SURFACE COATING FOR HARD DISK DRIVE CAVITY

FIELD OF THE INVENTION

This invention relates to the application of functional coatings to components with exposed surfaces within the clean cavity of the hard disk drive (HDD) such as head disk assembly (HDA) for increased reliability by lowering the number and size of free, third body particles.

BACKGROUND OF THE INVENTION

The HDA clean cavity contains various components including one or more components with a magnetic coating for storage of data, referred to as media, and one or more recording heads, referred to as head, for the writing and retrieval of the data onto and from the media. Coatings of diamond like carbon (DLC) are being applied to the head and the media to improve the wear characteristic by reducing the friction between these components with are moving relative to each other. In particular, the spacing between the media and the head is only a few angstroms. The head and the media move relative to each other. Any free particle on the surface of the media has a finite probability to cause damage to either the head or the media. This damage may result in the loss of data. The source of these free particles is the other components with exposed surfaces within the HDA.

The development of the technology of HDD supporting increases in aerial density over the past sixty years require that the head and media spacing be reduced. The reduction in the head and media spacing results in small particles of sub-micron dimensions having a higher likelihood of causing damage. Additionally, the introduction of perpendicular recording technology into the HDD has required changes to the media, resulting in the magnetic coatings on the media being susceptible to damage from any free particles within the HDA. Previously any hard particle from a metallic component had a much higher likelihood of resulting in damage to the media or head. In HDD using perpendicular recording technology, any free particle, including organic materials from both inorganic and organic materials, have the likelihood of causing damage to the media similar to a metallic particle on the older longitudinal recording media.

Current HDDs suffer from particle contamination during the operation and lead to short life span of HDD. Particles are generated from surfaces that expose to the air that circulate in high speed within the HDD enclosure. The turbulent air causes the particles to scatter on the media surfaces

and lead to early failure of the head and media interface which the flight height is just in terms of few nm in height. Hard particles are one of the main causes for such failure.

One of the possibilities is the hard particle generated from the inner surface of HDD enclosure and the components that within the HDD that form the HDA. Most of the surfaces, even though are highly polished or smooth, may be sources for the generation of particles through the external static attraction of dust or loose particles generated from the surfaces. An additional cause for particles to loosen from the exposed internal surfaces within the HDD is moisture or humidity within the ambient air.

The largest areas exposed and able to generate particles are the base plate and the top cover. Both are typically either EN plated or E-painted. For current 1.8" HDD, the top cover and base plate are usually EN plated. FIG. 1A-B show the SEM morphology 2,4 of EN coated stainless steel base plated. FIG. 1A and 1B shows SEM micrographs 2,4 of electroless nickel plating (EN). As shown in FIG. 1A, some areas of the coated surfaces consist of loosely adhered particles 8, in this sample shown in FIG. 1A Ni(P) particles. The loose particles might fall off during the HDD operation. The particles remain in the HDD and likelihood that particle drop on the media surfaces and cause damages between the head and media during the spinning in high speed. FIG. 2A-2C shows schematic diagrams 40,50,52 of particle generation form a surface such as an EN layer. The EN grow mechanism is originated from islands that form in the EN layer, where the islands form grains 44 and grain boundaries 44, as shown in the diagram 40 of FIG. 2A. FIG. 2B shows in diagram 50 the weak point 46 of the EN failure contributed for degradation over time due to humidity or a weak link. FIG. 2C shows in diagram 52 loose and hard free particles 48 created that potentially could cause damage.

Attempts have been made to reduce risk of damage to the head or media. One attempt is to position a high efficiency filter within the HDA cavity to remove the free particles during operation. However, the filter is only effective on a small percentage of the air flowing between the head and media. Thus, the source of these free particles has to be treated so as to slow down the release of the particles before the reliability is improved.

As of now, there are two coatings for the motor base and the top cover components. One of the coatings uses is electrocoating of paint (e-coating) with a thickness between 4,000 and 10,000 nanometers (4 to 10 microns). The advantage of e-coating is the cost. The disadvantages of e-coating are control of Sn outgassing, scratch resistance, non-conducting, cleanliness and ability to remove particles from the surface during cleaning. The other coating is electroless nickel plating (EN) coating with a minimum thickness of 5,000 nanometers (5 microns) and maximum thickness

up to 60,000 nanometers (60 microns). The disadvantages of EN coatings are cost, quality control for adhesion, cleanliness, and ability to remove particles form the surface during cleaning. The voice coil magnet with associated pole and the disk clamp are typically coated with EN. The voice coil wire is insulated with uncoated PVC. The other aluminum and steel parts are only chemically passivated and the plastic parts are typically uncoated.

Previously, contamination within the HDA is managed by cleaning of the components of the HDA and subsequently handing these components in clean rooms. Components with common coatings such as electroless nickel plating and electrical paint deposition (e-coatings) are subjected to multiple cleaning cycles including detergents, ultrasonic washes, and rinses with DI water. Improvements to the cleanliness of the HDA components is by increasing the number of cleanings and rinse cycles, using sprays, and improving detergents. The clean rooms assembly's requirements have been improved. Hence, now the HDA components are handled in clean bags, moved in clean containers, and are assembled in environment near to Class 1. Class 1 is the clean room classification where the particle counts do not exceed a total of 3000 particles/m^3 of a size of 0.5µm (micron) or greater. The greatest particle present in any sample typically does not exceed 5µm (micron).

These attempts to improve are unable to meet the required HDA cleanliness of the current HDD technology. Particle contamination within the HDA is resulting in consumer data loss. The technology being used to manage data loss such as RAID systems and/or data back-up and recovery systems are both expensive and difficult to manage.

Within the HDA, a ramp is incorporated to remove the head from contact with the media during non use. Removing the head from the media provides the capability for the HDD to experience high shock levels with a lower likelihood of data loss or decrease in reliability. The ramp generates fine particles during the process of lifting the head off the media and again when loading the head onto the media.

Existing methodology that is used to prepare, and to clean the components with surfaces exposed interior to the HDA is no longer capable to meet current new product requirements. There is thus a need to minimize such problem and incident and thus to increase the mean time between failure (MTBF) of the HDD. There is a need for a new methodology to reduce the number of small particles, for example, 0.05 micron size and smaller.

SUMMARY

An aspect of the invention is a hard disk drive (HDD) having a base, a cover, and a head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity, the surfaces being coated with a coating to decrease the number of free particles and limit the size of the free particles that contaminate the head disk assembly.

An aspect of the invention is a method of reducing contamination in a hard disk drive (HDD), the hard disk drive having a base, a cover, and a head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity, coating a surface in the disk drive cavity with a coating to decrease the number of free particles and limit the size of the free particles that contaminate the head disk assembly.

In embodiments of the invention the coating comprises a single layer. The coating may comprise multiple layers. The coating may be applied with wet chemical deposition or physical vapor deposition. The coating may comprise hybrid layers, wherein the coating is applied with a wet chemical deposition and physical vapor deposition.

In an embodiment the coating may comprise nanoparticles. The coating may be nonconductive with, for example, at least 10^9 Ohm-cm resistivity. The coating may be antistatic with, for example, 10^3 Ohm-cm to 10^9 Ohm-cm resistivity. The coating may be conductive with, for example, 10^{-6} Ohm-cm to 10 Ohm-cm resistivity.

In an embodiment the coating may be applied to any metallic component for the purpose of protecting the component from corrosion. The coating may be applied to any component to improve the component's anti-static characteristics. The coating may be applied to any component to increase the component's electrical conductivity. The coating may be applied to any component to increase the head disk assembly overall electro-magnetic shielding characteristic. The coating may be applied in a process that integrates ultrasonic cleaning process immediately before coating deposition and in the same controlled environment. The coating may be applied in a process that integrates an in-line interlocking system of clean environments including an environment for the deposition of the coating.

In an embodiment the head disk assembly comprises a ramp and a mating assembly, the coating applied to the ramp for the reduction of particles generated during sliding of the mating part on the ramp. The coating may be applied to the mating part. The coating may be applied to the hard disk drive motor base component with exposed surfaces within the hard disk assembly that reduces the

number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning. The coating may be applied to the hard disk drive motor components with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning. The coating may be applied to the hard disk drive top cover with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning. The coating may be applied to the hard disk drive latch and latch assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning. The coating may be applied to the hard disk drive ramp assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning. The coating may be applied to the hard disk drive voice coil assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

In an embodiment the coating is a thin layer film of nanometer thickness or micrometer thickness. The coating may be applied on an electroless nickel (EN) plating layer.

An aspect of the invention provides use of a micron coating for decreasing the number of free particles and limit the size of the free particles that contaminate a head disk assembly in a hard disk drive, the hard disk drive having a base, a cover, and the head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.

An aspect of the invention provides use of multiple coatings having a top coating of a thin film of nanometer thickness for decreasing the number of free particles and limit the size of the free particles that contaminate a head disk assembly in a hard disk drive, the hard disk drive having a base, a cover, and the head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.

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components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that embodiments of the invention may be fully and more clearly understood by way of non-limitative example from the following description taken in conjunction with the accompanying drawings in that like reference numerals designate similar or corresponding elements, regions and portions, and in which:

FIG. 1A-1B show SEM morphology of EN coated surfaces;

FIG. 2A-2C shows schematic diagrams of particle generation form a surface;

FIG. 3 shows expanded perspective views of components and assemblies with exposed surfaces within a head disk assembly (HDA) in accordance with an embodiment of the invention;

FIG. 4 shows flow chart diagram of an embodiment of the invention;

FIG. 5 shows an OI surface coating in accordance with an embodiment of the invention;

FIG. 6A-6B show SEM morphology of EN coated surfaces applied in accordance with an embodiment of the invention; and

FIG. 7 shows a table showing the comparison of results achieved with a surface coating in accordance with an embodiment of the invention compared with a conventional process of cleaning without the surface coating in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

FIG. 3 shows expanded perspective views of components and assemblies with exposed surfaces within a HDD 10 in accordance with an embodiment of the invention. The HDD 10 comprises a first cover 12 and a second cover 32. The HDA comprises components such as spindle 14 for disk 24 and read/write heads 20 and actuator 22. The printed circuit cable 16 and base casting connects to the printed circuit board 30 via connector 26 and I/O connector 28. The internal components

include spindle motor components, all of the HDA enclosures, recording head and recording media as well as the HDA. The HDA clean cavity contains various components including one or more components with a magnetic coating for storage of data, referred to as media, and one or more recording heads, referred to as head, for the writing and retrieval of the data onto and from the media. Application of coatings having nanoparticles forming nano or micron films in accordance with an embodiment of the invention to the head and the media to improve the wear characteristic by reducing the friction between these components with are moving relative to each other.

The surface to be coated may be defined as any surfaces (metal, plastic, ceramic, conductor, insulator, and the like) that expose to the environment (the surface interface with the air circulation) that housed the platter and read/write head inside the HDD. For example, base plate, top cover, spindle motor and spindle components to assemble the platter, latch and latch assemble, ramp assembly, voice coil, flexible printed circuit, connectors and the like. The application of the coating reduces the number of particles that are generated from the surfaces during the operation of the HDD. The coating functionalities may further include adhesion, mechanical strength, corrosion resistant, antistatic discharged (ASD), and the like.

HDA may be defined as all the components housed within the HDD enclosure to form the essential parts for HDD excluded the PCBA. HDA may be defined as components to be the components that with any of the surfaces expose to the air that circulate within the enclosure during the operation. For example, components include base plate, top cover, spindle motor and spindle components to assemble the platter, latch and latch assemble, ramp assembly, voice coil, flexible printed circuit, connectors, and the like. In general, all mechanical parts with metal or non-metal surface can be sources for loose particle generation.

Examples of the application of the coating in accordance with embodiments of the invention are discussed. An application in accordance with an embodiment of the invention is an Organic-Inorganic (OI) coating that may comprise, for example, the following mixture:

a. Metal alkoxides or metal chlorides where the Metal group may be Si, Ti and the like;
b. Inorganic nano-particles, for examples, metal nano-particles, Zn, Ti, Cr, Cu, Au, Pt and etc and metal oxides, TiO2, Al_2O_3 and others;
c. Carbon nano-particles or nanotubes;
d. Other additives, stabilizes and necessary chemistries.

The coating may be deposited by dipping, spraying, spinning and any method that suitable for wet chemical deposition. The solution may be formulated with different viscosity to suit for various deposition methods.

An application in accordance with an embodiment of the invention is a physical vapor deposition (PVD) or chemical vapor deposition coating that could be from any of deposition technology that about to offer continuous thin film with thicknesses of no more than 10μm, preferable less than 5 μm and typically less than 2μm. The coating shall be continuous, homogenous and dense (non-porous). The coating may be deposited, for example, by:

a. Magnetron sputtering or high power immersion sputtering with either linear or round shape that energized by either RF, mid frequency, DC pulsed, DC or other energy sources.

b. Evaporation that may be e-beam evaporation or thermal evaporation for both ceramic and metal coating.

c. Plasma enhanced, ECR or thermal CVD that able to deposit various metal and ceramic coating on metal and non-metal surfaces.

d. Arc or filtered arc that able to provide very dense and hard coating which possibly to deposit with as long particle as possible.

Materials that may be deposited on the metal, semi-metal or insulator surface may be, for example Ti, Cr, Au, Pt, Ag, SiO_2, TiO_2, Al_2O_3, CrN, TiN, TiAlN, C, or the like. It will be understood that C could be in the form of graphite, amorphous diamond like carbon or nano-crystal diamond like carbon structure, metal containing carbon network, or the like. Basically, may be any hard coating that able to offer dense and continuous coating.

In an embodiment of the invention, a layer may comprise electrolytic or electroless plating with conductive metal or conductive metal with inclusion of polymer or polymer with inclusion of conductive nanosize metal particles.

Organic-Inorganic (OI) coatings having nanoparticles in accordance with an embodiment of the invention provide clean surfaces within hard disk drive (HDD) components. An application of functional coatings having nanoparticles that deposited to the Hard Disk Drive (HDD) enclosure inner surface and components that assemble the Head Disk Assembly (HDA) is disclosed. An application for the coating of HDD components, for example, within the head disk assembly (HDA) in general and to the use of coatings being a thin film of nanometer or micrometer thickness that may comprise nanoparticles on the individual components with surfaces exposed within the clean cavity of the HDD. The use of coatings in accordance with an embodiment of the invention increases the reliability of the HDD against data loss since the coatings have the properties of reducing the number and size of particles on the coated components and of improving the efficiency of removing particles deposited on the surfaces of the coated component using the industry's existing aqueous cleaning systems. The properties of the coatings are adjusted to improve the other surface properties of wear resistance, corrosion resistance, electrostatic efficiency, and conductivity. Multiple coatings may be used, one or more of which use

nano-particles, to meet all of the HDD requirements, including an exterior coating for reduction in the number and size of particles within the HDA.

In an embodiment, the coating is the surface and structure of the thin film and may comprise amorphous or nano-size grains. The surface has little to no loose particles. The coating has sufficient adhesion and strength that is able to deposit to metals, ceramics and insulators. The coating may be conductive or with resistant qualities that provide anti-static discharged properties (10^5 to 10^8 Ohm-cm).

The organic-inorganic (OI) process for coatings in accordance with an embodiment of the invention may include for example, an initial OI coating is a nano-ceramics with organo-polysiloxan applied with a solvent base solution and in a dip coater. The initial coating may be a material such as with 24 wt% Silicon Oxide, 5 wt% resin, 32 wt% IPA, and 39 wt% BCS. The part coated is a carbon steel base plate washed in a commercial aqueous based cleaning system using ultrasonic cleaning and DI water. After rinsing and drying the component is further processed through a standard acid bath to etch the surface and remove all oxidation and loosely adhered particles. Further cleaning could use e-beam or other higher energy surface cleaning systems. The component is processed through a standard dip coater and oven cured at 40°C for 20 minutes. After curing, the part is handled in a class 1,000 clean room and place sealed in clean bags. The coating thickness may be 1,000 and 2,000 nano-meters (1 to 2 microns).

This coating is cleaner than the existing industry coatings, showing LPC measurements of counts per sq inch of surface as shown in the table of FIG. 7. FIG. 7 shows a table 90 showing the comparison of results achieved with a surface coating in accordance with an embodiment of the invention 94,96 compared with a conventional process 92 of cleaning without the surface coating in accordance with an embodiment of the invention. The typical steel base plate with electroless nickel (EN) coating is measured as a control. The number of particles counted at 0.3 microns and below is 4,813 particles per sq inch of surface. The number of particles counted at 0.3 microns for the coated part is 1,732 particles, a 60% reduction in the number of particles shedding from the surface.

The particle count uses a commercial liquid particle counter, DI water, and ultrasonic to remove particles that are counted with a laser detector. The component is passed through the liquid particle counting process a number of times, until the counter detects a nearly constant reading from test to test. This reported number is a measure of the cleanliness of the surface. More importantly, the probability of media damage and data loss with the HDA is directly proportional to the number of particles released from the surface. A 60% reduction in the number of particles

counter reflects a 60% decrease in the probability of data loss or a 60% increase in the reliability of the HDD for data loss due to a 3 body collision between the head, media, and a free particle.

An OI coating is used for the deposition of a coating meeting the stringent specification for cleanliness for parts within the HDA at a favorably low temperature which minimized the mechanical distortion and internal stress induced within the component material.

The OI materials are used to make the coatings for the mechanical components within the HDA. Low cost dip coating equipment is used to deposit coatings on both metal and plastic parts for all components internal to the HDA.

FIG. 5 shows the application 70 of a coating 74 using OI nano-particles 72. The surface coatings deposited with OI nano-particles on a surface 76 within the HDA have characteristics of no loose or imbedded particles and easy cleaning in existing HDD aqueous ultrasonic equipment. Due to the nature of the coating, fine particles cannot be trapped temporarily and then released from small voids in the coatings. The OI process deposits closely packed small nano-particles onto the component surface 76. The nanostructure of the coating is controlled by the choice of coating material and the process parameters of solvents, time, and baking temperatures.

An example of the methodology in applying the coating in accordance with an embodiment of the invention is a combination of above coating methods to form a single or hybrid system coating on different surfaces and different parts to achieve better cleanliness. Cleanliness may be defined with readings and measures taken by the Liquid Particle Counter (LPC). The part to be measured is dipped into the DI water with ultrasonic agitation. The part is washed several times until the particle value obtained is stable. A reading for example of a conventional EN plated 1.8" base plate shows a final reading for the EN coated base plate is around 3000-6000 particle, for example 4768 (>0.3μm)/cm^2. The quality of the coating could be fluctuating depending on the batches and subsequent HPA analysis revealed that there is presence of NiP particles corresponding to the EN coating. Such SEM micrographs are shown in FIG. 1A-1B of EN coated substrate as discussed.

An example of an embodiment of the invention includes application of coating on base plates and top covers by aluminum or steel. The base plates and top covers typically manufactured by stamping and forming the dimension and shape. Some areas are machined to the specification. The part is treated with de-burring process to remove some shape edges. FIG. 6A and 6B illustrate the SEM micrographs 80,82 of an organic-inorganic (OI) coated substrate at 3,500 magnification shown in FIG 6A and at 5,000 magnification shown in FIG. 6B.

In embodiments, single, multiple or hybrid layers may be deposited. In a single layer embodiment, the single layer may comprise a single OI layer coating. In a multi layer embodiment, the multi layer may comprise multiple OI layer coating. In a hybrid layer embodiment, the hybrid layer may comprise electroless or electroplating of metal, metal with polymer network or polymer with metal inclusion as base layer, such as electroless Ni or electroplating of Zn and follow by single or multiple layer of OI. One of the possible formulations 60 with EN as base layer and followed by single layer OI is shown in FIG. 4. Where layer 1 is a layer of electroless nickel plating (EN) where the process flow comprises pretreatment and EN plating 62, followed by electroless nickel plating 63, solution preparatin 64, dip coating 66, curing of substrate(s) 68, and cleaning process 69.

Before performing electroless nickel plating, the material to be plated must be cleaned by a series of cleaning chemicals such as bases and acids, this process is called the pre-treatment process of parts for EN plating. Failure to remove unwanted "soils" from the part's surface would result in poor plating. Each pre-treatment chemical must be followed by water rinsing (normally two to three times) to remove the chemical that adheres to the surface. Degreasing removes oils from surface; acid cleaning removes scaling. Activation is done with a weak acid etch, or nickel strike, or, in the case of non-metallic substrate, a proprietary solution. After the plating process, plated materials must be finished with an anti-oxidation or anti-tarnish chemical (trisodium phosphate, chromate etc) and pure water rinsing to prevent unwanted stains. The rinsing materials must then be completely dried off or sometimes baked off to obtain the full hardness of the plating film.

Electroless nickel plating is an auto-catalytic reaction used to deposit a coating of nickel on a substrate. The alloys with different percentage of phosphorus, ranging form 2-5 (low phosphorus) to up to 11-14 (high phosphorus) are possible. The metallurgical properties of alloys depend on the percentage of phosphorus.

In this embodiment layer 2, the OI layer, may comprise for example 20 ml of Methyl-trimethoxysilan, 0.6 ml of Sulphuric acid, 50 ml of De-ionized (DI) water, 150 ml of Methanol, 0.05 grams of Polyvinyl pyrrolidone (PVP K30). Alternately metal/ceramic nanoparticles may be added. In the solution preparation in accordance with an embodiment of the invention the process flow may comprise metal/ceramic nanoparticles and PVP-300K are added into DI water followed by ultrasonic stirring for 5 minutes. With stirring, concentrated sulphuric acid is added drop-wise into the mixture, followed by addition of methyl-trimethoxysilan and allowed to ultrasonic for 30 minutes. Finally, methanol solvent is added and the mixture is allowed to mechanical stirred (~600rpm) for 20 minutes to achieve a homogeneous suspension.

Dip coating may comprise the following steps where the substrate is submerged into the above prepared mixture and held in the mixture for 2 to 5 seconds. Next, the substrate is withdrawn from

the mixture and is rotated at room temperature for 1 minute. With the substrate rotating, hot air is applied to dry the substrate at about 100°C for 5 minutes. The dried substrate is then cured in vacuum oven at 130°C for 4 hours. Lastly, the substrate is then cleaned, dried and inspected.

Properties of the coating in an embodiment of the invention may comprise a thickness of preferably 50nm-5 μm. The particle density with LPC method is preferably 200 – 2000 particles (>0.3μm) / cm^2. Under hard particles analysis (HPA), no trace of NiP particles is detected.

In another embodiment, base plates and top covers may be coated by aluminum or steel where the base plates and top covers typically manufactured by stamping and forming the dimension and shape. Some areas are machined to the specification. The part may be treated with de-burring process to remove some shape edges. In embodiments, single, multiple or hybrid layers may be deposited.

In a single layer embodiment, the layer may comprise a single PVD layer coating. In a multi layer embodiment, the multi layer may comprise multiple PVD layer coatings with a mixture of materials or properties, such as Cr-Cu-Cr-Cu... or any metal, metal nitride or metal oxide combinations with each layer of 5 to 500nm and final thickness of 50nm to 5μm. The layer may comprise a carbon network with different diamond (sp3) to graphite (sp2) ratio, such as high sp3, low sp3 multiple layer to form the final coating of 50nm to 2μm thickness.

Hybrid layers consist of electroless or electroplating of metal, metal with polymer network or polymer with metal inclusion as base layer, such as electroless Ni or electroplating of Zn and followed by a single or multiple layer of PVD coating. One embodiment of the possible formulations with EN as base layer and followed by single layer PVD is, for example the recipe comprises layer 1 being a electroless nickel plating (EN) base layer with a process flow including pretreatment and EN plating. As discussed, performing electroless nickel plating, the material to be plated must be cleaned by a series of cleaning chemicals such as bases and acids, this process is called the pre-treatment process. Failure to remove unwanted "soils" from the part's surface would result in poor plating. Each pre-treatment chemical must be followed by water rinsing (normally two to three times) to remove the chemical that adheres to the surface. Degreasing removes oils from surface; acid cleaning removes scaling. Activation is done with a weak acid etch, or nickel strike, or, in the case of non-metallic substrate, a proprietary solution. After the plating process, plated materials must be finished with an anti-oxidation or anti-tarnish chemical (trisodium phosphate, chromate etc) and pure water rinsing to prevent unwanted stains. The rinsing materials must then be completely dried off or sometimes baked off to obtain the full hardness of the plating film. Electroless nickel plating is an auto-catalytic reaction used to deposit a coating of nickel on a substrate. The alloys

with different percentage of phosphorus, ranging form 2-5 (low phosphorus) to up to 11-14 (high phosphorus) are possible. The metallurgical properties of alloys depend on the percentage of phosphorus.

Layer 2 in this embodiment is a PVD coating where the PVD process comprises high immersion power sputtering may be used to deposit the seed layer to promote the adhesion between EN and PVD coating. Magnetron sputtering process to create the multilayer of Cr and Cu with each thickness of 10nm each and final thickness of 1μm. The properties of the layer may for example have arrange of conductivity such as 10^{-6} to 10^{-4} Ohm-cm, with a thickness of 200 to 5 μm and a particle count of 200 to 2000 particles/cm^2.

In another embodiment of the invention, the application of the coating may be applied to polymer surfaces, for example base for arm assembly and voice coil and flexible circuitry. Coating may be applied for example using one of the following layers of hybrids of all:

1. OI coating with dipping, spraying or spinning method to offer a layer of coating on the plastic surfaces. The layer is able to offer the properties such as reducing the particle generation as well as to be anti-static to reduce the attraction of particle during the assembly. In additional, the additional layer of such coating may further prevent the static damage to the circuitry and head during the assembly and test. The resistivity of the coating may be adjusted from 10^9 to 10^5 Ohm-cm.

2. PVD coating to offer a layer of hard coating on the plastic surfaces. The layer is able to offer the properties such as reducing the particle generation as well as to be anti-static to reduce the attraction of particle during the assembly. In additional, the additional layer of such coating may further prevent the static damage to the circuitry and head during the assembly and test. The resistively of the coating may be adjusted from 10^8 to 10^{-6} Ohm-cm

In another embodiment of the invention, the application of the coating may be applied to metal surfaces, for example, all aluminum, stainless steel surfaces, and the like. PVD coating could be applied to the surface to enhance the cleanliness and smoothness. The materials may comprise such materials as Cu, Cr, Ni, Ti, DLC (diamond like carbon), metal nitride, metal oxide. Embodiments may comprise multilayer structures or mixtures of the materials.

The OI process may deposit films with the required characteristic of cleanliness, hardness, durability, corrosion resistance, EMI shielding, no outgassing, scratch resistance, excellent adhesion, and conductivity as required by the HDD industry. These film coatings may be deposited

on metal stampings and castings, and on plastics. In addition to pure elemental coatings, other compound coatings and coatings with doping may be developed to address current and future HDD requirements.

One additional advantage of the process is that the raw components may be ultrasonically cleaned and dried within a controlled environment prior to coatings, keeping the entire process and coating materials free from contaminations.

The invention is susceptible of a variety of modifications. For example, other systems than the OI nano materials and dip coating equipment may be used to generate the coatings. Other components introduced into the HDA with exposed surfaces may be coated with this or similar coatings. Different or additional coating materials may be used to enhance or improve the properties of the coatings.

While the invention has been illustrated and described as embodied in a disk storage drive, it is not intended to be limited to the details shown, since various modifications and changes may be made without departing in any way from the spirit of the present invention. For example, the extension of the patent extends to all magnetic recording systems with relative movement between the recording Head and the recording Media.

A coating of the HDD voice coil assembly components with exposed surfaces within the HDA that reduces the number of potential particles on its internal surface, and provides for the removal of particles with higher efficiency during cleaning. The voice coil assembly components are the coil, the arm, the coil-arm assembly, the flex circuit assembly, the coil-arm-flex assembly, the flextures, the magnets, the pole, the magnet pole assembly, and all of the remaining components providing the for Head positioning function in the HDD.

Without further analysis, the foregoing so fully reveal the gist of the present invention that others may, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention.

While embodiments of the invention have been described and illustrated, it is to be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

CLAIMS:

1. A hard disk drive (HDD) having a base, a cover, and a head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity, the surfaces being coated with a coating to decrease the number of free particles and limit the size of the free particles that contaminate the head disk assembly.

2. The hard disk drive as claimed in claim 1 wherein the coating comprises a single layer.

3. The hard disk drive as claimed in claim 1 wherein the coating comprises multiple layers.

4. The hard disk drive as claimed in any one of claims 1-3 wherein the coating is applied with wet chemical deposition.

5. The hard disk drive as claimed in any one of claims 1-3 wherein coating is applied with physical vapor deposition.

6. The hard disk drive as claimed in any one of claims 1-5 wherein coating comprises hybrid layers, wherein the coating is applied with a wet chemical deposition and physical vapor deposition.

7. The hard disk drive as claimed in claim 4 wherein the coating comprises nanoparticles.

8. The hard disk drive as claimed in claim 7 wherein the coating is nonconductive with at least 10^9 Ohm-cm resistivity.

9. The hard disk drive as claimed in claim 7 wherein the coating is antistatic with 10^3 Ohm-cm to 10^9 Ohm-cm resistivity.

10. The hard disk drive as claimed in claim 7 wherein the coating is conductive with 10^{-6} Ohm-cm to 10 Ohm-cm resistivity.

11. The hard disk drive as claimed in any one of claims 1-10 wherein the coating is applied to any metallic component for the purpose of protecting the component from corrosion.

12. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to any component to improve the component's anti-static characteristics.

13. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to any component to increase the component's electrical conductivity.

14. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to any component to increase the head disk assembly overall electro-magnetic shielding characteristic.

15. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied in a process that integrates ultrasonic cleaning process immediately before coating deposition and in the same controlled environment.

16. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied in a process that integrates an in-line interlocking system of clean environments including a environment for the deposition of the coating.

17. The hard disk drive as claimed in any one of the preceding claims wherein the head disk assembly comprises a ramp and a mating assembly, the coating applied to the ramp for the reduction of particles generated during sliding of the mating part on the ramp.

18. The hard disk drive as claimed in claim 17 wherein the coating is applied to the mating part.

19. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive motor base component with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

20. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive motor components with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

21. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive top cover with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

22. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive latch and latch assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

23. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive ramp assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

24. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied to the hard disk drive voice coil assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

25. The hard disk drive as claimed in any one of the preceding claims wherein the coating is a thin layer film in nanometer thickness.

26. The hard disk drive as claimed in any one of the preceding claims wherein the coating is a thin film in micrometer thickness.

27. The hard disk drive as claimed in any one of the preceding claims wherein the coating is applied on an electroless nickel (EN) plating layer.

28. A method of reducing contamination in a hard disk drive (HDD), the hard disk drive having a base, a cover, and a head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity, coating a surface in the disk drive cavity with a coating to decrease the number of free particles and limit the size of the free particles that contaminate the head disk assembly.

29. The method as claimed in claim 28 wherein the coating comprises a single layer.

30. The method as claimed in claim 28 wherein the coating comprises multiple layers.

31. The method as claimed in any one of claims 28-30 wherein the coating is applied with wet chemical deposition.

32. The method as claimed in any one of claims 28-30 wherein coating is applied with physical vapor deposition.

33. The method as claimed in any one of claims 28-32 wherein coating comprises hybrid layers, wherein the coating is applied with a wet chemical deposition and physical vapor deposition.

34. The method as claimed in claim 31 wherein the coating comprises nanoparticles.

35. The method as claimed in claim 34 wherein the coating is nonconductive with at least 10^9 Ohm-cm resistivity.

36. The method as claimed in claim 34 wherein the coating is antistatic with 10^3 Ohm-cm to 10^9 Ohm-cm resistivity.

37. The method as claimed in claim 34 wherein the coating is conductive with 10^{-6} Ohm-cm to 10 Ohm-cm resistivity.

38. The method as claimed in any one of claims 28-37 wherein the coating is applied to any metallic component for the purpose of protecting the component from corrosion.

39. The method as claimed in any one of claims 28-37 wherein the coating is applied to any component to improve the component's anti-static characteristics.

40. The method as claimed in any one of claims 28-37 wherein the coating is applied to any component to increase the component's electrical conductivity.

41. The method as claimed in any one of claims 28-37 wherein the coating is applied to any component to increase the head disk assembly overall electro-magnetic shielding characteristic.

42. The method as claimed in any one of claims 28-37 wherein the coating is applied in a process that integrates ultrasonic cleaning process immediately before coating deposition and in the same controlled environment.

43. The method as claimed in any one of claims 28-37 wherein the coating is applied in a process that integrates an in-line interlocking system of clean environments including a

environment for the deposition of the coating.

44. The method as claimed in any one of claims 28-37 wherein the head disk assembly comprises a ramp and a mating assembly, the coating applied to the ramp for the reduction of particles generated during sliding of the mating part on the ramp.

45. The method as claimed in claim 44 wherein the coating is applied to the mating part.

46. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive motor base component with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

47. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive motor components with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

48. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive top cover with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

49. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive latch and latch assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

50. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive ramp assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

51. The method as claimed in any one of claims 28-37 wherein the coating is applied to the hard disk drive voice coil assembly with exposed surfaces within the hard disk assembly that reduces the number of potential particles on the surface of the component, and provides for the removal of particles with higher efficiency during cleaning.

52. The method as claimed in any one of claims 28-37 wherein the coating is a thin layer film in nanometer thickness.

53. The method as claimed in any one of claims 28-37 wherein the coating is a thin film in micrometer thickness.

54. The method as claimed in any one of claims 28-37 wherein the coating is applied on an electroless nickel (EN) plating layer.

55. Use of a micron coating for decreasing the number of free particles and limit the size of the free particles that contaminate a head disk assembly in a hard disk drive, the hard disk drive having a base, a cover, and the head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.

56. Use of multiple coatings having a top coating of a thin film of nanometer thickness for decreasing the number of free particles and limit the size of the free particles that contaminate a head disk assembly in a hard disk drive, the hard disk drive having a base, a cover, and the head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.

57. Use of multiple coatings having a top coating of thin film of micrometer thickness for decreasing the number of free particles and limit the size of the free particles that contaminate a head disk assembly in a hard disk drive, the hard disk drive having a base, a cover, and the head disk assembly having hard disk drive components, the base, cover and components having surfaces defining a disk drive cavity and the coating applied on the surfaces of the disk drive cavity.