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(54) **CORROSION INHIBITOR OF NICU FOR HIGH PERFORMANCE WRITERS**

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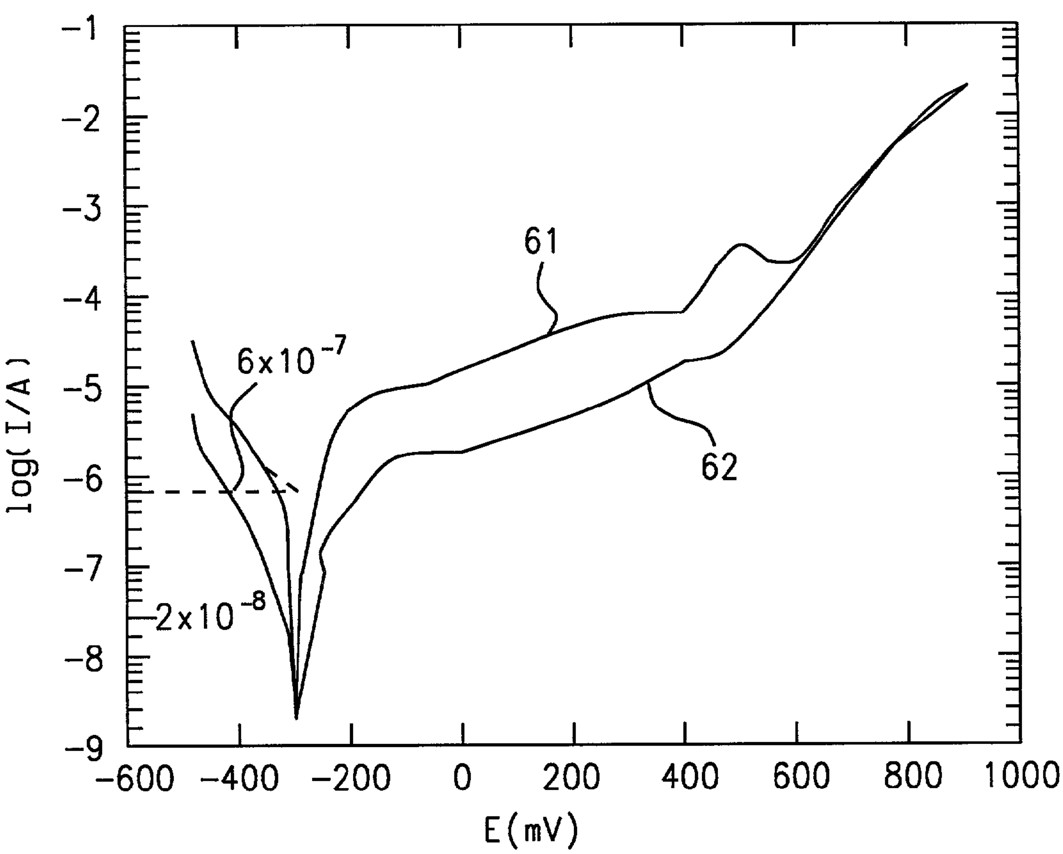
(57) **ABSTRACT**

The problem of copper corrosion that occurs in the presence of strong alkaline developing solutions during photo rework has been overcome by protecting all exposed copper bearing surfaces from attack. Two ways of achieving this are described. In the first method, benzotriazole (BTA) is added to the developing solution which is then used in the normal way, developing time being unaffected by this modification. In the second method, the surface that is to receive the photoresist is first given a dip in a solution of BTA, following which the photoresist is immediately applied and processing, including development, proceeds as normal. For both methods the result is the elimination of all copper corrosion during development.



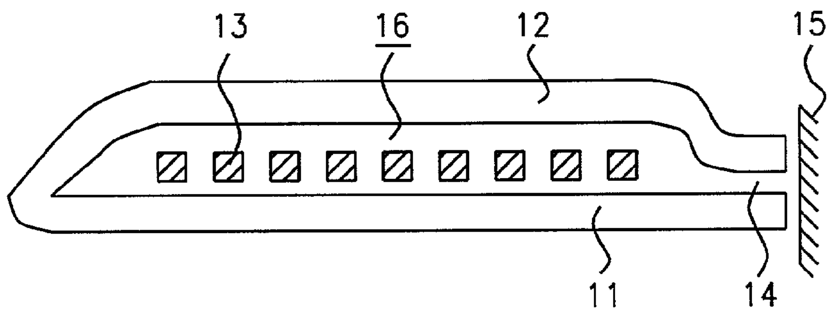


FIG. 1 – Prior Art

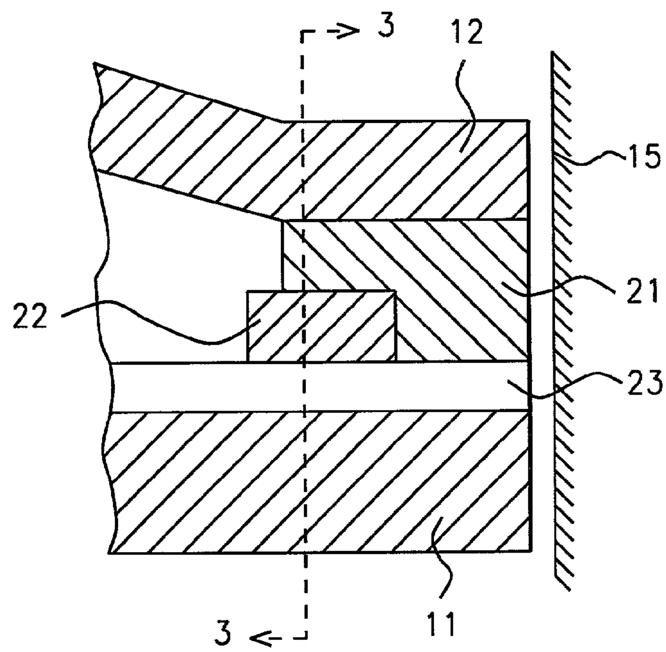


FIG. 2

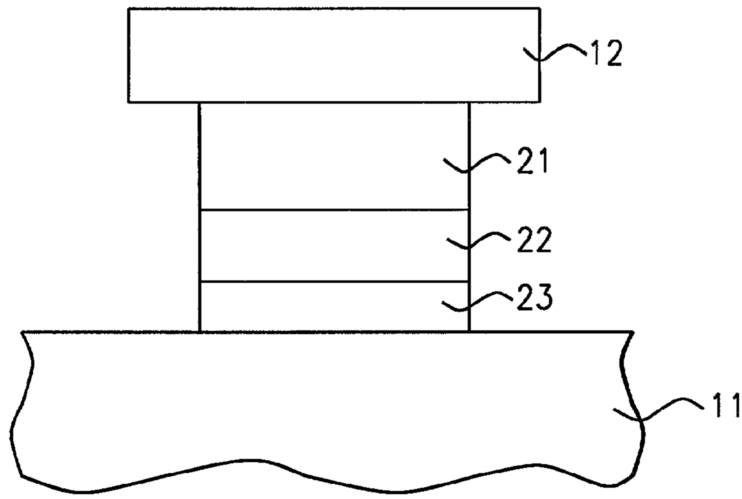


FIG. 3

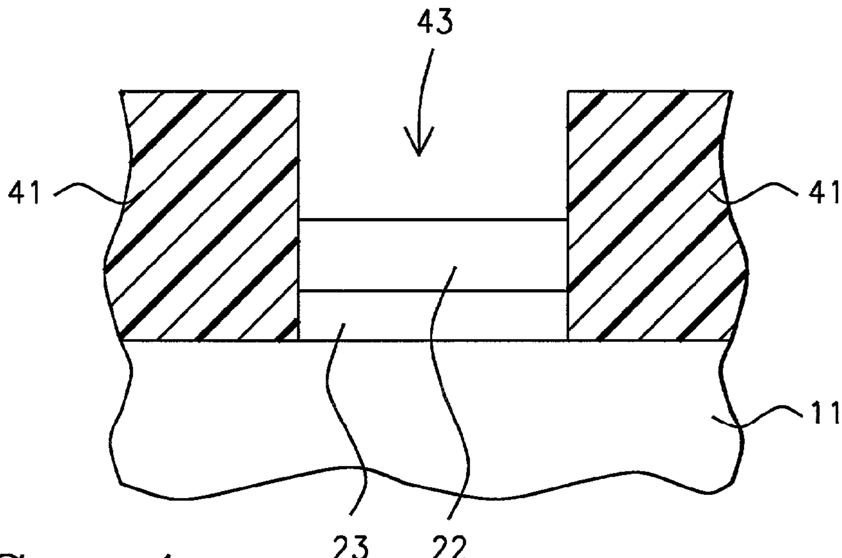


FIG. 4

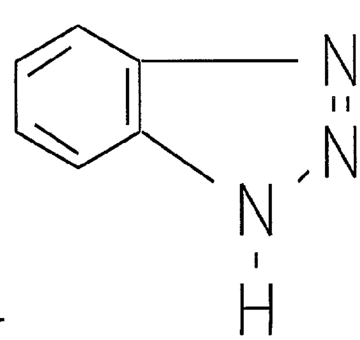
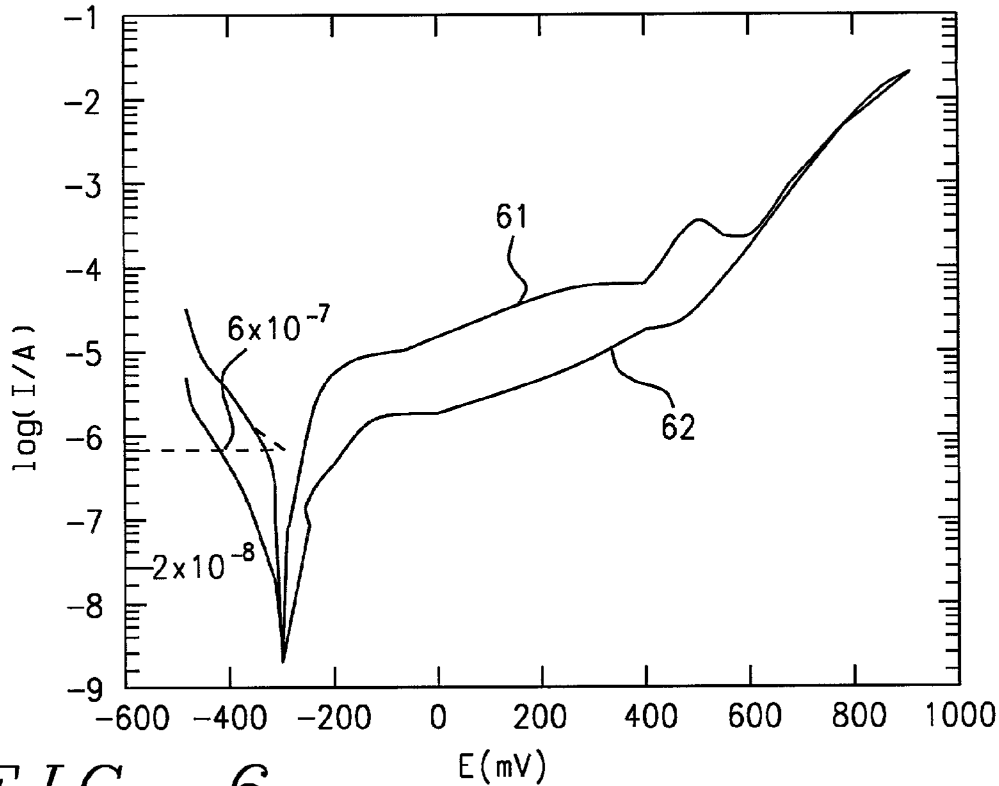
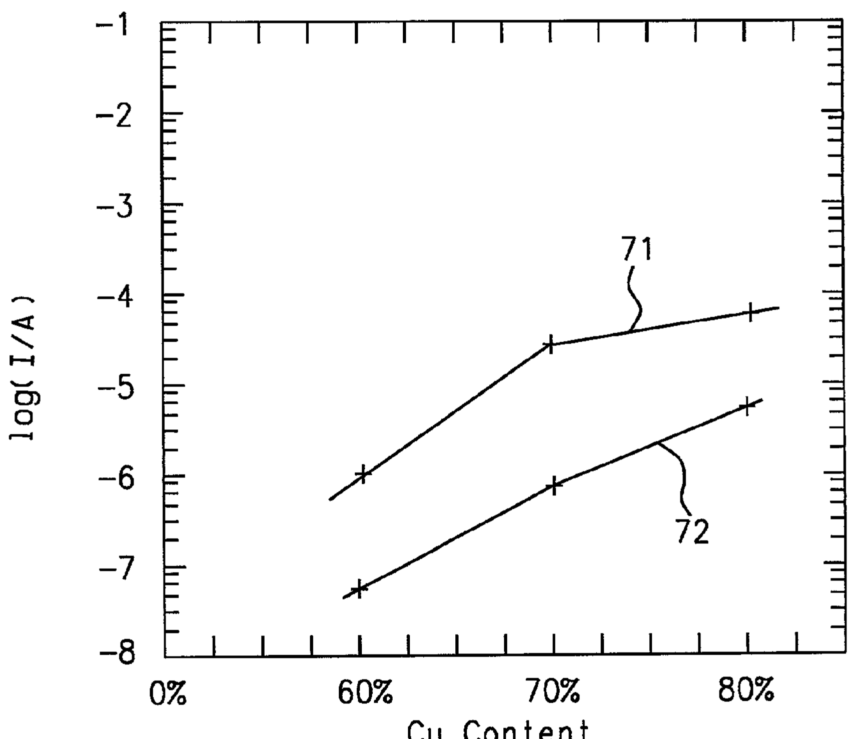


FIG. 5



-1
-2
-3
-4
-5
-6
-7
-8
-9
log(I/A)
-600 -400 -200 0 200 400 600 800 1000
E(mV)
61
62
6x10^-7
2x10^-8

FIG. 6



-1
-2
-3
-4
-5
-6
-7
-8
log(I/A)
0% 60% 70% 80%
Cu Content
71
72

FIG. 7

CORROSION INHIBITOR OF NICU FOR HIGH PERFORMANCE WRITERS

FIELD OF THE INVENTION

[0001] The invention relates to the general field of photoresist processing in the presence of copper, with particular application to the manufacture of write heads for magnetic disk systems.

BACKGROUND OF THE INVENTION

[0002] Referring to **FIG. 1**, we show, in schematic representation, a cross-sectional view of a write head for a magnetic disk system. The magnetic field needed to perform the write operation is generated by flat coil **16** made up of a number of turns, with **13** being an example of one side of a single turn. Surrounding the flat coil is magnetic material comprising upper and lower pole pieces **12** and **11** respectively. These pole pieces are joined at one end (on the left in this figure) and are separated by small gap **14** at the other end. The magnetic field that is generated by flat coil **16** ends up being concentrated at gap **14**. It is sufficiently powerful that the fringing field that extends outwards away from gap **14** is capable of magnetizing the magnetic storage medium over whose surface **15** the head 'flies'. The distance between gap **14** and surface **15** is typically between about 10 and 50 nm.

[0003] In the course of manufacturing the various layers that make up the gap region it is often found to be convenient to use copper, either alone or in combination with other materials, in one or more of the layers. As is well known, most or all of these layers will be shaped by means of photolithography. Additionally, a given photolithographic step may not always be implemented exactly as intended, for example misalignment between related structures may have occurred. Under such circumstances it is often possible to strip the unsatisfactory layer of photoresist and repeat the photolithographic step, a process referred to as photo rework.

[0004] Certain types of photoresist (notably positive resists) are developed using solutions that are very alkaline, typically having a pH in the range from 10 to about 14. In most cases this poses no problems. However, when one of the afore-mentioned pure or partial copper layers comes into contact with such a high pH solution, it is subject to attack. Thus, when using alkaline developers, any exposed copper must either be kept away from the developer or some way must be found to render the copper immune to attack. The present invention discloses a solution that is based on the second of these alternatives.

[0005] No references that describe the exact process of the present invention were uncovered in the course of a routine search of the prior art. Several references of interest were, however, found. For example, U.S. Pat. No. 5,236,552 (Fang) shows a photoresist stripping solution containing a corrosion inhibitor such as BTA. U.S. Pat. No. 5,863,710 (Wakiya et al.) shows a developer solution with an aluminum corrosion inhibitor. U.S. Pat. No. 5,635,339 (Murray) shows a photo-thermographic element using BTA as a co-developer. U.S. Pat. No. 5,316,573 (Brusic et al.) forms a corrosion inhibiting layer by dipping in a solution of copper and BTA. U.S. Pat. No. 5,304,252 (Condra et al.) shows a mask removing process with a corrosion inhibitor of BTA for a printed circuit board.

SUMMARY OF THE INVENTION

[0006] It has been an object of the present invention to provide a process for developing photoresist in the presence of copper bearing material without corroding the latter.

[0007] Another object of the invention has been to be able to perform photo rework in the gap region of the write head of a magnetic disk system without affecting copper bearing surfaces nearby.

[0008] These objects have been achieved by protecting all exposed copper bearing surfaces from attack by strongly alkaline solutions of the type used to develop photoresist. Two ways of achieving this are described. In the first method, benzotriazole (BTA) is added to the developing solution which is then used in the normal way, developing time being unaffected by this modification. In the second method, the surface that is to receive the photoresist is first given a dip in a solution of BTA, following which the photoresist is immediately applied and processing, including development, proceeds as normal. For both methods the result is the elimination of all copper corrosion during development.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a schematic cross-section of a write head for a magnetic disk system.

[0010] **FIG. 2** is a closeup view of the gap region of the write head seen in **FIG. 1**.

[0011] **FIG. 3** shows the object illustrated in **FIG. 2** viewed from a different direction.

[0012] **FIG. 4** shows a photoresist frame used for forming a non-magnetic step layer.

[0013] **FIG. 5** shows the molecular structure of BTA.

[0014] **FIG. 6** is a polarization curve for a nickel-copper alloy in developing solutions with and without added BTA.

[0015] **FIG. 7** plots the exchange current as a function of copper content for a nickel-copper alloy in developing solutions with and without added BTA.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] In **FIG. 2** we show (schematically) a closeup view of the gap region that is part of **FIG. 1**. In order to concentrate the magnetic flux to the maximum extent possible, the size of the upper pole piece is reduced in the immediate vicinity of the gap. Thus, in addition to the upper and lower pole pieces, **12** and **11** respectively, seen in **FIG. 1, a** second upper pole piece **21** has been introduced between pole piece **12** and the gap layer **23**, the latter being a layer of an insulating material such as alumina or nickel-copper. As can be seen, second pole piece **21** has been further reduced in cross-sectional area where its lower surface contacts gap layer **23**.

[0017] This reduction in area of the lower portion of **21** is conveniently implemented by introducing a layer of non-magnetic material, in the form of step **22**, prior to the formation of **21**. Because it can be processed in a manner similar to nickel-iron, nickel-copper (between about 40 and 70 weight % copper) has been found to be a suitable material from which to build the non-magnetic step **22**.

[**0018**] **FIG. 3** is across-section of **FIG. 2** made through plane **3-3**. Once lower pole piece **11** in place, a layer **23** of gap material (such as alumina or nickel copper) is laid down to a thickness between about 1,000 and 4,000 Angstroms.

[**0019**] Referring now to **FIG. 4**, in order to form non-magnetic step layer **22**, layer **41** of photoresist is first laid down and then patterned to form frame **43** inside which layer **22** can now be grown. With layer **22** in place, the same frame can be used to contain layer **21** while it is being grown. However, it is possible that the exact position of frame **43** relative to other parts of the structure is unsatisfactory, in which case photo rework becomes necessary.

[**0020**] It then becomes necessary to remove photoresist layer **41** and replace it with a fresh second photoresist layer which can be re-exposed and developed so as to locate frame opening **43** where it belongs. As previously noted, the developer is strongly alkaline so some of the copper within layer **22** is liable to be attacked, resulting in undesirable corrosion of the top surface of step **22**. The present invention provides two ways to protect the copper from attack by the developer which we now disclose as two separate embodiments.

First embodiment

[**0021**] In this approach, we modify the developer itself by adding to it a complexing agent that protects the copper from the alkaline solution. Although any one of several possible complexing agents could have been used, our preferred choice has been benzotriazole (BTA) which is added to a standard water based developer (such as LDD-26W) at a concentration between about 0.2 and 2 gms./liter. The molecular structure of BTA is illustrated in **FIG. 5**. The modified developing solution for the photoresist is then used in the normal way. That is, the photoresist is developed for a time period that is between about 2 and 10 minutes, this being the same time as that required for development in a developing solution having no BTA. Thus, the process is essentially unchanged, except that the copper corrosion no longer occurs.

Second embodiment

[**0022**] In the second embodiment, the photoresist developer is not modified. Instead, after removing the misaligned layer of photoresist, the structure is dipped in an aqueous solution of BTA (at a concentration of between about 0.5 and 2 gms./liter for between about 0.5 and 15 minutes. It is then immediately coated with a fresh layer of photoresist which is then exposed and developed in the usual way. The presence of the BTA solution at the interface between the photoresist and the copper-bearing layer is then sufficient to prevent any corrosion of the copper from occurring during photoresist development. Note that the photoresist is developed for a time period that is between about 2 and 10 minutes, this being the same time as that required for development even if no pre-dip in a BTA solution has taken place.

[**0023**] For both embodiments, following the successful development of the photoresist, the new, correctly located, frame is now in position so that part **12** of the upper pole piece can be formed without part **21** being attacked. Finally, the reworked layer of photoresist is removed.

[**0024**] By way of explaining why the process of the present invention is effective in suppressing the dissolution of copper in alkaline solution, we refer to **FIG. 6**. which is a polarization curve for $Cu_{60}Ni_{40}$ in an unmodified developing solution (curve **61**) and $Cu_{60}Ni_{40}$ in a developing solution to which 1.0 gm/liter of BTA has been added (curve **62**). In both cases a plot was made of Log(I/A), where I and A are current and area respectively, vs voltage between an electrode made of the NiCu alloy and a standard calomel reference electrode. These curves show that the exchange current decreases by 1½orders of magnitude when BTA is added. This shows that the addition of the BTA has substantially reduced the dissolution rate of the NiCu.

[**0025**] In **FIG. 7** we plot the exchange current density (log I/A) as a function of copper content within the NICu alloy. Curve **71** is for the unmodified developer while curve **72** is for the developer with 1 gm/liter of BTA added. This data shows that the exchange current will decrease with BTA addition for NiCu films having different copper concentrations. This demonstrates that BTA addition is effective to inhibit corrosion of NiCu films over the full range of copper content.

[**0026**] While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A process for developing photoresist in the presence of copper, comprising:

providing a surface that includes some copper;

providing a developing solution for the photoresist;

modifying said developing solution by adding to it a quantity of BTA;

coating said surface with the photoresist and then exposing the photoresist; and

using the modified solution, developing the photoresist whereby any of the copper that comes into contact with the modified developing solution is unaffected by the development process.

2. The process of claim 1 wherein the quantity of BTA that is added makes its concentration in the developer to be between about 0.2 and 2 gms./liter.

3. The process of claim 1 wherein the developing solution has a pH between about 10 and 14.

4. The process of claim 1 wherein the resist is a positive photoresist.

5. The process of claim 1 wherein the photoresist is developed for a time period that is between about 2 and 10 minutes, said time period being the same as that required for development in a developing solution having no BTA.

6. A process for pre-wetting a surface that contains some copper, comprising:

dipping said surface into an aqueous solution of BTA;

then coating said surface with a layer of photoresist; and exposing the photoresist and then developing it whereby, when development has been completed, the copper is unaffected.

7. The process of claim 6 wherein the BTA has a concentration in the aqueous solution of between about 0.5 and 2 gms./liter.

8. The process of claim 6 wherein the pH of the developing solution is between about 10 and 14.

9. The process of claim 6 wherein the resist is a positive photoresist.

10. The process of claim 6 wherein the surface is dipped in the solution of BTA for between about 0.5 and 15 minutes.

11. The process of claim 6 wherein the photoresist is developed for a time period that is between about 2 and 10 minutes, said time period being the same as that required for development in a developing solution having no BTA.

12. A process for doing photo re-work during manufacture of a write-head for a magnetic disk system, comprising:

providing a lower pole piece;

depositing a layer of gap material on the lower pole piece;

depositing and patterning a first layer of photoresist on the layer of gap material, thereby forming a first frame;

within said first frame, forming a step layer of a non-magnetic material that includes copper;

removing said first layer of photoresist;

depositing and exposing a second layer of photoresist on the step layer;

providing a developing solution for the photoresist;

modifying said developing solution by adding to it a quantity of BTA;

using the modified solution, developing the second layer of photoresist, whereby any copper in the step layer that comes into contact with the modified developing solution is unaffected by the development process, thereby forming a second frame. within said second frame, forming an upper pole piece layer; and

removing said second layer of photoresist.

13. The process of claim 12 wherein the quantity of BTA that is added makes its concentration in the developer to be between about 0.2 and 2 gms./liter.

14. The process of claim 12 wherein the resist is a positive photoresist.

15. The process of claim 12 wherein said non-magnetic material is an alloy of copper and nickel containing between about 40 and 70% copper.

16. A process for doing photo re-work during manufacture of a structure that is part of a write-head for a magnetic disk system, comprising:

providing a lower pole piece;

depositing a layer of gap material on the lower pole piece;

depositing and patterning a first layer of photoresist on the layer of gap material, thereby forming a first frame;

within said first frame, forming a step layer of a non-magnetic material that includes copper;

removing said first layer of photoresist;

dipping the structure in an aqueous solution of BTA;

then coating the structure with a second layer of photoresist;

exposing the second layer of photoresist and then developing it, whereby any copper in the step layer that comes into contact with developing solution is unaffected by the development process, thereby forming a second frame.

within said second frame, forming an upper pole piece layer; and

removing said second layer of photoresist.

17. The process of claim 16 wherein the BTA has a concentration in the aqueous solution of between about 0.5 and 2 gms./liter.

18. The process of claim 16 wherein the resist is a positive photoresist.

19. The process of claim 16 wherein the surface is dipped in the solution of BTA for between about 0.5 and 15 minues.

20. The process of claim 16 wherein said non-magnetic material is an alloy of copper and nickel containing between about 40 and 70% copper.

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