the high temperatures of welding for melting metal surface, the thin layers of metal obtained from electrodeposition cannot join and unite metal pieces in a mechanically strong or durable way.

[0006] It is with these issues in mind, among others, that aspects of the present disclosure were conceived.

SUMMARY

[0007] The following embodiments and aspects thereof are described and illustrated with systems, tools and methods meant to be exemplary and illustrative, not limiting in scope. In various embodiments, one or more of the above-described problems have been reduced or eliminated, while other embodiments are directed to other improvements.

[0007a] According to a first aspect, there is provided an apparatus, including: a source of countercharge; an electrode; an electrolyte in contact with the electrode and through which a first current between the source of countercharge and electrode flows; and a waveform generating device coupled with the electrode, the waveform generating device inducing an alternating current electric waveform on the electrode in the presence of the first current.

[0007b] According to a second aspect, there is provided a method, including: applying a first current between a source of countercharge and an electrode in contact with an electrolyte through which the first current between the source of countercharge and electrical flows; and applying an alternating current electric waveform on the electrode, the electric waveform having an energy density greater than 0 mA/cm^2 and less than 300 mA/cm^2 and a frequency between 35 kHz and 10 GHz.

[0008] Provided herein is a method comprising inducing a first current between a source of a countercharge and a first electrode, the first current being through an electrolyte. A second current is induced across the first electrode. The second current is transverse to the first current, and the second current inducing a relativistic charge across the first electrode. The method may further comprise applying a signal cancellation to reduce a far-field radiation from the first electrode.

[0009] The present disclosure also provides a method comprising inducing an electric field between a source of a countercharge and a first electrode, the electric field having field lines through an electrolyte. A potential is induced across a surface of the first electrode. The induced potential bends the field lines proximate the surface such that metal from the electrolyte follows a path of the bent field lines to deposit the metal onto the surface.

[0010] The present disclosure further provides a method comprising inducing a potential across a surface of an electrode in the presence of a chemical potential between an electrolyte and the surface of the electrode. The induced potential relativistically charges the surface of the electrode.

[0011] The present disclosure provides a corroding electrode comprising one or more metal species selected from the group consisting of metal particles, metal ions, and combinations thereof. The corroding electrode dissolves when a first current is applied between the corroding electrode and a first electrode through an electrolyte, thereby suspending the one or more metal species into the electrolyte.

CLAIMS

1. An apparatus, comprising:

a source of countercharge;

an electrode;

an electrolyte in contact with the electrode and through which a first current between the source of countercharge and electrode flows; and

a waveform generating device coupled with the electrode, the waveform generating device inducing an alternating current electric waveform on the electrode in the presence of the first current.

2. The apparatus of claim 1, wherein the alternating current electric waveform is a second current.

3. The apparatus of claim 1, wherein the alternating current electric waveform is a potential across the electrode.

4. The apparatus of claim 1, wherein the alternating current electric waveform is selected from the group consisting of sinusoid, square, triangle, ramp, saw tooth, and combinations thereof.

5. The apparatus of claim 1, wherein the alternating current electric waveform comprises a plurality of waveforms based on harmonics of one or more frequencies at which the electrolyte or the electrode exhibits absorption of the one or more frequencies.

6. The apparatus of claim 1, wherein the alternating current electric waveform has a period matched to a diffusion rate of a component in the electrolyte.

7. The apparatus of claim 1, wherein the alternating current electric waveform in the presence of the first current bends electric field lines proximate the electrode to effect deposition of metal from the electrolyte onto the electrode and corrosion of metal from the electrode into the electrolyte.

8. The apparatus of claim 1, wherein the alternating current electric waveform relativistically charges the electrode to effect deposition of metal from the electrolyte onto the electrode and corrosion of metal from the electrode into the electrolyte.

9. The apparatus of claim 1, wherein the alternating current electric waveform has an offset between 0°and 180°degrees relative to the first current.

10. The apparatus of claim 1, wherein the alternating current electric waveform has an energy density greater than 0 mA/cm^2 and less than 300 mA/cm^2.

11. The apparatus of claim 1, wherein the alternating current electric waveform has a frequency between 35 kHz and 10 GHz.

12. The apparatus of claim 1, wherein the alternating current electric waveform has a frequency between 100 kHz and 5 GHz.

13. The apparatus of claim 1, wherein the alternating current electric waveform has a power between -100 dbm and 100 dbm.

14. The apparatus of claim 1, wherein the alternating current electric waveform has a voltage between 1 and 40 volts peak-to-peak (Vpp).

15. The apparatus of claim 1, wherein the alternating current electric waveform is offset by a direct current offset voltage greater than -6 V and less than 6 V.

16. The apparatus of claim 1, wherein the alternating current electric waveform has an offset between 0°and 180° degrees relative to the first current, an energy density greater than 0 mA/cm^2 and less than 300 mA/cm^2, has a frequency between 35 kHz and 10 GHz, a power between 100 dbm and 100 dbm, and a voltage between 1 and 40 volts peak-to-peak (Vpp).

17. The apparatus of claim 1, further comprising a pair of channels in electrical communication with the electrode, through which pair the first current and the alternating current electric waveform are combined and applied to the electrode.

18. A method, comprising:

applying a first current between a source of countercharge and an electrode in contact with an electrolyte through which the first current between the source of countercharge and electrical flows; and

applying an alternating current electric waveform on the electrode, the electric waveform having an energy density greater than 0 mA/cm^2 and less than 300 mA/cm^2 and a frequency between 35 kHz and 10 GHz.

19. The method of claim 18, wherein the alternating current electric waveform has an offset between 0° and 180° degrees relative to the first current.

20. The method of claim 18, wherein the alternating current electric waveform has a power between -100 dbm and 100 dbm.

21. The method of claim 18, wherein the alternating current electric waveform has a voltage between 1 and 40 volts peak-to-peak (Vpp).

22. The method of claim 18, wherein the alternating current electric waveform comprises a direct current offset voltage greater than -6 V and less than 6 V.

23. The method of claim 18, wherein the alternating current electric waveform is selected from the group consisting of sinusoid, square, triangle, ramp, saw tooth, and combinations thereof.

24. The method of claim 17, wherein the alternating current electric waveform comprises a plurality of waveforms based on harmonics of one or more frequencies at which the electrolyte or the electrode exhibits absorption of the one or more frequencies.

25. The method of claim 17, wherein the alternating current electric waveform has a period similar to a diffusion rate of a component in the electrolyte.

26. The method of claim 17, wherein the alternating current electric waveform when in the presence of the first current bends electric field lines proximate the electrode to effect

deposition of metal from the electrolyte onto the electrode and corrosion of metal from the electrode into the electrolyte.

27. The method of claim 18, wherein the alternating current electric waveform relativistically charges the electrode to effect deposition of metal from the electrolyte onto the electrode and corrosion of metal from the electrode into the electrolyte.

28. The method of claim 18, further comprising combining the first current and the alternating current electric waveform before applying them to the electrode through a pair of channels.

29. The method of claim 18, wherein the electrode is carbon cloth.

30. The method of claim 29, wherein the carbon cloth is coated with a layer of metal presenting a single crystalline face.

31. The method of claim 18, further comprising impregnating the electrode with a metal before applying the first current or applying the alternating current electric waveform.

32. The method of claim 31, wherein the electrode is a para-aramid fiber.