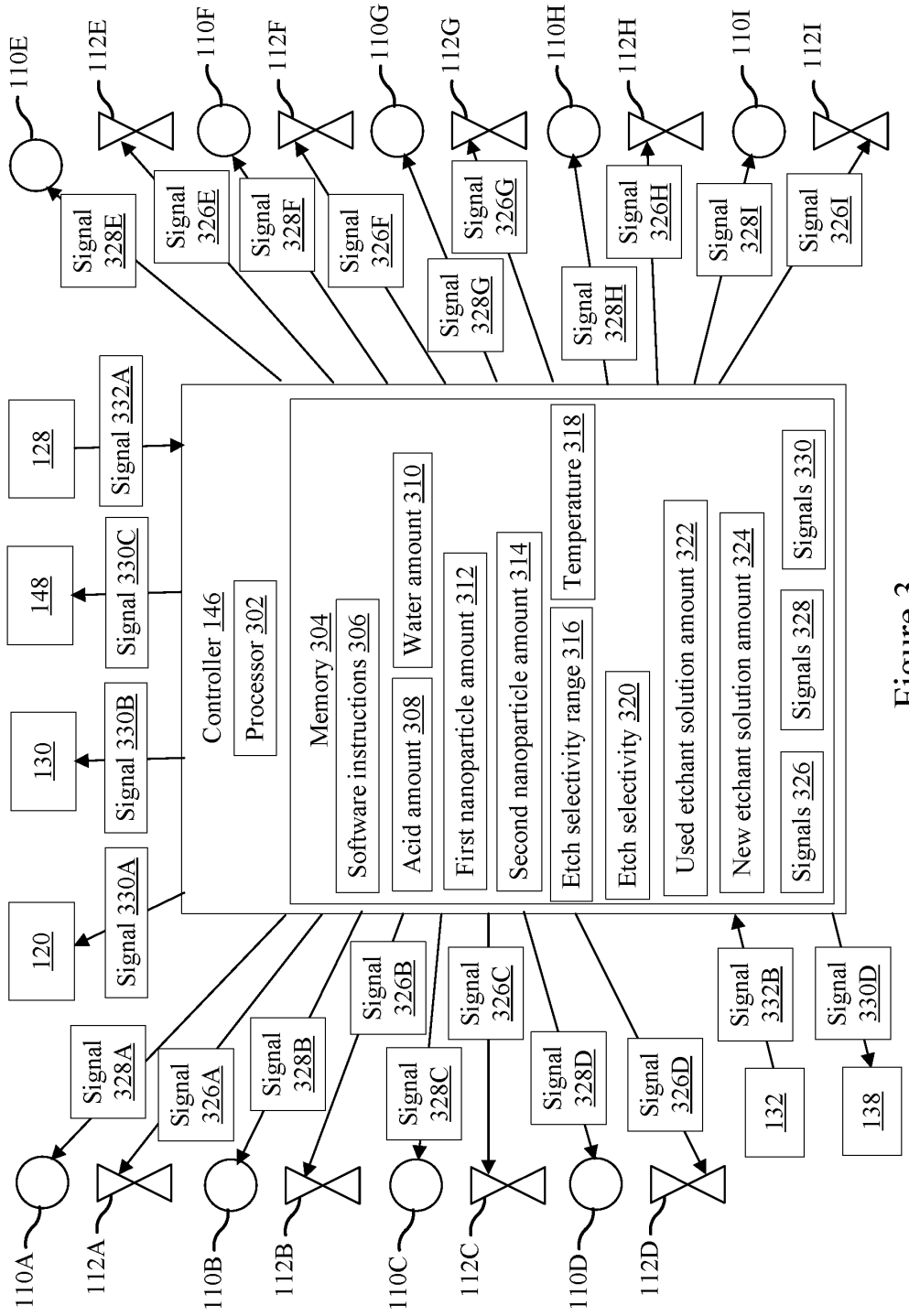

110A
112A
110B
112B
110C
112C
110D
112D
110E
112E
110F
112F
110G
112G
110H
112H
110I
112I
120
130
148
128
132
138
Signal 328A
Signal 326A
Signal 328B
Signal 326B
Signal 328C
Signal 326C
Signal 328D
Signal 326D
Signal 328E
Signal 326E
Signal 328F
Signal 326F
Signal 328G
Signal 326G
Signal 328H
Signal 326H
Signal 328I
Signal 326I
Signal 330A
Signal 330B
Signal 330C
Signal 332A
Signal 332B
Signal 330D
Controller 146
Processor 302
Memory 304
Software instructions 306
Acid amount 308
Water amount 310
First nanoparticle amount 312
Second nanoparticle amount 314
Etch selectivity range 316
Temperature 318
Etch selectivity 320
Used etchant solution amount 322
New etchant solution amount 324
Signals 326
Signals 328
Signals 330

Figure 3

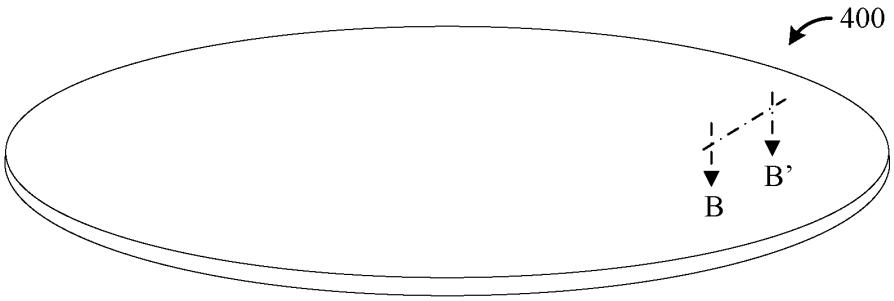


Figure 4A

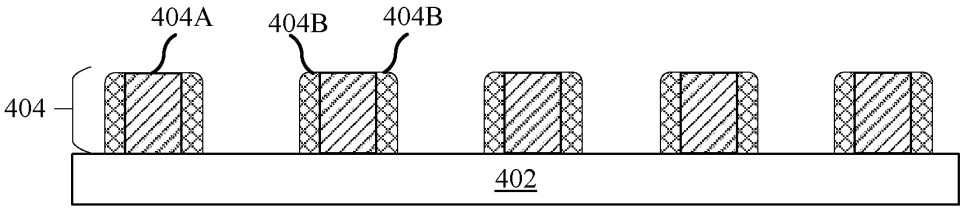


Figure 4B

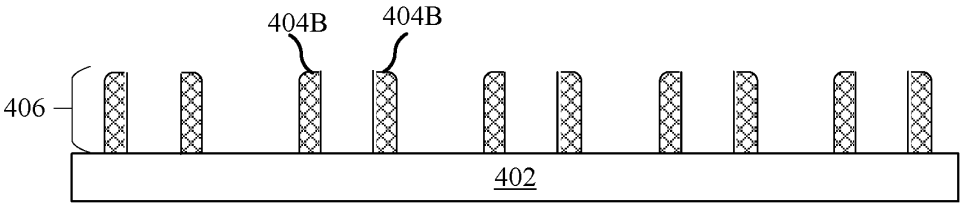


Figure 4C

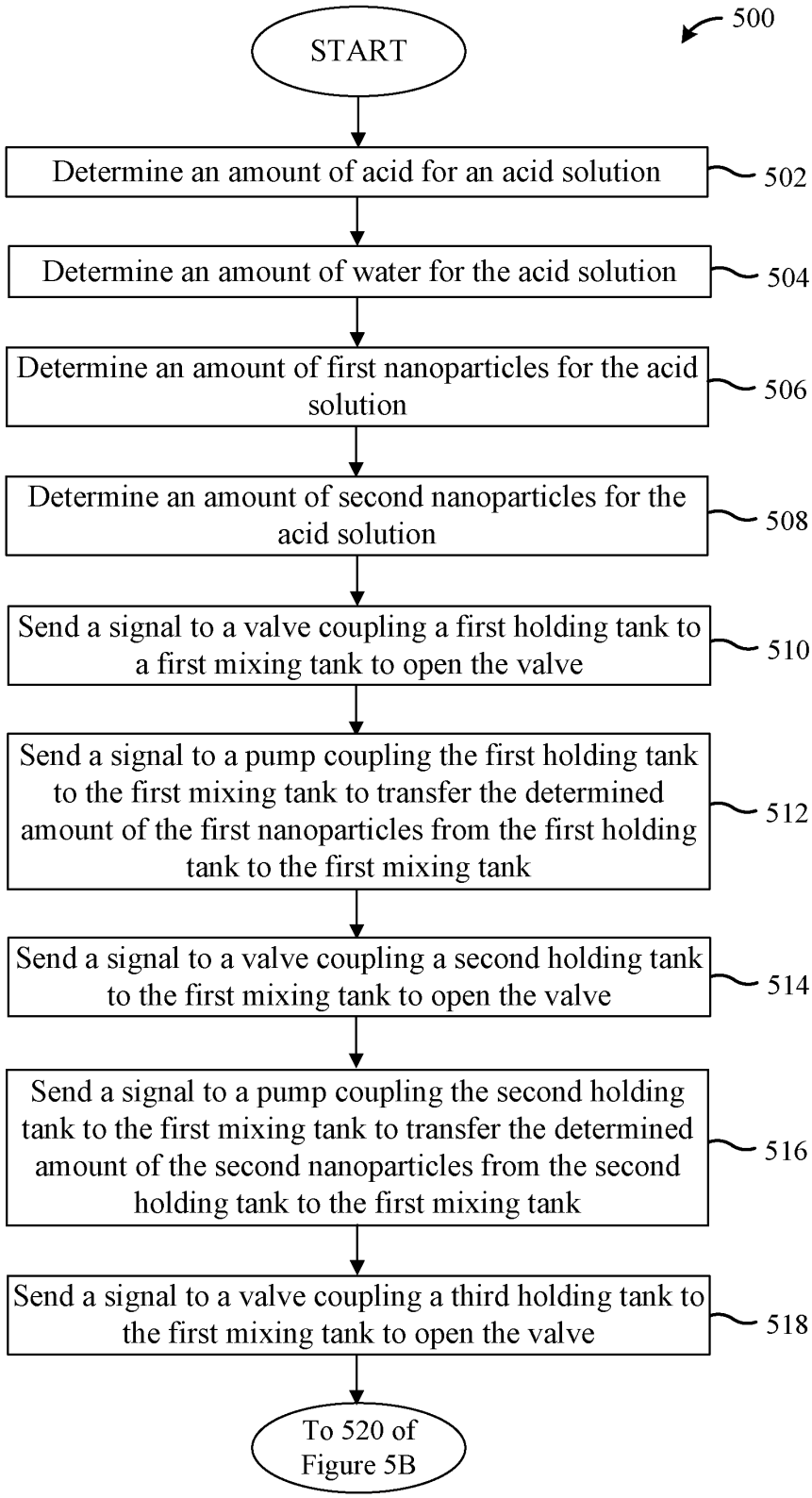

500
START
Determine an amount of acid for an acid solution
502
Determine an amount of water for the acid solution
504
Determine an amount of first nanoparticles for the acid solution
506
Determine an amount of second nanoparticles for the acid solution
508
Send a signal to a valve coupling a first holding tank to a first mixing tank to open the valve
510
Send a signal to a pump coupling the first holding tank to the first mixing tank to transfer the determined amount of the first nanoparticles from the first holding tank to the first mixing tank
512
Send a signal to a valve coupling a second holding tank to the first mixing tank to open the valve
514
Send a signal to a pump coupling the second holding tank to the first mixing tank to transfer the determined amount of the second nanoparticles from the second holding tank to the first mixing tank
516
Send a signal to a valve coupling a third holding tank to the first mixing tank to open the valve
518
To 520 of Figure 5B

Figure 5A

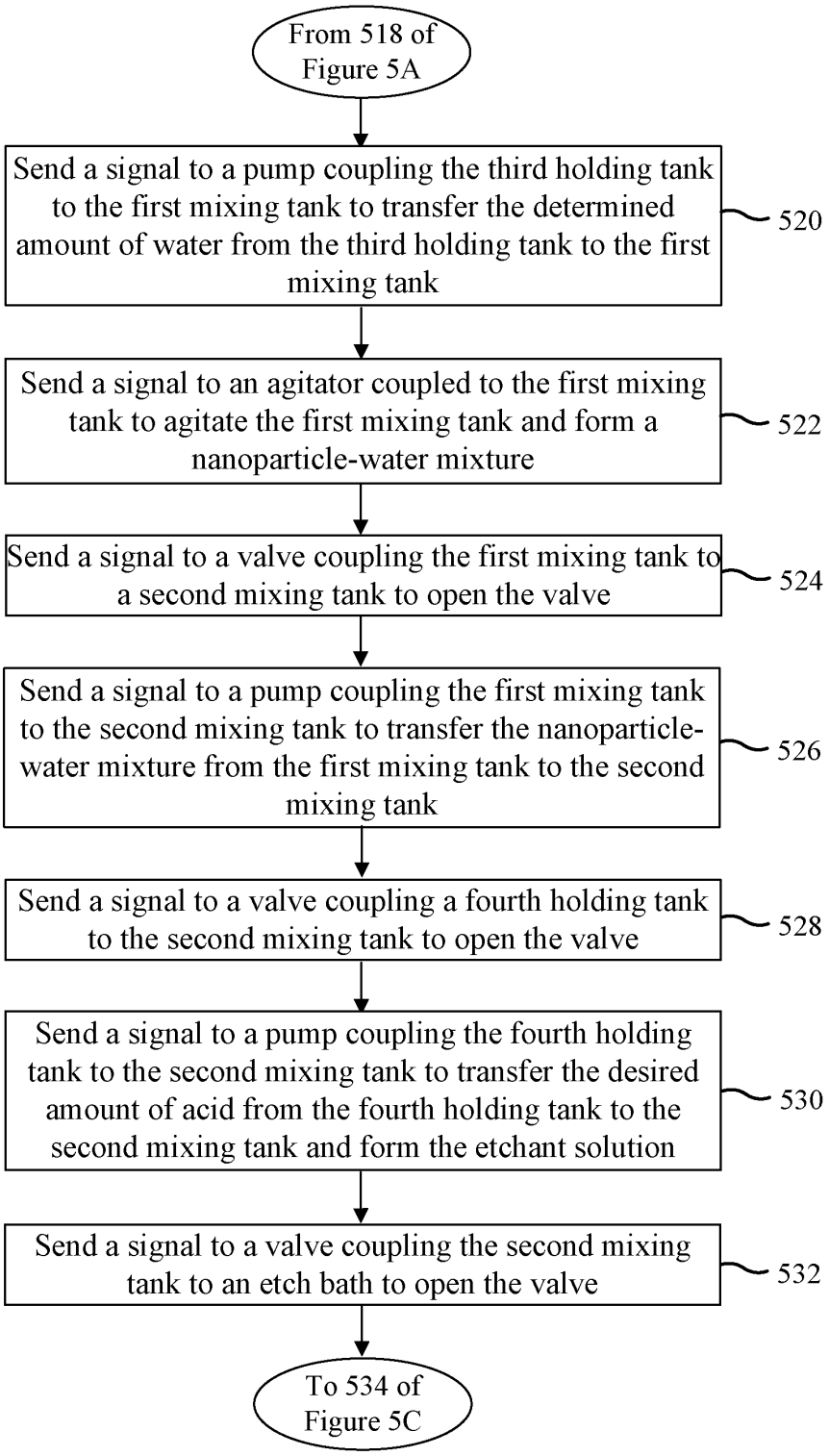

From 518 of Figure 5A
Send a signal to a pump coupling the third holding tank to the first mixing tank to transfer the determined amount of water from the third holding tank to the first mixing tank
520
Send a signal to an agitator coupled to the first mixing tank to agitate the first mixing tank and form a nanoparticle-water mixture
522
Send a signal to a valve coupling the first mixing tank to a second mixing tank to open the valve
524
Send a signal to a pump coupling the first mixing tank to the second mixing tank to transfer the nanoparticle-water mixture from the first mixing tank to the second mixing tank
526
Send a signal to a valve coupling a fourth holding tank to the second mixing tank to open the valve
528
Send a signal to a pump coupling the fourth holding tank to the second mixing tank to transfer the desired amount of acid from the fourth holding tank to the second mixing tank and form the etchant solution
530
Send a signal to a valve coupling the second mixing tank to an etch bath to open the valve
532
To 534 of Figure 5C

Figure 5B

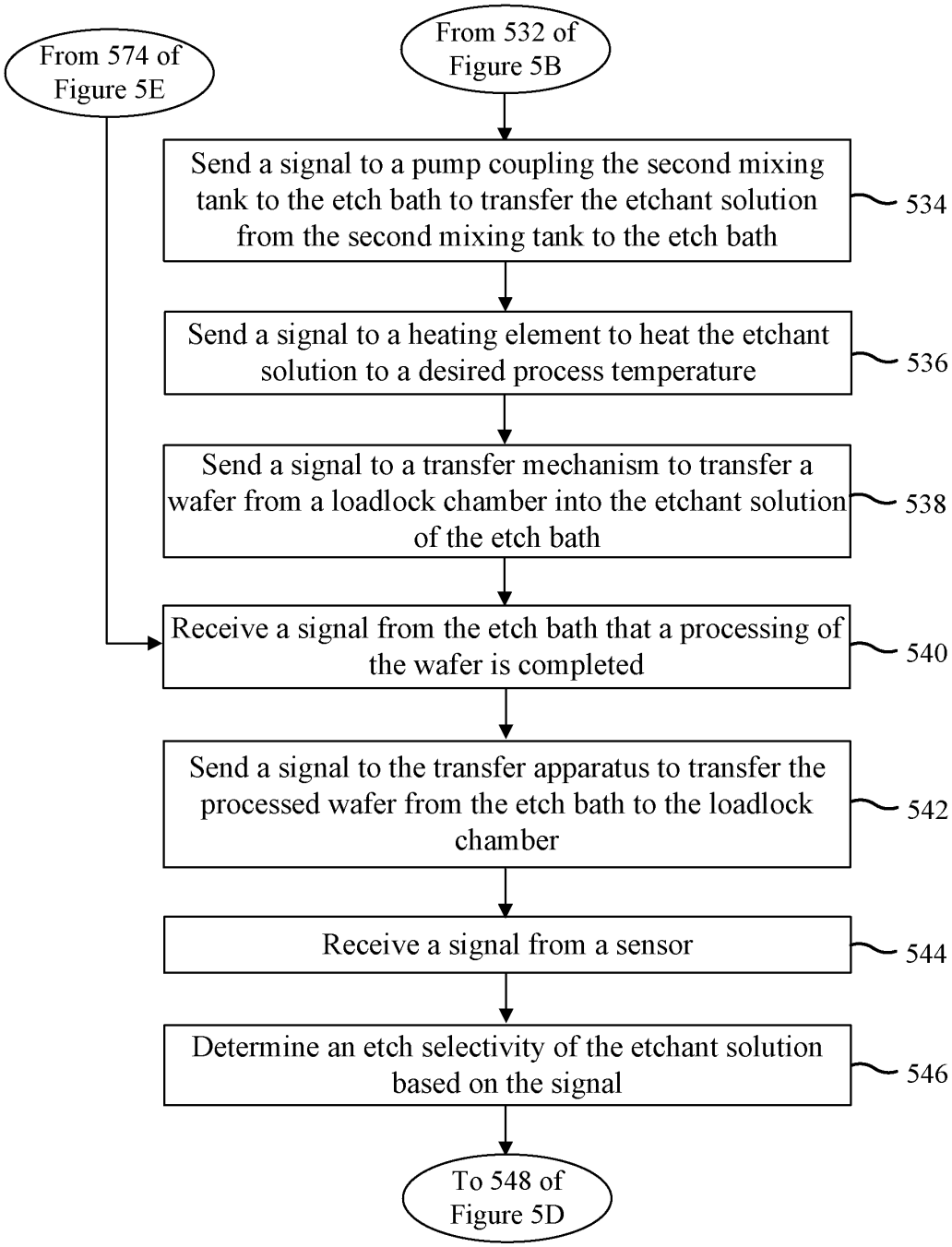

From 574 of Figure 5E
From 532 of Figure 5B
Send a signal to a pump coupling the second mixing tank to the etch bath to transfer the etchant solution from the second mixing tank to the etch bath
534
Send a signal to a heating element to heat the etchant solution to a desired process temperature
536
Send a signal to a transfer mechanism to transfer a wafer from a loadlock chamber into the etchant solution of the etch bath
538
Receive a signal from the etch bath that a processing of the wafer is completed
540
Send a signal to the transfer apparatus to transfer the processed wafer from the etch bath to the loadlock chamber
542
Receive a signal from a sensor
544
Determine an etch selectivity of the etchant solution based on the signal
546
To 548 of Figure 5D

Figure 5C

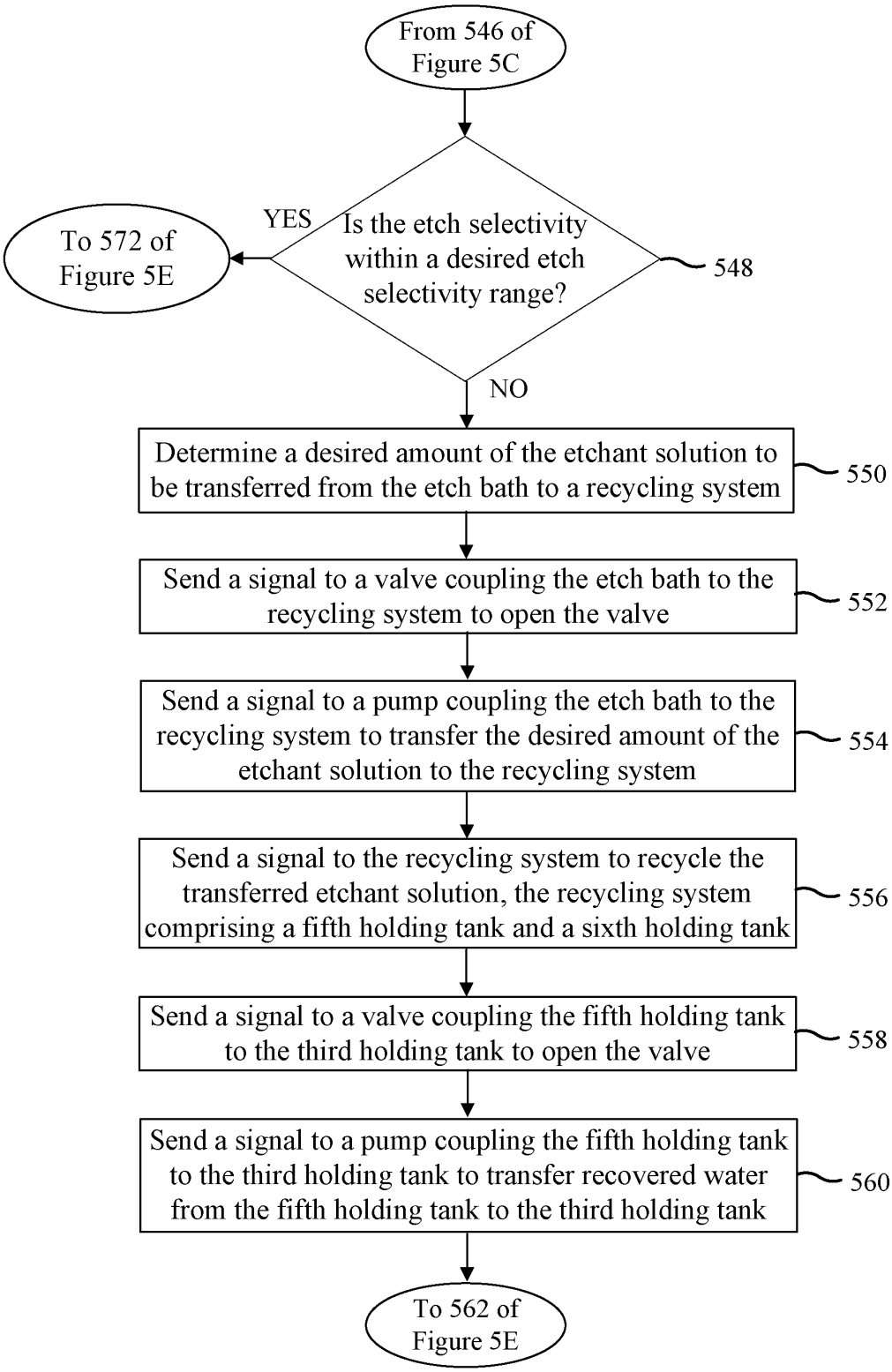

From 546 of Figure 5C
Is the etch selectivity within a desired etch selectivity range?
548
YES
To 572 of Figure 5E
NO
Determine a desired amount of the etchant solution to be transferred from the etch bath to a recycling system
550
Send a signal to a valve coupling the etch bath to the recycling system to open the valve
552
Send a signal to a pump coupling the etch bath to the recycling system to transfer the desired amount of the etchant solution to the recycling system
554
Send a signal to the recycling system to recycle the transferred etchant solution, the recycling system comprising a fifth holding tank and a sixth holding tank
556
Send a signal to a valve coupling the fifth holding tank to the third holding tank to open the valve
558
Send a signal to a pump coupling the fifth holding tank to the third holding tank to transfer recovered water from the fifth holding tank to the third holding tank
560
To 562 of Figure 5E

Figure 5D

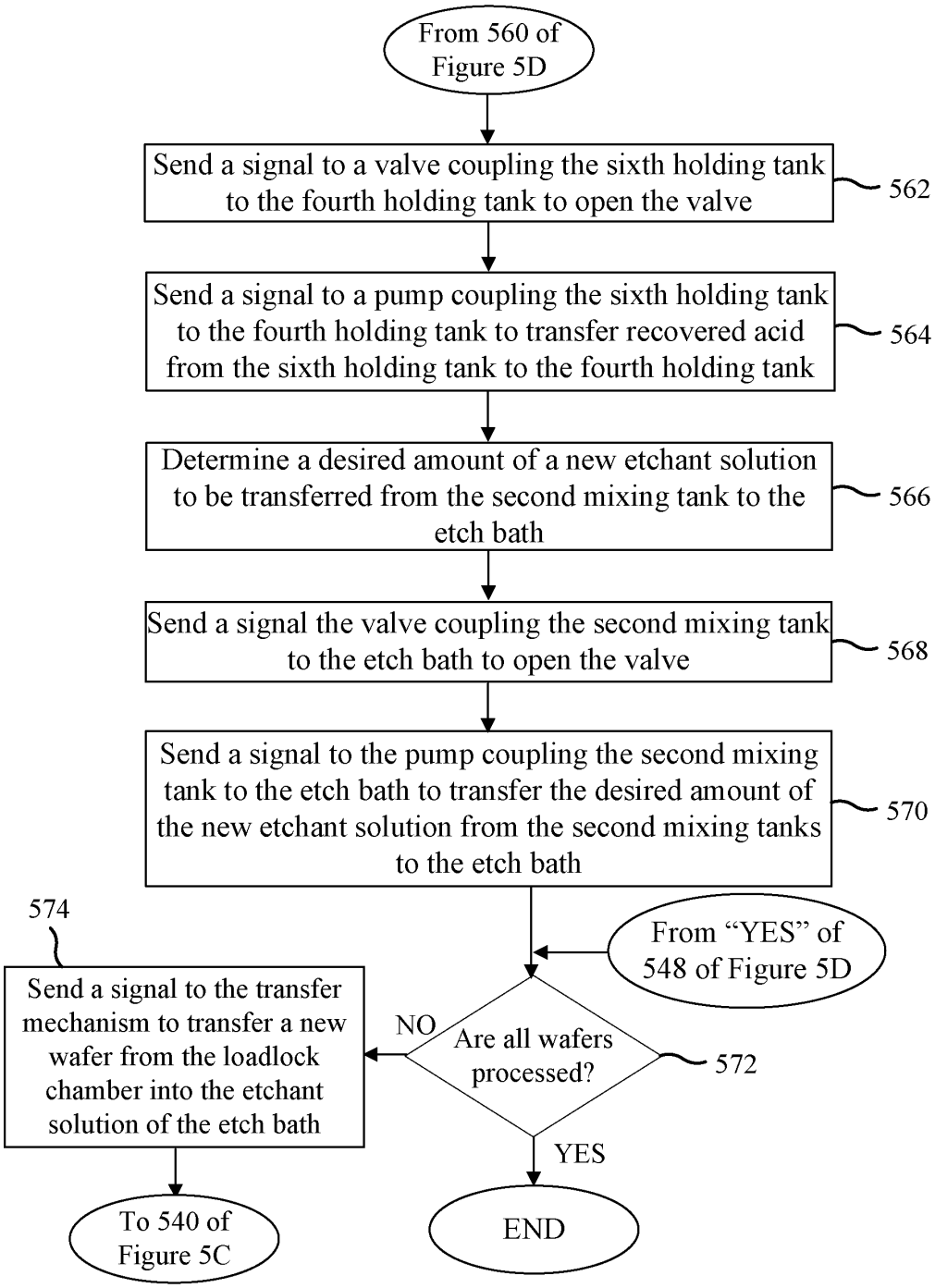

From 560 of Figure 5D
Send a signal to a valve coupling the sixth holding tank to the fourth holding tank to open the valve
562
Send a signal to a pump coupling the sixth holding tank to the fourth holding tank to transfer recovered acid from the sixth holding tank to the fourth holding tank
564
Determine a desired amount of a new etchant solution to be transferred from the second mixing tank to the etch bath
566
Send a signal the valve coupling the second mixing tank to the etch bath to open the valve
568
Send a signal to the pump coupling the second mixing tank to the etch bath to transfer the desired amount of the new etchant solution from the second mixing tanks to the etch bath
570
From "YES" of 548 of Figure 5D
Are all wafers processed?
572
NO
YES
574
Send a signal to the transfer mechanism to transfer a new wafer from the loadlock chamber into the etchant solution of the etch bath
To 540 of Figure 5C
END

Figure 5E

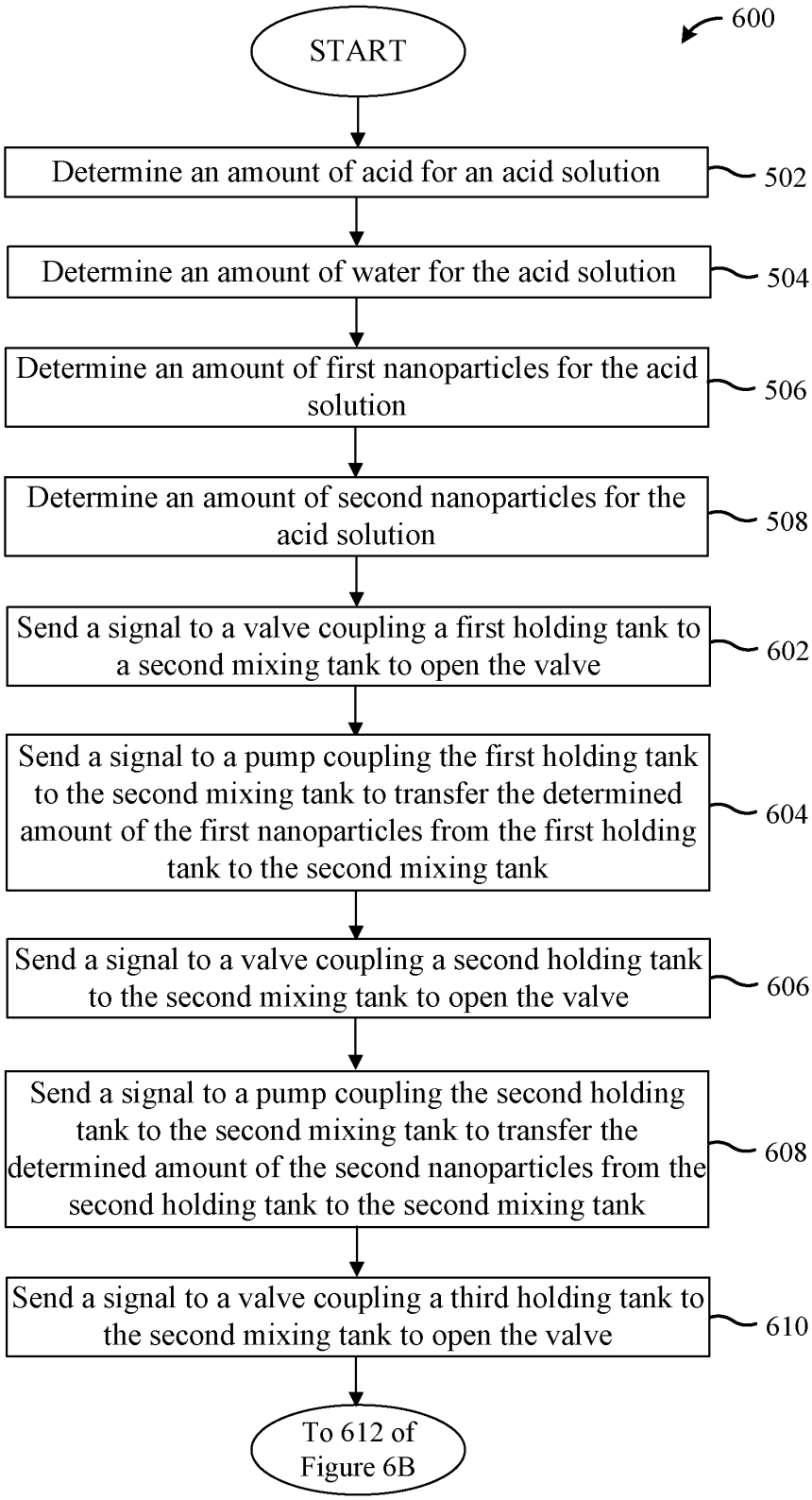

600
START
Determine an amount of acid for an acid solution
502
Determine an amount of water for the acid solution
504
Determine an amount of first nanoparticles for the acid solution
506
Determine an amount of second nanoparticles for the acid solution
508
Send a signal to a valve coupling a first holding tank to a second mixing tank to open the valve
602
Send a signal to a pump coupling the first holding tank to the second mixing tank to transfer the determined amount of the first nanoparticles from the first holding tank to the second mixing tank
604
Send a signal to a valve coupling a second holding tank to the second mixing tank to open the valve
606
Send a signal to a pump coupling the second holding tank to the second mixing tank to transfer the determined amount of the second nanoparticles from the second holding tank to the second mixing tank
608
Send a signal to a valve coupling a third holding tank to the second mixing tank to open the valve
610
To 612 of Figure 6B

Figure 6A

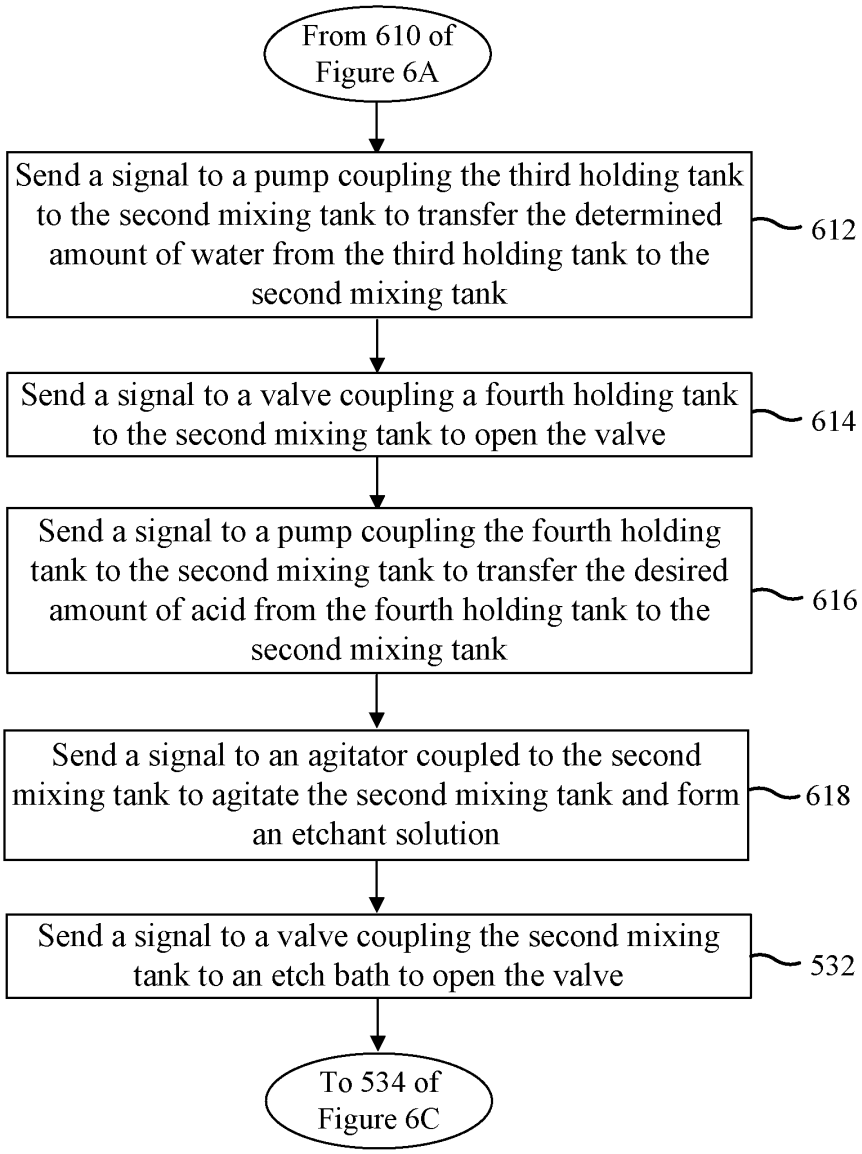

From 610 of Figure 6A
Send a signal to a pump coupling the third holding tank to the second mixing tank to transfer the determined amount of water from the third holding tank to the second mixing tank
612
Send a signal to a valve coupling a fourth holding tank to the second mixing tank to open the valve
614
Send a signal to a pump coupling the fourth holding tank to the second mixing tank to transfer the desired amount of acid from the fourth holding tank to the second mixing tank
616
Send a signal to an agitator coupled to the second mixing tank to agitate the second mixing tank and form an etchant solution
618
Send a signal to a valve coupling the second mixing tank to an etch bath to open the valve
532
To 534 of Figure 6C

Figure 6B

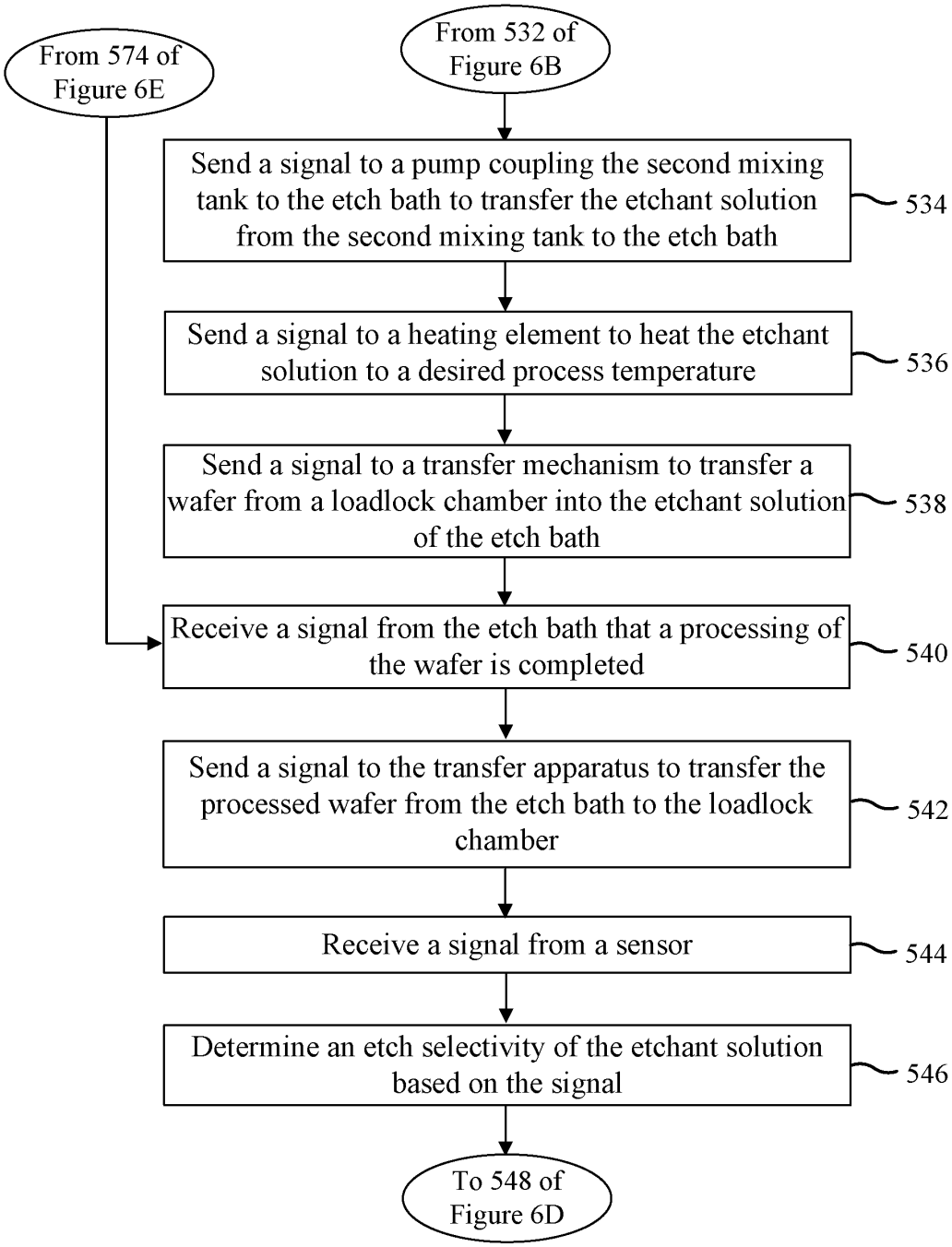

From 574 of Figure 6E
From 532 of Figure 6B
Send a signal to a pump coupling the second mixing tank to the etch bath to transfer the etchant solution from the second mixing tank to the etch bath
534
Send a signal to a heating element to heat the etchant solution to a desired process temperature
536
Send a signal to a transfer mechanism to transfer a wafer from a loadlock chamber into the etchant solution of the etch bath
538
Receive a signal from the etch bath that a processing of the wafer is completed
540
Send a signal to the transfer apparatus to transfer the processed wafer from the etch bath to the loadlock chamber
542
Receive a signal from a sensor
544
Determine an etch selectivity of the etchant solution based on the signal
546
To 548 of Figure 6D

Figure 6C

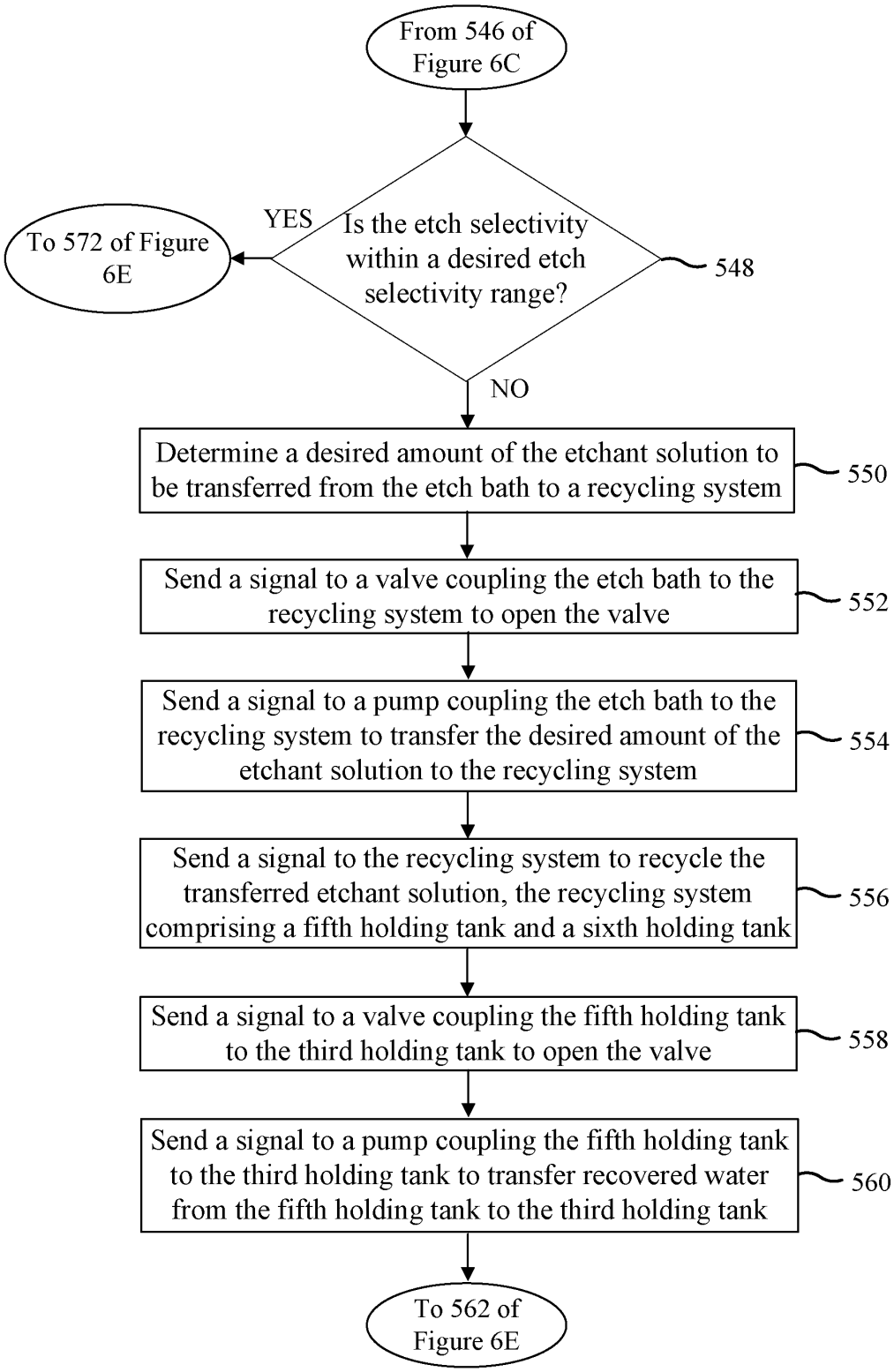

From 546 of Figure 6C
Is the etch selectivity within a desired etch selectivity range?
548
YES
To 572 of Figure 6E
NO
Determine a desired amount of the etchant solution to be transferred from the etch bath to a recycling system
550
Send a signal to a valve coupling the etch bath to the recycling system to open the valve
552
Send a signal to a pump coupling the etch bath to the recycling system to transfer the desired amount of the etchant solution to the recycling system
554
Send a signal to the recycling system to recycle the transferred etchant solution, the recycling system comprising a fifth holding tank and a sixth holding tank
556
Send a signal to a valve coupling the fifth holding tank to the third holding tank to open the valve
558
Send a signal to a pump coupling the fifth holding tank to the third holding tank to transfer recovered water from the fifth holding tank to the third holding tank
560
To 562 of Figure 6E

Figure 6D

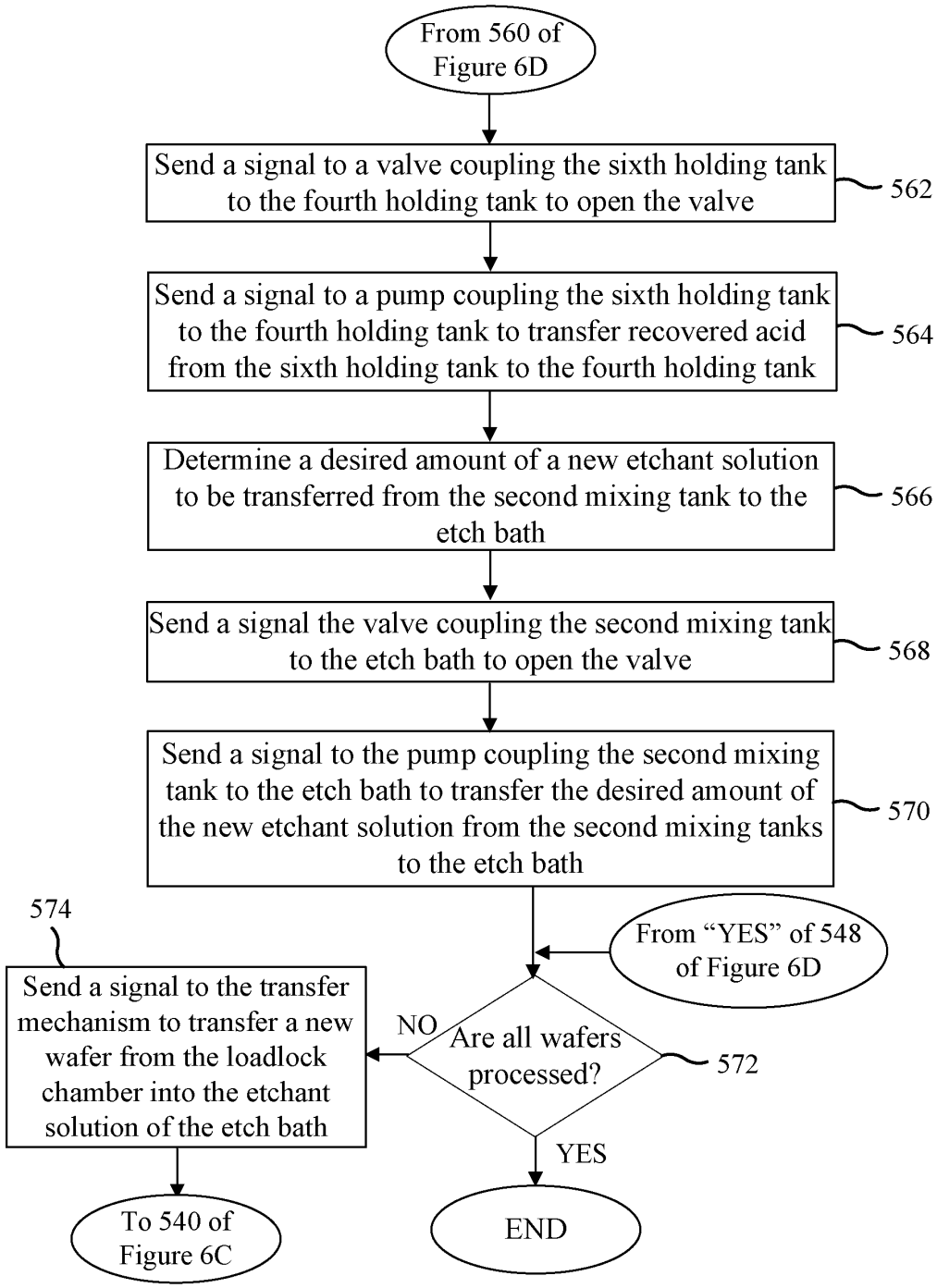

From 560 of Figure 6D
Send a signal to a valve coupling the sixth holding tank to the fourth holding tank to open the valve
562
Send a signal to a pump coupling the sixth holding tank to the fourth holding tank to transfer recovered acid from the sixth holding tank to the fourth holding tank
564
Determine a desired amount of a new etchant solution to be transferred from the second mixing tank to the etch bath
566
Send a signal the valve coupling the second mixing tank to the etch bath to open the valve
568
Send a signal to the pump coupling the second mixing tank to the etch bath to transfer the desired amount of the new etchant solution from the second mixing tanks to the etch bath
570
From "YES" of 548 of Figure 6D
Are all wafers processed?
572
NO
YES
574
Send a signal to the transfer mechanism to transfer a new wafer from the loadlock chamber into the etchant solution of the etch bath
To 540 of Figure 6C
END

Figure 6E