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TITLE: A LASER CLEANING APPARATUS AND METHOD

THIS INVENTION relates to a laser cleaning apparatus and method* for removing contaminants from a magnetic head slider. More particularly, this invention relates to a process which effectively removes solid film and particulate contaminants, such as white particles, disk lubricant, redeposition contaminants, epoxy, epoxy resin and traces thereof, finger prints, embedded metals composed of aluminium, iron, chromium, nickel, silicon, manganese, molybdenum, tin and other inorganic and organic materials from any part of a slider.

In the disk drive industry, the transducer head flying height, ie, the distance between a magnetic head slider surface of a read/write head and the disk surface, has been continually reduced to increase the recording density on the disk. At present, the flying height is about or below 0.1mm. This means that even submicron solid film or particulate contaminants, such as white particles, disk lubricant, redeposition contaminants, epoxy, finger prints, the embedded metals composed of aluminium, iron, chromium, nickel, silicon, manganese, molybdenum, tin and other inorganic and organic materials, can damage both the magnetic head slider and the disk surface. Such damage can lead to a failure of the disk drive system. It has been found that an important cause of this form of failure is the accumulation of solid film and particulate contaminants on the slider surface. Thus, the cleanliness of the magnetic head slider surface is critical.

Solid film and particulate contaminants on magnetic head sliders are generated from the manufacturing processes of magnetic head sliders and the data transducer head gimbal assembly. For instance, the manufacturing process incorporates a lapping process which involves polishing the slider on a rotating plate with slurry as a medium. The

lapping process generates a thick Sn film and deposits some Sn particles on magnetic head sliders. This poses a major problem to the industry.

Traditional ultrasonic cleaning techniques are inefficient for removing these solid film and particulate contaminants, especially thick solid film and submicron particulate contaminants, from magnetic head sliders. There is a need to develop an alternative cleaning technique.

The above-mentioned ultrasonic surface cleaning method is effective to remove most organic contaminations and some particles. However, this surface cleaning method is not suited to the removal of submicron particles and thick film contaminants, such as white particles, disk lubricant, redeposition contaminants, epoxy, finger prints, embedded metals comprising of aluminium, iron, chromium, nickel, silicon, manganese, molybdenum, tin and other inorganic and organic materials, from magnetic head sliders.

In addition, the ultrasonic surface cleaning method uses organic solvents such as trichloroethylene and CFCs which are toxic and cause harm to the human body and which are not environmentally friendly.

Furthermore, personnel working with such cleaning processes may have health problems due to ultrasonic noise and the vaporisation of the organic solvents.

The use of organic solvents in an ultrasonic surface cleaning process means that a number of cleaning steps are performed which makes such a cleaning process both inefficient and costly. Additionally, it is not

possible to remove some film or particulate contaminants using ultrasonic cleaning methods.

The efficiency of ultrasonic surface cleaning techniques is also limited by the handling of the slider to be cleaned into and out of respective solvent baths. The surfaces are cleaned by chemically reacting the surface with the solvent. Additionally, the cleaning of surfaces of large pieces is difficult. Moreover, such techniques do not effectively remove small particles nor thick film contaminants from magnetic head sliders.

This invention seeks to solve the above-mentioned problems of conventional ultrasonic cleaning methods and to provide an apparatus and method for cleaning magnetic head sliders without the use of ultrasonics or organic solvents. Methods and apparatus embodying the invention provide a new cleaning technique which replaces wet cleaning processes such as the ultrasonic cleaning of sliders in organic solvents. An apparatus and method embodying the invention uses a dry process which is easily and cheaply implemented and which is feasible and effective for cleaning magnetic head sliders.

Accordingly, one aspect of the present invention provides a laser cleaning apparatus for cleaning a magnetic head slider, the apparatus comprising: a laser generator for generating a number of laser beam pulses having a predetermined laser fluence selected at a level below the damage threshold of a magnetic head slider to be cleaned; and means for directing the laser beam onto the slider to be cleaned.

A further aspect of the present invention provides a method of cleaning a magnetic head slider comprising the steps of: generating a number of laser beam pulses having a predetermined laser fluence selected at a level below the damage threshold of the magnetic head slider to be cleaned; and directing the laser beam onto the slider to be cleaned.

Preferably, the method includes the further step of storing a number of predetermined sets of one or more operation parameters necessary to achieve optimal cleaning conditions for respective specific contaminants to be removed from the slider.

In order that the present invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of an embodiment of a cleaning apparatus according to the present invention;

Figures 2a, 3a, 4a, 5a, 6a and 7a are optical micrographs of respective slider surfaces before cleaning; and

Figures 2b, 3b, 4b, 5b, 6b and 7b are optical micrographs of the respective slider surfaces after cleaning by various methods embodying the present invention.

Referring to Figure 1, an apparatus embodying the present invention comprises a dry cleaning system for the surface dry cleaning of magnetic slider heads. The dry cleaning system comprises an excimer laser generator 1

which generates a pulsed laser beam with a short wavelength, (i.e. in the ultraviolet wavelength range).

The pulse beam from the excimer laser generator 1 is converted to have a flat fluence profile by a beam homogeniser 2. The size and the shape of the pulse beam from the beam homogeniser 2 is controlled by an electrically and automatically controlled aperture 3. A plano-convex quartz lens 4 is placed on an electric stage 5 which is movable to focus or defocus the beam to reduce or enlarge the beam size thereby adjusting the beam fluence. The beam size and the fluence can be finally controlled by both the aperture 3 and the lens 4. A beam splitter 8 directs the beam onto a belt conveyor 6. A minor portion of the beam passes through the beam splitter and is directed onto an energy meter 9 so that the total energy of the pulse beam can be detected. A magnetic head slider 20 to be cleaned is placed on the belt conveyor 6 which moves the slider 20 into position under the beam for laser cleaning. The speed of the belt conveyor 6 is controlled by a speed controller 7. In practice a plurality of sliders 20 would be located on the belt conveyor 6 and sequentially irradiated by the laser beam.

In response to the energy meter 9 reading, the beam size, i.e. the spot size of the beam, and fluence of the pulse beam striking the surface of a slider 20 can be adjusted by the electronically controlled aperture 3 and the position of the focusing lens 4.

The excimer laser generator 1, the electronically controlled aperture 3, the electric stage 5, the speed controller 7 and the energy meter 9 are all connected to a central computer 10 (having a CPU 10a, a ROM 10b and a RAM 10c) by an interface 11.

The ROM 10b, stores a number of programs or a library of operation parameters which are specific to optimise the cleaning of a particular surface contaminant to be removed from a slider 20. The parameters include the repetition rate of the pulse beam from the excimer laser generator 1, the size and the shape of the aperture 3, the position of the lens 4 on the stage 5, and the velocity of the belt conveyer 6, controlled by the speed controller 7, carrying the sliders 20. The parameters can be controlled independently or dependently of one another. Other parameters can be memorised in the programs or as values to optimise the conditions necessary to clean specific surface contaminants.

The RAM 10c is used as a working memory area for the CPU 10a to execute the programs held in the ROM 10b.

The above-described cleaning system does not require a special environment and can, therefore, be used in atmosphere, in air, without requiring any solvents, a vacuum or any other special conditions. This cleaning system is therefore easily implementable at a low cost.

In the above-described cleaning system, the repetition rate of the pulse beam from the laser generator 1, the shape and size of the electronic aperture 3, the position of lens 4 which is controlled by the electric stage 5, and the speed of the belt conveyer 6 which is adjusted by the speed controller 7 can be appropriately selected by the central computer 10. The solid film and particulate contaminants on slider surfaces 20 can therefore be removed under optimal conditions for each specific contaminant to be cleaned.

Once the optimal conditions have been selected, the slider surface 20 is irradiated by the pulse beam from the excimer laser generator 1 and the contaminants on the slider surface 20 are removed by excimer laser-induced photo-decomposition, laser ablation, slider surface or contaminant vibration and momentum transfer due to the impact of the laser pulse. The slider surface 20 is cleaned by one or more of these effects.

Figures 2 to 7 illustrate examples of the optimal conditions for cleaning various contaminants from a slider 20 and the effectiveness of cleaning methods embodying the present invention.

Figures 2a and 2b show, respectively, the optical micrographs of a slider surface 20 contaminated with Al particles before and after excimer laser cleaning with a laser fluence of 300 mJ/cm^2 , a pulse number of 100, and a repetition rate of 10Hz. The Al particles are efficiently removed under these cleaning conditions.

Figures 3a and 3b show, respectively, the optical micrographs of a slider surface 20 contaminated with film contaminants before and after excimer laser cleaning with a laser fluence of 100 mJ/cm^2 , a pulse number of 1,000, and a repetition rate of 10Hz. The film contaminants are efficiently removed under these cleaning conditions.

Figures 4a and 4b show, respectively, the optical micrographs of a slider surface 20 contaminated with Sn contaminants before and after excimer laser cleaning with a laser fluence of 100 mJ/cm^2 , a pulse number of 2,000, and a repetition rate of 10Hz. The Sn contaminants are efficiently removed under these cleaning conditions.

Figures 5a and 5b show, respectively, the optical micrographs of a slider surface 20 contaminated with lubricant contaminants before and after excimer laser cleaning with a laser fluence of 100 mJ/cm^2 , a pulse number of 1,000 and a repetition rate of 10Hz. The lubricant contaminants are efficiently removed under these cleaning conditions. Figure 5b is magnified with respect to Figure 5a.

Figures 6a and 6b show, respectively, the optical micrographs of a slider 20 contaminated with white particles before and after excimer laser cleaning with a laser fluence of 100 mJ/cm^2 , a pulse number of 1,000, and a repetition rate of 10Hz. The white particles are efficiently removed under these cleaning conditions.

Figures 7a and 7b show, respectively, the optical micrographs of a slider surface 20 contaminated with embedded metals before and after excimer laser cleaning with a laser fluence of 100 mJ/cm^2 , a pulse number of 2,000, and a repetition rate of 10Hz. The embedded metals are efficiently removed under these cleaning conditions.

The efficiency of laser cleaning processes embodying the present invention increase rapidly with increased laser fluence. Thus, the pulse number required for a cleaning process can be decreased by increasing the beam fluence. Therefore, a slider surface 20 can be cleaned with minimum pulse number if the fluence is selected at just under the damage threshold of the magnetic head slider 20. The laser cleaning efficiency almost has no dependence on the repetition rate. Therefore, a high repetition rate is selected to save cleaning time. The cleaning efficiency can be extremely high if a high power, high repetition rate laser is used. Laser cleaning

efficiency also increases with increasing pulse number. Therefore, one can obtain a high cleaning efficiency by increasing the pulse number at a lower laser fluence to avoid causing damage to slider surfaces.

The optimal laser cleaning parameters are that the laser fluence is selected at just under the damage threshold of the magnetic head slider, the repetition rate is high and the pulse number is small enough for high cleaning efficiency and high cleaning speed.

In the above-mentioned examples, a KrF excimer laser is used as a short wavelength pulse laser. In fact, besides a KrF excimer laser, other lasers such as an XeCl excimer laser (wavelength 308nm), an ArF excimer laser (wavelength 193nm), solid-state lasers, semiconductor lasers which can produce pulse beams with a short wavelength under approximately 400nm can also be used for cleaning processes embodying the present invention. The pulse width can also be selected with an appropriate range.

Furthermore, cleaning processes embodying the present invention allow real-time in-situ monitoring by a charge coupled device (CCD) camera and surface reflectivity measurements to be taken by a laser probe using acoustic waves generated by laser-induced surface vibrations from the slider surface.

CLAIMS:

1. A laser cleaning apparatus for cleaning a magnetic head slider, the apparatus comprising: a laser generator for generating a number of laser beam pulses having a predetermined laser fluence selected at a level below the damage threshold of a magnetic head slider to be cleaned; and means for directing the laser beam onto the slider to be cleaned.
2. An apparatus according to Claim 1, wherein a controllable aperture is provided, the laser beam passing through the aperture.
3. An apparatus according to Claim 2, wherein the size and/or shape of the aperture is controllable and comprises an operation parameter of the apparatus.
4. An apparatus according to any preceding claim, wherein focusing means is provided and comprises an operation parameter of the apparatus, the laser beam passing through the focusing means.
5. An apparatus according to Claim 4, wherein the focusing means is mounted on a stage which is movable to reduce or enlarge the beam size, the position of the stage comprising an operation parameter of the apparatus.
6. An apparatus according to any preceding claim, wherein the slider to be cleaned is located on a conveyor belt.



7. An apparatus according to Claim 6, wherein the speed of the conveyor belt is controllable by a speed controller and comprises an operation parameter of the apparatus.

8. An apparatus according to any preceding claim, wherein an energy meter is provided to measure the total energy of the laser beam pulse being directed onto the slider being cleaned, the total energy comprising an operation parameter of the apparatus.

9. An apparatus according to any preceding claim, wherein the laser generator generates a laser beam having a controllable fluence and repetition rate which both comprise independent operation parameters of the apparatus.

10. An apparatus according to any preceding claim, wherein a controller is provided to control one or more of the operation parameters of the apparatus.

11. An apparatus according to Claim 10, wherein memory means are provided to store one or more of the operation parameters of the apparatus.

12. An apparatus according to Claim 11, wherein the memory means comprises a store of predetermined sets of one or more operation parameters necessary to achieve optimal cleaning conditions for respective specific contaminants to be removed from the slider.



13. A method of cleaning a magnetic head slider comprising the steps of: generating a number of laser beam pulses having a predetermined laser fluence selected at a level below the damage threshold of the magnetic head slider to be cleaned; and directing the laser beam onto the slider to be cleaned.

14. A method according to Claim 13 comprising the further step of passing the laser beam through an aperture, the size and/or shape of the aperture being controllable and comprising an operation parameter of the method.

15. A method according to Claim 13 or 14, wherein the beam passes through focusing means which reduces or enlarges the size of the beam.

16. A method according to Claim 15, wherein the focusing means is mounted on a stage which is movable to reduce or enlarge the beam size, the method comprising the further step of adjusting the position of the stage, the position of the stage comprising an operation parameter of the method.

17. A method according to any one of Claims 13 to 16 comprising the further step of locating the slider to be cleaned on a conveyor belt and moving the slider with respect to the laser beam, the speed of the conveyor belt being controllable by a speed controller and comprising an operation parameter of the method.

18. A method according to any one of Claims 13 to 17 comprising the further step of measuring the total energy of the laser beam pulse being directed onto the slider being cleaned, the total energy comprising an operation parameter of the method.



19. A method according to any one of Claims 13 to 18, wherein the laser generator generates a laser beam having a controllable fluence and repetition rate which both comprise independent operation parameters of the method.

20. A method according to any one of Claims 13 to 19 comprising the further step of controlling one or more of the operation parameters.

21. A method according to Claim 20 comprising the further step of storing one or more of the operation parameters.

22. A method according to Claim 20 or 21 comprising the further step of storing a number of predetermined sets of one or more operation parameters necessary to achieve optimal cleaning conditions for respective specific contaminants to be removed from the slider.

23. A method according to any one of Claims 13 to 22, wherein the fluence is in the region of 100 to 300 mJ/cm².

24. A method according to any one of Claims 13 to 23, wherein the number of pulses is in the region of 100 to 2000.

25. A method according to any one of Claims 13 to 24, wherein the repetition rate is in the region of 10Hz.