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(54) Title: COPPER COATING <div data-bbox="434 1167 1324 1789" data-label="Image"> </div> (57) Abstract <p>A metal surface, usually copper, is micro-roughened to improve adhesion of polymeric materials, by the use of an adhesion-promoting composition comprising hydrogen peroxide, an inorganic acid, a corrosion-inhibitor which is for example a triazole, tetrazole or imidazole, and a quaternary ammonium surfactant. The process is of particular value in production of multi-layer PCBs to promote inter-layer adhesion.</p>		

COPPER COATING

In the production of a printed circuit board (PCB), in
5 a first (multi-step) stage, a "bare board" is prepared and
in a second (multi-step) stage, various components are
mounted on the board. The present invention relates to the
first stage in which the bare board is manufactured and to
the provision of an adhesion promotion step to improve
10 adhesion within a multi-layer board. A multi-layer board
comprises at least one insulating layer and at least one
conducting layer which comprises a conducting circuit
pattern. The conducting layer is therefore, generally, a
discontinuous sub-layer in the form of a circuit pattern.
15 The board may also comprise conductive pads and/or through-
holes. The conducting layer pattern and the conductive
pads and/or through holes are generally formed from copper.
The insulating layers are generally formed from fibreglass
bonded with epoxy-based resin.

20 Generally, a bare board is formed from an inner-layer
and at least one outer-layer. The expression inner-layer
as used in the PCB industry generally refers to a composite
of at least two layers (comprising an insulating layer and
a conducting layer), or more usually, three layers: a
25 central insulating layer, and on either side, a copper
conducting layer. The outer-layer which may be a pre-preg
may be a single insulating layer. Alternatively, it may
comprise both an insulating layer and a conducting layer.

During the manufacture of a PCB, at least one outer
30 layer is adhered to the conducting layer of the inner-layer
so that an insulating layer of the outer-layer is
innermost, contacting the conducting layer of the inner-
layer.

Preferably, a multi-layer board will be formed from at
35 least one inner layer and at least two outer layers, one
outer layer to be adhered to each conducting layer of the
inner-layer.

It has been found that in trying to permanently bond a copper conducting layer and an insulating layer to one another, it is difficult to provide a sufficiently strong bond. If a weak bond is formed, during the second manufacturing stage where components are mounted on the board, or later during use, delamination of the board may occur. In particular, the copper surface tends to oxidise on exposure to the atmosphere to form a tarnished layer on its surface. If an insulating layer is adhered directly to this tarnished layer, the bond will be weak and will eventually fail. Many methods of overcoming this problem have been proposed, the most commonly used method is to remove the tarnished layer and to form a strongly adherent copper oxide layer, known as black or brown oxide.

In order to form a black or brown oxide layer on a copper surface as preparation for adhesion, the copper surface generally undergoes in sequence, a cleaning step, a rinsing step, a caustic pre-rinse and an oxide processing step. In the oxide processing step, the temperature is generally no less than 50°C and the contact time with an oxidising solution is from 5 to 7 minutes. This contact time and relatively high processing temperature are disadvantageous as the high energy requirement and time period required increase processing costs. In addition, there are an undesirably high number of process steps.

However, the black or brown oxide layer adheres well to the copper and also forms a surface having good surface roughness so that adhesion to the neighbouring insulating layer is effective.

It would be desirable to form a surface which provides good adhesion to the copper and good surface roughness to provide adhesion to the neighbouring insulating layer (or other organic coating layer), using a simplified process and preferably also which does not require such high temperatures or such long processing times.

Metal treatment involving the use of acidic peroxide solutions is known. For example in CA-A-1250406, metals

such as iron, copper or their alloys are treated using a solution comprising hydrogen peroxide for metal pickling or polishing. The hydrogen peroxide solution is stabilised using a block of a solid stabiliser and optionally in addition a corrosion inhibitor such as benzotriazole and anionic or nonionic surfactant.

Because hydrogen peroxide decomposition is a problem, many hydrogen peroxide-based compositions have been developed, each comprising a different type of stabiliser system.

Cleaning or polishing compositions based on hydrogen peroxide are described for example in US-A-3556883 discloses compositions comprising hydrogen peroxide, sulphuric acid and alcohol stabilisers for cleaning of for example, metal wires. Other similar cleaning compositions are described in US-A-3756957 where a stabiliser for the hydrogen peroxide is selected from the group of aliphatic amines and their salts, alkoxy amines, aliphatic acid amines and aliphatic imines.

For use in the PCB industry, such compositions are known and have been described as etchant compositions to be used in the etching step for forming the copper circuit pattern: a layer of conductive foil, generally copper foil mounted on an insulating layer is partially protected in a pattern which corresponds to the final desired circuit pattern. The foil is then contacted with an etching solution and the areas of foil which are unprotected are etched away, leaving the desired circuit patterns. In etching processes, the metal foil which is contacted with the hydrogen peroxide-based composition is etched away for complete removal. This type of etchant composition and process is described for example in US-A-4144119, US-A-4437931, US-A-3668131, US-A-4849124, US-A-4130454, US-A-4859281 and US-A-3773577. In the latter two references, the etching composition also comprises a triazole to increase the rate of metal dissolution achieved by the etching composition.

In GB-A-2203387 a copper etching process is described with an etch bath regeneration step. A hydrogen peroxide etching composition comprising stabilisers including wetting agent is disclosed for cleaning copper surfaces of a PCB prior to electroplating an additional, thickening copper layer onto the conducting layer which is formed from copper. After the electroplating step a photoresist or screen resist is applied.

In US-A-4051057 (and DE-A-2555809) a bright dip composition for polishing/pickling metal surfaces, for instance of copper, comprises sulphuric acid, a hydroxy acid, such as citric acid, hydrogen peroxide, a triazole and/or a tertiary fatty amine. The final product should not have "pittings". The incorporation of surfactant is said to increase the rate of etching/removal of oxide from the surface, whilst the incorporation of benztriazole is said to improve the "levelling effect".

In US-A-3948703 chemical copper polishing compositions are described containing hydrogen peroxide, an acid and an azole compound. The compositions may also contain a surfactant and nonionic surfactants are used in the worked examples.

In US-A-4956035 chemical polishing compositions for metal surfaces comprise an etching composition, such as ferric chloride or peroxy sulphuric acid with a quaternary ammonium cationic surfactant and a secondary surfactant.

In GB-A-2106086 hydrogen peroxide/acid compositions are used to etch, chemically mill or bright dip copper surfaces. The compositions contain triazole compounds to stabilise them against decomposition by heavy metal ions.

In JP-A-06-112646 a copper surface is roughened to improve adhesion in laminates in the production of multi-layer PCBs. The roughening is carried out by a two-step process, each step involving treatment with a hydrogen peroxide/sulphuric acid composition. Both compositions must be free of corrosion inhibitor.

In JP-A-03-140481 to '84 copper surfaces are pretreated prior to lamination with a hydrogen peroxygen/sulphuric acid composition to form a roughened surface. In '484 the composition contains an additive (CB-896),
5 manufactured by the Mekki Co., which is said to accelerate the process and inhibit decomposition of peroxide.

In US-A-3773577 a copper etchant based on sulphuric acid and hydrogen peroxide contains an aliphatic amine, examples being primary or tertiary amines. The amines are
10 not surface active. In JP-A-03-79778 a copper etchant based on sulphuric acid and hydrogen peroxide contains a triazole and chloride ion together with an alcohol or glycol. In JP-A-51-27819 a copper etchant based on hydrogen peroxide and sulphuric acid contains a tetrazole
15 and optionally a tertiary amine or an alcohol.

The present inventors have surprisingly found that the use of a hydrogen peroxide-containing aqueous composition on a copper surface forms a cleaned copper surface which is micro-roughened and has sufficiently good porosity that a
20 particularly strong bond may be formed with an organic layer, as is required in the preparation of multi-layer PCBs.

In accordance with the present invention, there is provided a process for treating a metal surface comprising
25 contacting the conducting layer of the surface with an adhesion promotion composition comprising 0.1 to 20% by weight hydrogen peroxide, an inorganic acid, an organic corrosion inhibitor and a surfactant in an adhesion promotion step to form a micro-roughened conversion-coated
30 surface.

The process of the invention is particularly useful for forming a multi-layer PCB comprising an inner-layer and an outer-layer, the inner layer comprising at least one insulating layer and at least one conducting layer and the
35 outer-layer comprising at least an insulating layer, in which the conducting layer is the metal whose surface is treated in the invention. After the adhesion promotion



step a polymeric material is preferably adhered directly to the conducting layer of the inner-layer. The polymeric material may be the insulating layer of the outer-layer or for direct adhesion to the insulating layer of the outer-layer.

The process of the invention may also be used to provide a roughened surface to which polymeric materials such as photo imageable resins, solder masks, adhesives or polymeric etch resists have improved adhesion, usually in the manufacture of PCBs.

The process is particularly suitable where the metal is copper or a copper alloy. The process is hereinafter described by reference to the application to copper surfaces but it is to be understood that it can also be used for other metals. The process of the present invention has been found to be particularly advantageous as it overcomes the need for forming a black or brown copper oxide layer, as in the prior art processes. As explained above, the conducting layers of the inner-layer and/or outer-layer (which is optionally clad on the one side with the conducting layer) generally comprises copper or a copper alloy.

The adhesion promotion composition is an aqueous composition which comprises hydrogen peroxide, an inorganic acid, one or more organic corrosion inhibitors, preferably selected from triazoles, tetrazoles and imidazoles and a surfactant, preferably a cationic surfactant.

The adhesion promotion composition has been found to form a roughened conversion coated surface. From atomic surface analysis this coating is believed to comprise a complex of copper with the corrosion inhibitor on the conducting layer. This coating, it is believed, provides greater surface area so that good adhesion with the neighbouring organic coating can be formed.

Hydrogen peroxide is present in the adhesion promotion composition at a concentration of at least 0.01% by weight active hydrogen peroxide and preferably at least 1.0% by

weight hydrogen peroxide. The concentration of hydrogen peroxide is no greater than 20%, preferably no greater than 10%, more preferably no greater than 5% by weight, most preferably no greater than 4% by weight. It has been found that when the concentration of hydrogen peroxide in the adhesion promotion composition is too high the structure of the roughened surface of the conducting layer forms a somewhat coral-like structure which is more fragile than the desired roughening effect, so that it forms a weaker bond than when lower concentrations of hydrogen peroxide are used. The most preferred concentration of hydrogen peroxide is from 0.5% by weight of the adhesion promotion composition to 4% by weight.

The inorganic acid in the adhesion promotion composition is preferably provided by phosphoric acid, nitric acid, sulphuric acid, or mixtures thereof. Sulphuric acid is particularly preferred. The concentration of acid in the composition is generally at least 1%, preferably at least 8% and most preferably at least 9% by weight of the composition. Generally the concentration of acid in the composition will be no greater than 50%, preferably no greater than 30% and most preferably no greater than 20% by weight of the total composition.

The corrosion inhibitor is usually selected from one or mixtures of more than one triazole, tetrazole and imidazole. Triazoles are particularly preferred and optionally substituted benzotriazoles are most preferred. Suitable substituents are for example C_{1-4} alkyl substituents.

The corrosion inhibitor is preferably present in the adhesion promotion composition in an amount of at least 0.0001% by weight, preferably at least 0.0005%. Particularly desirable results are achieved with concentrations of at least 0.1%, more preferably more than 0.5% by weight and sometimes more than 1% by weight. Generally, the corrosion inhibitor will be present in the



composition in an amount no greater than 20% by weight and preferably no greater than 10% and more preferably less than 5% by weight of the total weight of the adhesion promotion composition. High concentrations, such as more
5 than 5% can be desirable as they can allow a reduction in the processing time. Preferably, however, the concentration is less than 5% or even less than 1%.

The surfactant is preferably a cationic surfactant, usually an amine surfactant. Most preferably it is a
10 quaternary ammonium surfactant is preferably one or more ethoxylated fatty amines. Preferably the surfactant will be a C_{10-40} surfactant, that is a surfactant comprising at least one (preferably one) C_{10-20} alkyl group. Suitable surfactants have at least one, preferably two hydroxy lower
15 alkyl groups, that is C_{1-4} hydroxyalkyl, and one or, less preferably, two lower alkyl, that is C_{1-4} -alkyl groups, attached to the nitrogen atom. Particularly preferred quaternary ammonium surfactants are isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and
20 isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride.

Generally the surfactant will be present in the composition in an amount of at least 0.001% by weight, preferably at least 0.005% by weight or even 0.01% by
25 weight. Generally, the surfactant will be present in the adhesion promotion composition in amounts no greater than 5%, preferably no greater than 3% and preferably no greater than 2.5% by weight. It has been found that if the concentration of surfactant is increased significantly
30 above 5%, the micro-roughened surface of the metal which forms the good adhesion promotion lacks uniformity so that good adhesion may not be provided over the entire surface of the conducting layer.

Preferably, the weight percentage of surfactant in the
35 adhesion promotion composition will be below the weight percentage corrosion inhibitor in the composition.



Other optional components may be incorporated in the composition. A preferred additional component comprises stabilising agent for the hydrogen peroxide. Suitable stabilising agents may be those mentioned in the patents
5 above. Examples include dipicolinic acid, diglycolic and thiodiglycolic acid, ethylene diamine tetraacetic acid and its derivatives, magnesium salt of an aminopolycarboxylic acid, sodium silicate, phosphates, phosphonates and sulphonates.

10 When the composition includes stabilising agent, preferably the stabilising agent is present in an amount of from 0.001% or even at least 0.005% by weight of the adhesion promotion composition. Generally there will be no
15 more than 5% by weight, preferably no more than 1% by weight in the composition.

The adhesion promotion composition may be made up by mixing the components in an aqueous solution, preferably formed using deionised water. In accordance with standard
20 safe practice, hydrogen peroxide will be added to the composition in a diluted form. The components forming the adhesion promotion composition will be mixed as required.

The copper surface is contacted with the adhesion promotion composition generally without any pre-treatment. The copper surface may have previously been provided with
25 a tarnish-inhibiting coating eg by incorporating the tarnish inhibitor into a resist stripping composition used in an immediately preceding step of etch resist stripping. Tarnish inhibitors used in such strippers are, for example a triazole or other coating. If so, it may be desirable to
30 pre-clean the copper surface with an acidic pre-cleaner such as PC 7078 or PC 7087 (tradenames of Alpha Metals Limited), before contact with the composition. Preferably prior to contact with the adhesion promotion composition, the copper surface will be substantially dry. Apart from
35 such a cleaning step, it is generally unnecessary to carry out any pretreating steps. In a preferred embodiment of the invention the adhesion promotion step follows

immediately after an etch resist stripping step or there is a single precleaning step between the etch resist stripping step and the adhesion promotion step.

5 Contact with the adhesion promotion composition may be by any conventional means for example by immersion in a bath of the adhesion promotion composition or by spraying or any other means of contact. Contact may be as part of a continuous process.

10 Generally contact of the copper surface with the adhesion promotion composition will be at a temperature no greater than 75°C, most preferably the temperature will be less than 50°C, for instance at ambient temperatures, for example from 10 to 35°C, usually above 15°C, most preferably from 20 to 30°C. The contact time will
15 generally be no less than 1 second, preferably no less than 5 seconds and often at least 10 seconds, most preferably at least 30 seconds. The maximum contact time may be up to 10 minutes, although preferably the contact time is no greater than 5 minutes, most preferably no greater than 2 minutes.
20 A contact time of about 1 minute or less than 1 minute is particularly preferred. It is surprising that the compositions can provide desirable results with such short processing times, that is with contact times of less than 2 minutes.

25 If the contact time of the adhesion promotion composition with the copper surface is too long, there is a risk that the copper surface may be etched away due to dissolution and/or that a deposit other than the micro-porous crystalline deposit which forms the micro-roughened
30 surface, will be deposited onto the surface of the conducting material.

The process has been found to be particularly advantageous because it can be used to replace the black copper oxide adhesion promotion step in a considerably
35 reduced number of steps. The micro-roughened surface which is formed provides good adhesion to an adjacent polymeric coating for example an epoxy bonded fibre glass resin of a

neighbouring insulating layer, or a resist material. The invention is particularly useful when used in combination with a bonding resist, for example as described in PCT/GB94/02258. The invention has also been found to be particularly useful when the copper which is treated is a foil produced in a drum side treatment process, which provides a copper foil in which the smooth, drum side is provided with an adhesion enhancing plating and the other side is rough, either or both sides being treated in the method, preferably the drum side, at least, being treated. The DSTF may be as described in WO-A-9421097 which is incorporated herein by reference and the present method is therefore used in addition to the adhesion promoting step suggested in that specification. The foil is thus provided on its drum side only with an adhesion enhancing plating, preferably of copper-zinc particles. The foil has been electrodeposited onto a smooth surface and preferably has a nominal conductive thickness in the range 2.5 to 500 μ m. The rough (or matte) side which is not coated with an adhesion enhancing plating may have a roughness R_z value of less than 10.2 μ m, ie the foil is a low profile foil, or less than 5.1 μ m (ie a very low profile foil) or it may be a standard foil (that is any roughness value).

After contact of the copper surface with the adhesion promotion composition to form the micro-roughened surface, generally a pre-preg layer may be placed directly adjacent to the copper surface and the pre-preg layer adhered directly to the copper surface in the adhesion step, forming a multi-layer PCB. Generally in the adhesion step heat is applied to initiate the adhesion reaction. In the adhesion step, mechanical bonding is due to penetration of the polymeric material of the insulating layer into the micro-roughened surface provided in the adhesion promotion step. As an alternative to the pre-preg layer, the polymeric material applied directly on top of the micro-roughened surface produced in the adhesion promotion step

a polymeric photo-resist, screen-resist solder mask or adhesive material may be directly applied.

As mentioned above, the present invention avoids the use of multi-step microetch processes which require additional steps between a microetch step and the subsequent PCB manufacturing steps between a microetch step and the subsequent PCB manufacturing step in which a polymeric layer is applied to the copper, including alkali dips, oxide and reducer steps. Although it may be desirable to follow the adhesion promotion step with a rinse step, it is often adequate to rinse just with water. The treated surface is optionally subsequently dried. According to a preferred embodiment of the process a polymeric material is subsequently adhered to the micro-roughened surface with no intermediate steps between the adhesion promotion step and the adhesion of the polymeric material, or with a single rinse and/or drying step.

Preferably a pre-preg insulating layer may be applied directly to the micro-roughened surface and in the adhesion step, pressure is also applied by placing the layers which are to form the multi-layer laminate of the PCB of at least the inner layer and outer-layer, in a press. Where pressure is applied it is generally from 100 to 400 psi, preferably from 150 to 300 psi. The temperature of this adhesion step will generally be from 100°C, preferably from 120°C to 200°C. The adhesion step is generally carried out for any period from 5 minutes to 3 hours, most usually from 20 minutes to 1 hour, but is for sufficient time and pressure and at a sufficiently high temperature to ensure good adhesion between the first and second layers. During this adhesion step, the polymeric material of the insulating layers which is generally an epoxy resin, tends to flow ensuring that the conductive pattern in the metal is substantially sealed between insulating layers and subsequent penetration of water and air is avoided.

If desired, several layers may be placed together in the adhesion step to effect lamination of several layers in



a single step to form the multi-layered board. As will be seen, the present invention provides a considerably simplified process over the known processes and provides a conducting surface formed from copper or other metals which has good adhesion.

The present invention also includes an adhesion promotion composition comprising 0.1% to 20% by weight hydrogen peroxide, an inorganic acid, 0.5 to 2.5% by weight of an organic corrosion inhibitor, preferably comprising triazole, tetrazole and/or imidazole and a cationic surfactant. In a particularly preferred composition, the composition also comprises a stabilising agent for hydrogen peroxide selected from those mentioned above.

Examples of the invention are given below:

Example 1-8

Adhesion promotion compositions 1-8 were made up by mixing the components in the various weight percentages given in Table 1 to form aqueous compositions.

Figure 1 shows the type of surface resulting on copper foil without an adhesion promotion treatment. Figure 2 shows the results obtained using a chemical cleaner as discussed above. Figure 3 illustrates the results obtained after treating copper foil in accordance with the present invention.

Standard copper foil has a smooth surface topography (fig. 1). The use of chemical microetch cleaners based upon sodium persulphate or ferric chloride chemically modifies the surface. The etching component does not dissolve the surface in a uniform manner, and the surface roughness is increased (fig. 2). The mechanism of the process described in the present invention is quite different. In this case copper is dissolved at the surface, this copper reacts with the inhibitor components to produce a film on the surface. This film is believed to be crystalline in nature because of its repeating structure. The colour of the film is red brown, and often shows the distinctive "cracked-mud" appearance under



magnification (fig. 3). It is this unusual surface structure that is believed to be the key to the excellent adhesion obtained with polymeric materials. They are able to flow into the fissures of the surface giving a good key.

- 5 The micro-roughened surface of the copper foil treated according to the invention is clear from these results.

Table 1

Component	Weight %							
	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Hydrogen Peroxide	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Sulphuric Acid	15	8.5	-	-	8.5	-	8.5	8.5
Nitric Acid	-	-	9.5	-	-	-	-	-
Phosphoric Acid	-	-	-	7.4	-	14.8	-	-
Benzotriazole	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
*Tomah Q 14-2	0.01	0.01	0.01	0.01	-	0.01	-	0.02
*Tomah Q 17-2	-	-	-	-	-	-	0.01	-
*Tomah E14-2	-	-	-	-	0.01	-	-	-
Deionised Water	to 100	to 100	to 100	to 100	to 100	to 100	to 100	to 100

* Trade name of Exxon Chemicals

Example 9

The solution in example 1 was used to treat copper-clad PCB inner layer panels. The solution was used at about 45°C with a contact time of 60 seconds. Half of the
5 panels were clad in Polyclad DSTFoil (trade mark of Polyclad Laminates, Inc. of West Franklin, New Hampshire, USA). After processing it was immediately noted that the DSTFoil samples had a much darker red-brown coloration than those with standard copper foil. The inner layers were
10 then pressed into 4 layer PCB'S following normal procedures. The PCB's were finished, and then tested for "pink-ring" and delamination following industry standard tests IPC-TM-650 & MIL-P-55110D respectively. All of the panels passed these tests.

15 In a further test standard copper foil & DSTFoil samples were treated with the solution in example 1. These foils were then laminated to prepreg material for the purpose of testing peel strengths in accordance with MIL-P-13949. Mean peel test values for the standard foil were in
20 the range 5.5-6.5 pounds per inch and those for the DSTFoil were in the range 6.5-7.5lb/in. Both foils showed performance equal or better than the generally accepted requirement of 5-6 pounds per inch. (Achieved using conventional alkaline black oxide processes as the copper
25 treatment.)

Example 10

Samples of typical simple single-sided PCB's were obtained before the application of solder resist. One example was passed through a mechanical brushing machine,
30 the other was treated with the solution in example 1. Both PCB's were then coated with a UV curing solder resist (supplied by Alpha Metals) using a screen printing technique. After the solder resist had been UV cured, adhesion of the resist was tested by immersing the samples
35 which had been brushed showed extensive blistering of the solder resist. The sample treated with this invention showed no blistering up to the point when the test was



terminated, at which point thermal degradation of the PCB substrate had occurred.

In a further test, the above was repeated using a photoimageable dry-film soldermask from the Dupont company.

- 5 In this case a similar improvement in adhesion was noted. It was also noted that the use of this pretreatment to enhance adhesion did not interfere with the clean development of the solder resist after imaging. This problem known as "resist lock-in" has been encountered with
10 other adhesion promoting processes.

**CLAIMS**

1. A process for treating a metal surface comprising contacting the metal surface with an adhesion promotion composition comprising 0.1 to 20% by weight hydrogen peroxide, an inorganic acid, an organic corrosion inhibitor and a surfactant in an adhesion promotion step to form a micro-roughened conversion-coated surface.
2. A process according to claim 1 in which the metal is copper or a copper alloy, preferably copper, more preferably a drum side treated copper foil.
3. A process according to claim 1 or claim 2 in which hydrogen peroxide is present in the adhesion promotion composition at a concentration of 1.0% to 4.0% by weight hydrogen peroxide.
4. A process according to any preceding claim in which the inorganic acid is phosphoric acid, nitric acid, sulphuric acid, or mixtures thereof, preferably sulphuric acid.
5. A process according to any preceding claim in which the concentration of acid in the composition is in the range 1 to 50%, preferably 9-20%.
6. A process according to any preceding claim in which the corrosion inhibitor is a triazole, tetrazole and/or imidazole, preferably a triazole, most preferably a benzo-triazole.
7. A process according to any preceding claim in which the corrosion inhibitor is present in the adhesion promotion composition in an amount of at least 0.0001% by weight, preferably at least 0.0005%, more preferably at least 0.1% and no greater than 20% by weight and preferably no greater than 10% by weight, more preferably up to 5% and most preferably up to 1% of the total weight of the adhesion promotion composition.
8. A process according to any preceding claim in which the surfactant is a cationic surfactant, preferably a quaternary ammonium surfactant.





- 9 A process according to claim 8 in which the quaternary ammonium surfactant is an ethoxylated fatty amine, preferably selected from isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride.
- 5
10. A process according to any preceding claim in which the surfactant is present in the composition in an amount of at least 0.1% by weight, preferably at least 0.5% by weight, and no greater than 5%, preferably no greater than 3% and most preferably no greater than 2.5% by weight.
- 10
11. A process according to any preceding claim in which the metal surface is contacted with the adhesion promotion composition without any pre-treatment.
12. A process according to any preceding claim which is carried out at a temperature up to 75°C, preferably in the range 15 to 35°C, most preferably 20 to 30°C.
- 15
13. A process according to any preceding claim in which the contact time is in the range 10 s to 10 minutes, preferably in the range 30 s to 2 minutes.
- 20
14. A process according to any preceding claim in which a polymeric material is subsequently adhered to the micro-roughened conversion coated surface, preferably with no steps between the adhesive promotion step and the step of adhering the polymeric material or with a single rinse and/or drying step.
- 25
15. A process according to any preceding claim which is for forming a multi-layer PCB comprising an inner-layer and an outer-layer, the inner layer comprising at least one insulating layer and at least one conducting layer and the outer-layer comprising at least an insulating layer, in which the metal surface which is treated is a conducting layer.
- 30
16. A process according to claim 15 in which, after the adhesion promotion step, a pre-preg layer is placed directly adjacent to the conducting layer and the two layers adhered to one another in the adhesion step, forming a multi-layer PCB.
- 35





17. An adhesion promotion composition comprising 0.1 to 20.0% by weight hydrogen peroxide, an inorganic acid, 0.5 to 2.5% by weight of an organic corrosion inhibitor and a cationic surfactant.
- 5 18. A composition according to claim 17 in which the concentration of hydrogen peroxide is in the range 1 to 4% by weight.
- 10 19. A composition according to claim 17 or 18 in which the surfactant is a quaternary ammonium surfactant, preferably an ethoxylated fatty amine, more preferably selected from isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride and in which the surfactant is present in the composition in an amount of at least 0.001% by weight, 15 preferably at least 0.005% by weight or even more than 0.01% by weight, and no greater than 5%, preferably no greater than 3% and preferably no greater than 2.5% by weight.
- 20 20. A composition according to any of claims 17 to 19 in which corrosion inhibitor comprises a triazole, tetrazole and/or imidazole in a concentration in the range 0.0005% to 10% by weight.
21. A composition according to any of claims 17 to 20 which comprises a stabiliser for hydrogen peroxide.
- 25 22. A composition according to claim 21 in which the stabiliser is selected from sulphonic acid, alcohols, aliphatic amines and their salts, alkoxy amines, aliphatic acid amines and aliphatic imines.
- 30 23. A composition according to claim 21 or 22 in which the acid is sulphuric acid.



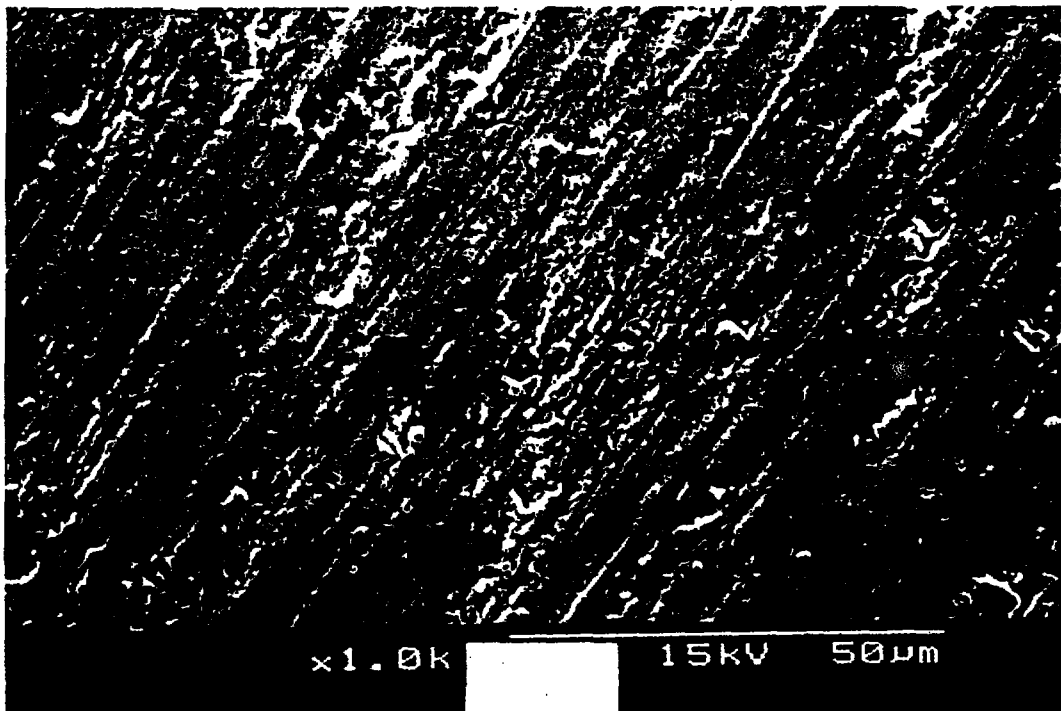


Figure 1

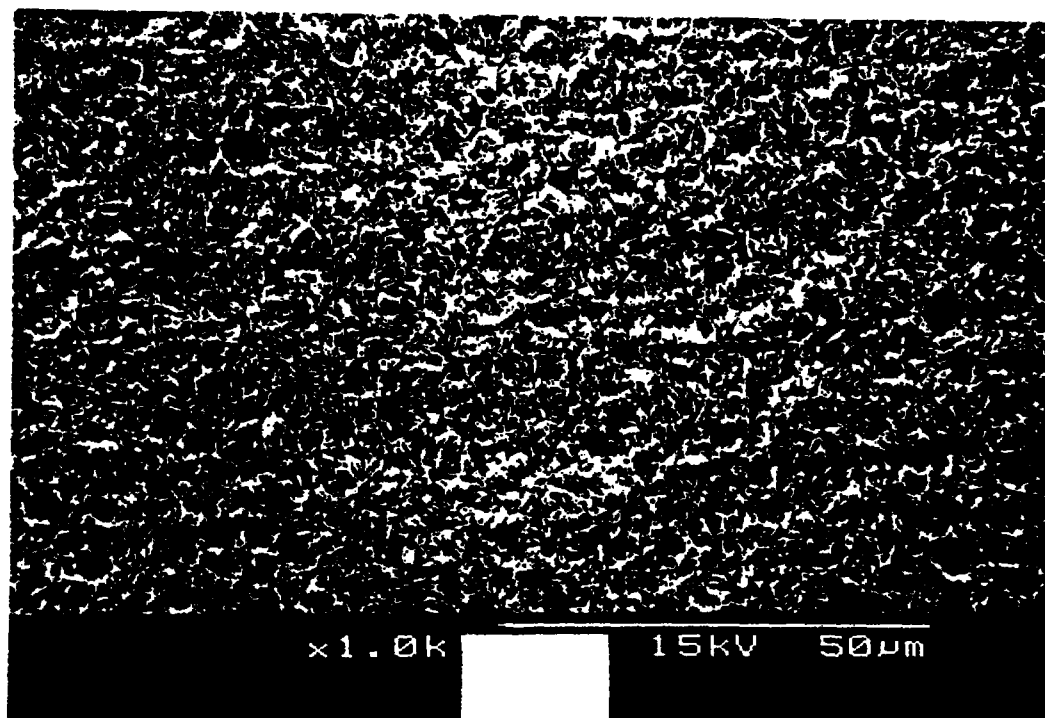


Figure 2

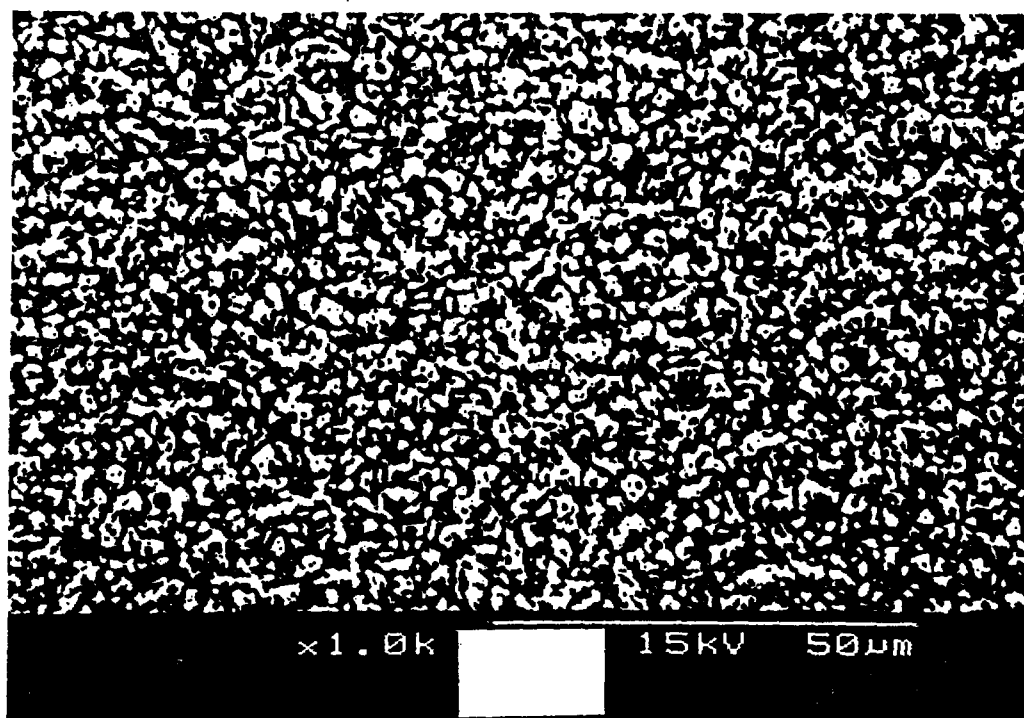


Figure 3

In JP-A-03-140481 to '84 copper surfaces are pretreated prior to lamination with a hydrogen peroxygen/sulphuric acid composition to form a roughened surface. In '484 the composition contains an additive (CB-896), manufactured by the Mekki Co., which is said to accelerate the process and inhibit decomposition of peroxide.

In US-A-3773577 a copper etchant based on sulphuric acid and hydrogen peroxide contains an aliphatic amine, examples being primary or tertiary amines. The amines are not surface active. In JP-A-03-79778 a copper etchant based on sulphuric acid and hydrogen peroxide contains a triazole and chloride ion together with an alcohol or glycol. In JP-A-51-27819 a copper etchant based on hydrogen peroxide and sulphuric acid contains a tetrazole and optionally a tertiary amine or an alcohol.

The present inventors have surprisingly found that the use of a hydrogen peroxide-containing aqueous composition on a copper surface forms a cleaned copper surface which is micro-roughened and has sufficiently good porosity that a particularly strong bond may be formed with an organic layer, as is required in the preparation of multi-layer PCBs.

In accordance with the present invention, there is provided a process of forming a micro-roughened conversion coated metal surface, which process comprises contacting the metal surface with an adhesion promotion composition comprising 0.1 to 20% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, at least 0.0001% by weight of an inorganic corrosion inhibitor and at least 0.001% by weight of a cationic surfactant in an adhesion promotion step whereby a micro-roughened conversion-coated surface is formed.

AMENDED SHEET

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The process of the invention is particularly useful for forming a multi-layer PCB comprising an inner-layer and an outer-layer, the inner layer comprising at least one insulating layer and at least one conducting layer and the outer-layer comprising at least an insulating layer, in which the conducting layer is the metal whose surface is treated in the invention. After the adhesion promotion

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AMENDED SHEET

weight hydrogen peroxide. The concentration of hydrogen peroxide is no greater than 20%, preferably no greater than 10%, more preferably no greater than 5% by weight, most preferably no greater than 4% by weight. It has been found that when the concentration of hydrogen peroxide in the adhesion promotion composition is too high the structure of the roughened surface of the conducting layer forms a somewhat coral-like structure which is more fragile than the desired roughening effect, so that it forms a weaker bond than when lower concentrations of hydrogen peroxide are used. The most preferred concentration of hydrogen peroxide is from 0.5% by weight of the adhesion promotion composition to 4% by weight.

The inorganic acid in the adhesion promotion composition is preferably provided by phosphoric acid, nitric acid, sulphuric acid, or mixtures thereof. Sulphuric acid is particularly preferred. The concentration of acid in the composition is at least 1%, preferably at least 8% and most preferably at least 9% by weight of the composition. The concentration of acid in the composition will be no greater than 50%, preferably no greater than 30% and most preferably no greater than 20% by weight of the total composition.

The corrosion inhibitor is usually selected from one or mixtures of more than one triazole, tetrazole and imidazole. Triazoles are particularly preferred and optionally substituted benzotriazoles are most preferred. Suitable substituents are for example C_{1-4} alkyl substituents.

The corrosion inhibitor is present in the adhesion promotion composition in an amount of at least 0.0001% by weight, preferably at least 0.0005%. Particularly desirable results are achieved with concentrations of at least 0.1%, more preferably more than 0.5% by weight and sometimes more than 1% by weight. Generally, the corrosion inhibitor will be present in the

composition in an amount no greater than 20% by weight and preferably no greater than 10% and more preferably less than 5% by weight of the total weight of the adhesion promotion composition. High concentrations, such as more than 5% can be desirable as they can allow a reduction in the processing time. Preferably, however, the concentration is less than 5% or even less than 1%.

The surfactant is a cationic surfactant, usually an amine surfactant. Most preferably it is a quaternary ammonium surfactant which is preferably an ethoxylated fatty amine. Preferably the surfactant will be a C_{10-40} surfactant, that is a surfactant comprising at least one (preferably one) C_{10-20} alkyl group. Suitable surfactants have at least one, preferably two hydroxy lower alkyl groups, that is C_{1-4} hydroxyalkyl, and one or, less preferably, two lower alkyl, that is C_{1-4} -alkyl groups, attached to the nitrogen atom. Particularly preferred quaternary ammonium surfactants are isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride.

Generally the surfactant will be present in the composition in an amount of at least 0.005% by weight or even 0.01% by weight. Generally, the surfactant will be present in the adhesion promotion composition in an amount of from 0.5% to 5%, preferably no greater than 3% and more preferably no greater than 2.5% by weight. It has been found that if the concentration of surfactant is increased significantly above 5%, the roughened surface of the metal which forms the good adhesion promotion lacks uniformity so that good adhesion may not be provided over the entire surface of the conducting layer.

Preferably, the weight percentage of surfactant in the adhesion promotion composition will be below the weight percentage corrosion inhibitor in the composition.

a polymeric photo-resist, screen-resist solder mask or adhesive material may be directly applied.

5 As mentioned above, the present invention avoids the use of multi-step microetch processes which require additional steps between a microetch step and the subsequent PCB manufacturing steps between a microetch step and the subsequent PCB manufacturing step in which a polymeric layer is applied to the copper, including alkali dips, oxide and reducer steps. Although it may be desirable to follow the adhesion promotion step with a
10 rinse step, it is often adequate to rinse just with water. The treated surface is optionally subsequently dried. According to a preferred embodiment of the process a polymeric material is subsequently adhered to the micro-roughened surface with no intermediate steps between the adhesion promotion step and the adhesion of the polymeric
15 material, or with a single rinse and/or drying step.

Preferably a pre-preg insulating layer may be applied directly to the micro-roughened surface and in the adhesion step, pressure is also applied by placing the layers which are to form the multi-layer laminate of the PCB of at least
20 the inner layer and outer-layer, in a press. Where pressure is applied it is generally from 689 to 2756 kPa (100 to 400 psi). Preferably from 1033 to 2066 kPa (150 to 300 psi). The temperature of this
25 adhesion step will generally be from 100°C, preferably from 120°C to 200°C. The adhesion step is generally carried out for any period from 5 minutes to 3 hours, most usually from 20 minutes to 1 hour, but is for sufficient time and pressure and at a sufficiently high temperature to ensure
30 good adhesion between the first and second layers. During this adhesion step, the polymeric material of the insulating layers which is generally an epoxy resin, tends to flow ensuring that the conductive pattern in the metal is substantially sealed between insulating layers and
35 subsequent penetration of water and air is avoided.

If desired, several layers may be placed together in the adhesion step to effect lamination of several layers in

a single step to form the multi-layered board. As will be seen, the present invention provides a considerably simplified process over the known processes and provides a conducting surface formed from copper or other metals which has good adhesion.

5 The present invention also includes within its an adhesion promotion composition comprising 0.1 to 20.0% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, 0.5 to 2.5% by weight of an organic corrosion inhibitor and at least 0.1% by
10 weight of a cationic surfactant.

Examples of the invention are given below:

Example 1-8

15 Adhesion promotion compositions 1-8 were made up by mixing the components in the various weight percentages given in Table 1 to form aqueous compositions.

20 Figure 1 shows the type of surface resulting on copper foil without an adhesion promotion treatment. Figure 2 shows the results obtained using a chemical cleaner as discussed above. Figure 3 illustrates the results obtained after treating copper foil in accordance with the present invention.

25 Standard copper foil has a smooth surface topography (fig. 1). The use of chemical microetch cleaners based upon sodium persulphate or ferric chloride chemically modifies the surface. The etching component does not dissolve the surface in a uniform manner, and the surface roughness is increased (fig. 2). The mechanism of the process described in the present invention is quite
30 different. In this case copper is dissolved at the surface, this copper reacts with the inhibitor components to produce a film on the surface. This film is believed to be crystalline in nature because of its repeating structure. The colour of the film is red brown, and often
35 shows the distinctive "cracked-mud" appearance under

Example 9

The solution in example 1 was used to treat copper-clad PCB inner layer panels. The solution was used at about 45°C with a contact time of 60 seconds. Half of the panels were clad in Polyclad DSTFoil (trade mark of Polyclad Laminates, Inc. of West Franklin, New Hampshire, USA). After processing it was immediately noted that the DSTFoil samples had a much darker red-brown coloration than those with standard copper foil. The inner layers were then pressed into 4 layer PCB'S following normal procedures. The PCB'S were finished, and then tested for "pink-ring" and delamination following industry standard tests IPC-TM-650 & MIL-P-55110D respectively. All of the panels passed these tests.

In a further test standard copper foil & DSTFoil samples were treated with the solution in example 1. These foils were then laminated to prepreg material for the purpose of testing peel strengths in accordance with MIL-P-13949. Mean peel test values for the standard foil were in the range 98.18 to 116 kg/m (5.5-6.5 pounds per inch) and those for the DSTFoil were in the range 116 to 133.87 kg/m (6.5-7.5lb/in). Both foils showed performance equal or better than the generally accepted requirement of 89.25 to 107.1 kg/m (5-6 pounds per inch). (Achieved using conventional alkaline black oxide processes as the copper treatment).

Example 10

Samples of typical simple single-sided PCB's were obtained before the application of solder resist. One example was passed through a mechanical brushing machine, the other was treated with the solution in example 1. Both PCB'S were then coated with a UV curing solder resist (supplied by Alpha Metals) using a screen printing technique. After the solder resist had been UV cured, adhesion of the resist was tested by immersing the samples which had been brushed showed extensive blistering of the solder resist. The sample treated with this invention showed no blistering up to the point when the test was

**CLAIMS:**

1. A process of forming a micro-roughened conversion coated metal surface, which process
5 comprises contacting the metal surface with an adhesion promotion composition comprising 0.1 to 20% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, at least 0.0001% by weight of an inorganic corrosion inhibitor and at least 0.001% by
10 weight of a cationic surfactant in an adhesion promotion step whereby a micro-roughened conversion-coated surface is formed.
2. A process according to claim 1 in which the
15 metal is copper or a copper alloy, preferably copper, more preferably a drum side treated copper foil.
3. A process according to claim 1 or claim 2 in which hydrogen peroxide is present in the adhesion
20 promotion composition at a concentration of 1.0% to 4.0% by weight hydrogen peroxide.
4. A process according to any preceding claim in which the inorganic acid is phosphoric acid, nitric
25 acid, sulphuric acid, or mixtures thereof, preferably sulphuric acid.
5. A process according to any preceding claim in which the concentration of acid in the composition
30 is in the range from 9 to 20% by weight.
6. A process according to any preceding claim in which the corrosion inhibitor is a triazole, tetrazole and/or imidazole, preferably a triazole,
35 most preferably a benzotriazole.





7. A process according to any preceding claim in which the corrosion inhibitor is preset in the adhesion promotion composition in an amount of from 0.0005% to 20% by weight.

5

8. A process according to any preceding claim in which the surfactant is a quaternary ammonium surfactant.

10

9. A process according to claim 8 in which the quaternary ammonium surfactant is an ethoxylated fatty amine, preferably selected from isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride.

15

10. A process according to any preceding claim in which the surfactant is present in the composition in an amount of from 0.5% to 5% by weight.

20

11. A process according to any preceding claim which is carried out at a temperature of up to 75°C.

25

12. A process according to any preceding claim in which the contact time is in the range 10s to 10 minutes.

30

13. A process according to any preceding claim in which a polymeric material is adhered to the microroughened conversion coated surface, immediately after the adhesive promotion step with an optional, intermediate single rinse and/or drying step.

35

14. A process according to any preceding claim which is for forming a multi-layer PCB comprising an





inner-layer and an outer-layer, the inner layer comprising at least one insulating layer and at least one conducting layer and the outer-layer comprising at least an insulating layer, in which the metal surface which is treated is a conducting layer.

15. A process according to claim 14 in which, after the adhesion promotion step, a pre-preg layer is placed directly adjacent to the conducting layer and the two layers adhered to one another in the adhesion step, forming a multi-layer PCB.

16. An adhesion promotion composition comprising 0.1 to 20.0% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, 0.5 to 2.5% by weight of an organic corrosion inhibitor and at least 0.001% by weight of a cationic surfactant.

17. A composition according to claim 14 in which the concentration of hydrogen peroxide is in the range 1 to 4% by weight.

18. A composition according to claim 16 or 17 in which the surfactant is a quaternary ammonium surfactant, preferably an ethoxylated fatty amine, more preferably selected from isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride and in which the surfactant is present in the composition in an amount of from 0.005% by weight to 5% by weight.

19. A composition according to any of claims 16 to 18 in which corrosion inhibitor comprises a triazole, tetrazole and/or imidazole in a





concentration in the range of 0.0005% to 10% by weight.

20. A composition according to any one of claims
5 16 to 19 which comprises a stabiliser for hydrogen peroxide.

21. A composition according to claim 20 in which
10 the stabiliser is selected from sulphonic acid, alcohols, aliphatic amines and their salts, alkoxy amines, aliphatic acid amines and aliphatic imines.

22. A composition according to claim 20 to 21 in
15 which the acid is sulphuric acid.

23. Copper having a micro-roughened surface
which is obtainable by the process as claimed in any
one of claims 1 to 15 and which has an appearance
under a 1000 times magnification substantially as
20 illustrated in Figure 3 of the accompanying drawings.

This Sheet Has Been Replaced





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REPLACEMENT SHEET

22 MAY 1998

CLAIMS

1. A process of forming a micro-roughened conversion coated copper or copper alloy surface, which process comprises contacting the copper or copper alloy surface with an aqueous adhesion promotion composition consisting of from 0.1% to 20% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, from 0.0001% to 20% by weight of an inorganic corrosion inhibitor, from 0.001% to 5% by weight of a cationic surfactant, optionally a stabilising agent for the hydrogen peroxide and the balance water.
2. A process according to claim 1 in which the copper is a drum side treated copper foil.
3. A process according to claim 1 or claim 2 in which hydrogen peroxide is present in the adhesion promotion composition at a concentration of 1.0% to 4.0% by weight hydrogen peroxide.
4. A process according to any preceding claim in which the inorganic acid is phosphoric acid, nitric acid, sulphuric acid, or mixtures thereof, preferably sulphuric acid.
5. A process according to any preceding claim in which the concentration of acid in the composition is in the range from 9 to 20% by weight.
6. A process according to any preceding claim in which the corrosion inhibitor is a triazole, tetrazole and/or imidazole, preferably a triazole, most preferably a benzotriazole.

REPLACEMENT SHEET

22 MAY 1998



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7. A process according to any preceding claim
in which the corrosion inhibitor is present in the
adhesion promotion composition in an amount of from
5 0.0005% to 20% by weight.

8. A process according to any preceding claim
in which the surfactant is a quaternary ammonium
surfactant.

10

9. A process according to claim 8 in which the
quaternary ammonium surfactant is an ethoxylated fatty
amine, preferably selected from isodecyloxypropyl
dihydroxyethyl methyl ammonium chloride and
15 isotridecyloxypropyl dihydroxyethyl methyl ammonium
chloride.

10. A process according to any preceding claim
in which the surfactant is present in the composition
20 in an amount of from 0.5% to 5% by weight.

11. A process according to any preceding claim
which is carried out at a temperature of up to 75°C.

12. A process according to any preceding claim
25 in which the contact time is in the range 10s to 10
minutes.

13. A process according to any preceding claim
30 in which a polymeric material is adhered to the micro-
roughened conversion coated surface, immediately after
the adhesive promotion step with an optional,
intermediate single rinse and/or drying step.

14. A process according to any preceding claim
35



5 which is for forming a multi-layer PCB comprising an inner layer and an outer layer, the inner layer comprising at least one insulating layer and at least one conducting layer and the outer layer comprising at least an insulating layer, in which the metal surface which is treated is a conducting layer.

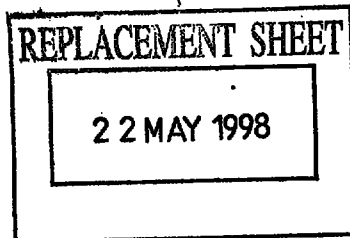
10 15. A process according to claim 14 in which, after the adhesion promotion step, a pre-preg layer is placed directly adjacent to the conducting layer and the two layers adhered to one another in the adhesion step, forming a multi-layer PCB.

15 16. An aqueous adhesion promotion composition consisting of from 0.1% to 20.0% by weight hydrogen peroxide, from 1% to 50% by weight of an inorganic acid, from 0.5% to 2.5% by weight of any organic corrosion inhibitor, from 0.001% to 5% by weight of a cationic surfactant, optionally a stabilising agent
20 for the hydrogen peroxide and the balance water.

25 17. A composition according to claim 14 in which the concentration of hydrogen peroxide is in the range 1 to 4% by weight.

30 18. A composition according to claim 16 or 17 in which the surfactant is a quaternary ammonium surfactant, preferably an ethoxylated fatty amine, more preferably selected from isodecyloxypropyl dihydroxyethyl methyl ammonium chloride and isotridecyloxypropyl dihydroxyethyl methyl ammonium chloride and in which the surfactant is present in the composition in an amount of from 0.005% by weight to 5% by weight.

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Substitute sheet - 19/5/98

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19. A composition according to any of claim 16 to 18 in which corrosion inhibitor comprises a triazole, tetrazole and/or imidazole.

5 20. A composition according to any one of claims 16 to 19 which comprises a stabiliser for hydrogen peroxide.

10 21. A composition according to claim 20 in which the stabiliser is selected from sulphonic acid, alcohols, aliphatic amines and their salts, alkoxy amines, aliphatic acid amines and aliphatic imines.

15 22. A composition according to claim 20 to 21 in which the acid is sulphuric acid.

20 23. Copper having a micro-roughened conversion coated surface in which the surface coating comprises a complex of copper with a corrosion inhibitor which is obtainable by the process as claimed in any one of claims 1 to 15.