Nov. 2, 1965 E. G. CHAPDELAINE 3,215,609

ELECTROPLATING TEST CELL AND METHOD

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FIG. 1

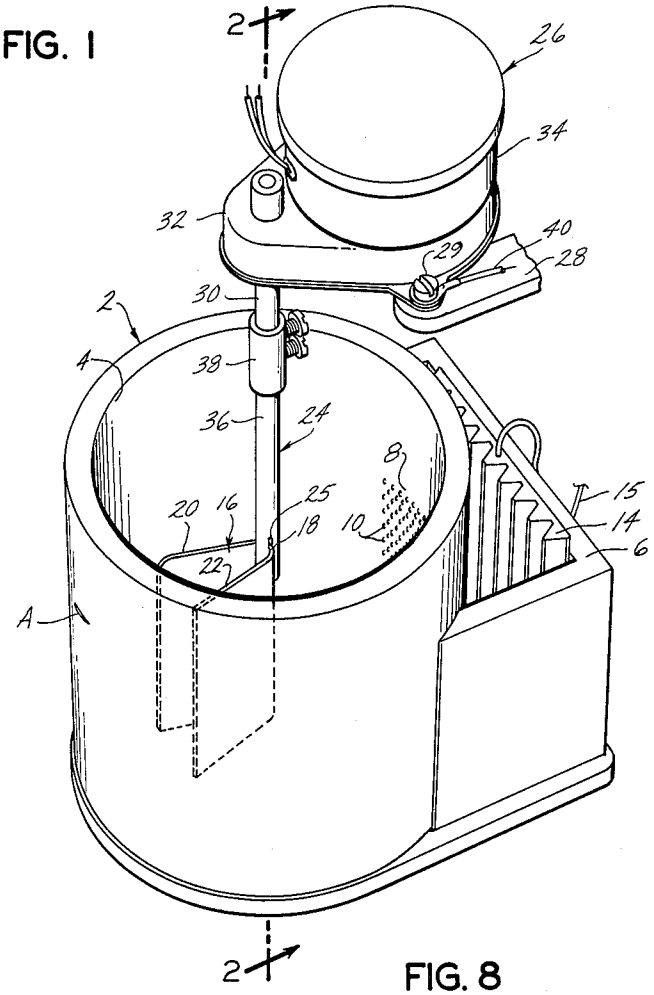


FIG. 7

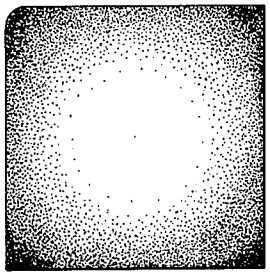
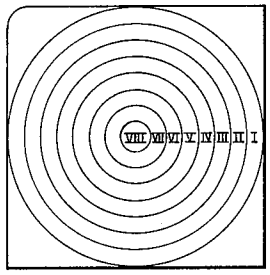


FIG. 8



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FIG. 3

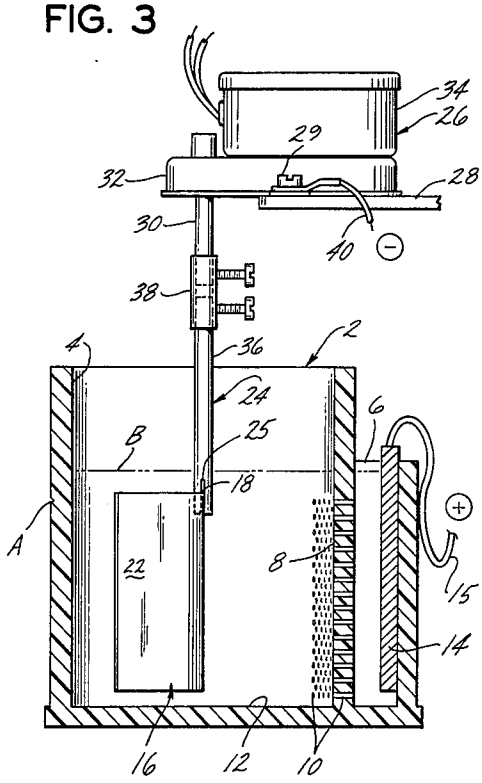


FIG. 2

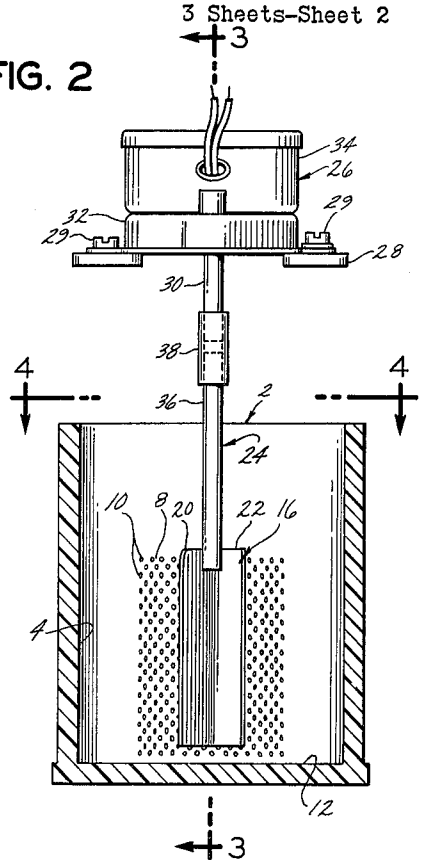


FIG. 4

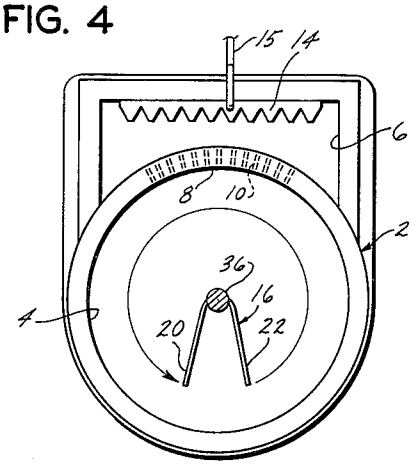
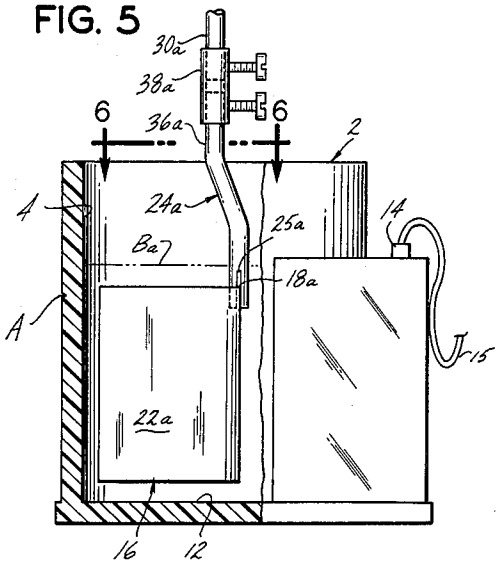


FIG. 5



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FIG. 6

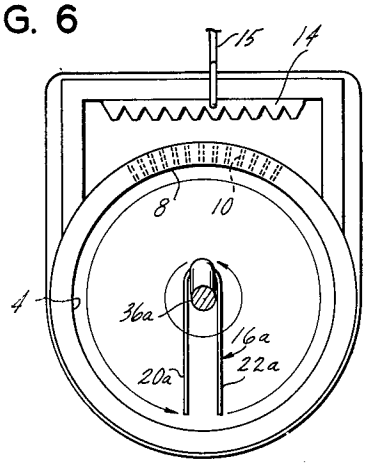


FIG. 9

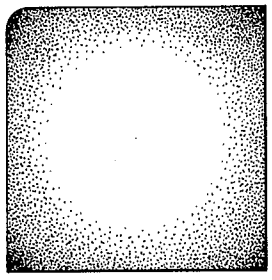


FIG. 10

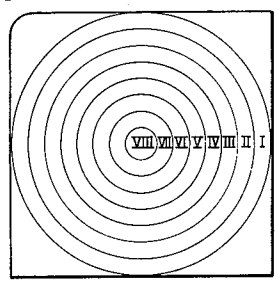


FIG. 11

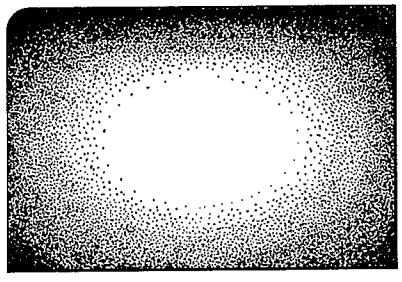
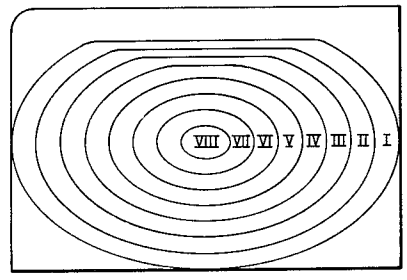


FIG. 12



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3,215,609

ELECTROPLATING TEST CELL AND METHOD

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14 Claims. (Cl. 204—1)

The present invention relates to electroplating and, more particularly, to an electroplating test cell and method for simulating conditions in a barrel plating apparatus to enable evaluation of plating conditions and electrolytes.

For electroplating small articles, it is generally customary to employ a barrel plating apparatus wherein the workpieces are placed within a perforated barrel which rotates through the electrolyte in a tank about a generally horizontal axis. Anodes are suspended in the tank along the sides of the barrel and cables with metallic ends carry current to the parts or workpieces in the barrel. As the barrel rotates through the electrolyte, the workpieces rotate therewith for a portion of the revolution and fall downwardly through the electrolyte. As the workpieces change their orientation with respect to the anodes during the revolution of the barrel, various portions of their surface will be in opposition to the anodes or at an angle thereto. The distance the current must travel will thus vary with resultant variation in the current density across the various surfaces of a given workpiece, and the current density is further subject to great variations due to the effective insulation or isolation of workpieces disposed inwardly of other workpieces, i.e. in the center of the mass, since the current flow will be intercepted preferentially by the workpiece or surfaces closest to the anodes. Thus, the current density will vary widely across the workpieces with wide variations possible in the resultant plate so that the conditions of the plating operation are usually calculated on the basis of a relatively low current density to ensure a satisfactory surface.

Heretofore, various test cells for evaluating conditions in an electroplating operation have been proposed. Hull United States Patent No. 2,149,344 is perhaps illustrative of the most widely employed unit for evaluating a "still" plating system; i.e., wherein the workpieces are immersed in a fixed position relative to the cathode. Winters United States Patent No. 3,007,861 describes a test cell which seeks to simulate conditions of cathode movement and bath circulation by vertically reciprocating the cathode. However, heretofore there has been no test cell which would effectively duplicate the conditions occurring in the barrel plating apparatus and provide a readily interpretable test panel.

It is an object of the present invention to provide a test cell for simulating the conditions in barrel plating operations in order to determine the optimum current density and electrolyte formulation.

Another object is to provide such a test cell which may be readily and relatively economically fabricated and which is simple and highly effective in operation.

A further object is to provide such a cell in which the test cathode is simply and economically fabricated and is readily interpretable.

Still another object is to provide a method for simulating and evaluating conditions in a barrel plating operation which is simple, effective and relatively economical and which utilizes a test cathode which is readily fabricated and easily interpreted.

Other objects and advantages will be apparent from the following detailed description and claims and the attached drawing wherein:

FIGURE 1 is a perspective view of an electrolytic test cell embodying the present invention with the mounting brackets and support fragmentarily illustrated;

FIGURE 2 is a cross-sectional view of the apparatus generally along the line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary cross-sectional view generally along the line 3—3 of FIGURE 2;

FIGURE 4 is a cross-sectional view of the apparatus generally along the line 4—4 of FIGURE 2;

FIGURE 5 is a fragmentary side elevational view of apparatus having an alternative embodiment of shaft and cathode and having a portion of the cell wall broken away to reveal internal construction;

FIGURE 6 is a cross-sectional view along the line 6—6 of FIGURE 5;

FIGURE 7 is a plan view of a test cathode panel plated at 1 ampere in accordance with the present invention and illustrating the surface appearance thereof;

FIGURE 8 is a plan view of the test panel of FIGURE 7 diagrammatically showing the current density areas;

FIGURE 9 is a plan view of a test cathode panel similarly plated at ½ ampere;

FIGURE 10 is a plan view similar to FIGURE 8 diagrammatically showing the current density areas of the panel of FIGURE 9;

FIGURE 11 is a plan view of a rectangular panel of enlarged lateral dimension plated similarly to that of FIGURE 7; and

FIGURE 12 is a plan view similar to FIGURE 8 diagrammatically showing the current density areas of the panel of FIGURE 11.

It has been found that the foregoing and related objects may be readily attained by a method in which an anode is suspended in an electrolyte and a cathode is rotated in the electrolyte at a predetermined distance from the anode while current is supplied to the anode and rotating cathode. The cathode is constructed with portions projecting laterally to define a recess therebetween so that variations in the current density occur along the surface thereof during rotation to produce conditions comparable to the variations in current density occurring during tumbling of the workpieces in a plating barrel. The cathode most conveniently is a sheet metal panel folded at its vertical center line to provide a base portion and a pair of leg portions so as to create a recess between the laterally projecting leg portions and produce a diminishing current density inwardly from the ends of the leg portions, and this sheet metal panel may be unfolded and compared with known standards for facile evaluation. To further simulate the conditions in the plating barrel, a tank is employed which provides distinct chambers for the cathode and anode which are separated by a wall which is pervious to the electrolyte and current.

By folding the cathode from a sheet metal panel to provide a base portion and a pair of leg portions and suspending it by the base portion for rotation about an axis coincident therewith or parallel thereto along a plane through the center of the folded panel, the resultant channel-shaped recess provides a diminishing current density pattern towards the base portion representative of the wide variations in current density occurring on various surfaces of the workpiece during tumbling in a plating barrel. By varying the spacing between the leg portions, variations in the current density pattern can be effected to accommodate and provide a means for evaluating more closely any given current value; i.e. as the free ends of the leg portions are moved from a diverging to a parallel and closer position, the restriction in the path therebetween to the base portion of the panel will decrease

further the current density values inwardly of the opening therebetween due to the closer proximity of charged surfaces which tend to attract the metallic ions.

Most desirably, the tank is fabricated from a transparent synthetic plastic material to facilitate visual inspection of the operation of the cell and is dimensioned and configured to utilize efficiently a predetermined amount of electrolyte, preferably selected to enable ready interpolation of the amounts of various additives thereto such as brighteners, acids and alkalies. To the end of achieving optimum dimensioning and configuration, the cathode chamber is preferably cylindrical or circular in cross section to accommodate the circular path of rotation of the cathode therein.

Referring now in detail to the attached drawings, a test cell embodying the present invention is therein illustrated as having a tank generally designated by the numeral **2** and fabricated from a transparent synthetic plastic mateiral with a generaly cylindrical cathode chamber **4** and an anode chamber **6** separated by the arcuate wall portion **8**. As seen in FIGURES 1–3, the wall portion **8** between the anode and cathode chambers is provided with a multiplicity of apertures or perforations **10** spaced about its surface so as to make it pervious to passage of electrolyte and current. As shown in the drawings, the tank **2** may be conveniently fabricated from a cylindrical tube and U-shaped piece for the cathode and anode chambers **4**, **6**, respectively, which are sealed to each other and to a base sheet **12**, thus facilitating the placement of the perforations **10**. Although the cathode chamber **4** may be polygonal in cross section, the use of a circular cross section provides optimum utilization of a given volume of electrolyte by accommodating and conforming to the path of rotation of the cathode. Most desirably, the tank **2** is dimensioned to operate with a predetermined standard volume of electrolyte which provides a convenient factor for controlled additions and interpolations, e.g. 267 milliliters to which a 2 gram or 1 milliliter addition will equal, respectively, 1 ounce and 0.48 fluid ounce per gallon. To facilitate predetermined electrolyte volume determination, a notch or other level mark A may be provided on the tank wall.

In the anode chamber **6** is suspended a metal anode **14** of generally conventional configuration and having a lead wire **15** which may be of sufficient strength to provide the means of suspension. As shown, the anode chamber **6** and anode **14** are dimensioned to provide a spacing between the anode **14** and the wall portion **8** between the two chambers **4**, **6**.

Suspended in the cathode chamber **4** is a sheet metal cathode panel generally designated by the numeral **16** which has been folded along its vertical center line into a generally V-shaped structure having an arcuate base or center portion **18** and a pair of diverging leg portions **20**, **22**. The cathode panel **16** is rotatably carried by the shaft **24** which engages its center or base portion **18**, conveniently by force fitting it into the notch **25** in the lower end of the shaft as illustrated. The shaft **24** is in turn supported in and driven by the drive mechanism **26** which is so mounted on the brackets **28** of a support stand (not shown) by the screws **29** as to orient the axis of rotation of the shaft **24** at the center of the cathode chamber **4**.

The shaft **24** most desirably has a separate upper element **30** which is journalled in the gear box portion **32** of the drive mechanism and is driven by an electric motor (not shown) in the motor housing portion **34**. A removable lower element **36** is connected to the upper element **30** by a sleeve coupling **38** so as to facilitate mounting of the cathode panels **16** and to enable replacement of the lower element should it become corroded or overly plated due to contact with the various electrolytes. Current is supplied to the cathode panel **16** by the lead wire **40** which is conveniently secured to the drive mechanism **26** at the screw **29** for one of the mounting brackets **28** with the metallic drive mechanism and shaft completing the conductive path.

In the embodiment of FIGURES 5 and 6, a rectangular sheet metal panel **16***a* has been substituted which is of enlarged lateral dimension so that, when folded, its leg portions **20***a*, **22***a* are of greater lateral dimension than the inside radius of the cathode chamber **4**. To permit the cathode **16***a* to rotate freely within the cathode chamber **4**, a lower shaft element **36***a* is provided having a laterally or angular extending portion intermediate its length so that its lower end is laterally offset relative to its upper end. In this manner, the rectangular sheet metal panel **16***a* is rotated about an axis parallel to but laterally displaced from its center line towards the free ends of the leg portions **20***a*, **22***a* along a plane perpendicular thereto and between the leg portions **20***a*, **22***a*. The lateral displacement in the shaft portion **36***a* should be dimensioned to accommodate the excess lateral dimension of the cathode panel **16***a* thus enabling it to freely rotate within the cathode chamber **4** with the path of rotation being indicated by the arrows in FIGURE 6. In this embodiment, the leg portions **20***a*, **22***a* have been folded further than those of FIGURES 1–4 so that they extend in substantially parallel spaced relationship and provide a generally U-shaped structure having a recess or path of generally uniform lateral dimension therebetween thus increasing the tendency of the metallic ions to plate thereon before reaching the base portion **18***a*.

Referring now to the operation of the apparatus, a predetermined volume of electrolyte is placed in the tank **2**, conveniently by filling to the indicator line A on the cathode chamber **4** wall before inserting the anode **14** and cathode panel **16** to avoid variations in displacement as a result thereof. The cathode panel **16** is inserted into the notch **25** in the lower shaft element **36** which is then secured in the sleeve coupling **38**, and the anode **14** is suspended in the electrolyte in the anode chamber **6**, the electrolyte level during operation being generally indicated by the dotted line B in FIGURE 3. Direct current is supplied to the leads **15**, **40** while the drive mechanism **26** is rotating the shaft **24** and the cathode panel **16** through the electrolyte. As the cathode panel **16** rotates, metal is plated upon its outer or unrecessed surface as it moves into and out of opposition with the anode **14** and similarly upon its inner or recessed surface in diminishing amounts towards the vertical midpoint of its center line or fold line. As will be readily appreciated, some metal ions will travel through the electrolyte above and below the outer ends of the cathode panel **16** and thence into the spacing between the leg portions to deposit along the upper and lower edges of the panel. There will also be some "stealing" of metallic ions by the metallic shaft element **36**, but generally these factors may be ignored since the deposits along the lateral dimension are those primarily considered in evaluating the results.

The plating operation is continued for a predetermined length of time with current and electrolyte passing freely through the apertures or perforations **10** of the wall **8** between the anode and cathode chambers to simulate the flow occurring in the barrel plating apparatus. Upon completion of the plating cycle, the lower shaft element **36** and cathode panel **16** are removed and separated, and the cathode panel **16** is flattened to permit visual examination of the metal plate formed on its inner sursurface. FIGURE 7 is a representative panel formed by plating a 2 inch x 2 inch steel panel with zinc at 1 ampere for ten minutes, the center having a bright plate and the dullness increasing towards the edges as indicated by the intensity of the stippling.

The amperage used in the test cell will generally be selected on an empirical basis to reproduce the current density pattern and effect upon the workpieces in the actual barrel plating apparatus as a result of previous observations and correlation since various barrel plating

apparatus and operations will require different conditions. Generally, however, the test cell will be operated at 0.5 to 2.5 amperes, and preferably 0.5 to 1.5 amperes, to provide ideal data in the low current density range. The visual examination of the test panel may be cursory and purely qualitative with the technician noting only whether the desired brightness of plate has been achieved in the center or other predetermined area of the panel representing the desired current density in the barrel plating apparatus. However, for more quantitative evaluation, the thickness of the plated metal may be measured and the apparent current density determined at any given point, or the panel may be compared with a template or scale giving the values for various locations laterally of the panel at various amperages.

Indicative of the apparent current density pattern on the test panel of FIGURE 7 is the diagrammatic pattern of FIGURE 8, although some distortion from concentricity actually occurred along the top and bottom edges. the several values determined by measuring the thickness of the plated metal were determined as follows:

Zone	Plated Metal Thickness, in. $\times 10^{2^3}$	Apparent Current Density, Amps/ft.$_2$
I	Inaccurate	Inaccurate
II	13.0	15.0
III	7.0	7.0
IV	4.0	5.0
V	3.5	4.5
VI	3.0	4.0
VII	2.5	3.0
VIII	2.5	3.0

To enlarge the lower current density range and obtain more readily discernible results therein, the current may be reduced to produce a panel such as shown in FIGURE 9 wherein the bright range has been enlarged in proportion to the decrease in current, which in the illustrated panel was from 1 ampere in FIGURE 7 to ½ ampere in FIG-9. The apparent current density in the several zones indicated in FIGURE 10 is essentially halved as follows:

Zone:	Apparent current density, amps/ft.^{2}
I	Inaccurate.
II	7.5.
III	3.5.
IV	2.5.
V	2.2.
VI	2.0.
VII	1.5.
VIII	1.5.

An alternative method of enlarging the low current density areas is by use of a rectangular test panel providing an enlarged lateral dimension to produce panels such as shown in FIGURES 11 and 12. The zones are generally elongated in the lateral direction to provide a generally elliptical pattern although the lower current density occurring along the top edge of the panel due to the presence of the conductive metal shaft flattens the elliptical configuration towards the upper edge.

Although a generally V-shaped sheet metal cathode with diverging leg portions defining an included angle of about 15 to 45 degrees is generally satisfactory for most test work, occasionally it may be desired to increase the total range of current density reflected on the panel at a given amperage. This is done simply by restricting the opening or channel between the outer ends of the leg portions as shown in FIGURES 5 and 6 by orienting the leg portions in a generally parallel extending position to provide a generally U-shaped cathode. This will diminish the current reaching the center portion of the test panel since the metal ions will tend to plate out on the leg portions during passage therebetween due to their proximity and thus increase the total range of current rensity reflected in the deposit.

As will be readily appreciated, the cathode test panels should be of substantially uniform size and configuration to ensure reproduceable and interpretable results. Accordingly, standard sized panels should be folded about forming mandrels in suitable apparatus for both the U-shaped and V-shaped structures.

The speed of rotation (r.p.m.) of the shaft should be selected to produce a linear speed at the outer ends of the panel approximating that of the linear speed of the plating barrel. For example, a plating barrel of 14-inch diameter rotating at 6 r.p.m. will be effectively simulated by a 2-inch panel rotating at 40 (42) r.p.m. The temperature of the electrolyte can be controlled by preheating it prior to insertion into the cell, or by use of an immersion heater located in the anode chamber or in some other non-interfering position, or by placing the cell upon a suitable heating unit for which method of heating the cell may be more desirably fabricated from porcelain or other temperature- and chemical-resistant material.

Thus, it can be seen that the test cell and method of the present invention provide a simple and highly effective means of duplicating the conditions occurring in barrel plating apparatus so as to permit facile evaluation of changes in bath formulation. In this manner, it is relatively easy to modify the commercial operation by making such modifications in the test cell operation as are necessary to achieve optimum brightness of plate in the current density range approximating that at the surfaces of the workpieces. The action of the recessed surface rotating about its axis or an axis parallel thereto into and out of effective plating relationship with the anode effectively simulates the condition occurring with a single workpiece as a surface moves into opposed, effective plating relationship with the anode, becomes reoriented as the workpiece rotates and falls, and becomes effectively insulated from plating relationship by being disposed within a mass of other workpieces. The cathodes are simply and economically fabricated from sheet metal and can be readily evaluated visually on a qualitative basis or on a quantitative basis by a template or scale or by actual measurement of the thickness of the plated metal.

Although but one embodiment of the invention has been shown and described herein, it will be understood that modifications may be made within the spirit of the invention.

Having thus described the invention, I claim:

1. An electroplating test apparatus comprising a tank; an anode suspended in said tank in substantially vertical relationship; a cathode of predetermined surface area, said cathode consisting of a metallic member having a centrally disposed base portion and a pair of spaced apart leg portions extending laterally therefrom to define a recess therebetween, said base portion extending in substantially vertical relationship and each of said leg portions extending in a substantially vertical plane and having its outer free edge extending substantially vertically and substantially rectilinearly; means rotatably suspending said cathode for rotation in said tank in spaced relationship laterally relative to said anode including shaft means supporting said cathode at its base portion for rotation about a substantially vertical axis, said leg portions providing variation in lateral spacing between portions of the surface thereof and said anode; and means for supplying current to said anode and cathode to produce current flow through an electrolyte received in said tank during operation of the apparatus with variation in the current density occurring across the surface of said cathode leg portions inwardly of the outer free edges and towards said base portion during rotation thereof.

2. An electroplating test apparatus comprising a tank having a first chamber of generally cylindrical configuration and a second chamber separated by a wall pervious to passage of liquid and current; an anode suspended in said second chamber in substantially vertical relationship and substantially rectilinearly in the vertical plane; a cathode of predetermined surface area consisting of a

sheet metal member folded along its center line and having a vertically extending base portion and a pair of spaced apart leg portions extending laterally therefrom, each of said leg portions extending in a substantially vertical plane and having its outer free edge extending substantially rectilinearly and substantially vertically, said leg portions defining a recess therebetween and providing variation in lateral spacing between portions of the surface thereof and said anode; means rotatably suspending said cathode in said first compartment for rotation therein including a vertically extending shaft having its lower end engaged with said base portion of said cathode; and means for supplying current to the anode and cathode to produce current flow through an electrolyte received in said tank during operation of the apparatus with variation in the current density occurring across the surface of said cathode leg portions inwardly of the outer free edges and towards said base portion during rotation thereof.

3. The electroplating test apparatus in accordance with claim 1 wherein said cathode is a sheet metal panel of substantially U-shaped cross-section having generally parallel leg portions.

4. The electroplating test apparatus in accordance with claim 1 wherein said cathode is a metal panel of substantially V-shaped cross-section having a pair of generally diverging leg portions.

5. The electroplating test apparatus in accordance with claim 1 wherein said tank has a cathode chamber in which said cathode is free to rotate and an anode chamber in which said anode is suspended, said chambers being separated by a generally vertical wall pervious to passage of electrolyte and current.

6. The electroplating test apparatus in accordance with claim 1 wherein said shaft means supports said cathode for rotation about an axis substantially coincident with said base portion.

7. The electroplating test apparatus in accordance with claim 1 wherein said shaft means supports said cathode for rotation about an axis parallel to but laterally spaced from said base portion at a point on an imaginary vertical plane drawn from the center of said base portion and extended intermediate said leg portions to bisect substantially said recess therebetween.

8. The electroplating test apparatus of claim 2 wherein said tank is fabricated from a transparent synthetic plastic.

9. The electroplating test apparatus of claim 2 wherein said pervious wall has a multiplicity of apertures spaced about the surface thereof.

10. The method of simulating barrel plating operation for laboratory evaluation comprising suspending an anode in an electrolyte; rotating a cathode in said electrolyte at a distance laterally spaced from said anode, said cathode consisting of a metallic member having a centrally disposed base portion and a pair of spaced leg portions projecting laterally therefrom to define a recess therebetween, said base portion extending in substantially vertical relationship and each of said leg portions extending in a substantially vertical plane and having its outer free edge extending substantially vertically and substantially rectilinearly; and supplying current to said anode and rotating cathode to produce current flow through said electrolyte with variation in the current density along the surface of said cathode leg portions inwardly of the outer free edges and towards said base portion.

11. The method of simulating barrel plating operation for laboratory evaluation of plating conditions comprising suspending an anode in an electrolyte in substantially vertical relationship; rotating in said electrolyte at a distance laterally spaced from said anode a cathode having predetermined surface area and consisting of a sheet metal member folded along its vertical center line into a base portion and a pair of spaced apart leg portions extending laterally therefrom to define a recess therebetween, said base portion extending in substantially vertical relationship and each of said leg portions extending in a substantially vertical plane and having its outer free edge extending substantially vertically and substantially rectilinearly; supplying current to said anode and rotating cathode to produce current flow through said electrolyte with variation in the current density and the metal plate deposited along the surface of said rotating cathode leg portions inwardly of the outer free edges and towards said base portion; and thereafter flattening said cathode to evaluate the metal plate deposited inwardly of the ends of said leg portions and towards the base portion.

12. The method in accordance with claim 11 wherein said cathode is rotated about an axis coincident with the vertical center line of its base portion.

13. The method in accordance with claim 11 wherein said cathode is rotated about an axis parallel to but laterally spaced from said vertical center line of its base portion and at a point on an imaginary vertical plane drawn therefrom and extended intermediate said leg portions to bisect substantially said recess therebetween.

14. The method of simulating barrel plating operation for laboratory evalution of plating conditions comprising providing a tank having an anode chamber and a cathode chamber separated by a wall pervious to passage of electrolyte and current, said tank containing an electrolyte for the plating operation to be evaluated; suspending an anode in the electrolyte in said anode chamber in substantially vertical relationship and extending substantially rectilinearly in the vertical plane; rotating in the electrolyte in said cathode chamber a cathode having predetermined surface area and consisting of a sheet metal member folded along its vertical center line into a base portion extending substantially vertically and a pair of spaced apart leg portions extending laterally therefrom to define a recess therebetween, said base portion extending in substantially vertical relationship and each of said leg portions extending in a substantially vertical plane and having its outer free edge extending substantially vertically and substantially rectilinearly; supplying current to said anode and rotating cathode to produce current flow through said electrolyte and pervious wall with variation in the current density and the metal plate deposited along the surface of said rotating cathode leg portions inwardly of the outer free edges and towards said base portion; and thereafter flattening said cathode to evaluate the metal plate deposited inwardly of the ends of said leg portions and towards the base portion.

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JOHN H. MACK, *Primary Examiner.*

MURRAY TILLMAN, WINSTON A. DOUGLAS, *Examiners.*