United States Patent [19]

Cordone et al.

[11] **3,922,208**

[45] **Nov. 25, 1975**

[54] **METHOD OF IMPROVING THE SURFACE FINISH OF AS-PLATED ELNISIL COATINGS**

[75] Inventors: **Leonard G. Cordone,** Allen Park; **William A. Donakowski; John R. Morgan,** both of Dearborn Heights; **Karl Roemming,** Detroit, all of Mich.

[73] Assignee: **Ford Motor Company,** Dearborn, Mich.

[22] Filed: **Mar. 6, 1974**

[21] Appl. No.: **448,799**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 413,153, Nov. 5, 1973, abandoned.

[52] **U.S. Cl.** **204/16;** 204/26; 204/238; 204/272

[51] **Int. Cl.²** **C07C 51/44;** B01D 3/00

[58] **Field of Search**... 204/26, 16, DIG. 7, 237-241, 204/232, 212, 259, 260, 275, 272

[56] **References Cited**

UNITED STATES PATENTS

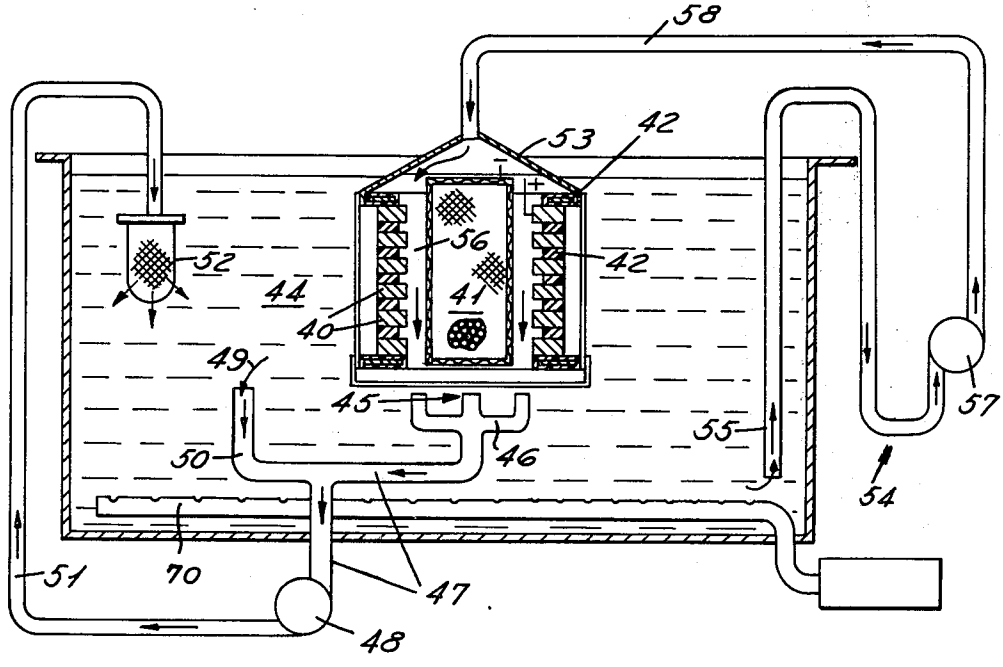
2,406,956	9/1946	Matthews	204/272
2,431,949	12/1947	Martz	204/272
2,487,399	11/1949	Thurber	204/238
3,061,525	10/1962	Grazen	204/16
3,450,625	6/1969	Ramsey et al.	204/237
3,514,389	5/1970	Stephan et al.	204/237
3,640,799	2/1972	Stephan et al.	204/16

Primary Examiner—T. M. Tufariello
Attorney, Agent, or Firm—Joseph W. Malleck; Keith L. Zerschling

[57] **ABSTRACT**

A method and apparatus is disclosed for electrolytically depositing a nickel-silicon carbide dispersion onto an epitrochoid surface of a rotor housing for a rotary internal combustion engine. The electrolyte contains a high concentration of said silicon particles which must be uniformly distributed in the dispersion and be free of debris for achieving high wear-resistance if the dispersion is to serve as a functional part of said engine. A unique filtering system is employed having a first screening barrier enclosing the anode assembly and a trap containing a second screening barrier located in the electrolyte remote from said anode assembly. Each of said barriers have a mesh size effective to prevent passage of anode debris but to permit passage of the desirable silicon carbide particles. The electrolyte is drawn through the first barrier into the anode assembly and then separated for introduction to the trap for return to the electrolyte after passing through said second barrier. Air agitation is used to scrub said second screening barrier for promoting a continuous operation. Means may also be employed to separate another portion of the electrolyte which is then mixed with the other separated solution for introduction together to said second screening barrier; a unique baffle is employed to set up a tortuous path for electrolyte entering said means to prevent clogging under continuous operation, such as from air bubbles. To increase plating speed, a further modification may be employed utilizing forced turbulant electrolyte between the anode and cathode.

17 Claims, 3 Drawing Figures



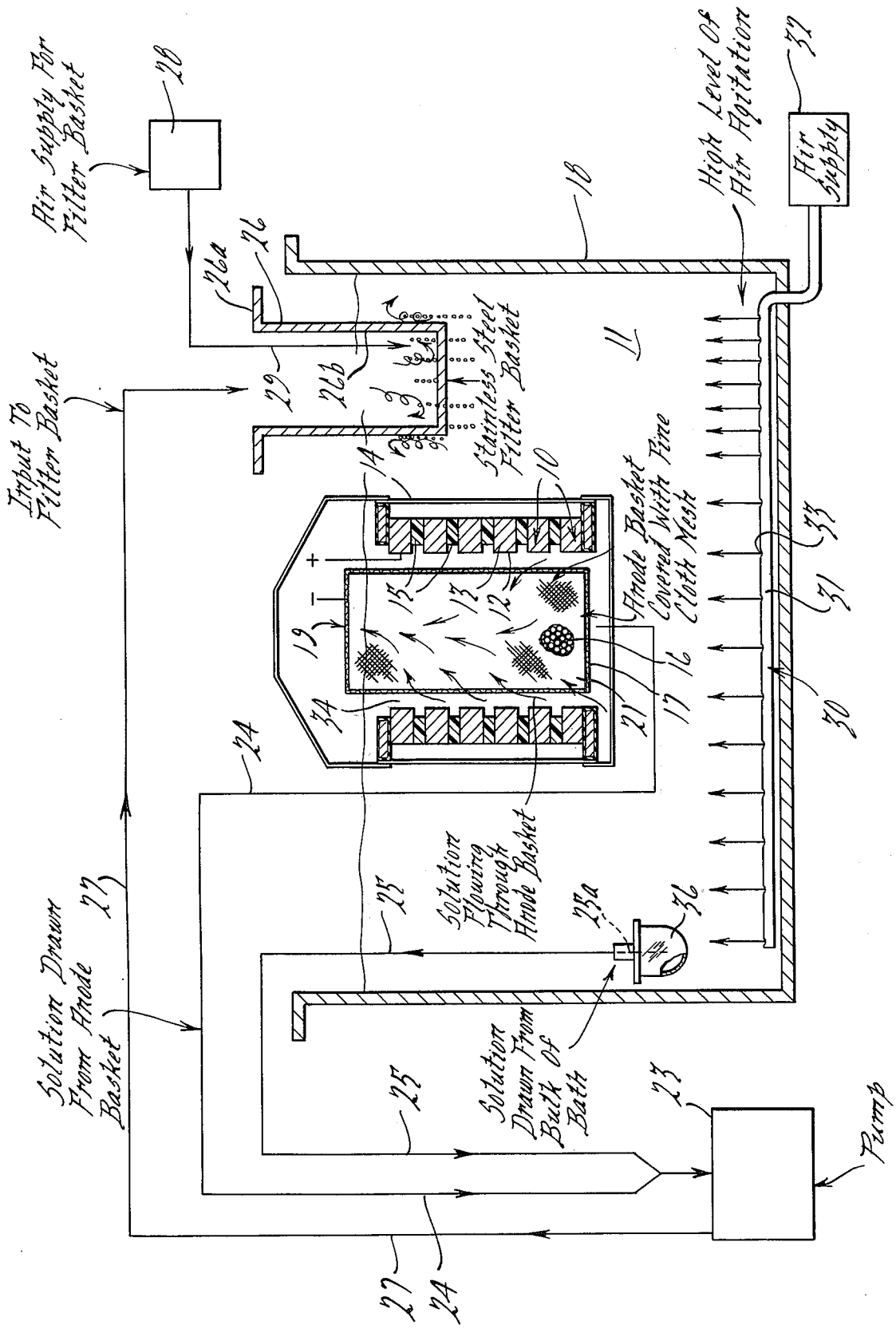

Air Supply For Filter Basket
28
26a
26
18
High Level Of Air Agitation
37
Air Supply
Input To Filter Basket
29
26b
Stainless Steel Filter Basket
11
14
10
Anode Basket Covered With Fine Cloth Mesh
15
13
12
19
16
17
21
24
35
37
30
Solution Flowing Through Anode Basket
25
25a
26
Solution Drawn From Bulk Of Bath
Solution Drawn From Anode Basket
27
25
23
Pump
27
24

FIG. 2

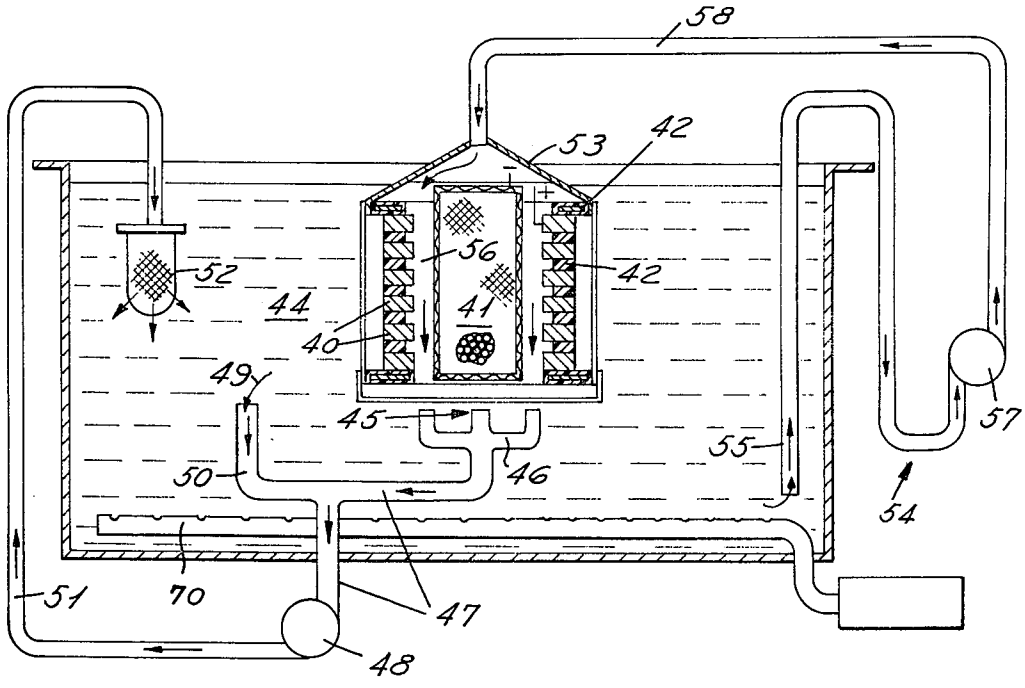
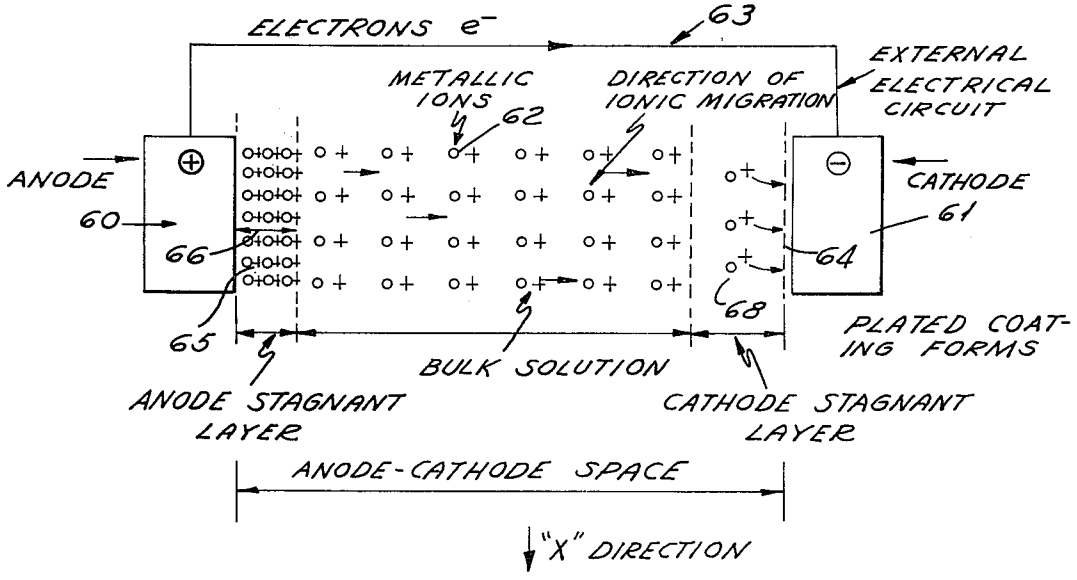

58
53
42
56
42
52
44
41
40
49
45
46
55
57
50
54
51
70
47
48

FIG. 2A


ELECTRONS e⁻
63
EXTERNAL ELECTRICAL CIRCUIT
METALLIC IONS
62
DIRECTION OF IONIC MIGRATION
ANODE
60
66
65
CATHODE
61
64
68
PLATED COATING FORMS
BULK SOLUTION
ANODE STAGNANT LAYER
CATHODE STAGNANT LAYER
ANODE-CATHODE SPACE
"X" DIRECTION

METHOD OF IMPROVING THE SURFACE FINISH OF AS-PLATED ELNISIL COATINGS

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of our abandoned application Ser. No. 413,153, filed Nov. 5, 1973 and having the same title as the present application.

BACKGROUND OF THE INVENTION

The need for highly wear-resistant coatings useful as functional parts of a rotary internal combustion engine has taken on new importance. One of the more successful techniques has been to electrolytically deposit a nickel composite having a uniform dispersion of silicon carbide particles. The coating can be deposited on a mandrel and then transferred to a die-cast machine where an aluminum housing or supporting structure is cast thereabout. Alternatively, the supporting structure can be cast first and then immersed in a plating solution for direct plating of a controlled coating of nickel with inert particles of silicon carbide deposited throughout, the structure being arranged cathodically in the plating system.

The efficient electroplater seeks not only to carry out an electroplating system or process at a low cost, but to produce platings which are of good quality. For purposes of a rotary engine application, good quality means a high degree of homogeneity and cleanliness, and uniform thickness. To achieve these characteristics, uniformity of electrolyte suspension, constant anode area, constant current flow and freedom from contamination are factors which must be considered and overcome. The first factor has been overcome by way of an invention disclosed in co-pending application Ser. No. 413,154 assigned to the assignee of this invention. The next two factors have been overcome by still another invention disclosed in co-pending application Ser. No. 413,155 (also assigned to the assignee of this invention), pertaining to the use of a unique anode assembly. The last factor is a problem overcome by the present invention in a new efficient manner.

Contamination is an increased problem partly due to the use of the unique foraminous semi-conforming anode assembly of said co-pending application. A collection of small nickel pieces are nested together which result in greater anode surface area to release debris into the electrolyte; a considerable amount of this matter can be generated during a plating operation. Such debris is principally undissolved nickel along with some carbon and silicon intentionally added as formulation for the anode material. Anode debris is further increased by an attendant increase in the speed of plating resulting from forcing more current through the electroplating apparatus. It is important that mechanisms be found to increase the speed of plating if this technique is to be utilized for fabricating functional parts as opposed to a mere decorative coating.

The simple technique of removing the debris by conventional filtering circuits is not an answer to the present problem since the improved electrolyte must contain higher concentrations of suspended inert particles (such as silicon carbide) and since the removal of debris must lend itself to continuous operation and hopefully at an increases in plating speed.

SUMMARY OF THE INVENTION

The primary object of the invention is to provide a method and apparatus for improving the technique of electroplating composites of metal and inert particles, particularly with respect to overcoming the problem of a high incidence of anode debris encountered in the process.

Another object of this invention is to provide a technique for removing unwanted particles on a continuous basis from an electroplating system while permitting desirable and intended particles to be retained in the solution in a manner that renders a highly homogeneous electroplated product.

Yet still another object is to provide a method and apparatus for increasing the plating speed while conforming to the above objects.

Particular features pursuant to the above objects comprise the use of a first foraminous barrier having a mesh size which is effective to entrain unwanted particles within an anode assembly while allowing the passage of desirable particles therethrough. Means is provided or steps are taken to positively draw the plating solution through said first barrier and then to separate said drawn solution for transfer through a second foraminous barrier for return to the solution. The second foraminous barrier is disposed in a remote location of the solution from that of the anode assembly and has a mesh size effective to trap the unwanted anode debris therein while permitting the passage of the desirable inert particles for eventual deposition on a cathode. Steps or means are employed to agitate the passage of the separated solution through said second barrier for maintaining its effectiveness; a mechanism for such agitation comprises the use of an independent gas supply which is directed to scrub the interior of the trap; alternatively, a gas medium may be introduced in a predetermined pattern throughout the bottom horizontal zone of said solution. The latter may be accomplished by the use of conduits arranged in such zone each having minute perforations for emitting the gas as bubbles and at a flow rate to prevent laminar or phase separating conditions. Part of the emitted gas is particularly directed upwardly against and through the second barrier.

Plating speed can be increased dramatically by introducing forced turbulant recirculated electrolyte between the anode and cathode.

Still another object of this invention is to provide a process for improving the surface finish of an as-plated composite of a metal and dispersed inert particles while permitting an increase in the speed of plating.

SUMMARY OF THE DRAWINGS

FIG. 1 is a schematic illustration of a preferred apparatus for carrying out the method of this invention and which apparatus operates as a unique feature of this invention; and

FIG. 2 is an apparatus similar to that in FIG. 1 but incorporating means for increasing plating speed.

DETAILED DESCRIPTION

Referring to FIG. 1, a preferred apparatus for carrying out the subject invention is illustrated. The articles **10** to be plated are immersed in an electrolytic bath **11** to serve as the cathode in the electrolytic system. Here, several articles to be coated each comprise an epitrochoid surface **12** carried by a rotor housing **13** for a ro-

tary internal combustion engine; the housing surfaces **12** are of cast aluminum. The housings are stacked in series on a harness **14** and are separated one from the other by suitable inert spacers **15.**

Also immersed in the bath is an anode assembly **12.** Conventionally, bar type anodes have been used in electroplating and as the bar would be consumed in the course of electroplating, it would take on the form of a sphere or an irregular sponge-like mass whose overmost surface was much reduced with respect to the original anode. This has been overcome by the provision of a anodically inert basket formed of a metal which is effective to act as a conductor to the active anode metal contained in the basket; the active anode metal is in piece form, each of the pieces being in contact one with the other to as a plastic coated basket is utilized, conductive strips or rod electrodes are placed in the basket to make contact with the anodic pieces; preferably the basket can be formed of a metal such as titanium which forms an anodic film on its surface which affords corrosion resistance and electrical insulation, the basket thereby being rendered anodically inert. The anodic film formed on the titanium does not continue to grow as a function of electrolysis time, but reaches a finite thickness for any given voltage; time ratio in an electrolyte of constant composition. Thus, the basket is only a conductor of electricity to the anode pieces contained in the basket for proper dissilution. Constant current flow is maintained with these alternative mechanisms since the effective resistance of the anode does not vary; the titanium basket does not corrode and therefore the level of current flow is relatively even.

Inert particles are suspended in the electrolytic bath which will plate out along with the intended metal. A low voltage is applied between the cathode and the anode, causing a current to pass through the electrolytic solution, which electrolizes and plates the cathodic article with the anodic material to the desired thickness. In this way, articles may be plated with various metals, such as silver, copper, cadmium, nickel and a variety of other metals. The present invention is primarily concerned with anode structures for electroplating nickel.

The anode assembly **19** used here is of the above type. A replenishable pile of anode pieces **16** are vertically stacked within foraminous titanium basket **17,** the assembly being almost fully immersed in the electrolytic bath **11** contained by tank **18.** The basket **17** is ana elongated closed structure having small closely spaced openings along the length thereof. The foraminous character of the basket may be provided either by weaving the basket from titanium strands or by constructing the basket side walls from expanded titanium sheet metal and held in position by grooved titanium end plates. In either case the side walls are formed which is in a substantially epitrochoid configuration conforming substantially to the cathode except at reverse curvatures where a predetermined variance is desired. Washing may be applied over the side wall to prevent current throw at spacing between housings or at edges. The basket receives an electrical potential, but due to the anodic film thereon, acts solely as a conductor to pieces **16.**

Although not fully shown, the basket may be suspended from a conductive positive bus bar by means of a conductive hook and the article to be coated may be supported on an electrolytically conductive rack which is suspended by another conductive negative bus bar. A source of DC voltage is connected between the negative and positive bus bar conductors.

The electrolyte is of an acidic composition appropriate to a nickel plating operation and containing a high quantity of inert fine particles to be dispersed in the plated nickel. In industrial nickel plating processes there are at least 13 types of electroplating bath solutions, the choice of which depends on the type and thickness of the deposit required. Various nickel plating baths are disclosed in "Practical Nickel Plating" published by International Nickel Plating, Inc.

A preferred bath makeup comprises about 600 grams/liter of nickel sulfamate, about 120 grams/liter of silicon carbide having a mesh size no greater than 325 (more significantly, the mean dimension of the particles should not be greater than **3** microns) and a shape which is acicular or spherical. The bath further contains about 17 grams/liter of nickel chloride, about 45 grams/liter of boric acid (H_3Bo_3) and about 2.5 grams/liter of a stress reliever, such as saccharin, the remainder being water. A cathode current density is maintained at about 19–21 amps/decimeter^2, or about 200 amps/ft^2.

During electrolysis, the nickel pieces break off to form nickel debris primarily and to some extent traces of carbon and silicon which are contained in the nickel pieces originally. Such nickel debris tends to range in size upwardly from 80 microns.

A unique filtering system **20** is employed comprising a first barrier or screen **21,** here formed as a fine mesh cloth, mounted about and enclosing the anode assembly **19.** The cloth preferably has a mesh size of about 80, but can be varied between 60 and 100 for the type of bath makeup here used and provided a mesh differential is maintained with the trap to be described. Most importantly, the screen **21** should have a mesh size effective to prevent passage of nickel debris, solid carbon and silicon additions, while permitting passage of the particular inert particles selected for the dispersion coating. Pump **23** is effective to positively draw the electrolyte through a passage **24;** the latter passage extends into and through the anode assembly **19** to draw electrolyte from the interior thereof. The electrolyte will flow under suction, as indicated by the arrows in FIG. **1** from around the narrow space between the anode and cathode, through the cloth **21,** wall of the basket **17** and thence upwardly to passage **24.**

Similarly another portion of the electrolyte is drawn into passage **25** from a location remote from said anode assembly and mixed with the other separated portion of the electrolyte in passage **29.** The mixture is then conveyed through passage **27** under the influence of pump **23** to a second screening barrier **26** or trap formed as a stainless steel basket having a mesh size of about 100. The basket or trap is immersed in the electrolyte **11** with an open top **26a** held above the surface of the bath. The mixture of the separated quantities of solution will be introduced from passage **27** into the interior of basket **26** in a manner so that the mixture will flow from the interior to the electrolyte surrounding basket **26.**

To enable the filter system to operate continuously for purposes of commercially coating functional thicknesses without interruption, clogging of basket **26** by anode debris must be eliminated. To this end, a pressurzied supply **28** of air or other gas is directed by passage **29** or other means along the interior walls **26b** of the basket **26** to perform a scrubbing action whereby

unwanted debris is maintained agitated and in suspension within the fluid in the basket. The basket has a mesh size predetermined to allow the egress of silicon carbide particles or other desirable particles, but prevent passage of the nickel anode debris.

In addition means **30** is employed to introduce air or other suitable gas supply throughout the entire bottom horizontal zone of the electrolyte. A plurality of passages or tubes **31** are arranged adjacent the bottom wall of tank **18** and are commonly connected to a pressurized air supply **32.** Minute perforations **33** are provided in a predetermined pattern along the tubes to introduce the air in a stream of bubbles; each stream rises to affect a narrow cone of electrolyte immediately above each perforation. As a combination, the bubble streams prevent laminar or phase separation in the electrolyte insuring uniform distribution and high density of suspension of the desired silicon carbide particles. The air streams are particularly effective in carrying the uniform suspension into the narrow space **34** between the anode and cathode; in addition, the air streams immediately beneath basket **26** serve to augment the scrubbing action of air from supply **28.**

To prevent clogging of the entrance **25***a* to passage **28,** a baffle **36** is used to create a tortous path for solution being sucked thereinto. The baffle may be formed as a simple inverted cup comprising an inert material such as plastic.

A preferred method for carrying out the present invention comprises:

a. providing an electrolyte solution containing a nickel salt selected from the group consisting of nickel chloride, nickel sulfate, nickel fluoroborate, and nickel sulfamate. Introduce a high level of inert wear-resistant particles to the solution, at least in a concentration of 100 grams/liter.
b. suspend a semi-conforming anode assembly within said solution in juxtaposition to a cathode article to be coated, the anode assembly having foraminous walls of mesh metal which is anodically inert although carrying the anode current. A collection of anode pieces is stacked in the assembly interengaged with said walls.
c. surround said anode assembly with a fine mesh cloth on the order of 80 mesh.
d. provide a remote foraminous trap immersed (mesh size no larger than 0.100) in said solution but convenient to the surface of the solution for cleaning acess.
e. while a potential is maintained between said anode and cathode, positively draw said solution through said cloth into the interior of said anode assembly where it then separated.
f. introduce the separated solution to the interior of said trap for passage through the trap walls for return to the solution.
g. provide an air supply to direct a stream of bubbles for continuously scrubbing the interior of said trap walls, and provide an air supply of between 75–125 c.c./minute/ cm^2 for scavenging the entire solution as well as the outer walls of the trap and anode assembly.
h. positively draw another quantity of solution from a location in said electrolyte remote from the anode assembly and mixing said another quantity with first separated solution prior to introduction to the trap.

Maintaining a differential in the mesh size between the anode cloth and trap is essential to efficient operation of the filtering system. Only in this way will there be filtering of substantially all debris at the trap, rather than have the debris collected and deposited at the cloth. Such differential must be determined with respect to the rate of flow if the separated solution is conveyed and with respect to plating speed. In this case, the preferred differential is **20,** the anode cloth having a mesh of 80 and the trap having a mesh of 100.

Turning now to FIG. **2,** there is illustrated an alternative embodiment which is a modification of the apparatus of FIG. **1** effective to dramatically increase plating speed. The magnitude of the speed increase obtainable by the use of the alternative apparatus is at least twofold over the best speed obtainable with the apparatus of FIG. **1.** As in FIG. **1,** the rotor housings **40** to be coated act as cathodes and the foraminous basket **41** acts as an anode while being positioned centrally within the stack of rotor housings. The rotor housings **40** are separated one from the other by insulation **42** similar to that of FIG. **1.** The comparable anode pieces **43** are stationed within the anode basket and perform as in the preferred embodiment. Electrolyte **44** is drawn from a location **45** in the bath immediately below the basket **41;** at this location a plurality of entrance tubes **46** receive the electrolyte which has just exited from the space between the anode and cathodes or has migrated through the basket. The tubes are commonly connected to a conduit **47** to convey the electrolyte as drawn by a first pump **48** similar to that of the preferred embodiment. Additionally, electrolyte is drawn from a remote location **49** through tube **50** which joins with the principal conduit **47.** The electrolyte is pumped and conveyed through exit conduit **51** to the filtration basket **52** having a design similar to that in FIG. **1.** Basket **52** has a mesh size effective to permit the passage of the carbide particles but entrain anode debris; filtration is carried out as previously described wherein a fine mesh cloth, on the order of 80 mesh, surrounds the anode assembly and the stainless steel basket or trap is immersed in the electrolyte near the surface having a mesh size of about 100 and therefore contains a slightly smaller mesh than the cloth bag around the anode assembly; this differential is critical as described in the preferred embodiment.

The anode assembly is uniquely covered with a manifold **53** attached to the top of the stack of rotor housings **42** and separated by insulation **42.** A separate recirculting system or means **54** is effective to draw electrolyte from a remote portion **55** of the bath and force the separated electrolyte under high pressure through conduit **58** into the manifold **53** and through the chimney-like space **56** defined between the semi-conforming anode assembly **41** and the rotor housings **42.** The spacing between the anode and cathode, and the pump capacity, must be such as to insure turbulant flow in the chimney-like space therebetween. To achieve this, the solution flow speed in the chimney-like space should be in the range of 1–15 feet per second and the anode-cathode space should have a lateral dimension no greater than 0.3 inches. The pump **57** preferably may have a flow rate of 400–500 g.p.m.

The high plating speed or deposition results from the turbulant flow continuously breaking down the stagnant layers which form naturally at both the anode and the cathode surfaces. FIG. **2** (a) shows the major transport phenomenon occurring during such high-speed

plating. As the anode **60** dissolves, metallic ions **62** go into the solution. The metallic ions migrate toward the cathode under the influence of electromotive force supplied through an external circuit **63.** The ions are reduced at the cathode surface and form the plated coating **64.** As shown in the diagram, conditions exist as illustrated when the solution velocity through the anode-cathode space is in the X direction and is zero. Stagnant layers **65** achieve their maximum thickness **66** under such conditions. The anode stagnant layer is rich in metallic ions and the cathode stagnant layer **68** is depleted of metallic ions, said depletion being compared to the concentration of metallic ions in the bulk solution. Current flow through the external circuit and the plating speed are limited by the diffusion which must occur through the stagnant layers, most particularly, the cathode stagnant layer. The diffusion process will occur more readily if the stagnant layers are decreased in thickness. A decrease in thickness can be achieved by flowing the solution in the X direction sufficiently rapid to cause turbulence in the anode-cathode chimney-like space **56** (of FIG. **1**) which is the purpose of this modification. Higher current densities can be employed which result in higher plating and deposition rates at twice and preferably **10** times that of FIG. **1.** In this system it is also important that the air supply means **70** be used to introduce bubbles as shown in FIG. **1** to the lower portion of the bath for maintaining a low level of constant agitation.

We claim as our invention:

1. A method for improving the surface condition of an electroplated metal composite containing fine inert particles, said composite being electrolytically deposited upon a cathodically constituted article juxtaposed a semi-conforming foraminous anode, both said anode and cathode article being immersed in a plating solution, the method comprising:

a. surrounding said anode with an inert screen having a mesh size greater than the average particle size of said inert particles, but effective to trap debris emminating from said anode,

b. providing a removable foraminous trap in said solution at a location remote from said anode and having a mesh size substantially equal to or smaller than the mesh of said screen but larger than the size of said inert particles,

c. positively drawing said plating solution through said screen in a direction toward the interior of said anode and thence separating said drawn solution,

d. positively passing said separated solution through said trap in a direction from the interior of said trap to the surrounding solution, said passing being carried out while bubbling gas through said trap to scrub the separated solution as it passes through the trap whereby anode debris is continuously prevented from clogging said trap insuring the passage of said inert particles.

2. A method as in claim **1,** in which the mesh of said screen is in the range of 60–100.

3. The method of claim **1,** in which the mesh of said trap is in the range of 80–120.

4. The method as in claim **1,** in which said gas is air and is introduced at a plurality of predetermined statious located throughout the bottom horizontal zone of said solution effective to agitate the entire bath as well as agitate the separated solution passing through said trap.

5. A method as in claim **1,** in which said trap is arranged as a rigid foraminous basket immersed in the upper horizontal zone of said solution and having the top thereof open and exposed to the surrounding atmosphere.

6. The method as in claim **1,** in which said anode is comprised of a foraminous anodically inert enclosure containing a plurality of anodically active metal pieces, said enclosure being effective to pass current to said anode pieces for purposes of dissolution.

7. The method as in claim **1,** in which said anode is constituted of a titanium basket having a plurality of nickel pieces stacked in intimate contact within said basket.

8. The method as in claim **6,** in which said anode pieces are comprised of nickel.

9. The method as in claim **1,** in which the separated solution is joined with another separated portion of the solution drawn from a location in the solution remote from the anode, said joined separated solutions being introduced together into said trap.

10. In an apparatus for conducting coelectrodeposition of a metal and uniformly distributed inert particles, the apparatus having a tank containing a nickel sulfamate type plating solution into which is immersed an article to be coated, the improvement comprising:

a. a hollow foraminous anodically constituted assebmly substantially conforming to the shape of said article to be coated and having a perforate barrier disposed between the exterior of said assembly and said solution, said perforate barrier having a mesh size greater than the average particle size of said inert particles, but effective to trap debris generated within said anode assembly,

b. a metallic foraminous barrier immersed in said solution at a location remote from said anode, said remote barrier having a mesh size effective to permit the passage of said silicon carbide particles but trap anode debris,

c. means for positively drawing said solution through said first barrier into the interior of said hollow anode assembly and thence separated from said solution,

d. means for introducing said separated solution to said second barrier before migration back into said solution whereby said debris generated within said anode assembly is trapped within said second barrier for ease of removal, and

e. means for agitating the separated solution passing through said second barrier for maintaining said barrier free of clogged debris.

11. The apparatus as in claim **10,** in which said first barrier is particularly comprised of a flexible cloth surrounding said anode assembly, said cloth having a mesh size of about 80.

12. The apparatus as in claim **10,** in which said anode assembly is particularly comprised of an anodically inert basket having a collection of anodically active pieces interengaged therein.

13. The apparatus as in claim **12,** in which said anode pieces consist essentially of nickel and said anodically inert material is comprised of titanium having a titanium oxide coating thereon.

14. The apparatus as in claim **10,** further comprising means to positively draw a portion of the solution from a remote location from said anode assembly and thence to mix said drawn portion with said first separated solution when introduced to the second barrier.

15. The apparatus as in claim 10, in which said means for maintaining agitation is comprised of at least one conduit disposed substantially in the bottom horizontal zone of said solution and having a plurality of minute perforation therealong whereby air is conducted and introduced to the solution, said air being released through said perforations to generate a predetermined pattern of bubbles effective to effect eddy currents in said solution preventing laminar conditions, at least some of said bubbles being directed to migrate through said second barrier.

16. Apparatus for filtering an electroplating system having a foraminous anode assembly and a remote screen comprising:

a. means regulating the degree of foraminous openings in said anode assembly so as to insure the retention of anode debris within the assembly while permitting the entrance of solution containing fine particles therethrough,

b. means for drawing the solution of said system into, upwardly and out so as to be separated from said solution, reintroduced to said solution through said screen, and

c. means for agitating the separated fluid passing through said screen.

17. Apparatus as in claim 14, in which said means drawing a portion of said solution has a baffle covering the entrance thereto creating a tortous path for solution drawn thereinto to prevent clogging and air blockage.

* * * * *