

A COATING PROCESS

Technical Field

The present invention generally relates to a coating process for the application of a uniform surface coating to hard disk components with exposed surfaces.

Background

Thin film coatings with precise uniformity and zero particle contamination are crucial precursors affecting the life span and operation of hard disk drives. This is particularly pertinent in the electronics and microelectronics industry, where the feature dimensions of integrated circuit components fall often within and below the micrometer range. Any free particles from the ambient environment, or which are generated during the coating process, adhere to the surface of the coated component, which may have a detrimental effect on the performance of the component. The problem is further aggravated when high-speed destructive particles generated during the process cause irrevocable damage to the coated surface and hence affects the function of the hard disk. Hard particles, like ceramic particles, are considered killer defects in the hard disk drive industry as such defects may potentially destroy the key functions of the hard disk. An effective coating process should hence satisfy the following requirements: negligible in-situ generation of particles, minimal human handling and transfer, environmentally approved means of disposal of unwanted material waste and most importantly, high

throughput without compromises on the quality and uniformity of the film.

A common coating technique for hard disk housings is spray coating. Spray coating involves the application of a coating, such as a gel coat or plastic coating, to a component by means of a spray gun. Unfortunately, spray coating does not offer precise film uniformity because areas such as the edges, corners and uneven surfaces on the hard disk housing do not receive an equivalent amount of coating material as compared to the centre and flat surfaces of the housing. Hence, precise thickness control is difficult to achieve. Furthermore, there is unnecessary wastage of time and coating material as both sides of the component would have to go through multiple spraying, drying and curing steps. Throughput is often low as multiple coats are required to achieve the desired coating thickness. In addition, control of the spraying operation is challenging as the spray gun has to be controlled precisely to focus on the target component and not on the surrounding frames. Furthermore, spray coating facilities often pose as fire and explosion hazards due to the absence of a proper ventilation maintenance system.

Another common thin film deposition technique involves the immersing of a component into a tank containing coating material, removing the component from the tank, and allowing it to drain. The coated component can then be washed, rinsed and dried by force-drying or baking. Conventional coating processes typically employ the immersion-dwell-withdraw technique, which is limited by improper control of the withdrawal speed and method.

The drag force acting on the coated component is not uniform across the surface which inadvertently affects the uniformity of the film. Due to the uneven drag force, the film thicknesses at the edges and corners of the housing are normally larger than that at the centre of the housing. This not only creates a non-uniform coating, accumulation and coagulation of the coating material may occur, resulting in lumps on the coating. Enhanced system features should be in place for fine-tuning of the dip profile but such features are usually absent in existing coating processes.

Besides the lack of surface profile tuning features, one primary disadvantage associated with conventional coating processes is the excessive manhandling of the hard disk housing throughout the coating process. The coating process typically entails a plurality of coating, washing, rinsing and drying steps, which require the housing to be loaded and unloaded sequentially either manually or automatically. Such a long process line inevitably introduces undesirable particle generation and inter-station cross contamination. More importantly, transfer of the coated hard disk housing introduces process instability. Each process step operates at a different optimum condition. Not only is process control made complicated with multiple transfers, throughput of the process and hence profitability will also be affected since time must be allocated for each station to reach its optimum operating condition. Furthermore, the inter-station transfer of the housings itself and individual maintenance of each station consume process time and renders the entire manufacturing system inefficient.

Another disadvantage of conventional coating processes lies in the physical space requirements of the various modules. Such coating processes typically take place in a clean room environment of class 100 or below where there are at most 100 particles with size $\geq 0.5 \mu\text{m}$. Each coating, washing, rinsing and drying station requires an incremental addition to physical space. This not only drives up the size requirements of the facility, but increases production costs as well. Furthermore, a larger cleanroom requires stringent maintenance and tighter air particle control. All these additional measures only serve to increase the manufacturing cost of the components and lower profitability.

In addition to the aforementioned disadvantages, coating processes usually employ toxic solvents which must be removed and disposed of in accordance with strict governmental guidelines through a process that is highly capital intensive. It is also a requirement for emitted gases to meet safety thresholds. A coater system integrated with an environmentally compliant waste disposal system, though necessary, drives up production costs tremendously. Furthermore, without proper recycling initiatives, such a complex integrated system often results in unnecessary material wastage and increased labor and capital costs.

Given the disadvantages of the aforementioned conventional coating processes, there is a need to provide an efficient integrated coating system which, when applied to electronic or microelectronic components, provides a uniform and particle-free thin film and one

which overcomes, or at least ameliorates, the disadvantages described above.

Summary of invention

According to a first aspect, there is provided a process for coating a hard disk housing component, the process comprising the steps of:

- (a) dipping one or more hard disk housing components in a curable coating bath;
- (b) removing the components from said curable coating bath to form a curable coating on the surface of the components, wherein the orientation of the coated components is such that the coating drips from a single point of the component to allow excess coating to drip therefrom and form a substantially uniform coating thereon.

Advantageously, the process may comprise the step of controlling the orientation of the coated components to enable the coating to drip from a single point. This means that excess coating does not form on the surface of the component except perhaps for the single point from which the coating drips. By allowing the coating to drip from a single point, the coating is substantially uniform in that the surfaces of the coating do not have any regions in which an excess of coating is present on the component after curing relative to other surfaces. That is, there is no "water-mark" effect in which some regions on the component have an excess coating while other regions do not have an excess of coating so that the overall surface appears relatively uniform. For example,

if the component was oriented such that the coating dripped from a region of the component, then that region from which the coating drips would, upon curing, tend to be somewhat thicker relative to other regions on the component.

The single point from which the coating drips is not large enough that it would be considered to be a region of the component. That is, for a three-dimensional component, the single point may be a corner of the component on which three edges meet rather than a whole edge where two edges meet. Typically, the single point from which the coating drips is located at the lowest vertical point relative to other regions of the component.

In disclosed embodiments, the control of the orientation of the component allows the user to control the location of the single dripping point. That is, the single dripping point can be predicted in the disclosed process.

According to a second aspect, there is provided a process for coating a hard disk housing component, the process comprising the step of:

- (a) dipping one or more hard disk housing components in a curable coating bath;
- (b) removing the components from said curable coating bath; and
- (c) curing the curable coating on the surface of the components.

The step of dipping the components is also much faster than other known coating processes for hard disk drive components, such as spray-drying and allows non-flat regions on the surface of the component to be

rapidly coated. Advantageously, the dipping allows coating of parts of the component that can not easily be coated in spray operation because the jet of spray would not have direct access to the inaccessible part. For example, if a first part of a component was covered by another second part, then only the second part would be coated by the jet spray and not the covered part. However, because in the first aspect described above, the whole component is dipped in the curable bath, both the covered and uncovered components are coated. Furthermore, a uniform coating can be obtained by adjusting the orientation of the component while it is being coated to allow excess coating to drip from a single point therefrom and produce a relatively thin film coating.

Advantageously, the flexibility to adjust the orientation of the coated hard disk housings may be achieved by securing the housings on a jig which suspends the housings and tilts them in more than one lateral direction while they are lowered into the coating bath so as to allow the coating to drip from a single point therefrom when the jig is withdrawn from the bath. This process prevents coagulation of the coating at localized spots such that a substantially uniform coating can be achieved. Even more advantageously, the process disclosed herein substantially improves the uniform thickness profile on the coated components. More advantageously, disclosed process which employs dipping to coat the hard disk components can coat a large number of components at any one time as the jig can contain a plurality of housings, thereby rendering the process to be implemented

in a coating process for high throughput of hard disk components.

In one embodiment, there is provided a process for coating a plurality of hard disk housing components, the process comprising the steps of:

mounting the plurality of hard disk housing components on a jig frame such that said components can not move with respect to said frame;

dipping the jig frame loaded with the plurality of components in a curable coating bath;

removing the jig frame loaded with the plurality of components from said curable coating bath to form a curable coating on the surface of the components, wherein the orientation of the jig frame is such that the coating on each component drips from a single point and allows excess coating on the components to drip therefrom and thereby form a substantially uniform coating thereon.

Advantageously, any excess residual coating material can be removed from the jig from which the housing is secured so that the coating will be uniform throughout the edges, corners and crevices of the hard disk housing. More advantageously, the removal of residual coating from a single corner of the tilted jig ensures that no coagulation of the coating material occurs. Even more advantageously, the excess coating material can be recycled for further use, thus reducing material cost.

Advantageously, the process disclosed herein produces coated hard disk housings with increased reliability against data losses since the coatings are ultra-clean with low particle count. The coatings on the

hard disk housings disclosed herein are also adjusted to improve the other surface properties of wear resistance, corrosion resistance, electrostatic resistance and conductivity.

In one embodiment, there is provided a process for coating a hard disk housing component, the process comprising the steps of:

- dipping one or more hard disk housing components in a curable coating bath;

- removing the components from said curable coating bath to form a curable coating on the surface of the components, wherein the

- orientation of the coated components is such that the coating drips from a single point and allows excess coating to drip from a single point to form a substantially uniform coating thereon.

Advantageously, the process disclosed herein produces coated hard disk components with substantially uniform thickness profiles. More advantageously, the absence of coagulated lumps on the coated component surfaces allows the components to undergo rapid drying, thereby shortening the overall process time. Even more advantageously, a high throughput can be achieved despite the plurality of dipping, drying and cleaning steps as a plurality of components can be coated simultaneously and dried at a faster rate compared to conventional coating processes.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "hard disk housing component" in the context of this specification refers to a housing for locating a hard disk therein and to parts of the housing. A hard disk typically has an enclosed cavity wherein a hard disk assembly is housed. The hard disk component includes a top plate, a base plate disk clamps, side walls as well and assembly of a complete hard disk housing.

The term "anti-static" in the context of this specification refers to the ability of a component not to retain or develop an appreciable amount of electrostatic charge. The component preferably remains substantially electrostatically neutral and significantly inhibits the occlusion of particles. By being in a neutral state, the anti-static component has not been subject to friction or other electrostatic charge generating processes.

The term "liquid particle count" or LPC in the context of this specification refers to a numerical measurement of the quantity and size of particles in *in-situ* or flowing liquids. Such measurements can be obtained using a commercially available Liquid Particle Counter.

The term "ultraclean" in the context of this specification refers to a LPC reading of less than 2 particles/cm² wherein the particle size is about 0.3 μ m in diameter.

The term "ultrasonic wash" or "ultrasonic rinse" in the context of this specification refers to washing and rinsing steps that uses ultrasound (usually from 15-400 kHz) and an appropriate cleaning solution to clean the hard disk housings.

The term "substantially" does not exclude "completely" e.g. a composition which is "substantially free" from Y may be completely free from Y. That is, the term "substantially" is to be interpreted as "completely" or "partially". Where necessary, the word "substantially" may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from

3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Disclosure of Optional Embodiments

Exemplary, non-limiting embodiments of a coating process will now be disclosed.

In one embodiment, there is disclosed a process for coating a hard disk housing component, the process comprising the steps of:

- (a) dipping one or more hard disk housing components in a curable coating bath;

removing the components from said curable coating bath to form a curable coating on the surface of the components, wherein the orientation of the coated components is such that the coating drips from a single point and allows excess coating to drip therefrom and form a substantially uniform coating thereon.

The hard disk housing may include components such as a top plate, a bottom plate and a disk clamp. The components may be coated separately or may be assembled to form the hard disk housing before coating.

The hard disk housing or components thereof may be dipped into a curable coating bath. The curable coating bath may be a sol-gel composition comprising silane-based compounds such as a tetraalkoxysilane, for example, tetraethoxysilane; an alkylsilane, for example, tetraethyl orthosilane; or an alkylalkoxysilane, for example, dimethyldiethoxysilane or methyltrimethoxysilane.

The curable coating bath may further comprise a pH adjusting compound such as an acid or an alkali to adjust the pH of the curable coating bath as appropriate. The silane-based compounds may be provided in an alcoholic solvent such as ethanol, propanol, isopropanol, butanol or pentanol; or may be provided in an aqueous medium. The curable coating bath may comprise a resin material to form a matrix.

The curable coating bath may comprise additives that confer a selected property to the coating. Exemplary types of additives that may be added include hardening agents such as zinc particles and stabilizing agents such as polyvinylpyrrolidone.

The hard disk housing or components thereof may be dipped into a curable coating bath at a temperature of about 20°C to about 100°C.

After dipping, the hard disk housing or components thereof may be removed from the curable coating bath to order to form a curable coating on the surface thereof. In order to form a substantially uniform coating on the surface of the hard disk housing or components thereof, the hard disk housing or components thereof may be oriented at any angle between 1° and 90° to allow any excess curable coating on the surfaces of the hard disk housing or components thereof to drip from a common point. The hard disk housing or components thereof may be oriented in at least one of a first angle (θ) and a second angle (ϕ) relative to the vertical plane (y). In one embodiment, the hard disk housing or components thereof may be oriented at the first angle (θ) and second angle (ϕ) simultaneously.

The first angle (θ) and/or second angle (ϕ) may be any angle between 1° and 90° and selected from the group consisting of about 10° to about 45° ; about 10° to about 30° ; about 10° to about 15° ; about 15° to about 45° ; about 30° to about 45° ; about 20° to about 30° ; and about 25° .

The coatings may confer certain properties to the hard disk housing or components thereof. These properties may include an anti-static property, an anti-dust property, an anti-corrosive property. The coatings may increase the conductivity of the hard disk housing or components thereof.

The thickness of the coating may be varied depending on the type of component coated. For example, where the component is the top plate of the hard disk housing, the thickness of the coating may be less than about 1 micron. The thickness of the coating on the top plate may be about 0.1 micron to about 1 micron; about 0.1 micron to about 0.8 micron; about 0.1 micron to about 0.6 micron; about 0.1 micron to about 0.4 micron; about 0.1 micron to about 0.2 micron; about 0.2 micron to about 1 micron; about 0.4 micron to about 1 micron; about 0.6 micron to about 1 micron and about 0.8 micron to about 1 micron.

In embodiments where the component to be coated is the bottom plate of the hard disk housing, the thickness of the coating may be less than about 10 micron. The thickness of the coating on the bottom plate may be selected from the group consisting of about 1 to about 10 micron; about 1 to about 8 micron; about 1 to about 6 micron; about 1 to about 4 micron; about 1 to about 2 micron; about 2 to about 10 micron; about 4 to about 10

micron; about 6 to about 10 micron and about 8 to about 10 micron.

The resistivity of the coatings on the components may be about 10^{-5} to about 10^{-8} ohm-cm; about 10^{-5} to about 10^{-7} ohm-cm; about 10^{-5} to about 10^{-6} ohm-cm; about 10^{-6} to about 10^{-8} ohm-cm and about 10^{-7} to about 10^{-8} ohm-cm.

The coated material may be RoHS (Restriction on Hazardous Substances) compatible.

One or more hard disk housing or components thereof may be suspended on one or more jigs forming a unitary jig frame. This may aid in increasing the throughput of the disclosed process by allowing a plurality of hard disk housing or components thereof to be coated at substantially the same time. Advantageously, the coating process can be applied onto the entire jig frame which can hold a plurality of jigs from which the hard disk housings or components thereof are secured thereto. This may increase the productivity and efficiency of the production process and may ensure that the entire housing or component is coated in one step. Hence, the disclosed process may reduce process time and material wastage.

The hard disk housing or components thereof may be secured to the jig frame by securing means such as a hook and a plurality of non-horizontal support bars. The securing means may comprise a top hook for allowing a top part of the component to be impaled thereon and a bottom support bar for allowing a bottom part of the component to be impaled thereon. A plurality of support bars are oriented in a non-horizontal manner such that the orientation of the secured hard disk components depends on the positioning of the support bars upon which they

are impaled thereon. The one or more jigs may then be mounted on the jig frame and the jig frame may then be dipped in the curable coating bath. The jig frame is lowered into the coating bath such that the top hooks of the jig frame do not contact the coating bath while the secured components are completely immersed. A coating is formed on the hard disk housing or components upon the withdrawal of the jig frame from the coating bath.

The jig frame may be dimensioned as desired and may comprise a number of rows and columns in order to contain a plurality of hard disk housings or components thereof.

The jig frame may comprise release mechanism to enable the easy release of the hard disk housing or components thereof from the jig frame after coating such that the hard disk housing or components thereof can be transferred from one jig frame to a further jig frame in a convenient manner. The release mechanism may be configured to release the hook and support bars mentioned above in an automated manner.

The hard disk housing or components thereof may be cleaned before the dipping step in order to substantially remove contaminants such as foreign particles, dust or grease that may be attached to the surfaces. The hard disk housing or components thereof may be cleaned by using an aqueous medium and a detergent.

The coated hard disk housing or components thereof may be dried after the curing step in order to substantially remove solvent that may still be present on the surfaces. A spin dryer, a blower or an oven may be used to dry the coated hard disk housing or components.

A further post-curing step may involve applying a jet of gas towards part of the coated components to at least remove any unwanted coated material. Excess coating material may cover tiny holes or features not intended to be coated. This pertains particularly to the disk clamp which contains a plurality of holes. During the coating process, the coating material may form thin films over the holes and harden to conceal the holes. Advantageously, a stream of gas may be passed towards the holes to remove any unwanted film formation. Hence, this may aid to substantially prevent hardening of coated material over the areas that are not intended to be coated.

The process may be repeated as desired in order to form a plurality of coating layers on the hard disk housing or components. This can be achieved by repeating the pre-dipping cleaning step, dipping step, removing step and adjusting step. Once a layer of coating has been applied onto the hard disk housing or component, the new layer has to be dried and cleaned to remove excess solvent before additional layers can be coated thereon. This may aid in preventing the existing and new layers from reacting or coagulating together. By carrying out the disclosed process, the coating layers may be substantially uniform and may have a desired thickness that depends on the type of material used in each curable coating bath and time spent for each dipping step. The uniformity of the first underlying layer may aid in ensuring that subsequent layers are substantially uniform.

The hard disk housing or components thereof may be removed from the jig frame before the surface coating is completely cured. The hard disk housing or components there may be transferred or mounted on a second jig frame in an automated manner such that the jig frame and fixtures of one coating station will not come in contact with those of the subsequent station to avoid cross contamination. The transfer of the hard disk housing or components from one jig frame to a second jig frame ensures that the hard disk housings undergo the curing step instead of the jig frames. Hence, this may prevent the coating of the jig frames and ensure that the jig frames can be reused.

The process may be undertaken in a clean room environment with minimal air particles. Preferably, the process as disclosed herein is undertaken in a clean-room environment of Class 100 such that there is less than 100 particles of size 0.5 microns in the room. This may ensure that minimal generation of dust occurs such that the final coated component exhibits a low particle count.

The clean room may include a number of cleaning, dipping, curing and drying stations such that the jig frames can be transported from one station to another in a clean-room environment. This may shorten the process line and time involved. The movement from one station to another may be automated with minimal or no manual involvement so as to reduce the chance of contamination.

Brief Description Of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the

disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1 shows a flow chart diagram of the process disclosed herein.

Fig. 2 is a schematic diagram showing a non-oriented jig frame comprising m rows and n columns of the jigs in which a plurality of hard disk housings can be contained. For illustrative purposes, only one jig is shown in Fig. 2 to be occupied by a hard disk housing.

Fig. 3a shows an expanded view of one jig of width W containing the hard disk housing. The origin ($x = 0$, $y = 0$, $z = 0$) is set at the centre of the housing. Fig. 3b shows the jig of Fig. 3a in which the housing is tilted in the x -direction such that the axes x and x' is subtended by a first angle (θ) relative to the vertical plane (y) and tilted in the z -direction such that the axes z and z' is subtended by a second angle (ϕ) relative to the vertical plane (y).

Detailed Description of Drawings

Fig. 1 shows a flow chart diagram of the process disclosed herein. The process (100) comprises a plurality of cleaning (110, 122) and drying steps (112, 118, 120, 124, 126) before or after the dip coating step (114). Particularly, the curing step (116) comprises a spin- or blow- drying step (118), followed by an oven drying step (120). Post cleaning is then achieved by an aqueous cleaning step (122) followed by a further oven drying step (124) and a final vacuum drying step (126).

The first pre-cleaning step (110) comprises the step of loading of a basket containing the hard disk housings onto a loading conveyor which further transfers the basket to an auto transfer station. The hard disk housing comprises the components of a base plate, a top plate, a disk clamp and other conventional connecting components. The basket containing the housings components then goes through an ultrasonic washing step wherein the housings are cleaned with detergent solution, which removes any grease or oil that may be present thereon. The cleaning step takes place in a 316-litre electro-polished stainless steel tank with a 4-sided weir overflow design. The heater capacity is 6kW and circulation of the cleaning solution occurs at 30 l/min. Temperature in the tank ranges from 45°C to 60°C. Ultrasonic rating is set at 40 kHz and 500W. Level control is achieved via float switches which act as protective level alarms. The pre-cleaning step (110) is designed for 2.5" and 3.5" top plates, 2.5" base plates and disk clamps. Following the washing step, the hard disk housings are then rinsed to remove remaining residue. The ultrasonic rinsing step takes place in the same tank wherein the temperature is now maintained at around 50°C, before the hard disk housings move on to a subsequent drying step (112).

In drying step (112), an oven is used as the dryer. The oven drying station consists of a high pressure scanner with 0.5 μ m filter and a pre-dry facility operating at 6 bar and 170 CFM. Drying takes place in a stainless steel oven. The heater capacity is 6 kW and blower capacity is 800 CFM. Slow velocity high air flow is achieved in drying step (112). The temperature in the

oven is maintained at 90°C wherein the temperature is digitally monitored and controlled. An auto sliding door and thermal controller with oven heat alarm maintains the temperature. The oven is also well insulated by a double-walled 2" thick insulating material. Drying takes place via full width air inlets which direct air flow and air outlets at the base which is connected to a recirculation blower.

The dip coating step (114) which follows sequentially from (112) comprises dipping the hard disk housings in a curable coating bath, removing the components from the bath to form a curable coating on the surface of the components, wherein the orientation of the coated housings is such that the coating drips from a single point and allows excess coating material to drip from the coated components. The coating material contained in the tanks is a solgel composition comprising tetra ethyl ortho silicate or tetra ethoxy silane, an acid or alkali, a solvent and water, a resin for matrix building and additives for hardening and stabilizing the coating bath. The solvent may be any alcohol, preferably isopropyl alcohol. The additives may be zinc particles for hardening purposes and polyvinylpyrrolidone for stabilization. However, the coating disclosed in the disclosed embodiment is an anti-static coating and any anti-static coatings known in the art could be utilised.

The housings may be placed in a plurality of jigs secured in a jig frame. The entire jig frame is then lowered into the coating bath wherein the components are completely immersed. The hard disk housings can be removed from the jig frame and mounted onto jig frame

before the curing step (116). Transfer of the jig frames in such a manner is fully automated such that the jig and fixture of one coating station will not come in contact with those of the subsequent station to avoid cross contamination. Firebreak features are present to isolate the heating source and coating chemicals which contain flammable solvents. Coating takes place in a three sequential 316-litre electro-polished stainless steel tanks with a 4-sided weir overflow design. All three tanks are removable and integrated. An additional non-functional tank for jig cleaning with IPA spray is also present. Safety features like fume exhaust connections are included. An auto sliding door is installed to prevent solvent evaporation. The coating station tank, filter and piping system are all modular with removable features such that the use can easily remove and replace with another set of tank, filter and piping system as and when required. All electrical and air input connections are also easily removable. The replacement and removal process takes no more than 5 minutes to ensure minimum downtime to the machine. The modular coating system is attached on wheels for transportation with an air seal top cover to prevent evaporation of solution.

The curing step (116) comprises a spin- or blow-drying step (118), followed by an oven drying step (120) wherein the drying conditions in (118) are the same as the oven dry step (112). Drying takes place in a stainless steel 304 oven. This is followed by a post-cleaning (122) step wherein the hard disk housings are cleaned and rinsed under the same pre-cleaning conditions as in (110). The hard disk housings then go through a

third oven dry step (124) under the same conditions of (112) and (120). The final process step involves vacuum drying the housings (126) in a vacuum oven. The low maintenance vacuum pump is capable of drawing down to 8 mbar in 30 seconds under no load condition. The pump is mounted on four corners of the oven with 400W internal infrared quartz lamps. The lamps have the flexibility to turn on or off during the vacuuming process. The oven further comprises a vacuum seal and an automatic sliding door. After (126), the hard disk housings are then unloaded on the unloading conveyor.

The coating formed after the curing step (116) is an anti-static, anti-dust, anti-corrosive and substantially uniform coating which is resistant to wear and friction. Multiple coatings may be applied by repeating the process (100) until the desired thickness is achieved. Specifically, a second coating may be applied by dipping the coated component in the curing coating bath, removing the components from the bath to form a second coating, wherein the orientation of the coated components is such that the coating drips from a single point and allows the excess coating material to drip in the same manner as the first coating application. A third coating may be applied onto the second coating in the same manner.

The coating process (114) may further comprise the step of blowing a jet of gas towards part of the coated hard disk housings so as to remove unwanted coated materials covering tiny holes or features. This pertains particularly to the disk clamp which contains a plurality of holes. During the coating process, the coating

material may form thin films over the holes and harden to conceal the holes.

The coating step (114) is executed by placing the hard disk housings in a jig frame as shown in Fig. 2 which comprises m rows and n columns of jigs (201a, 201b, ... 201(n), ... 20(m)a, ... 20(m)(n)) in which the hard disk housings can be contained during the dip coating process (114). Fig. 2 shows a jig frame in which, for illustrative purposes, only one jig (201a) is occupied by hard disk housing (300). The housing (300) is secured via a securing means in the form of a hook and a plurality of non-horizontal support bars; a top hook (not shown) and a bottom support bar (not shown) which is configured to secure and support each of the component at two respective parts: a top part and a bottom part within the jig (201a). The remaining jigs (201b, 202a, ... 20(m)(n)) may contain the hard disk housings in a similar manner. The entire holder is immersed in the solution of the coating material where it remains fully immersed and motionless to allow for the coating material to apply itself to the hard disk housings. The holder is then withdrawn from the coating solution.

The orientation of the holder is tilted such that any excess coating on the coated components accumulates at a single point from which the excess coating may be removed so as to achieve a uniform coating and to prevent coagulation of the coating material in crevices. A schematic of the non-orientated jig containing only one hard disk housing is illustrated in Fig. 3a. Fig. 3a shows an expanded view of the jig (201a) of width W containing the hard disk housing (300). The origin ($x =$

0, $y = 0$, $z = 0$) is set at the centre of the hard disk housing. When the housing is tilted in the x - and z -directions as shown in Fig. 3b such that the axes x and x' is subtended by a first angle (θ) relative to the vertical plane (y) and the axes z and z' is subtended by a second angle (ϕ) relative to the vertical plane (y), excess coating material drips and accumulates at a single point X of the jig. The orientation of the jig frame is such that the components may be tilted by (θ) and (ϕ) simultaneously. The angles (θ) and (ϕ) may range from 1° to 90° relative to the vertical plane (y). By supporting the jig in a tilted orientation, the components are oriented at two angles that are not in alignment with the vertical plane (y), the excess coating material can form from a singular point (ie at the bottom-most point "X" (ref Fig. 3b) of the component 201a). The advantage of this is that the coating material leaves the component 201a at a single point so that it creates a uniform coating as the excess coating drips from a central point and is directed to a container whereby the coating material can be reused. This step may be repeated to achieve the desired thickness of the coated material.

The properties of the coatings achieved in the process disclosed herein are adjusted to improve the other surface properties of wear resistance, corrosion resistance, electrostatic resistance and conductivity. Multiple coatings may be used to achieve the desired thickness. The coated material is RoHS (Restriction on Hazardous Substances) compatible. The thickness of the uniform coating is from about $1.0\ \mu\text{m}$ to $10\ \mu\text{m}$. The thickness of the coated material on the top plate is from

about 0.1 μm to 1.0 μm and the thickness of the coated material on the base plate is from 1.0 μm to 10 μm .

The coating may comprise nanoparticles and is applied for the purpose of protecting the housings from corrosion. The coating may also increase the hard disk housing's conductivity. The coating is conductive with 10^{-5} Ohm-cm to 10^{-8} Ohm-cm resistivity. The entire process (100) takes place in a cleanroom environment of Class 100 wherein there is not more than 100 particles of size $\geq 0.5 \mu\text{m}$. Cleanliness of the coating may be defined with readings and measurements taken by the Liquid Particle Counter (LPC). The hard disk housing is dipped into deionized water with ultrasonic agitation and washed several times until the particle value is obtained. The coating of the process disclosed herein have been analysed using LPC and registers a reading of about 100 to about 3000 particles/cm² for particle sizes $< 0.3 \mu\text{m}$. Under Hard Particle Analysis (HPA), a reading of 1 particle/cm² is obtained. No organic residue in the coating is detected. The process as disclosed herein substantially decreases the number of free particles and limits the size of the free particles that contaminate the hard disk housing. In addition, the process disclosed herein provides for the removal of particles with higher efficiency during cleaning.

Applications

It should be appreciated that the process disclosed herein is a simple yet efficient coating process that combines all coating, cleaning, passivating, drying and

post-cleaning steps within the same cleanroom environment so as to eliminate cross contamination.

Advantageously, the process disclosed herein substantially improves the thickness profile by comprising enhanced features such as a jig in which the hard disk housings are suspended, the orientation of the jig can be controlled such that the suspended housings are tilted according to the orientation of the jig. Even more advantageously, when the housings are suspended on the tilted jig, the coating material is allowed to drip according to the orientation of the jig so that any excess coating material can be accumulated and removed at an edge of the housing, thereby achieving uniformity of the coated material across the hard disk housing. Even more advantageously, the removal of residual coating from a designated corner of the housing ensures that no coagulation of the coating material occurs. Even more advantageously, the excess coating material can be recycled for further use, thus reducing material cost.

Advantageously, the process disclosed herein further enhances the uniformity of the coating by removing unwanted coated material covering holes on the disk clamp by passing an air stream through the holes. More advantageously, the presence of such enhanced features enables control of the thickness profile and hence the quality of the coat.

Advantageously, the process disclosed herein produces coated hard disk housings with increased reliability against data losses since the coatings are ultra-clean with low particle count. The coatings of the housings disclosed herein are also adjusted to improve

the other surface properties of wear resistance, corrosion resistance, electrostatic resistance and conductivity. More advantageously, the coating applied on the hard disk housings protects the housing from corrosion and increases the housing's electrical conductivity. Even more advantageously, the multiple cleaning steps disclosed in the process described herein substantially removes unwanted particles and grease on the housings that may be generated during the process.

More advantageously, the modular nature of the loading, washing, rinsing, coating and drying stations each housing different chemicals, allows easy maintenance and greater flexibility in increasing or decreasing the number of process tanks. The integration of the different stations not only reduces process time typically wasted on inter-station hard disk housing transfer, it also minimizes the time required for each module to achieve optimum reaction conditions. More advantageously, the use of jig frames holding a plurality of jigs increases the throughput of the process as many hard disk housings can be coated simultaneously. Advantageously, greater productivity can be achieved with a much shorter process line. Even more advantageously, transfer of the jig frames can occur seamlessly across modules to avoid cross contamination.

Advantageously, the proximity of the modules eliminates cross contamination since the housing to be coated remains within the enclosed system until all the process steps are completed. More advantageously, the confinement of the cleaning, passivating, drying and post-cleaning modules within a cleanroom environment

minimizes the generation of particles during transfer and from the surrounding ambient, hence ensuring low particle count and quality of the film coating. Even more advantageously, production and maintenance cost of the unified system disclosed herein will be much lower than a system comprising of different stations.

Advantageously, the disclosed automated coating process does not utilize any toxic solvents that require additional waste handling. More advantageously, the disclosed process does not encounter toxic gas emission or pollution issues that plague conventional coating processes. Even more advantageously, the disclosed process is an environmentally compliant process system.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A process for coating a hard disk housing component, the process comprising the steps of:
 - (a) dipping one or more hard disk housing components in a curable coating bath; and
 - (b) removing the components from said curable coating bath to form a curable coating on the surface of the components, wherein the orientation of the coated components is such that the coating drips from a single point of the component to allow excess coating to drip therefrom and form a substantially uniform coating thereon.
2. A process as claimed in claim 1, wherein a plane of said components are disposed in a vertical plane (y) such that the components are oriented in at least one of a first angle (θ) and a second angle (ϕ) relative to the vertical plane (y).
3. A process as claimed in claim 2, wherein the components are oriented in the first angle (θ) and the second angle (ϕ) simultaneously.
4. A process as claimed in claim 2, wherein the removing step (b) comprises orienting the components in the first angle (θ) followed by the second angle (ϕ).

5. A process as claimed in any one of claims 2 to 4, wherein at least one of said first angle (θ) and second angle (ϕ) is not zero.
6. A process as claimed in any one of the preceding claims, comprising the step of:
 - (c) curing the uniformly coated components.
7. A process as claimed in claim 6, wherein the curing step (c) comprises forming an anti-static coating upon curing.
8. A process as claimed in any one of the preceding claims, comprising the step of:
 - (d) applying a jet of gas towards part of the coated components to at least partly remove coating therefrom.
9. A process as claimed in any one of the preceding claims, comprising the step of:
 - (e) cleaning the components before said dipping step (a) to thereby remove any foreign particles thereon.
10. A process as claimed in any one of the preceding claims, comprising the step of:
 - (f) drying the coated components after said curing step (c) to substantially remove solvent in said curable composition.

11. A process as claimed in any one of the preceding claims, comprising the step of:
 - (g) mounting a plurality of said components on a jig frame that is capable of being dipped into said curable coating bath.
12. A process as claimed in claim 11, wherein said jig frame comprises means for securing said components to said frame.
13. A process as claimed in claim 12 or claim 13, wherein the orientation of the jig frame is adjusted while said plurality of components are secured thereto.
14. A process as claimed in claim 13, comprising the step of:
 - (h) removing the components from said jig frame before said curing step (c).
15. The process as claimed in claim 11, further comprising the step of:
 - (i) mounting the cured components onto a second jig frame.
16. The process as claimed in any one of the preceding claims, wherein the thickness of the uniform coating is 1.0 μm to 10.0 μm .

17. The process as claimed in any one of the preceding claims, wherein the coating is conductive with 10^{-5} Ohm-cm to 10^{-8} Ohm-cm resistivity.
18. The process as claimed in any one of the preceding claims, wherein the cleaning, dipping and curing steps are undertaken in a single cleanroom environment.
19. The process as claimed in any one of claims 2 to 18, wherein the first angle (θ) is less than 90° relative to said vertical plane (y).
20. The process as claimed in claim 19, wherein the first angle (θ) is less than 45° relative to said vertical plane (y).
21. The process as claimed in claim 20, wherein the first angle (θ) is disposed in said vertical plane (y).
22. The process as claimed in any one of claims 2 to 21, wherein the second angle (ϕ) is less than 90° relative to a horizontal plane (x) that is normal to said vertical plane (y).
23. The process as claimed in claim 22, wherein the second angle (ϕ) is less than 45° relative to said horizontal plane.

24. The process as claimed in claim 22, wherein the second angle (ϕ) is less than 30° relative to said horizontal plane.
25. A process for coating a hard disk housing component, the process comprising the step of:
- (a) dipping one or more hard disk housing components in a curable coating bath;
 - (b) removing the components from said curable coating bath; and
 - (c) curing the curable coating on the surface of the components.
26. A process as claimed in claim 25, wherein the process is undertaken in a clean room environment.
27. A process as claimed in claim 25, wherein the curing step (c) comprises forming an anti-static coating upon curing.
28. A process as claimed in any one of claims 25 to 26, comprising the step of:
- (d) applying a jet of gas towards part of the coated components to at least partly remove coating therefrom.
29. A process as claimed in any one of claims 25 to 28, comprising the step of:
- (e) cleaning the components before said dipping step (a) to thereby remove any foreign particles thereon.

30. A process as claimed in any one of claims 25 to 29, comprising the step of:
- (f) drying the coated components after said curing step (c) to substantially remove solvent in said curable composition.
31. A process as claimed in any one of claims 25 to 30, comprising the step of:
- (g) mounting a plurality of said components on a jig frame that is capable of being dipped into said curable coating bath.
32. A process as claimed in claim 31, wherein said jig frame comprises means for securing said components to said frame.
33. A process as claimed in claim 31 or claim 32, wherein the orientation of the jig frame is adjusted while said plurality of components are secured thereto.
34. A process as claimed in claim 31 or claim 32, comprising the step of:
- (h) removing the components from said jig frame before said curing step (c).
35. The process as claimed in claim 15, further comprising the step of:
- (i) mounting the cured components onto a second jig frame.

36. The process as claimed in any one of claims 25 to 35, wherein the thickness of the uniform coating is 1.0 μm to 10.0 μm .
37. The process as claimed in any one of claims 25 to 36, wherein the coating is conductive with 10^{-5} Ohm-cm to 10^{-8} Ohm-cm resistivity.