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(54) **Electroplating method for carbon fibers and apparatus therefor.**

(57) Performing continuous electric plating of a carbon fiber strand (5) in a plating bath (11), an electric current is supplied to the carbon fiber strand (5) in a liquid (12) or an inert gas outside the plating bath (11) and electric plating is performed in the plating bath using the carbon fiber strand (5) as the cathode.

A metal-coated carbon fiber strand having substantially no uneven color tone and plating defects may be obtained.

EP 0 149 763 A2

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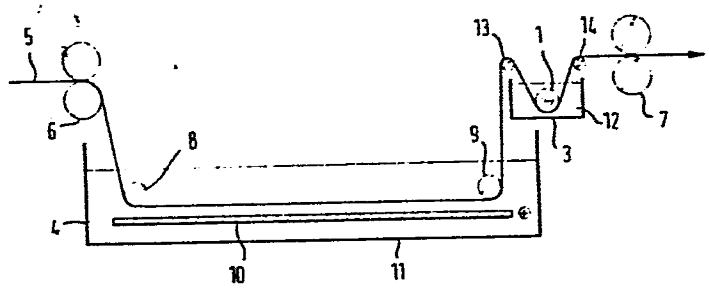
FIG.2



ELECTROPLATING METHOD FOR CARBON FIBERS AND APPARATUS THEREFOR

This invention relates to an electroplating method for carbon fiber strands and apparatus therefor.

The recent progress of carbon fiber-reinforced composite materials, which use carbon fibers as reinforcing fibers has been striking. In particular, when metal-coated carbon fibers are used as reinforcing fibers for electrically non-conductive materials such as thermosetting resins, thermoplastic resins, rubbers, papers, etc., composite materials result having excellent mechanical properties and greatly improved electric conductivity.

Recently, with the progress and increased use of computers, digital devices, etc., electromagnetic interference and high frequency interference have become significant problems, and composite materials using metal-coated carbon fibers as filler are being considered as so-called EMI shield materials (EMI: Electro Magnetic Interference), i.e., shield materials with respect to electromagnetic waves, etc. In particular, thermoplastic resin composite materials reinforced by metal-coated carbon fibers using thermoplastic resins such as polyamide, polyethylene, polypropylene, polystyrene, polyvinyl chloride, polycarbonate, polyacetal, polysulfone, an acrylonitrile-butadiene-styrene resin, polyethylene terephthalate, polybutylene terephthalate, polyphenylene oxide, etc., as the matrix material, and thermosetting resin composite materials reinforced by metal-coated fibers using thermosetting resins such as an epoxy resin, an unsaturated polyester resin, a phenol resin, etc., as the matrix material are excellent EMI shield materials having good mechanical properties and good formability.

Also, carbon fiber-reinforced metal composite materials wherein the same metal as used for coating carbon fibers is used as the matrix material, are excellent as light-weight structural materials, electrically conductive materials, slide materials, etc.

As a method for coating carbon fiber strands with a metal, there exist electroplating methods as described, for example, in U.S. Patent No. 3,662,283; JP-A-47,437/'73 and JP-A-169,532/'83, and Nippon Kinzoku Gakkai Shi (Journal of Metal Society of Japan), Vol. 38, No. 9, pp. 788-794 (1974). In order to apply uniform plating to every filament of a strand of carbon fibers by such plating methods, an electric current must be uniformly passed through every filament of the fiber strand but this is very difficult in practice.

As a method of passing an electric current through a carbon fiber strand, one method involves passing an electric current through a metallic roller and then bringing a carbon fiber strand into contact with the roller to pass the electric current to the carbon fiber strand, but in such a method it is impossible to bring every filament of the carbon fiber strand into contact with the roller, and therefor the electric current is passed through carbon fibers which are not in contact with the roller by the contact with the carbon fibers which are in contact with the roller. However, in general, the specific resistance of carbon fibers is of the order of 10^{-3} $\Omega \cdot cm$, which is much larger than the specific resistance of an ordinary metal of about 10^{-6} $\Omega \cdot cm$. Accordingly, in the case of passing an electric current through a carbon fiber strand in air, the contact resistance between the carbon fibers and a roller is large enough to generate heat, and the metal coating formed on the carbon fibers by electroplating tends to be oxidized by oxygen in the air and also by ozone generated by sparks occurring between the carbon fibers and the roller, which results in the occurrence of uneven color tone of the metal-coated carbon fiber strand, and the so-called plating defects such as burnt marks, lateral stripe marks, etc. If the metal coating is oxidized, the specific resistance of the metal-coated carbon fiber strand is increased, reducing the effect thereof as an EMI shield material.

An object of this invention is to provide an electroplating method for carbon fiber strands capable of overcoming the above-described difficulties and causing no uneven color tone and plating defects, and also to provide an apparatus for performing the method.

A further object of this invention is to provide a method for continuously applying electroplating uniformly onto every filament of a carbon fiber strand and to provide an apparatus for performing the method.

Thus, according to this invention, there is provided a continuous electroplating method for a carbon fiber strand which comprises continuously introducing a carbon fiber strand into an inlet of a metal plating bath and removing the carbon fiber from an outlet of the metal plating bath and applying an electric current to the carbon fiber strand in a liquid or an inert gas atmosphere outside of the metal plating bath and performing electroplating in the metal plating bath with the carbon fiber strand as the cathode.

According to another aspect of this invention, there is further provided a continuous electroplating apparatus for a carbon fiber strand for performing electroplating with the carbon fiber strand as a cathode, comprising an electroplating bath having an electric current applying section to the carbon fiber strand disposed in a liquid or an inert gas atmosphere outside the plating bath.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1 is a schematic view showing an example of the apparatus for performing the method of this invention using an inert gas;

Fig. 2 is a schematic view showing an example of the apparatus for performing the method of this invention using a liquid;

Fig. 3 is a schematic view showing an example of the apparatus for performing the method of this invention using three anodic metal plates, three electric current-applying sections and an inert gas at each electric current-applying section;

Fig. 4 is a schematic view showing an example of the apparatus for performing the method of this invention using three plating baths and also using a liquid at the electric current-applying sections;

Fig. 5 is a schematic view showing an example of the apparatus having a pre-treatment bath before the plating bath according to the invention; and

Fig. 6 is a schematic view showing an example of the apparatus shown in Fig. 5, said apparatus further having a means for spreading a carbon fiber strand disposed before the pre-treatment bath.

By the term "carbon fiber strand" in this specification is meant a carbon fiber strand or a graphite fiber strand usually composed of from about 100 to 100,000, and more generally from about 1,000 to 50,000, continuous fibers. The application of an electric current to the carbon fiber strand is generally performed by passing an electric current through a conductive roller such as a metallic roller and contacting the carbon fiber strand with the surface of the roller. In this invention, however, the whole conductive roller or at least the contacting portion of the conductive roller with a carbon fiber strand is disposed in a liquid or an inert gas atmosphere.

In this invention, the application of an electric current to the carbon fiber strand is performed at the position of the carbon fiber strand outside of the plating bath and in this case, the section of the application of electric current to a carbon fiber strand may be the inlet side or the outlet side of the plating bath, or may be both sides of the plating bath, but it is particularly preferred that an electric current is applied to a carbon fiber strand at the outlet side of the plating bath.

The liquid for use in this invention may be a non-electrolytic solution but is preferably an electrolytic solution. There is no particular restriction about the liquid for use in this invention if the liquid is inactive with respect to the fibers to be plated, however, when two or more plating baths are used and the section of applying electric current to the carbon fiber strand is disposed before at least one plating bath, it is preferred to use, for example, an aqueous solution containing the same component or components as that or those of the plating bath, and more preferably an electrolytic solution having the same composition as that of the plating bath, or an aqueous solution containing only the main component of the plating bath at a concentration from at least 20% of the concentration thereof in the plating bath to less than the concentration of the main component in the saturated solution thereof at the plating temperature. When an aqueous solution containing the same composition as that of the plating bath is used, it is preferred that the concentration of the composition in the aqueous solution is slightly lower, preferably more than 5% lower, more preferably more than 10% lower than that of the plating bath, since the concentration of a plating bath tends to increase during plating. By the term "the main component of a plating bath" is meant a salt of the metal which is plated on fibers.

When two or more plating baths are used and the section of applying electric current to a carbon fiber strand is disposed at the outlet side of the last plating bath or when a single plating bath is used and the section of applying electric current is disposed at the outlet side of the plating bath, the aqueous solution as described above can be used as the liquid, but the aqueous solution need not always necessarily be the same as the aqueous solution, and water and any other aqueous solution of an electrolyte such as an inorganic salt, for example, NaCl, Na_2CO_3, KCl, NH_4Cl, $CuSO_4$, $NiSO_4$ $ZnCl_2$, etc., can also be used.

The concentration of the solution is controlled so that the specific electric conductivity is preferably within the range of from 1×10^{-2} to 1 $\Omega^{-1} \cdot cm^{-1}$, more preferably from 2×10^{-2} to 5×10^{-1} $\Omega^{-1} \cdot cm^{-1}$.

The inert gas for use in this invention is, for example,

N_2, Ar, He, etc.

In the case of using a liquid or inert gas, no particular heating or cooling is necessary and the application of electric current is usually performed in the temperature range of from 10°C to 100°C, and preferably from 20 to 50°C.

Also, it is preferred that the conductive roller for the application of electric current be disposed at the outlet side of the carbon fiber strand.

When a liquid is used in this invention, the generation of heat by the contact resistance between the conductive roller and a carbon fiber strand can be minimized since the contact portion of the roller with the carbon fiber strand is in the liquid, whereby the oxidation of the coated metal formed on the fibers by electroplating does not occur. Also, when an inert gas is used in this invention, the contact portion of the roller with the carbon fibers is in an oxygen-free state since the portion is in the inert gas atmosphere, whereby the oxidation of the coated metal by high temperature oxidation, ozone oxidation, etc., does not occur even when heat is generated by the contact resistance. Accordingly, a metal-coated carbon fiber strand having neither uneven color tone nor so-called plating defects such as burnt marks, stripe marks, etc., can be obtained in this invention.

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The electric plating method of this invention can be used for plating a metal such as Cu, Ni, Cr, Zn, Cd, Pb, Sn, Au, Ag, etc., or alloys of at least two these metals, which can be used for ordinary electric plating.

The plating bath compositions for use in this invention are conventional, and examples of the plating bath compositions are as follows.

1. Ni plating composition:

(1) Hard nickel ordinary bath composition:

$NiSO_4 \cdot 6H_2O$	150-200 g/liter
NH_4Cl	10-20 g/liter
H_3BO_3	10-20 g/liter
Temperature	20-35°C
Electric current density	0.1-1 A/dm^2

(2) Watts bath composition:

$NiSO_4 \cdot 6H_2O$	240-300 g/liter
$NiCl_2 \cdot 6H_2O$	40-50 g/liter
H_3BO_3	25-35 g/liter
Temperature	40-70°C
Electric current density	0.1-5 A/dm^2

2. Cu plating composition:

(1) Copper sulfate bath composition:

$CuSO_4 \cdot 5H_2O$	125-250 g/liter
H_2SO_4	30-100 g/liter
Temperature	20-50°C

Electric current density	0.1-3 A/dm^2

(2) Copper fluoroborate bath composition:

$Cu(BF_4)_2$	220-250 g/liter
HBF_4	1.5-2.5 g/liter
Temperature	25-70°C
Electric current density	0.1-5 A/dm^2

3. Cr plating composition:

CrO_3	150-450 g/liter
H_2SO_4	1-5 g/liter
Temperature	40-70°C
Electric current density	0.1-10 A/dm^2

4. Zn plating composition:

$ZnSO_4 \cdot 7H_2O$	220-260 g/liter
NH_4Cl	10-20 g/liter
$Al_2(SO_4)_3 \cdot 18H_2O$	25-35 g/liter
$NaC_2H_3O_2 \cdot 3H_2O$	10-20 g/liter
Temperature	20-30°C
Electric current density	0.1-2 A/dm^2

5. Au plating composition:

$KAu(CN)_2$	6-18 g/liter
KCN	25-35 g/liter
K_2CO_3	10-20 g/liter
K_3HPO_4	25-35 g/liter
Temperature	50-60°C
Electric current density	0.05-0.5 A/dm^2

6. Ag plating composition:

AgCN	25-40 g/liter
KCN	45-65 g/liter
K_2CO_3	10-25 g/liter
Temperature	20-30°C
Electric current density	0.05-1 A/dm^2

The invention is further explained by reference to the accompanying drawings.

Fig. 1, Fig. 2 and Fig. 3 are schematic views each showing an example of the apparatus for performing the method of this invention. In Fig. 1 and Fig. 2, a carbon fiber strand 5 enters a plating bath 11 containing a plating bath composition 4 through inlet side nip rollers 6 and then is introduced to outlet side nip rollers 7 through an inlet side guide roller 8 and an outlet side guide roller 9, and through a seal box 2 in the case of Fig. 1 or a liquid bath 3 containing a liquid 12 in the case of Fig. 2.

The inside of the seal box 2 is filled with an inert gas such as N_2, Ar, He, etc., the pressure of which is slightly higher than the atmospheric pressure so that oxygen in air does not enter. Since the seal box 2 is connected to the plating bath 11, the seal box is shielded from external atmosphere. An electric current is applied to the carbon fiber strand 5 by contact with the surface of a conductive roller 1 for applying electric current placed in the seal box

2 or a liquid bath 3 (Figure 2), whereby a metal is plated on each filament of the carbon fiber strand 5 in the plating composition 4.

The electric current applying roller 1 is disposed in a seal box 2 as shown in Fig. 1 or in a liquid bath 3 as shown in Fig. 2 so that, in the latter case, the contact portion of the roller 1 with the carbon fiber strand 5 is in a liquid 12 in the bath 3. Numeral 10 shows a metal anode. Numerals 13 and 14 show guide rollers.

Fig. 3 shows the use of two or more plating baths and gas seal boxes which can be used in the manner of the apparatus shown in Fig. 1. Fig. 4 shows the use of two or more plating baths and liquid baths which can be used in the manner of the apparatus shown in Fig. 2.

Upon applying plating to each filament of a fiber strand, it is required to form proper space among the filaments for impregnating a liquid plating composition in the spaces among the filaments and also it is required to reduce the current density, and prolong the treatment period, and to adjust deposition of a metal onto the fiber in order to prevent bridging of the plated coating formed on the surface of the fiber strands, which disturbs the impregnation of the plating liquid composition into the inside of the fiber strand. Furthermore, in the case of applying metal plating onto a carbon fiber strand, lateral stripes are liable to form on the fibers in the direction at right angles to the longitudinal direction of the fiber strand in a conventional plating method and hence it is very difficult to obtain a metal-coated carbon fiber strand having no such lateral stripes by a conventional electroplating method.

Also, by a conventional method, for example, a method of applying an electrolytic solution onto a carbon fiber strand on an electric current applying roller as shown in Japanese Patent Application No. JP-A-169,532/'83, it is very difficult to obtain a metal-coated carbon fiber strand having no such lateral stripes.

In order to applying uniform and continuous electroplating without having lateral stripes onto every filament composing a carbon fiber strand, it is better as a preliminary to impregnate the carbon fiber strand with an aqueous electrolytic solution containing the main composition of the plating bath composition and then to introduce the carbon fiber strand into a plating bath, optionally through an electric current application section.

An aqueous electrolytic solution containing the main component of the plating bath composition is applied to a carbon fiber strand so that the inside of the carbon fiber strand is impregnated with the solution. The application of the electrolytic solution onto a carbon fiber strand is performed by passing the carbon fiber strand through a bath containing the electrolytic solution or by spraying the electrolytic solution onto the carbon fiber strand by a shower, etc. Furthermore, it is necessary to introduce the carbon fiber strand into the plating bath in a state such that the carbon fiber strand contains the electrolytic solution, that is, in a state such that the electrolyte does not deposit in or on the carbon fiber strand by evaporation of the solvent of the electrolytic solution. The content of the electrolytic solution impregnated in the carbon fiber strand is usually up to 200% by weight, and preferably higher than 5% by weight, based on the weight of the carbon fiber strand.

The elctrolytic solution usually contains, for example, a nickel salt, a Na, Ni or ammonium chloride, and a pH buffer in the case of nickel plating. Also, the electrolytic solution which is applied in a preliminary step to the carbon fiber strand may contain a nickel salt alone, which is the main component in the case of nickel plating, or may contain a nickel salt, a chloride as described above, and a pH buffer.

It is preferred that the concentration of the electrolytic solution for use in the case of preliminary application to a carbon fiber strand is from 20% of the concentration of the plating bath composition to less than the concentration of the saturated aqueous solution of the main component in the plating bath composition, more preferably from 50% of the concentration of the component to 90% of the concentration of the saturated aqueous solution of the component. If the concentration of the electrolytic solution is less than 20%, the difference of metal ion concentration between the surroundings of the carbon fiber strand and the central portion thereof in the plating bath is liable to become large and the thickness of the metal coating becomes uneven to cause the formation of lateral stripes.

Also, in the case of using a saturated aqueous solution of the component, it sometimes happens that the solvent is evaporated off from the solution before the carbon fiber strand containing the solution enters the plating bath to deposit the electrolyte in the spaces among the filaments of the carbon fiber strand and the surfaces of the strand, which results in hinder metal coating. The temperature at the application of the electrolytic solution onto the carbon fiber strand is generally in the range of from 10 to 80°C, and preferably from 20 to 50°C.

Furthermore, it is more effective to spread the filaments of a carbon fiber strand before or after or before and after preliminary application of the electrolytic solution onto the carbon fiber strand. As the method of spreading fibers of the carbon fiber strand, a conventional fiber opening method for fiber strands, i.e., a mechanical method, an electrical method, a method of utilizing a gas such as air, etc., can be used.

For example, the methods described in Japanese Patent Application No. JP-A- 131,023/'79, Japanese Patent Application No. JP-A- 106571/'84, etc., and a method using a guide roller or a guide bar can be utilized. In the case of using a guide roller or a guide bar, the roller or bar composed of a metal, glass, ceramic, etc., and having a radius or a curvature radius of 10 to 100 mm is preferably used. If the radius or curvature radius is less than 10 mm, the carbon fiber strand is damaged and filaments are cut to form fuzz, and if the radius or curvature radius is over 100 mm, the spreading of the carbon fiber strand becomes insufficient. By spreading the carbon fiber strand, every filament constituting the carbon fiber strand is uniformly plated without forming lateral stripes.

Fig. 5 and Fig. 6 are schematic views showing examples of the apparatus for performing the above-described pretreatments in the method of this invention.

In the examples shown in Fig. 5, a carbon fiber strand 5 is impregnated with an electrolytic solution by being passed through a pre-treatment bath 16 containing the electrolytic solution 15 containing the main component of a plating bath 11 and after the application of electric current by means of an electric current applying roller 18, is introduced into a plating bath 11. In the plating bath 11, a metal anode 10, a plating liquid composition 4 and a guide roller 8 are positioned, and the carbon fiber strand 5 is continuously passed through plating liquid composition 4.

Also, it is more effective to use a fiber spreading section having, for example, a guide rollers (or guide bars) 17 before the pre-treatment bath 16 containing an electrolytic solution 15 containing the main component of the plating bath 11.

Thus, by performing electroplating by introducing a carbon fiber strand into a plating bath after applying thereto an electrolytic solution containing the main component of the plating bath composition, a metal-coated carbon fiber strand wherein every filament constituting the carbon fiber strand is uniformly plated and having no lateral stripes can be obtained.

Examples of this invention are shown below.

Example 1

A carbon fiber strand composed of 12,000 filaments each having 7 μ diameter was continuously subjected to nickel plating using the apparatus shown in Fig. 1 having a seal box filled with an argon gas at a pressure of 1.2 atom ($1.2x10^5$ Pa) at a temperature of 30°C.

The plating bath composition was a hard nickel ordinary bath composition containing 150 g/liter of nickel sulfate, 15 g/liter of ammonium chloride and 15 g/liter of boric acid and the pH and the temperature of the plating bath composition were 6.0 and 25°C, respectively.

The travelling speed of the carbon fiber strand was 30 cm/min., the residence time in the plating bath was 5 minutes and the total electric current was 10 amperes.

For comparison, nickel plating was applied to carbon fiber strands under the same conditions as above except that the seal box was filled with air in place of argon gas.

The thickness of nickel coatings and the specific resistance of the nickel-coated carbon fiber strans were measured and the results are shown in Table 1 below.

Example 2

Nickel plating was applied to carbon fiber strands using the apparatus shown in Fig. 2 having a liquid bath for applying electric current containing an electrolytic solution having the same composition as that of the plating bath composition under the same conditions as in Example 1. The thickness of the nickel coating and the specific resistance of the nickel-coated carbon fiber strand were measured and the results thus obtained are shown in Table 1.

Table 1

	Thickness of Ni coating (μ)	Specific resistance (Ω·cm)
Example 1 (in argon)	0.28-0.32	5.4×10^{-5}
Comparison Example (in air)	0.27-0.32	1.7×10^{-4}
Example 2 (in electrolytic solution)	0.28-0.33	5.2×10^{-5}

As shown in the above results, in the cases of Examples 1 and 2, the specific resistance of the nickel-coated carbon fiber strands was greatly low as compared to the comparison example while the thickness of nickel coating was almost the same as that of the comparison example. This means that the nickel coating on each filament is uniform.

Furthermore, in the products of this invention obtained in Examples 1 and 2, uneven color tone and so-called plating defects such as burnt marks, lateral stripes, etc., were not observed.

Also, a resin composite material or a metal composite material using the product obtained in the foregoing examples of the present invention as the reinforcing material was excellent as an EMI shield material, a light-weight structural material, a conductive material, etc.

Example 3

A carbon fiber Besfight, HTA 7-12000 (Trade name of carbon fiber strand of 12,000 filaments having a diameter of 7 μ made by Toho Beslon Co., Ltd.) was continuously subjected to nickel plating. The travelling speed of the carbon fiber strand was 20 cm/min., the residence time in the plating bath was 5 min., the total electric current was 10 amperes, and the bath temperature was 25°C. The plating bath composition was a hard nickel ordinary plating composition containing 150 g/liter of nickel sulfate, 15 g/liter of ammonium chloride, and 15 g/liter of boric acid. A pre-treatment bath for preliminary application of an electrolytic solution to the carbon fiber strand was filled with an aqueous solution of 150 g/liter of nickel sulfate (100% of the nickel sulfate concentration of the plating bath composition) and the temperature of the pre-treatment bath was 25°C. The carbon fiber strand was passed through the pre-treatment bath, whereby the strand was impregnated with the electrolytic solution at a content of about 50%. Also, in other case of this example, three fiber opening guide rollers each having a radius of 25 mm were disposed in a straight line before the pre-treatment bath with a distance between the centers of the axes of 75 mm.

The cross-sections of the nickel-plated carbon fiber strands were observed by a scanning type electron microscope and the mean thickness of the nickel coating of the whole fiber strand, the thickness thereof on the fibers in the outermost portion of the strand, and the thickness thereof on the fibers in the central portion of the strand were measured. The outer portion is the portion of a fiber strand outside the portion of the 1/2 of the distance of the strand from the center of the strand in the radial direction of the strand, and the central portion is the remaining portion thereof. Also, nickel plating was applied to the carbon fiber strand under the same conditions as above, without preliminary applying the electrolytic solution to the carbon fiber strand and the thickness of nickel coating was measured in the same way as above. The results thus obtained are shown in Table 2.

Table 2

Application of electrolytic soln.	Opening guide roller	Thickness of Ni coating (μ) Mean	Outer portion	Central portion	Lateral stripe mark
Used	Used	0.27	0.25-0.29	0.24-0.27	None
Used	None	0.27	0.25-0.31	0.22-0.28	None
None	None	0.26	0.28-0.35	0.12-0.18	Observed

Example 4

The pre-treatment bath as in Example 3 was filled with an aqueous solution of 20 g/liter, 90 g/liter, or 150 g/liter of nickel sulfate or a nickel sulfate saturated aqueous solution of 30°C, and nickel plating was applied under the same conditions as in Example 3. The results thus obtained are shown in Table 3.

Table 3

Concentration of nickel sulfate aqueous soln.(g/l)	Thickness of Ni coating (μm) Mean	Outer portion	Central portion
20	0.26	0.25-0.32	0.15-0.20
90	0.27	0.26-0.31	0.22-0.28
150	0.26	0.24-0.29	0.23-0.28
Saturated soln.	(0.26)*	(0.24-0.30)	(0.20-0.25)

(*): Unplated portion of nickel was partially observed.

While the invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the scope thereof.

Claims:

1. An electroplating method for a carbon fiber strand characterised by continuously introducing a carbon fiber strand (5) into an inlet of a metal plating bath (11) and removing the carbon fiber strand (5) from an outlet of the metal plating bath (11) and applying an electric current to the carbon fiber strand in a liquid (12) or an inert gas atmosphere outside of the metal plating bath (11) and performing electroplating in the metal plating bath (11) with the carbon fiber strand (5) as the cathode.

2. An electroplating method as claimed in claim 1 characterised in that an electric current is applied to the carbon fiber strand (5) in a liquid (12) or an inert gas atmosphere at the outlet side of the carbon fiber strand outside the plating bath (11).

3. An electroplating method as claimed in claim 1 characterised in that two or more plating baths (11) are used and an electric current is applied to the carbon fiber strand (5) in a liquid (12) or an inert gas atmosphere at least at a position between the plating baths and a position at the outlet side of the last plating bath.

4. An electroplating method as claimed in claim 1 characterised in that the liquid (12) is an aqueous solution containing the same components as that of the plating bath (11).

5. An electroplating method as claimed in claim 1 characterised in that the liquid (12) is an aqueous solution having the same composition as that of the plating bath.

6. An electroplating method as claimed in claim 1 characterised in that the liquid (12) is an aqueous solution containing the metal salt contained in the plating bath.

7. An electroplating method as claimed in claim 6 characterised in that the concentration of the metal salt is from 20% of the concentration of the metal salt in the plating bath to less than the concentration of the saturated aqueous solution of the metal salt at the plating temperature.

8. An electroplating method as claimed in claim 7 characterised in that the concentration of the metal salt is lower than 90% of the concentration of the saturated aqueous solution of the metal salt at the plating temperature.

9. An electroplating method as claimed in claim 7 characterised in that the concentration of the metal salt is higher than 50% of the concentration of the plating bath.

10. An electroplating method as claimed in claim 1 characterised in that an electric current is applied to the carbon fiber strand (5) in the liquid (12) at the outlet side of the plating bath (11) in the case of using a single plating bath or at the outlet side of the last plating bath in the case of using two or more plating baths, and the liquid is water or an aqueous solution of an electrolytic inorganic salt.

11. An electroplating method as claimed in claim 10 characterised in that the electrolytic inorganic salt is a compound selected from the group consisting of NaCl, Na_2CO_3, KCl, NH_4Cl, $CuSO_4$, $NiSO_4$, and $ZnCl_2$.

12. An electroplating method as claimed in claim 10 characterised in that the concentration of the electrolytic inorganic salt is controlled so that the specific electrical conductivity is within the range of from 10^{-2} to $1\Omega^{-1}\cdot cm^{-1}$.

13. An electroplating method as claimed in claim 1 characterised in that the inert gas is a gas selected from the group consisting of N_2, He and Ar.

14. An electroplating method as claimed in claim 1 characterised in that the metal which is plated on carbon fibers is Cu, Ni, Cr, Zn, Cd, Pb, Sn, Au, Ag, or an alloy comprising at least two of said metals.

15. An electroplating method as claimed in claim 1 characterised in that the carbon fiber strand (5) to be plated is preliminarily impregnated with an aqueous solution containing the same metal salt as that contained in the plating bath (11).

16. An electroplating method as claimed in claim 15 characterised in that the concentration of the metal salt in the preliminary impregnating solution is from 20% of the concentration of the plating bath to less than the concentration of the saturated aqueous solution of the metal salt.

17. An electroplating method as claimed in claim 15 characterised in that the concentration of the metal salt in the preliminary impregnating solution is lower than 90% of the concentration of the aqueous saturated solution of the metal salt at the plating temperature.

18. An electroplating method as claimed in claim 15 characterised in that the concentration of the metal

salt in the preliminary impregnating solution is higher than 50% of the concentration of the plating bath.

19. An electroplating method as claimed in claim 15 characterised in that the content of the aqueous solution containing the metal salt is at least 5 weight % based on the weight of the carbon fiber strand.

20. An electroplating method as claimed in claim 15 characterised in that the content of the aqueous solution containing the metal salt is at most 200 weight % based on the weight of the carbon fiber strand.

21. An electroplating method as claimed in claim 15 characterised in that a spreading step is applied to the carbon fiber strand before the carbon fiber strand is impregnated with the aqueous solution.

22. A continuous electroplating apparatus for a carbon fiber strand for performing electric plating with the carbon fiber strand as the cathode characterised by an electric metal plating bath (11) having an electric current applying section for the carbon fiber strand disposed in a liquid (12) or an inert gas atmosphere outside of the plating bath (11).

23. A continuous electroplating apparatus as claimed in claim 22 characterised in that the electric metal plating bath (11) has a pre-treatment bath (16) for containing an aqueous electrolytic solution containing the metal salt contained in the plating bath (11) at the inlet side of the plating bath.

24. A continuous electroplating apparatus as claimed in claim 22 characterised in that the electric metal plating bath (11) has a section for spreading of the carbon fiber strand before the pre-treatment bath.

FIG.1

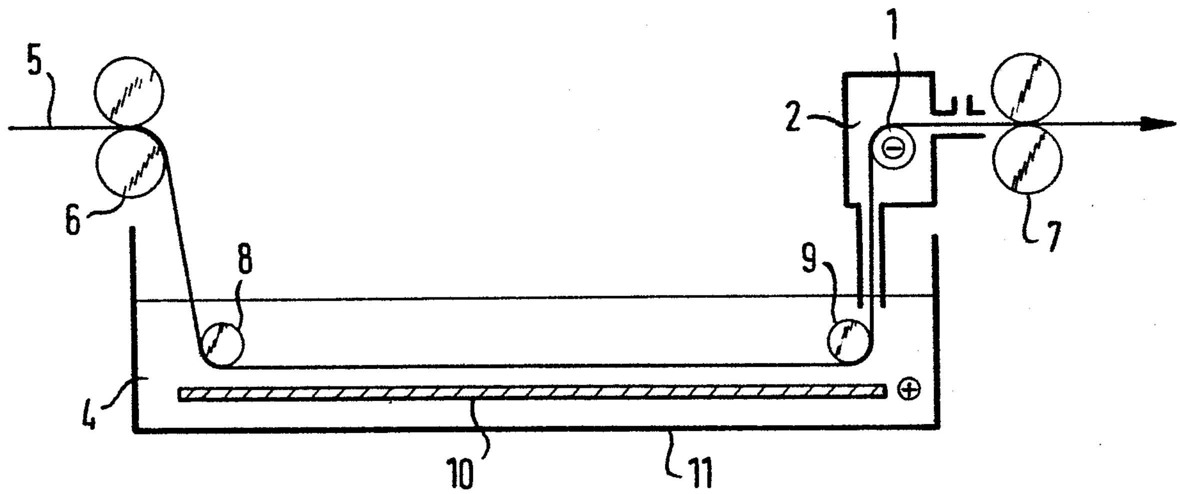

FIG.2

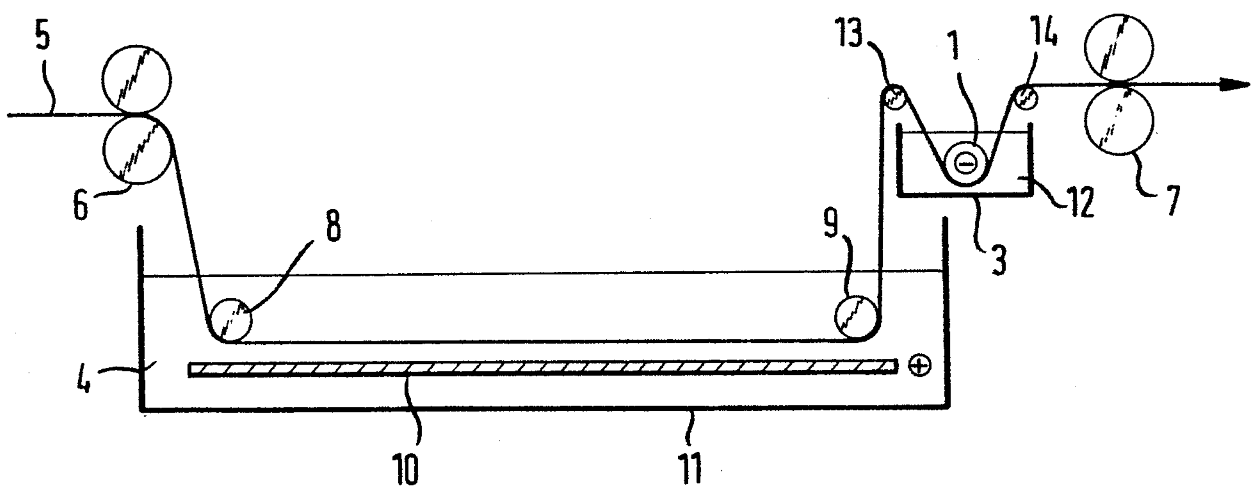

FIG. 3

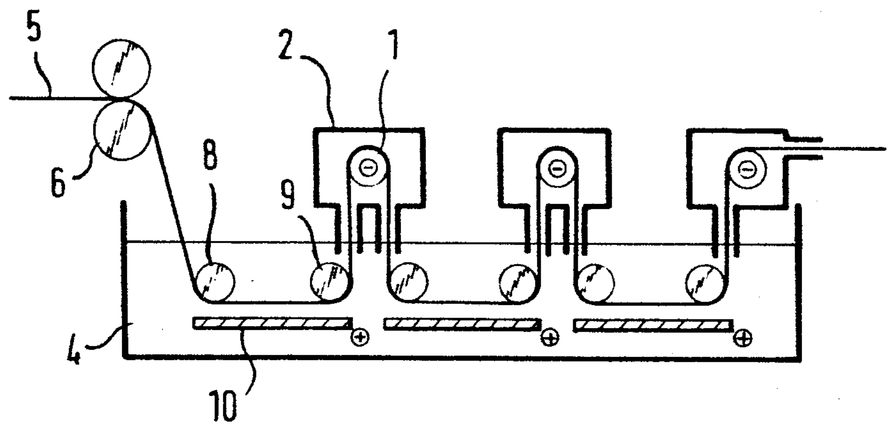

FIG. 4

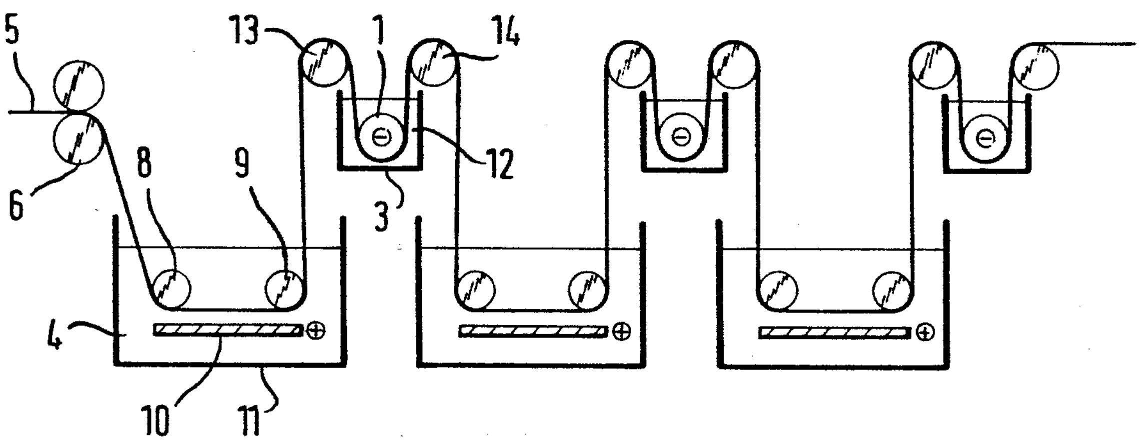

FIG. 5

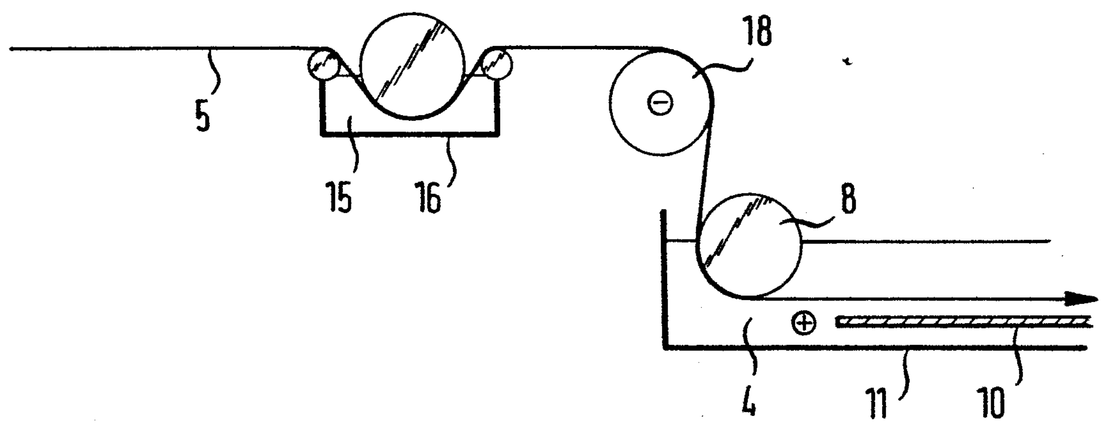

FIG. 6