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(54) **TWO ELECTRODE ELECTROCHEMICAL PURIFICATION CELL FOR MOLTEN SALT**

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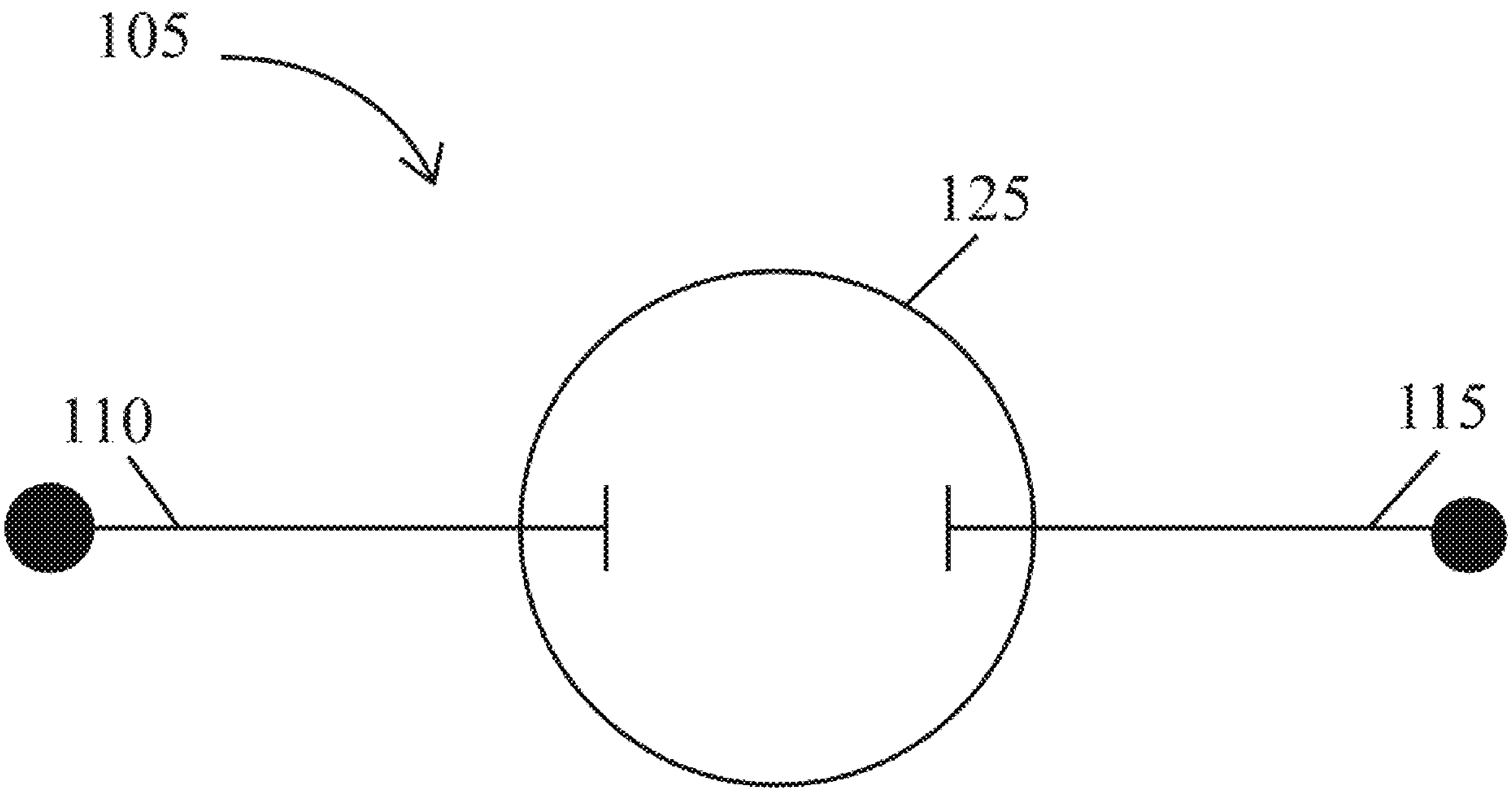
(57) **ABSTRACT**

Methods and systems for removing impurities from molten salts using an electrochemical purification system having two electrodes. When a voltage is applied to the two-electrode electrochemical purification system, ions from a counter electrode may react with impurities in the molten salt to form materials which can deposit on the working electrode and out of the molten salt. The systems and methods may be more effective at removing impurities than traditional methods and produce less harmful byproducts.



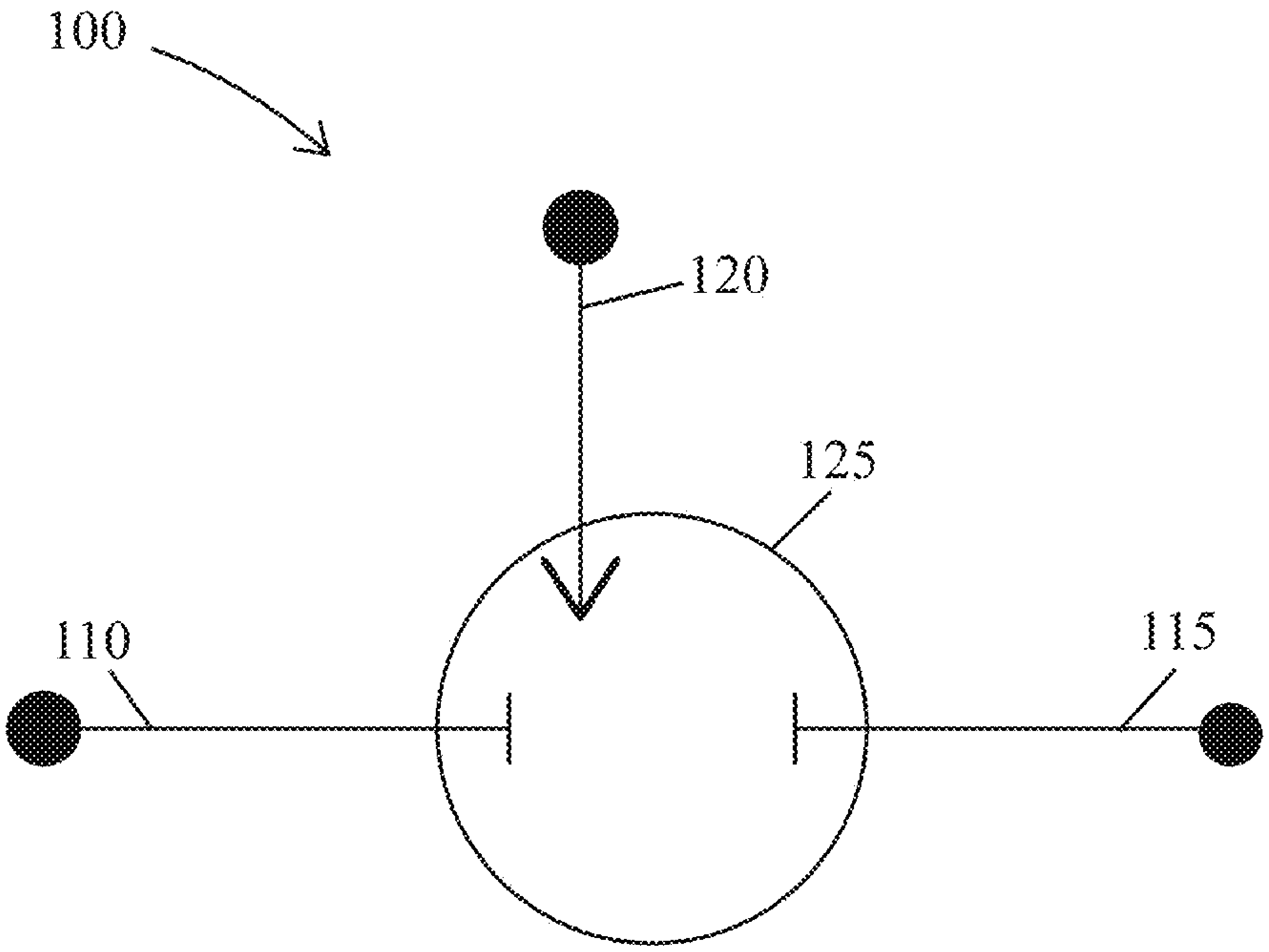


FIG. 1A

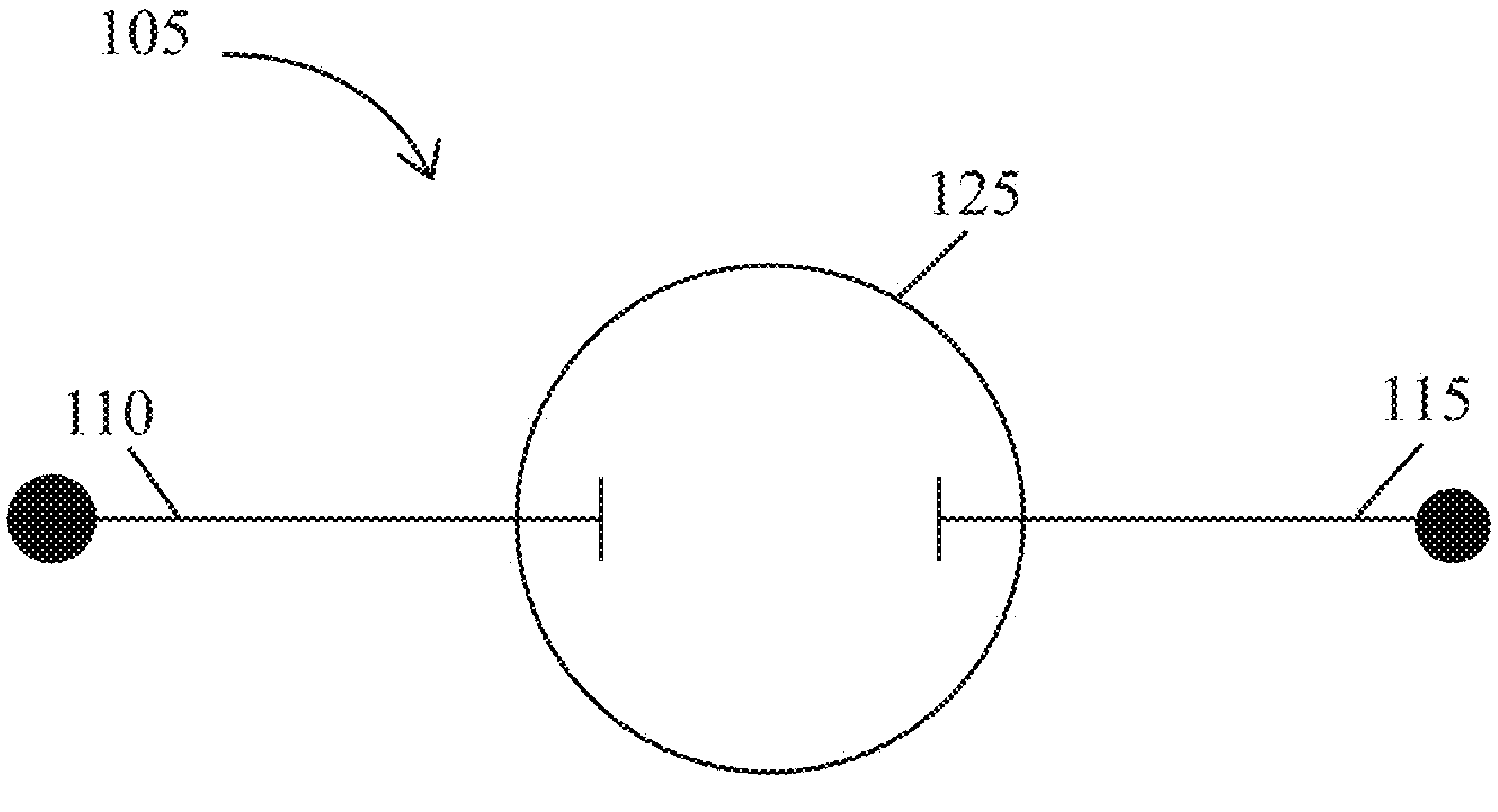


FIG. 1B

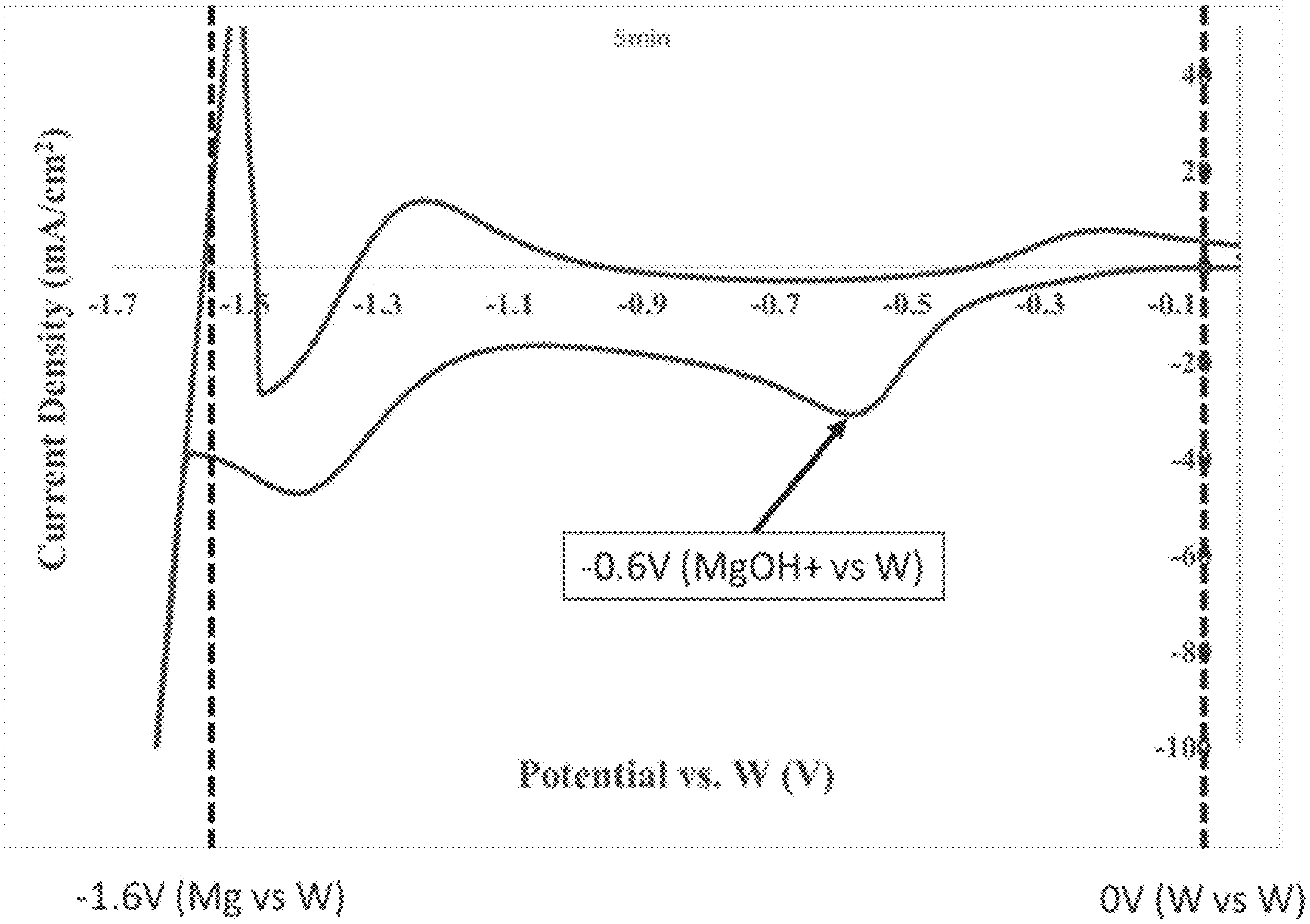

5min
Current Density (mA/cm²)
4
2
-2
-4
-6
-8
-10
-1.7
-1.5
-1.3
-1.1
-0.9
-0.7
-0.5
-0.3
-0.1
-0.6V (MgOH+ vs W)
Potential vs. W (V)
-1.6V (Mg vs W)
0V (W vs W)

FIG. 2

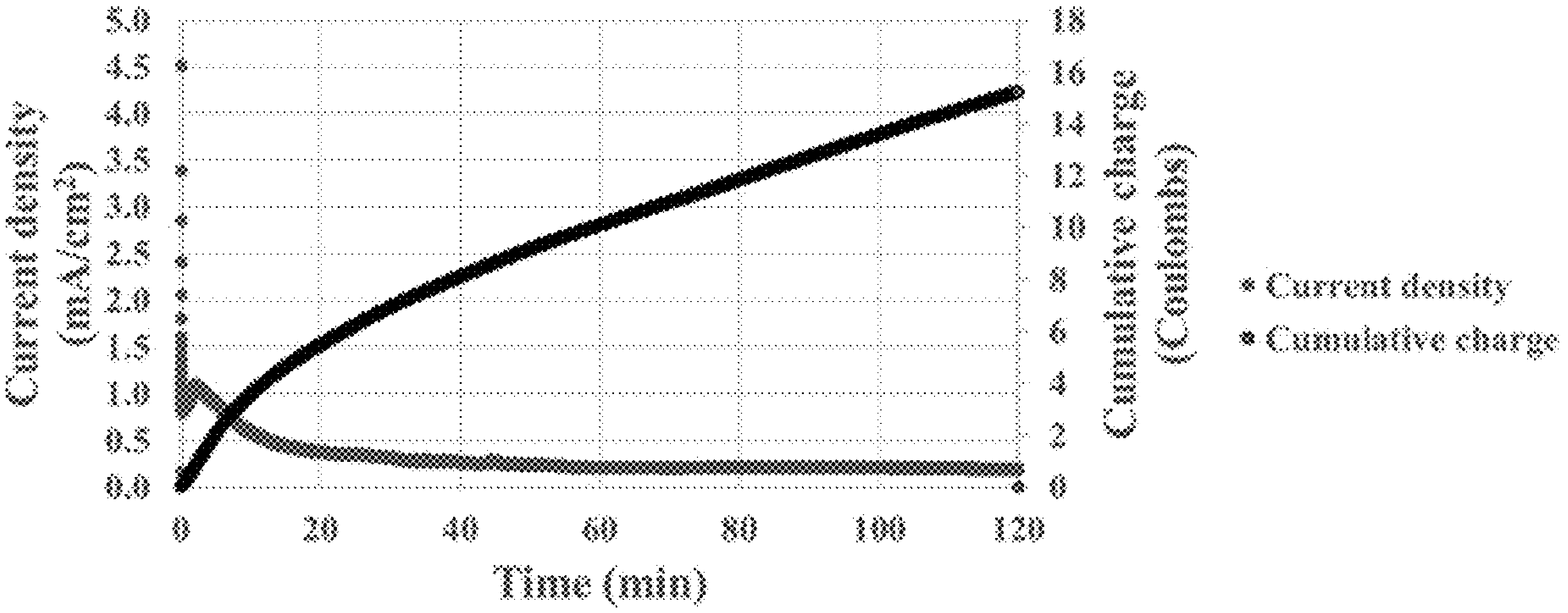

Current density (mA/cm²)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Cumulative charge (Coulombs)
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
Time (min)
● Current density
● Cumulative charge

FIG. 3

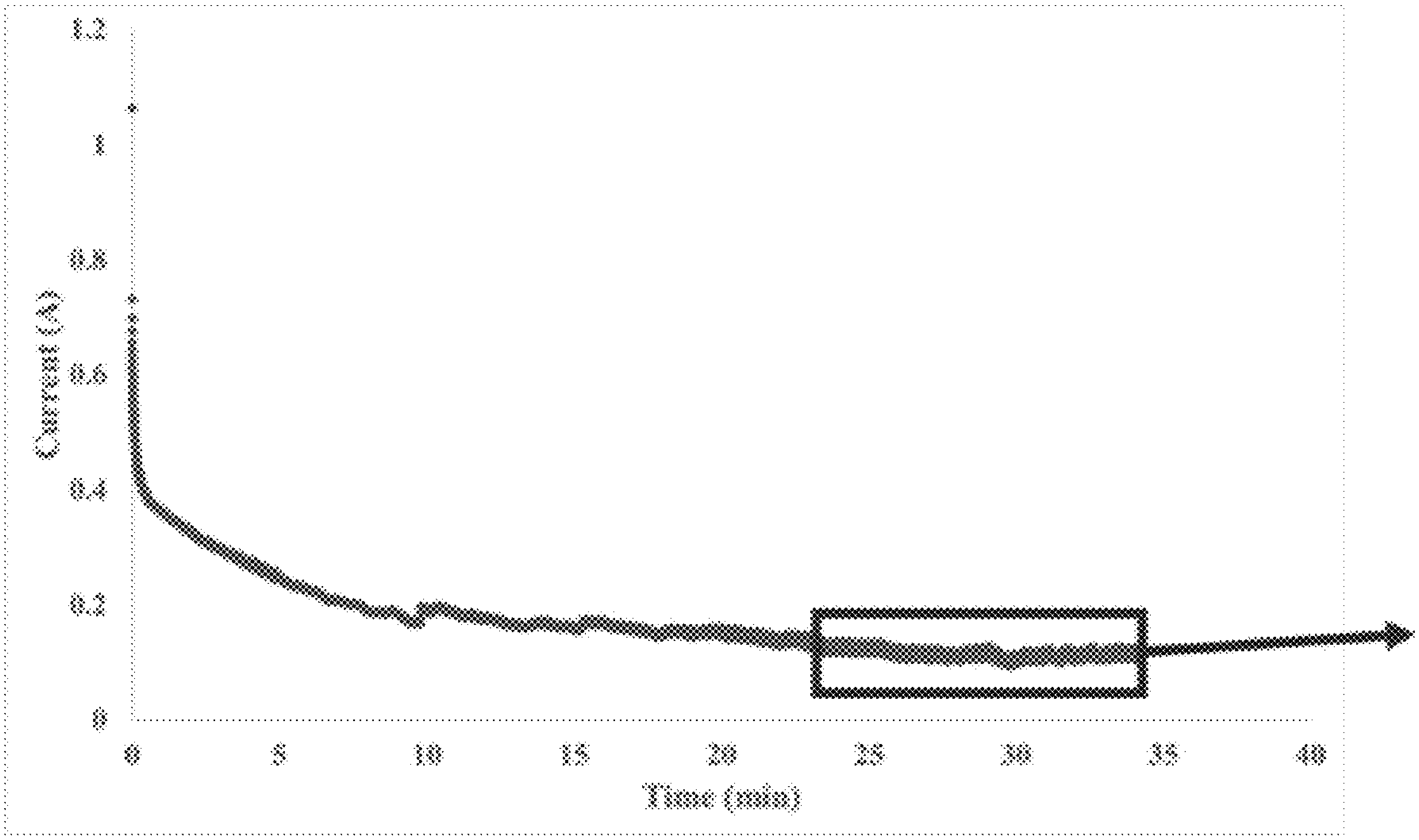

1.2
1
0.8
0.6
0.4
0.2
0
Current (A)
0
5
10
15
20
25
30
35
40
Time (min)

FIG. 4A

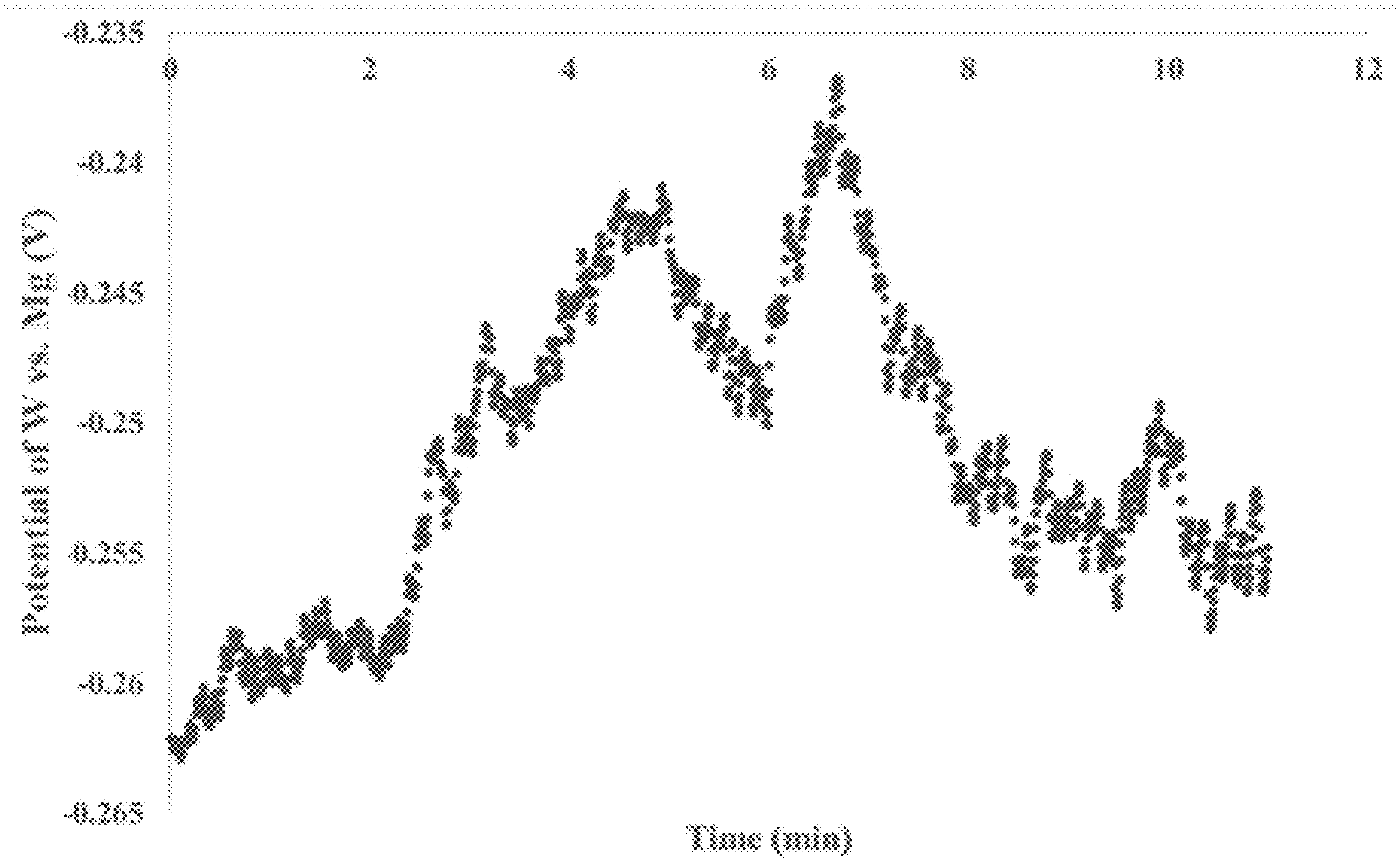

-0.235
-0.24
-0.245
-0.25
-0.255
-0.26
-0.265
Potential of W vs. Mg (V)
0
2
4
6
8
10
12
Time (min)

FIG. 4B

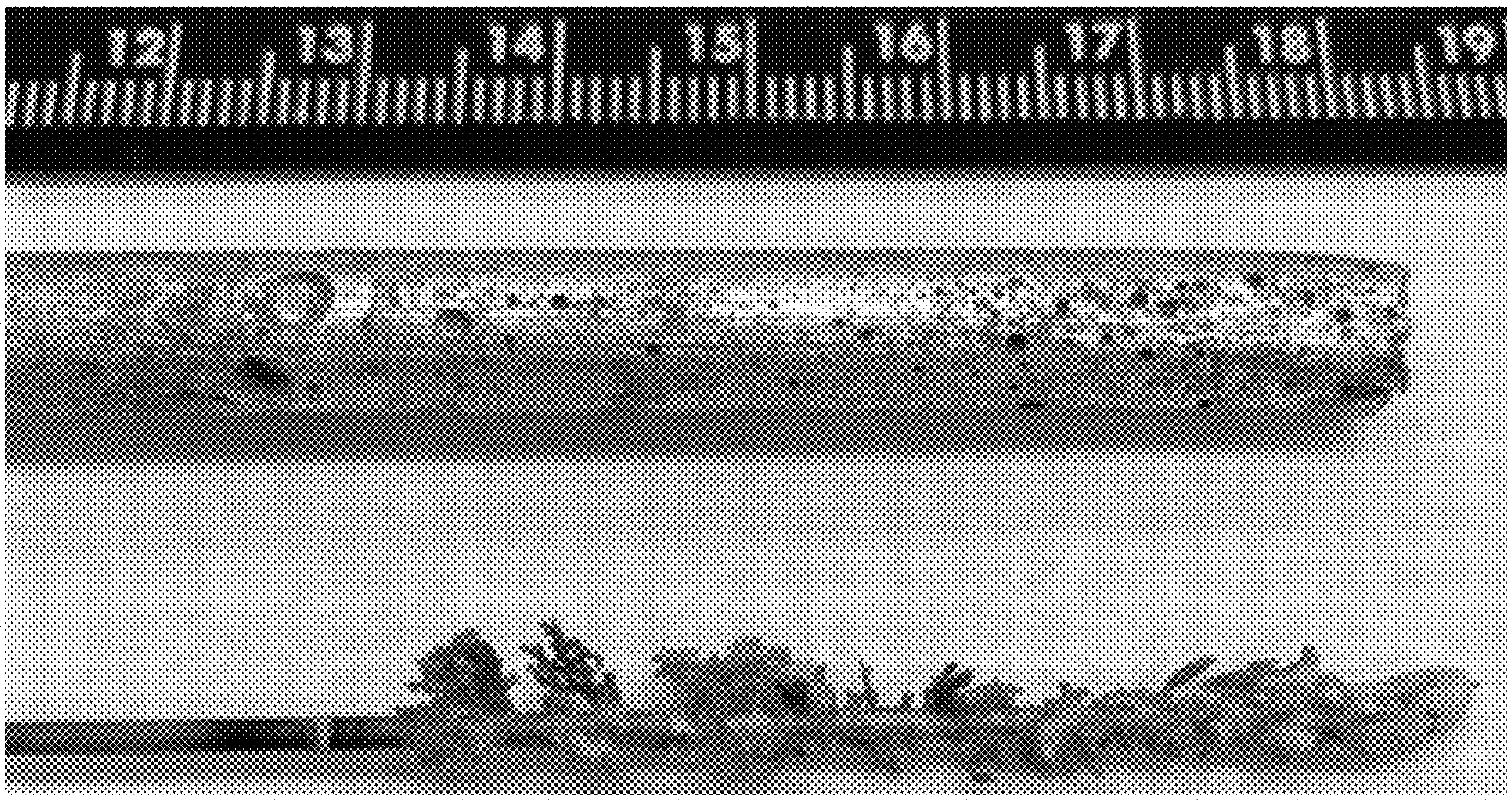


FIG. 5

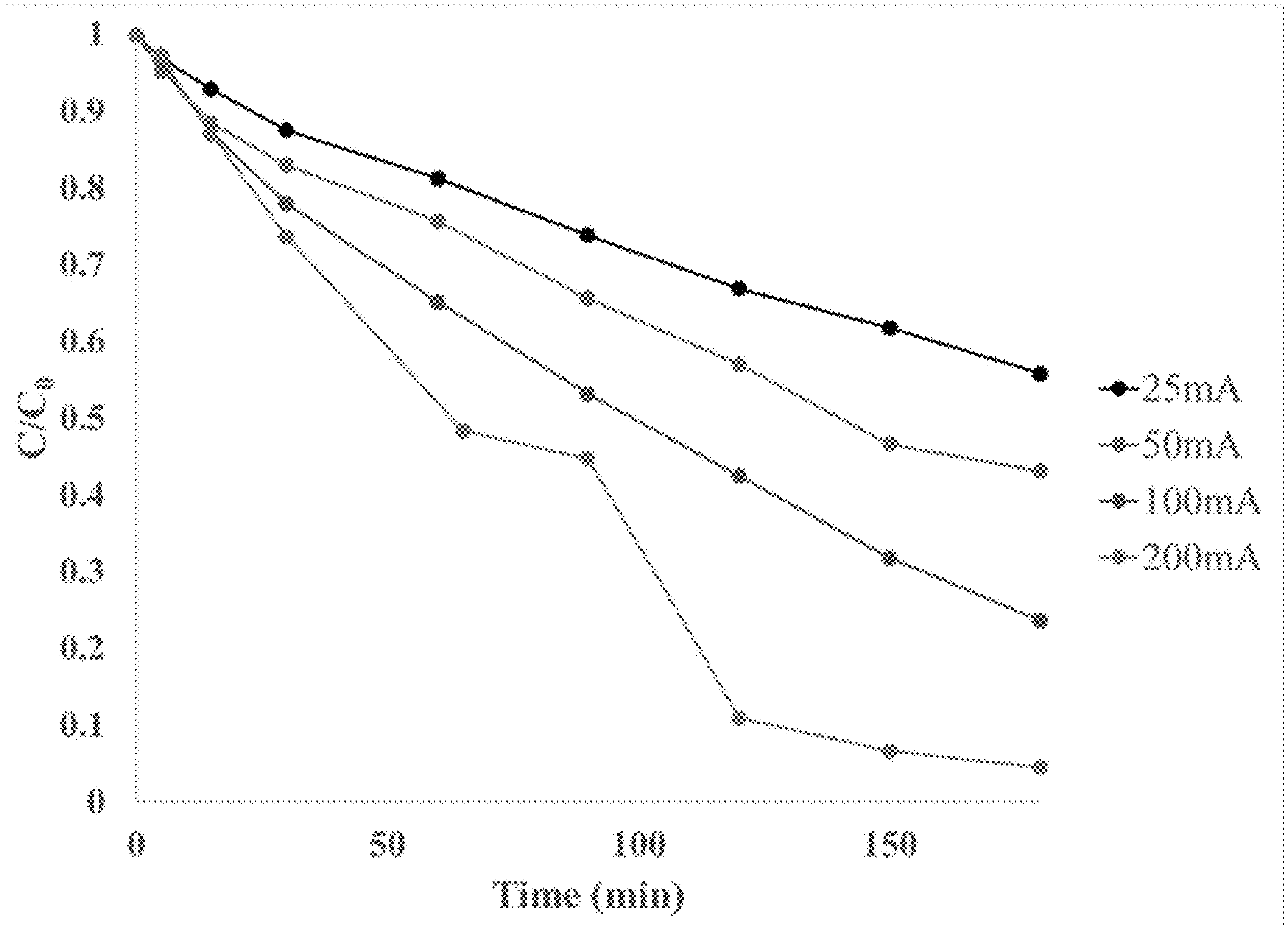

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
C/C_0
0
50
100
150
Time (min)
25mA
50mA
100mA
200mA

FIG. 6

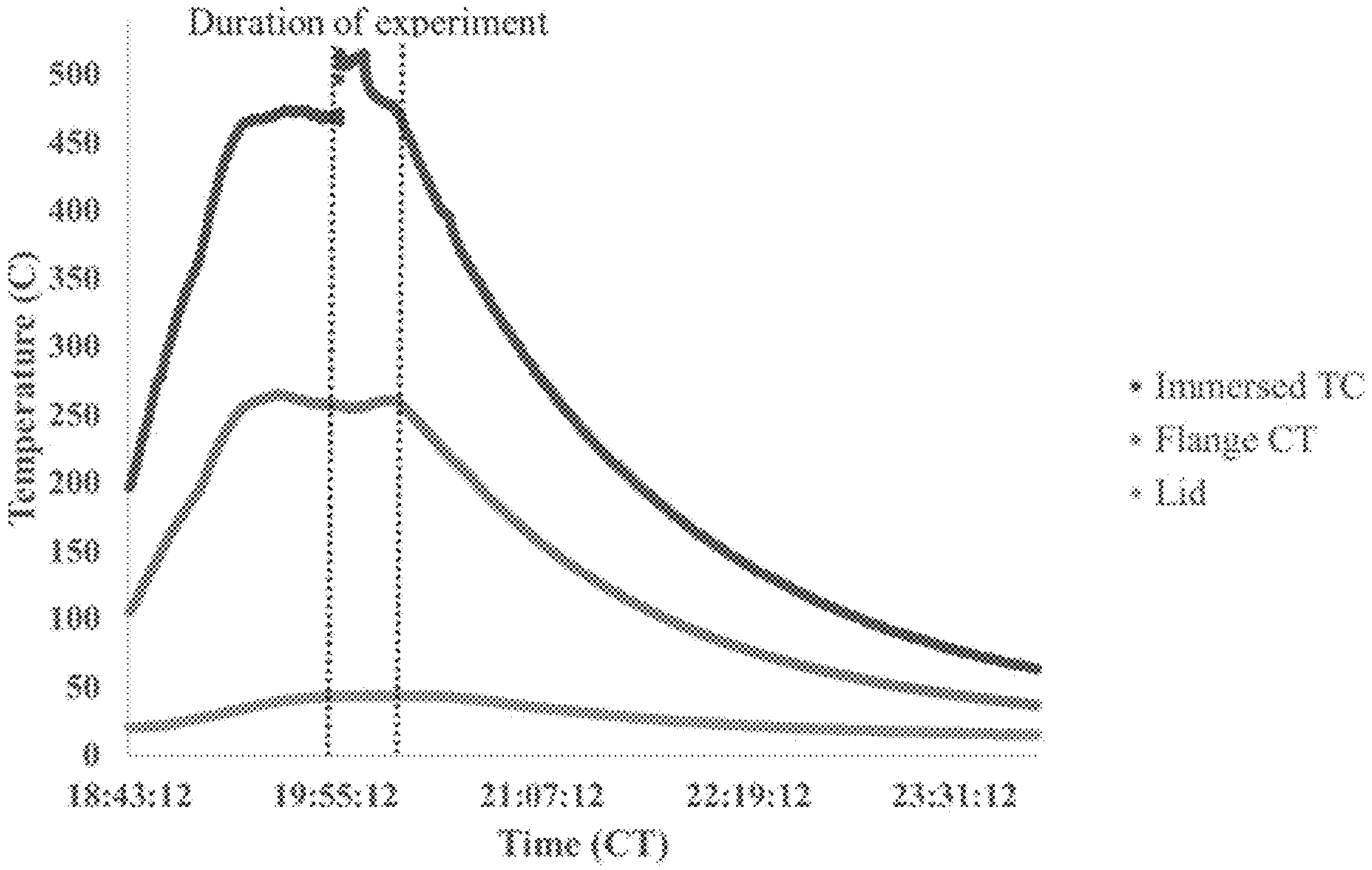

Duration of experiment
Temperature (C)
500
450
400
350
300
250
200
150
100
50
0
18:43:12
19:55:12
21:07:12
22:19:12
23:31:12
Time (CT)
Immersed TC
Flange CT
Lid

FIG. 7

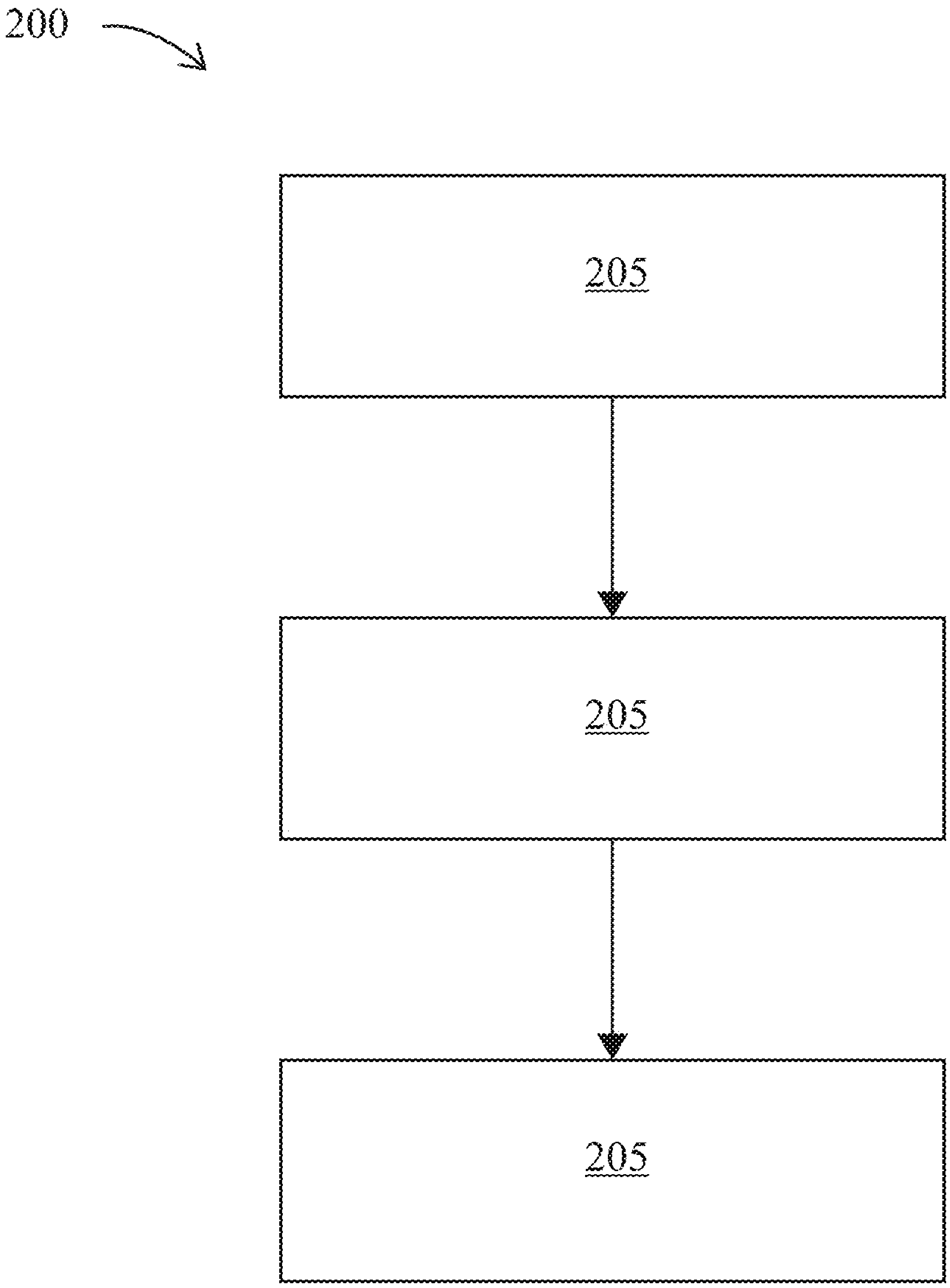


FIG. 8

TWO ELECTRODE ELECTROCHEMICAL PURIFICATION CELL FOR MOLTEN SALT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/480,355 filed on Jan. 18, 2023, the contents of which are incorporated herein by reference in their entirety.

CONTRACTUAL ORIGIN

[0002] This invention was made with government support under Contract No. DE-AC36-08GO28308 awarded by the Department of Energy. The government has certain rights in the invention.

BACKGROUND

[0003] Impurity control in magnesium (Mg) based chloride salts has been well established due to its industrial application in Mg electrowinning. In Mg electrowinning cells the purity of the salt affects the Faradaic efficiency of the unit and the rate of the graphite anode consumption. Typical strategies involve a slow heating step to remove residual moisture under a chlorinating environment to avoid formation of magnesium hydroxychloride (MgOHCl) and magnesium oxide (MgO). Slow heating is crucial to avoid the formation of MgOHCl, which has been found to decompose at temperatures above 550° C. However, slow heating is not an effective solution for purification of molten salts during plant operation, as cold-side temperatures of most concentrating solar power (CSP) plants are below the temperature for which this is effective. Thus, there remains a need for a means of purifying molten salts that is useable in CSP applications.

SUMMARY

[0004] An aspect of the present disclosure is a system for purifying a molten salt, the system including a tank for holding the molten salt, a plurality of electrodes positioned within the tank and including only a working electrode, and a counter electrode, and a voltage source, in which the voltage source is configured to provide a voltage to the working electrode. In some embodiments, the working electrode includes at least one of tungsten, silver, gold, platinum, palladium, or nickel. In some embodiments, the counter electrode includes magnesium (Mg). In some embodiments, the voltage is less than 5 V. In some embodiments, the counter electrode is configured to release an ion into the molten salt. In some embodiments, the ion is a magnesium ion (Mg+). In some embodiments, the molten salt is configured to react with the ion to form a mass on the working electrode. In some embodiments, the mass comprises a hydroxide. In some embodiments, the hydroxide is magnesium hydroxide ($MgOH^+$). In some embodiments, the molten salt includes a chloride salt. In some embodiments, the molten salt has a temperature, and the temperature is less than approximately 300° C.

[0005] An aspect of the present disclosure is a method for purifying a molten salt, the method including placing the molten salt in a tank containing a plurality of electrodes, applying a voltage, collecting a mass, in which the plurality of electrodes includes only a working electrode, and a counter electrode, and the applying comprises applying the voltage to the working electrode. In some embodiments, the working electrode includes at least one of tungsten, silver, gold, platinum, palladium, or nickel. In some embodiments, the counter electrode includes magnesium (Mg). In some embodiments, the voltage is less than 5 V. In some embodiments, as a result of the applying, the counter electrode releases an ion into the molten salt. In some embodiments, the ion is a magnesium ion (Mg+). In some embodiments, as a result of the applying, the molten salt reacts with the ion to form a mass on the working electrode. In some embodiments, the mass includes magnesium hydroxide ($MgOH^+$). In some embodiments, the molten salt includes a chloride salt.

BRIEF DESCRIPTION OF DRAWINGS

[0006] Some embodiments are illustrated in referenced figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than limiting.

[0007] FIG. **1**A illustrates a standard three-electrode electrochemical purification system, and FIG. **1**B a two-electrode electrochemical purification system according to some aspects of the present disclosure.

[0008] FIG. **2** illustrates a cyclic voltammetry scan obtained at approximately 250 mV/s and approximately 500° C. on tungsten (W) WE of the two-electrode purification system of the present disclosure.

[0009] FIG. **3** illustrates current and charge behavior during an approximately 2-hour electrolysis where the W WE was set to an increased potential of 1 V compared to the magnesium (Mg) counter electrode (CE) of the two-electrode electrochemical purification system of the present disclosure, according to some aspects of the present disclosure.

[0010] FIG. **4**A illustrates current behavior and FIG. **4**B illustrates potential measurement during electrolysis experiments on the two-electrode purification system of the present disclosure.

[0011] FIG. **5** illustrates a Mg CE (top) and a W WE (bottom), after electrolysis experiences in the two-electrode purification system of the present disclosure, according to some aspects of the present disclosure.

[0012] FIG. **6** illustrates current controlled experiments with the two-electrode purification system of the present disclosure.

[0013] FIG. **7** illustrates performance of a leak checking purification reactor during experiments of the two-electrode purification system of the present disclosure.

[0014] FIG. **8** illustrates a method of purifying molten salt according to some aspects of the present disclosure.

REFERENCE NUMERALS

[0015] **100** . . . traditional three-electrode system
[0016] **105** . . . two-electrode system
[0017] **110** . . . working electrode (WE)
[0018] **115** . . . counter electrode (CE)
[0019] **120** . . . reference electrode (RE)
[0020] **125** . . . tank
[0021] **200** . . . method
[0022] **205** . . . placing
[0023] **210** . . . applying
[0024] **215** . . . collecting

DETAILED DESCRIPTION

[0025] The embodiments described herein should not necessarily be construed as limited to addressing any of the particular problems or deficiencies discussed herein. References in the specification to "one embodiment", "an embodiment", "an example embodiment", "some embodiments", etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0026] As used herein the term "substantially" is used to indicate that exact values are not necessarily attainable. By way of example, one of ordinary skill in the art will understand that in some chemical reactions 100% conversion of a reactant is possible, yet unlikely. Most of a reactant may be converted to a product and conversion of the reactant may asymptotically approach 100% conversion. So, although from a practical perspective 100% of the reactant is converted, from a technical perspective, a small and sometimes difficult to define amount remains. For this example of a chemical reactant, that amount may be relatively easily defined by the detection limits of the instrument used to test for it. However, in many cases, this amount may not be easily defined, hence the use of the term "substantially". In some embodiments of the present invention, the term "substantially" is defined as approaching a specific numeric value or target to within 20%, 15%, 10%, 5%, or within 1% of the value or target. In further embodiments of the present invention, the term "substantially" is defined as approaching a specific numeric value or target to within 1%, 0.9%, 0.8%, 0.7%, 0.6%, 0.5%, 0.4%, 0.3%, 0.2%, or 0.1% of the value or target.

[0027] As used herein, the term "about" is used to indicate that exact values are not necessarily attainable. Therefore, the term "about" is used to indicate this uncertainty limit. In some embodiments of the present invention, the term "about" is used to indicate an uncertainty limit of less than or equal to ±20%, ±15%, ±10%, ±5%, or ±1% of a specific numeric value or target. In some embodiments of the present invention, the term "about" is used to indicate an uncertainty limit of less than or equal to ±1%, ±0.9%, ±0.8%, ±0.7%, ±0.6%, ±0.5%, ±0.4%, ±0.3%, ±0.2%, or ±0.1% of a specific numeric value or target.

[0028] Among other things, the present disclosure relates to methods and systems for removing impurities from molten salts using an electrochemical purification system having two electrodes. When a voltage is applied to the two-electrode electrochemical purification system, ions from a counter electrode may react with impurities in the molten salt to form materials which can deposit on the working electrode and out of the molten salt. The electrochemical method using a two-electrode electrochemical purification system as described herein is more effective at removing impurities than alternative chemical and thermal methods and produces less harmful byproducts.

[0029] In some embodiments, the two-electrode electrochemical purification system of the present disclosure may be used to purify a molten salt, which may include a halogen salt. Halogens in the halogen salt include bromine (Br), chlorine (Cl), fluorine (F), iodine (I), astatine (As), and/or Tennessine (Ts). In some embodiments, the halogen in the salt may be sodium (Na), magnesium (Mg), calcium (Ca), potassium (K), lithium (Li), strontium (Sr), barium (Ba), zinc (Zn), aluminum (Al), tin (Sn), iron (Fe), chromium (Cr), manganese (Mn), and/or nickel (Ni). Exemplary salts may be salts with the primary halogen being Cl (known as chloride salts) and having multiple cations, such as NaCl—KCl—$MgCl_2$. The two-electrode system of the present disclosure and the methods described herein were tested using NaCl—KCl—$MgCl_2$ as the molten salt, although other salts could be used with these two-electrode electrochemical purification systems and methods.

[0030] As used herein, the two-electrode electrochemical purification system of the present disclosure may also be referred to as a two-electrode electrochemical purification cell. An electrochemical cell is a device (or combination of devices) that can generate electrical energy from the chemical reactions occurring in it or (as with the two-electrode electrochemical purification system of the present disclosure) use the electrical energy supplied to it to facilitate chemical reactions in it.

[0031] FIG. **1**A illustrates a standard three-electrode electrochemical purification system **100**, and FIG. **1**B a two-electrode electrochemical purification system **105** according to some aspects of the present disclosure. In traditional three-electrode systems **100**, there is a working electrode (WE) **110**, a counter electrode (CE) **115**, and a reference electrode (RE) **120** positioned within a tank **125**. In the two-electrode system **105** of the present disclosure, there is a WE **110** and a CE **115** positioned in the tank **125**. A RE **120** is not present in the two-electrode system **105** (i.e., the CE **115** performs any needed functions traditionally performed by the RE **120**). In some embodiments, the three-electrode system **100** includes a working lead (not shown) and/or a working sense lead (not shown), one or both of which may be connected to the WE **110**. In some embodiments, the three-electrode system **100** includes a counter lead (not shown) and/or a reference lead (not shown), one or both of which may be connected to the CE **115**. The working lead and/or counter lead may allow for current/voltage to the applied to the WE **110** and/or CE **115**. The working sense lead and/or the reference lead may measure the current/voltage applied to the WE **110** and/or CE **115**. Together, the working lead, working sense lead, counter lead, and reference lead may be referred to as a potentiostat.

[0032] In some embodiments, the WE **110** and/or the CE **115** may be partially submerged in the molten salt. That is, at least a portion of the WE **110** and/or CE **115** will be immersed in the molten salt. For example, approximately 5-50% of the WE **110** and/or CE **115** may be submerged in the molten salt. In some embodiments, the WE **110** and/or the CE **115** may be in contact with the molten salt but not submerged. In some embodiments, the WE **110** and/or the CE **115** may be substantially submerged. For example, for a WE **110** and/or CE **155** with a length of approximately 160 mm approximately 3 mm may be immersed in the molten salt.

[0033] In some embodiments, the WE **110** may be at least one of tungsten (W), silver (Ag), gold (Au), platinum (Pt), palladium (Pd), or nickel (Ni). In experiments described herein, tungsten (W) was the primary material for the WE **110**, although other materials could be used. In some embodiments, the WE **110** has a diameter less than approximately 15 mm. In some embodiments, the WE **110** has a diameter in the range of approximately 0.5 mm to approximately 10 mm. In the experiments described herein, unless indicated otherwise, the diameter of the W WE **110** was approximately 5 mm.

[0034] In some embodiments, the CE **115** may be at least one of an alkali metal, an alkaline earth metal, a transition metal, or a metalloid. Examples of CE **115** materials include, but are not limited to, sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), francium (Fr), lithium (Li), beryllium (Be), strontium (Sr), radium (Ra), barium (Ba), magnesium (Mg), calcium (Ca), scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), silicon (Si), antimony (Sb), tellurium (Te), boron (B), arsenic (As), germanium (Ge), and/or astatine (At). In the experiments described herein, magnesium (Mg) was the primary material for the CE **115**, although other materials could be used. In some embodiments, the CE **115** has a diameter of less than approximately 15 mm. In some embodiments, the CE **115** has a diameter in the range of approximately 0.5 mm to approximately 10 mm. In the experiments described herein, unless indicated otherwise, the diameter of the Mg CE **115** was approximately 8 mm.

[0035] The two-electrode system **105** of the present disclosure utilizes electrowinning by the CE **115** to purify the molten salt. That is, when a voltage is applied to the WE **110**, ions from the CE **115** may be released into the molten salt (and thus react with the molten salt). These reactions may result in the coagulation of a mass on the WE **110**, which can then be removed.

[0036] FIG. **2** illustrates a cyclic voltammetry scan obtained at approximately 250 mV/s and approximately 500° C. on tungsten (W) WE of the two-electrode purification system of the present disclosure. In the data shown in FIG. **2**, a Mg anode (or CE **115**) and a W cathode (or WE **110**) were used. A power source with an approximately 100 A direct current (DC) power supply was used to create a potential of approximately −0.6 V vs. W. As seen in FIG. **2**, the redox peak at approximately −1.6 V vs. W WE **110** may be associated with Mg oxidation/reduction which may be the potential a Mg electrode CE **115** could operate at in the molten salt. In some embodiments, a two-electrode system **105** may have the W WE **110** set to approximately +1 V vs Mg CE **115** to target the magnesium hydroxide ($MgOH^+$) reduction peak (i.e., to attempt to maximize purification by removing the $MgOH^+$ out of the molten salt). The relatively low current density from the data collection from such a two-electrode system **105** is shown in FIG. **3**.

[0037] FIG. **3** illustrates current and charge behavior during an approximately 2-hour electrolysis experiment where the W WE **110** was set to an increased potential of approximately 1 V compared to the Mg CE **115** of the two-electrode electrochemical purification system **105** of the present disclosure, according to some aspects of the present disclosure. As seen in FIG. **3**, the limiting current density of approximately 0.2 mA/cm^2 was well below the previously observed limiting current density of approximately 78 mA/cm^2 in the traditional three electrode system **100**. Applying less current (as measured by the current density) may be why the two-electrode system **105** can operate at a significantly lower temperature than traditional three electrode systems **100**.

[0038] FIG. **4**A illustrates current behavior and FIG. **4**B illustrates potential measurement during electrolysis experiments on the two-electrode purification system of the present disclosure. As shown in FIG. **4**A the current behavior drastically when up to approximately 0.2 A (that is, approximately 0.1 A/cm^2). this behavior may be explained when observing the potential in FIG. **4**B which shows that the W WE **110** (or cathode) was more negative than the Mg CE **115** (or anode). That is, when looking at the potentials from FIG. **2**, it may be seen that the W WE **110** was at a potential more negative than the Mg CE **115**. That is, the Mg^+ ions were being electrorefined onto the W WE **110**. The electrodes after the experiment are shown in FIG. **5**.

[0039] FIG. **5** illustrates a Mg CE **115** (or anode) after experiment (top) and a W WE **110** (or cathode) after experiment (bottom), according to some aspects of the present disclosure. As shown from the data in FIGS. **4**A-B, clear dendrites (or mass) of Mg (or Mg^+) were formed on the W WE **110** after the experiment, supporting that prior purification results were due to an electrorefining process.

[0040] Experiments were performed to determine whether the desirable purification results were the result of the Mg electrorefining process. The experiments included repeating the electrolysis experiments and targeting the Mg reduction potential. To control the rate for this process, the currents were controlled in the two-electrode system **105** of the present disclosure. The concentration of $MgOH^+$ over time is shown in FIG. **6**.

[0041] To determine whether As shown in FIG. **6**, the electrorefining process was relatively highly efficient at removing the impurity $MgOH^+$. At approximately 200 mA (that is, approximately 85 mA/cm^2) the impurity was reduced by approximately 95% in approximately 3 hours.

[0042] A prototype of the two-electrode system **105** of the present disclosure was built and installed in a molten salt flow system. A ¼ inch stainless steel **316** tube was welded onto the lid of a reactor. Heat shields were also attached to the lid and bolted in a staggered formation in an attempt to minimize heat conduction. Also, the lid was attached to a tank **125** with a Grafoil gasket, a thermocouple, pressure relief valve, and a pressure transducer. The tank **125** was pressurized to approximately 10 psig with helium (He) and leak checked with a He detector. With the two-electrode system **105** installed, a molten salt flow experiment was conducted with approximately 50 lbs. of molten salt transferred from a first molten salt vessel through the tank **125** to a second molten salt vessel. The results are shown in FIG. **7**.

[0043] FIG. **7** illustrates performance of a leak checking purification reactor with a He detector, according to some aspects of the present disclosure. As shown in FIG. **7**, the salt started flowing through the reactor with the relatively sudden spike in temperature from the immerse thermocouple. Without electrodes, the heat shields allow for some convection to occur. Even then, the temperature at the flange did not exceed approximately 250° C., which is well below the maximum temperature rating of the graphite gasket (approximately 448° C.). Furthermore, the temperature at the lid stayed below approximately 50° C., which is well below the maximum temperature rating of the kalrez O-ring (approximately 250° C.). The salt flow experiment demonstrated the effective cooling design of the two-electrode system **105** and that no failure is expected from the gasket or O-rings. Based on these results, when the two-electrode system **105** is operating, the molten salt may have a temperature of less than approximately 500° C. In many embodiments the molten salt may have a temperature of approximately 250° C.

[0044] FIG. **8** illustrates a method **200** of purifying molten salt according to some aspects of the present disclosure. In some embodiments, the method **200** includes placing **205** the molten salt in a tank containing a plurality of electrodes, applying **210** a voltage, and collecting **215** a mass.

[0045] In some embodiments, the first step of the method **200** includes placing **205** the molten salt in a tank containing a plurality of electrodes. The plurality of electrodes includes a CE **115** and a WE **110**. In some embodiments, the WE **110** may be at least one of tungsten (W), silver (Ag), gold (Au), platinum (Pt), palladium (Pd), or nickel (Ni). In some embodiments, the CE **115** may be at least one of an alkali metal, an alkaline earth metal, a transition metal, or a metalloid.

[0046] In some embodiments, the next step in the method **200** includes applying **210** a voltage to the WE **110**. In some embodiments, the voltage applied **210** is less than approximately 5 V.

[0047] In some embodiments, as a result of the applying **210** the CE **115** releases an ion into the molten salt. When the CE **115** is Mg, the ion may be Mg^+. In some embodiments, as a result of the applying **210**, the molten salt reactions with the ion to form a mass on the WE **110**. The mass may be a hydroxide. If the CE **115** is Mg and the ion is Mg^+, the hydroxide may be $MgOH^+$.

[0048] In some embodiments, the next step in the method **200** includes collecting **115** a mass. The collecting **115** may involve removing the mass from the WE **110**. The removing may be done by scraping, washing, scrubbing, and/or rinsing the WE **110**. In some embodiments, the collecting **115** may include replacing the WE **110** with a new WE **110** that does not have a mass present on its surface.

EXAMPLES

[0049] Example 1. A system for purifying a molten salt, the system comprising:

- **[0050]** a tank for holding the molten salt;
- **[0051]** a plurality of electrodes positioned within the tank and consisting of:
  - **[0052]** a working electrode, and
  - **[0053]** a counter electrode; and
  - **[0054]** a voltage source; wherein:
- **[0055]** the voltage source is configured to provide a voltage to the working electrode.

[0056] Example 2. The system of Example 1, further comprising:

- **[0057]** a working lead; and
- **[0058]** a working sense lead; wherein:
- **[0059]** the working lead and the working sense lead are connected to the working electrode.

[0060] Example 3. The system of Example 1, further comprising:

- **[0061]** a counter lead; and
- **[0062]** a reference lead; wherein:
- **[0063]** the counter lead and the reference lead are connected to the counter electrode.

[0064] Example 4. The system of Example 1, wherein:

- **[0065]** the working electrode comprises at least one of tungsten, silver, gold, platinum, palladium, or nickel.

[0066] Example 5. The system of Example 4, wherein the working electrode comprises tungsten (W).

[0067] Example 6. The system of Example 1, wherein the working electrode has a diameter of less than 10 mm.

[0068] Example 7. The system of Example 6, wherein the working electrode has a diameter of less than 7 mm.

[0069] Example 8. The system of Example 6, wherein the working electrode has a diameter of approximately 5 mm.

[0070] Example 9. The system of Example 1, wherein:

- **[0071]** the counter electrode comprises at least one of an alkali metal, an alkaline earth metal, a transition metal, or a metalloid.

[0072] Example 10. The system of Example 9, wherein:

- **[0073]** the counter electrode comprises magnesium (Mg).

[0074] Example 11. The system of Example 1, wherein:

- **[0075]** the counter electrode has a diameter of less than 15 mm.

[0076] Example 12. The system of Example 11, wherein:

- **[0077]** the counter electrode has a diameter of less than 10 mm.

[0078] Example 13. The system of Example 11, wherein:

- **[0079]** the counter electrode has a diameter of approximately 8 mm.

[0080] Example 14. The system of Example 1, wherein:

- **[0081]** the voltage is less than 5 V.

[0082] Example 15. The system of Example 14, wherein:

- **[0083]** the voltage is approximately 1 V.

[0084] Example 16. The system of Example 1, wherein:

- **[0085]** the counter electrode is configured to release an ion into the molten salt.

[0086] Example 17. The system of Example 16, wherein:

- **[0087]** the ion is a magnesium ion (Mg^+).

[0088] Example 18. The system of Example 16, wherein:

- **[0089]** the molten salt is configured to react with the ion to form a mass on the working electrode.

[0090] Example 19. The system of Example 18, wherein:

- **[0091]** the mass comprises a hydroxide.

[0092] Example 20. The system of Example 19, wherein:

- **[0093]** the hydroxide is magnesium hydroxide ($MgOH^+$).

[0094] Example 21. The system of Example 1, wherein the molten salt comprises a halogen salt.

[0095] Example 22. The system of Example 1, wherein the molten salt comprises a chloride salt.

[0096] Example 23. The system of Example 1, wherein:

- **[0097]** the cation of the halogen salt may be at least one of Na, Mg, Ca, K, Li, Sr, Ba, Zn, Al, Sn, Fe, Cr, Mn, or Ni.

[0098] Example 24. The system of Example 1, wherein:

- **[0099]** the molten salt has a temperature, and
- **[0100]** the temperature is less than approximately 300° C.

[0101] Example 25. The system of Example 24, wherein:

- **[0102]** the temperature is less than approximately 250° C.

[0103] Example 26. A method for purifying a molten salt, the method comprising:

- **[0104]** placing the molten salt in a tank containing a plurality of electrodes;
- **[0105]** applying a voltage;

[0106] collecting a mass; wherein:

[0107] the plurality of electrodes consists of:

[0108] a working electrode, and

[0109] a counter electrode; and

[0110] the applying comprises applying the voltage to the working electrode.

[0111] Example 27. The method of Example 26, wherein:

[0112] a working lead and a working sense lead are positioned within the tank, and

[0113] the working lead and the working sense lead are connected to the working electrode.

[0114] Example 28. The method of Example 26, wherein:

[0115] the working electrode comprises at least one of tungsten, silver, gold, platinum, palladium, or nickel.

[0116] Example 29. The method of Example 27, wherein the working electrode comprises tungsten (W).

[0117] Example 30. The method of Example 26, wherein the working electrode has a diameter of less than 10 mm.

[0118] Example 31. The method of Example 30, wherein the working electrode has a diameter of less than 3 mm.

[0119] Example 32. The method of Example 31, wherein the working electrode has a diameter of approximately 1.5 mm.

[0120] Example 33. The method of Example 26, wherein:

[0121] a counter lead and a reference lead are positioned within the tank, and

[0122] the counter lead and the reference lead are connected to the counter electrode.

[0123] Example 34. The method of Example 26, wherein:

[0124] the counter electrode comprises at least one of an alkali metal, an alkaline earth metal, a transition metal, or a metalloid.

[0125] Example 35. The method of Example 26, wherein:

[0126] the counter electrode comprises magnesium (Mg).

[0127] Example 36. The method of Example 26, wherein:

[0128] the counter electrode has a diameter of less than 20 mm.

[0129] Example 37. The method of Example 36, wherein:

[0130] the counter electrode has a diameter of less than 10 mm.

[0131] Example 38. The method of Example 37, wherein:

[0132] the counter electrode has a diameter of approximately 8 mm.

[0133] Example 39. The method of Example 26, wherein:

[0134] the voltage is less than 5 V.

[0135] Example 40. The method of Example 39, wherein:

[0136] the voltage is approximately 1 V.

[0137] Example 41. The method of Example 26, wherein:

[0138] the molten salt has a temperature, and

[0139] the temperature is less than approximately 300° C.

[0140] Example 42. The method of Example 41, wherein:

[0141] the temperature is less than approximately 250° C.

[0142] Example 43. The method of Example 26, wherein:

[0143] as a result of the applying, the counter electrode releases an ion into the molten salt.

[0144] Example 44. The method of Example 43, wherein:

[0145] the ion is a magnesium ion (Mg^+).

[0146] Example 45. The method of Example 43, wherein:

[0147] as a result of the applying, the molten salt reacts with the ion to form a mass on the working electrode.

[0148] Example 46. The method of Example 45, wherein:

[0149] the mass comprises a hydroxide.

[0150] Example 47. The method of Example 46, wherein:

[0151] the hydroxide is magnesium hydroxide ($MgOH^+$).

[0152] Example 48. The method of Example 26, wherein:

[0153] the molten salt comprises a halogen salt.

[0154] Example 49. The method of Example 26, wherein:

[0155] the molten salt comprises a chloride salt.

[0156] Example 50. The method of Example 48, wherein:

[0157] the cation of the halogen salt may be at least one of Na, Mg, Ca, K, Li, Sr, Ba, Zn, Al, Sn, Fe, Cr, Mn, or Ni.

[0158] The foregoing discussion and examples have been presented for purposes of illustration and description. The foregoing is not intended to limit the aspects, embodiments, or configurations to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the aspects, embodiments, or configurations are grouped together in one or more embodiments, configurations, or aspects for the purpose of streamlining the disclosure. The features of the aspects, embodiments, or configurations may be combined in alternate aspects, embodiments, or configurations other than those discussed above. This method of disclosure is not to be interpreted as reflecting an intention that the aspects, embodiments, or configurations require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment, configuration, or aspect. While certain aspects of conventional technology have been discussed to facilitate disclosure of some embodiments of the present invention, the Applicants in no way disclaim these technical aspects, and it is contemplated that the claimed invention may encompass one or more of the conventional technical aspects discussed herein. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate aspect, embodiment, or configuration.

What is claimed is:

1. A system for purifying a molten salt, the system comprising:

a tank for holding the molten salt;

a plurality of electrodes positioned within the tank and consisting of:

a working electrode, and

a counter electrode; and

a voltage source; wherein:

the voltage source is configured to provide a voltage to the working electrode.

2. The system of claim **1**, wherein:

the working electrode comprises at least one of tungsten, silver, gold, platinum, palladium, or nickel.

3. The system of claim **1**, wherein:

the counter electrode comprises magnesium (Mg).

4. The system of claim **1**, wherein:

the voltage is less than 5 V.

5. The system of claim **1**, wherein:

the counter electrode is configured to release an ion into the molten salt.

6. The system of claim **5**, wherein:

the ion is a magnesium ion (Mg+).

7. The system of claim **5**, wherein:

the molten salt is configured to react with the ion to form a mass on the working electrode.

8. The system of claim **7**, wherein:
the mass comprises a hydroxide.

9. The system of claim **8**, wherein:
the hydroxide is magnesium hydroxide ($MgOH^+$).

10. The system of claim **1**, wherein the molten salt comprises a chloride salt.

11. The system of claim **1**, wherein:
the molten salt has a temperature, and
the temperature is less than approximately 300° C.

12. A method for purifying a molten salt, the method comprising:
placing the molten salt in a tank containing a plurality of electrodes;
applying a voltage;
collecting a mass; wherein:
the plurality of electrodes consists of:
  a working electrode, and
  a counter electrode; and
the applying comprises applying the voltage to the working electrode.

13. The method of claim **12**, wherein:
the working electrode comprises at least one of tungsten, silver, gold, platinum, palladium, or nickel.

14. The method of claim **12**, wherein:
the counter electrode comprises magnesium (Mg).

15. The method of claim **12**, wherein:
the voltage is less than 5 V.

16. The method of claim **12**, wherein:
as a result of the applying, the counter electrode releases an ion into the molten salt.

17. The method of claim **16**, wherein:
the ion is a magnesium ion (Mg+).

18. The method of claim **16**, wherein:
as a result of the applying, the molten salt reacts with the ion to form a mass on the working electrode.

19. The method of claim **18**, wherein:
the mass comprises magnesium hydroxide ($MgOH^+$).

20. The method of claim **12**, wherein:
the molten salt comprises a chloride salt.

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