CLAIMS

1. An electroplating apparatus for electroplating a metal on a substrate, the apparatus comprising:

(a) a plating chamber configured to contain an electrolyte, the plating chamber comprising a catholyte compartment and an anolyte compartment, wherein the anolyte compartment and the catholyte compartment are separated by an ion-permeable membrane;

(b) a substrate holder configured to hold and rotate the substrate in the catholyte compartment during electroplating;

(c) a primary anode positioned in the anolyte compartment of the plating chamber;

(d) an ionically resistive ionically permeable element positioned between the ion-permeable membrane and the substrate holder, wherein the ionically resistive ionically permeable element is adapted to provide ionic transport through the element during electroplating; and

(e) a secondary anode configured to donate plating current to the substrate, wherein the secondary anode is positioned such that the donated plating current does not cross the ion-permeable membrane separating the anolyte and catholyte compartments, and wherein the secondary anode is positioned such as to donate plating current through the ionically resistive ionically permeable element, wherein the ionically resistive ionically permeable element comprises at least three portions:

(i) an outer, ionically permeable portion;

(ii) a middle, ionically impermeable portion; and

(iii) an inner, ionically permeable portion,

wherein the apparatus is configured to donate plating current from the secondary anode through the outer, ionically permeable portion, but not through the inner ionically permeable portion.

2. The apparatus of claim 1, wherein the secondary anode is an azimuthally symmetrical anode.

3. The electroplating apparatus of claim 2, wherein the primary anode has a diameter or width that is smaller than a diameter or width of a plating face of the substrate.

4. The electroplating apparatus of claim 2, wherein a portion of the plating chamber housing the primary anode has a diameter or width that is smaller than a diameter or width of a plating face of the substrate.

5. The apparatus of claim 2, wherein the secondary anode is positioned in a secondary anode compartment, around the periphery of the plating chamber.

6. The apparatus of claim 2, wherein the secondary anode compartment is separated from the catholyte compartment by an ion-permeable membrane.

7. The apparatus of claim 2, wherein the secondary anode is a consumable anode.

8. The apparatus of claim 2, wherein the secondary anode is a consumable anode comprising copper.

9. The apparatus of claim 2, wherein the secondary anode is an inert anode.

10. The apparatus of claim 2, wherein the ionically resistive ionically permeable element is separated from a plating surface of the substrate by a gap of 10 mm or less.

11. The apparatus of claim 10, further comprising an inlet to the gap for introducing electrolyte flowing to the gap and an outlet to the gap for receiving electrolyte flowing through the gap, wherein the inlet and the outlet are positioned proximate azimuthally opposing perimeter locations of a plating face of the substrate, and wherein the inlet and outlet are adapted to generate cross-flow of electrolyte in the gap.

12. The apparatus of claim 2, wherein the secondary anode is positioned in a secondary anode compartment, and wherein the apparatus comprises one or more channels for irrigating the secondary anode in the secondary anode compartment.

13. The apparatus of claim 2, wherein the secondary anode is positioned in a secondary anode compartment, and wherein the apparatus comprises one or more channels for collecting and removing bubbles from the secondary anode compartment.

14. The apparatus of claim 2, wherein the ionically resistive ionically permeable element is azimuthally asymmetric and comprises an azimuthally asymmetrically positioned portion that does not allow the plating current to pass through the ionically resistive ionically permeable element.

15. The apparatus of claim 1, wherein the middle, ionically impermeable portion of the ionically resistive ionically permeable element has a smaller surface on a side of the ionically resistive ionically permeable element that is closest to the substrate than on the opposite side of the element.

16. The apparatus of claim 1, wherein the apparatus is configured to dynamically control the secondary anode during electroplating.

17. A method of electroplating a metal on a cathodically biased substrate, the method comprising:

(a) providing the substrate into an electroplating apparatus configured for rotating the substrate during electroplating, wherein the apparatus comprises: (i) a plating chamber configured to contain an electrolyte, the plating chamber comprising a catholyte compartment and an anolyte compartment, wherein the anolyte compartment and the catholyte compartment are separated by an ion-permeable membrane; (ii) a substrate holder configured to hold and rotate the substrate in the catholyte compartment during electroplating; (iii) a primary anode positioned in the anolyte compartment of the plating chamber; (iv) an ionically resistive ionically permeable element positioned between the ion-permeable membrane and the substrate holder, wherein the ionically resistive ionically permeable element is adapted to provide ionic transport through the element during electroplating and wherein the ionically resistive ionically permeable element comprises at least three portions: an outer, ionically permeable portion; a middle, ionically impermeable portion; and an inner, ionically permeable portion; and (v) a secondary anode configured to donate plating current to the substrate, wherein the secondary anode is positioned such that the donated

plating current does not cross the ion-permeable membrane separating the anolyte and catholyte compartments and wherein the secondary anode is positioned such as to donate plating current through the ionically resistive ionically permeable element;

(b) electroplating the metal on the substrate while rotating the substrate, and while providing power to the secondary anode and the primary anode, wherein the donated plating current from the secondary anode passes through the outer, ionically permeable portion of the ionically resistive ionically permeable element, but not through the inner ionically permeable portion.

18. The method of claim 17, further comprising:

(c) after electroplating metal on the substrate, electroplating metal on a second substrate that has a different distribution of recessed features in an outer portion of the second substrate than the substrate, without substituting any mechanical shields in the apparatus.