A New Sputtering System for Hard Disk Media

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ABSTRACT

A “Single Disk” sputtering system has been designed to provide the various process steps necessary to produce the advanced magnetic media required for high storage density hard disk drives. Industry demands for multiprocess capability, high throughput, low particulates, reliability, and low cost were the requirements influencing the design. The resulting system, the MDP-250A, is described and typical process results are shown.

Introduction

The disk drive industry has been experiencing a time of rapid change. Drives are becoming more compact, while the density of data storage and total storage capacity of the newer small drives has been steadily increasing. Disk drives can be purchased today with densities of 500 kilobytes per square inch of disk surface and a density of 2 gigabits per square inch of disk surface has been demonstrated in the lab.

Today, over 80% of all drives produced utilize 95mm disks, either single disks or multiple disks on a single spindle, and this size is slated to continue to be the most popular for the next several years, after which even more compact drives, using media 65mm and smaller, begin to challenge them. Hewlett Packard has introduced a drive, the Kitty Hawk, which is 1.5 x 1.5 x 2" and utilizes hard disk media only 34mm in diameter.

Not only are the disks smaller in diameter, they are also thinner as a result of the push for lower height, and lighter weight, drives. Changes are occurring also in the material out of which the disk is made. For years, all hard disks were made on aluminum substrates, but there is now considerable interest in alternate materials such as glass, glass-ceramic, and carbon.

This trend has placed much greater demands on the quality of the magnetic disk media which, in turn, is reflected in new requirements for the equipment used to manufacture the media.

Media Requirements

A cross section of the thin film layers of a typical magnetic disk is shown in Fig 1. Starting with a substrate of aluminum which has been nickel plated then polished or textured, a layer

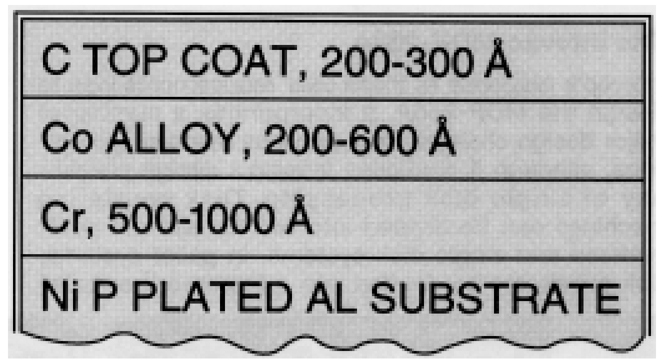

Figure 1 Typical structure of a thin film hard disk

of chromium 500 to 2000 Angstroms thick is sputter deposited. Then a layer of a magnetic alloy, 200 to 800 Å thick is sputtered, followed by a thinner (200 to 300 Å) protective top coat of carbon. Variations on this basic formula include heating and/or etch cleaning the substrate, cooling it, and depositing alternating layers of chromium and magnetic material. Typically DC sputtering is used, but a few producers prefer RF. DC bias voltage may be used, and for some layers, the carbon top coat for example, sputtering with a reactive gas may be done to increase media durability.

In addition to the machine requirements which are dictated by the various processes which must be done, users require other important features.

A. System cleanliness is highly important since the media must be free from particulates. The magnetic head of the disk drive flies on an air bearing at 200-500 Å above the disk surface. It does not take much of a particle to disrupt this, or to ruin the recording surface. The substrates must be exceptionally clean as they enter the sputtering system and the user expects few or no particulates to be added during the various process steps.

B. Media manufacturing is a volume business. Production lines are operated on a 24 hours per day, 7 day per week basis, so high throughput and reliable operation are mandatory. Fully automatic operation with minimal operator intervention is required to minimize the possibility of greater errors, and maximize throughput.

C. Process flexibility is increasingly important. Media production equipment must be capable of handling the process changes which occur when new substrate materials are introduced, or when R&D people discover process changes which could improve the magnetic characteristics or durability of advanced media. This implies a sputtering system which may initially have a spare process location or two, plus the ability to relocate process steps to different machine positions with minimum difficulty.

The Intevac MDP-250A

Intevac's response to these user requirements was to design the MDP-250A. It incorporates a number of major design changes from previous machine generations, although it continues Intevac's design philosophy of single disk processing. Disk sputtering machines can be divided into two categories; pallet systems and single disk systems. In pallet systems, disk substrates are loaded into a framework or pallet which is then passed by large rectangular magnetrons which sputter films on the pallet full of disks. In single disk systems, one disk at a time is entered into the system and passes through a series of relatively small process chambers with the sputter deposition accomplished by circular magnetrons using sputtering targets not much larger than the substrates.

The MDP-250A system is shown in Figs 2, 3, 4. Cassettes containing 25 substrates are automatically moved by a conveyor into a load lock where they are slowly pumped to high vacuum. The cassettes then move into a buffer chamber, which is maintained at high vacuum. In the buffer chamber a vertically moving pedestal lifts one disk at a time from the cassette and transfers it to a swing arm, which then positions it to be captured on a pedestal located on the rim of the disk transfer wheel. This wheel moves up and down and rotates, moving the disks sequentially into and out of the process chambers.

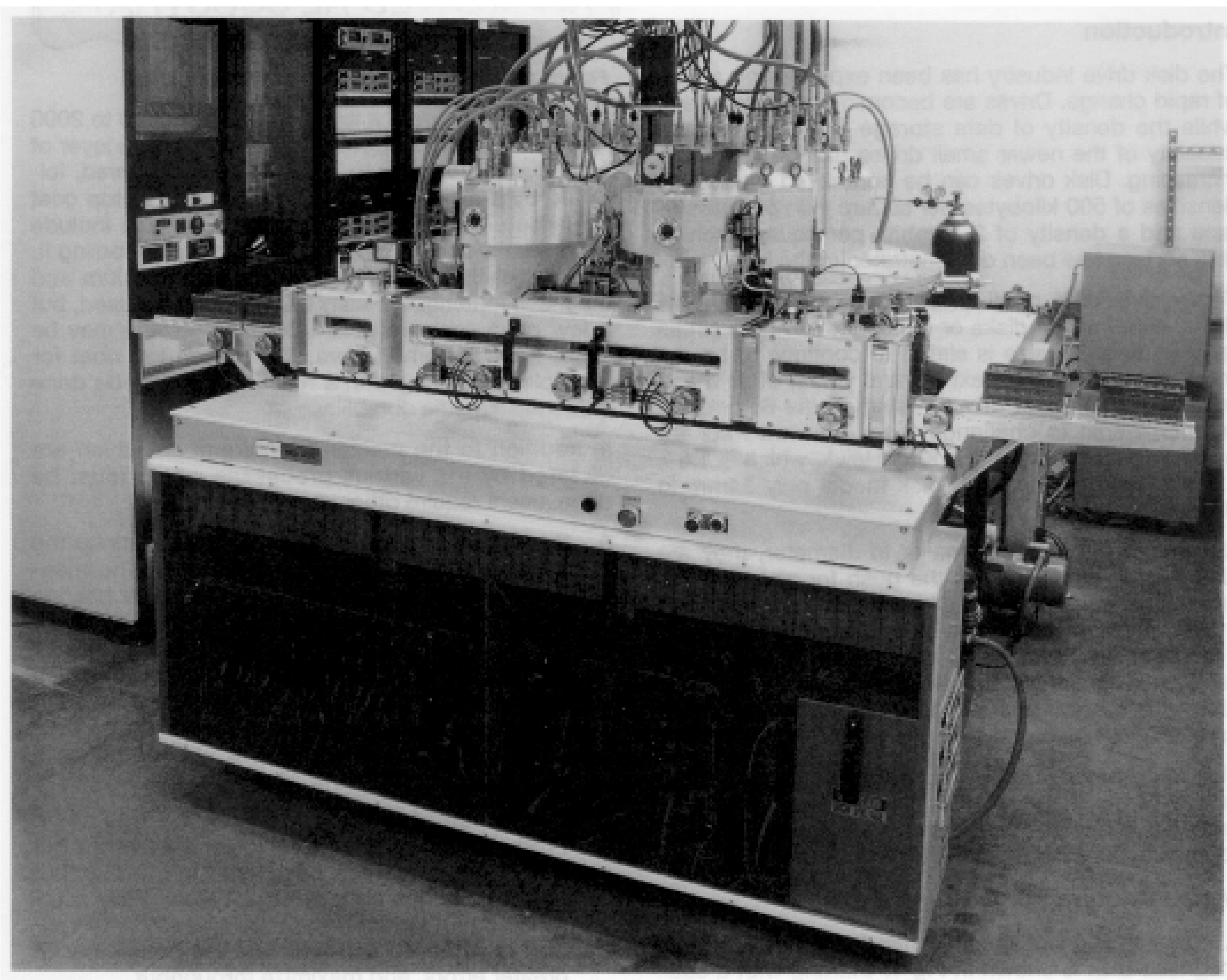

Figure 2 MDP-250A

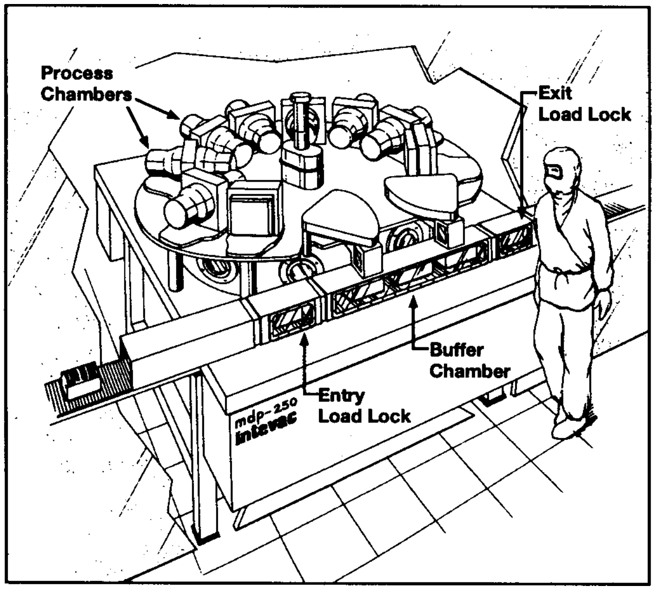

Figure 3 System Overview MDP-250A

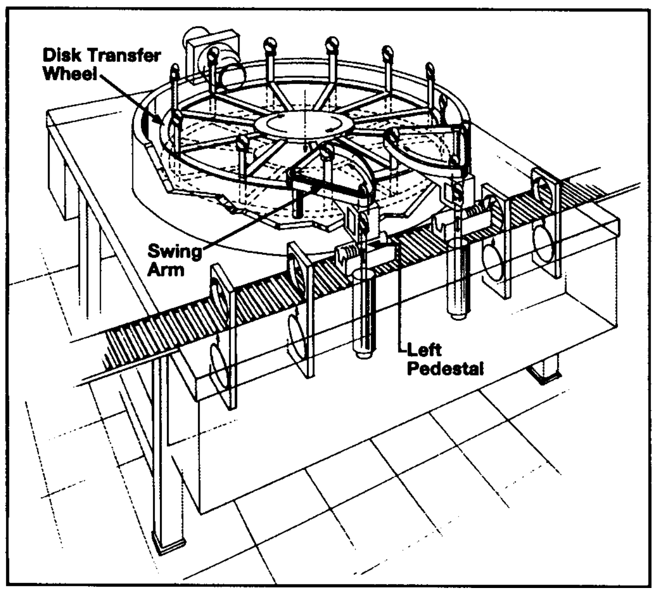

Figure 4 Transport System MDP-250A

When the wheel is in its up position, each process chamber is vacuum isolated from the transport chamber and from other process stations. Each station is separately pumped by either a cryopump or turbopump.

The disks pass through up to 9 process stations, then are removed by an exit swing arm, and placed in an empty position of the cassette. When it is full, the cassette moves into the exit load lock, from which it moves onto the exit conveyor.

We can examine how this system meets the criteria set by media manufacturers:

A. To ensure minimum particulate deposition on the disks we designed for relatively slow pumpdown of an entire cassette of disks. Over two minutes is allowed for this, to minimize turbulence. The load locks are vented with dry nitrogen when cassettes enter or leave, and an optional heater is available to minimize water vapor condensation on the load lock walls. Transport components are all below the level of the disks themselves, so any particles generated by transport have only a small chance of reaching the disk surfaces.

B. The system throughput is 360 disks per hour for today's typical media, a completed disk every 10 seconds. It takes about 3.5 seconds to transport disks from station to station, leaving 6.5 seconds for process. It is relatively small and inexpensive compared to in-line machines which typically have higher throughput. Many users like the idea of "granularity" in production since they may have several products in production at the same time and prefer two or three small production lines going simultaneously on different, or even the same, products rather than to funnel production through a large inline system. On a straight cost per disk produced basis, simple single disk systems are competitive with in-line systems for the high volume media now in production.

The system is fully automated, cassette to cassette. In addition, automatic loading and unloading of cassettes to and from the conveyer has been implemented by at least one manufacturer.

Some customers use the data logging feature of the system which enables them to transmit to a host computer the values of the parameters each disk sees at each process station. This is potentially valuable quality control information.

Process Stations

Figure 5 shows the Intevac "CM-Gun" magnetron sputter source. An electromagnet is used to provide the necessary magnetic field. The system controls the current to the electromagnet automatically so as to maintain the plasma impedance, and therefore the plasma voltage, constant as the target erodes. A software program is also available to gradually increase sputtering power as the target erodes so as to maintain deposition rate constant throughout the lifetime of the target.

The targets are small thick circular discs, without backing plates, which are clamped at the OD and ID against a permanent plate. The back of this plate is water cooled. This indirect cooling arrangement works well, even for target materials which have relatively poor thermal conductivity. However, another version of the source is also available which permits use of targets which are directly water cooled. This can be useful where operating at the highest power density, or maintaining the lowest possible target temperature, is important.

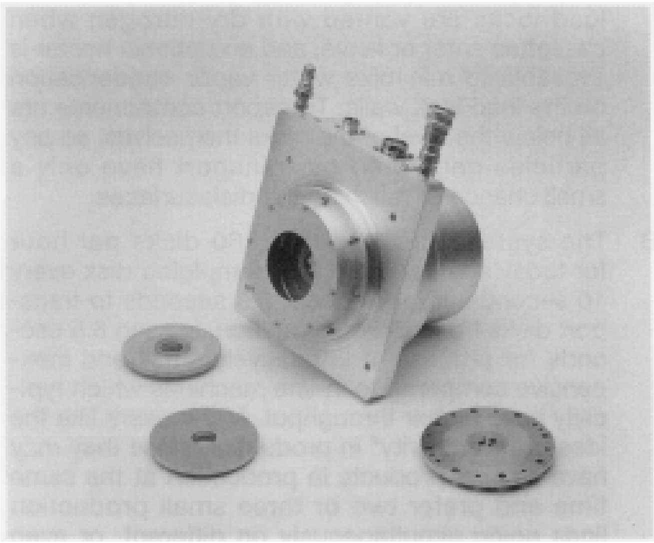

Figure 5 CM-Gun

Deposition rates for 65mm media are about 75Å/KWSEC for metals, and 14Å/KW-SEC for carbon. For 95mm media these rates are 47Å/KW-SEC and 7Å/KW-SEC respectively. 5KW power supplies are provided, with operation typically at about 3KW for metals and 1 to 2KW for carbon.

The disk heating station employs a bank of infrared bulbs on each side of the substrate, backed by a polished water cooled aluminum reflector. Input power available is 5KW. Heating rates for textured nickel phosphorus plated aluminum substrates, 95 mm OD, 0.031" thick, are about 16 degrees per kilowatt-second. Heating rates vary depending on the mass and absorbtivity of the substrate at the wave lengths of the IR bulbs. Temperatures near 260° C are desired for aluminum substrates, perhaps higher for glass or ceramic, but this can be achieved within the 6.5 seconds of process time available.

The cooling station is shown in Fig 6. Gas conduction of heat from the substrate to adjacent refrigerated plates is the cooling method used. Either hydrogen or helium, which have relatively good thermal conductivity, is introduced into the cooling chamber while it is vacuum isolated. The gas conducts heat from the substrate to the large copper blocks on each side of the disks. These blocks are cooled by liquid nitrogen or by using a commercial closed cycle refrigerator. The cooling rate for 65mm, 0.89mm thick aluminum substrates, a currently popular size, is about 26° C per second at 250° C initial temperature, using LN_2 as the coolant and helium as the conductor gas.

Power

The power distribution system is conventional. The system is designed to operate from a 3 phase 440-500 VAC line at either 50 or 60 Hertz. 100 to 150KVA is required, which is distributed to the control and power subsystems. 5KW power supplies, specifically designed for sputtering system application and operated in constant power mode are used for the DC plasma power. Power for the electromagnet coils of the sputtering guns is provided by low voltage, constant current, 10 ampere supplies. The IR heater is powered by a 5KW supply operated in constant power mode.

Control System

MDP-250A operation is automatically controlled by a computer program which displays commands and process information on a color monitor. A user interface is provided which allows an operator to monitor process and to access the programmable controller.

A programmable logic controller (PLC) handles digital input/output and analog output signals. The PLC program continuously polls sensor devices, activates switches, valves, and transducers, coordinates all system subunits, and monitors completion of requested actions. Analog inputs are routed directly to the operator interface computer.

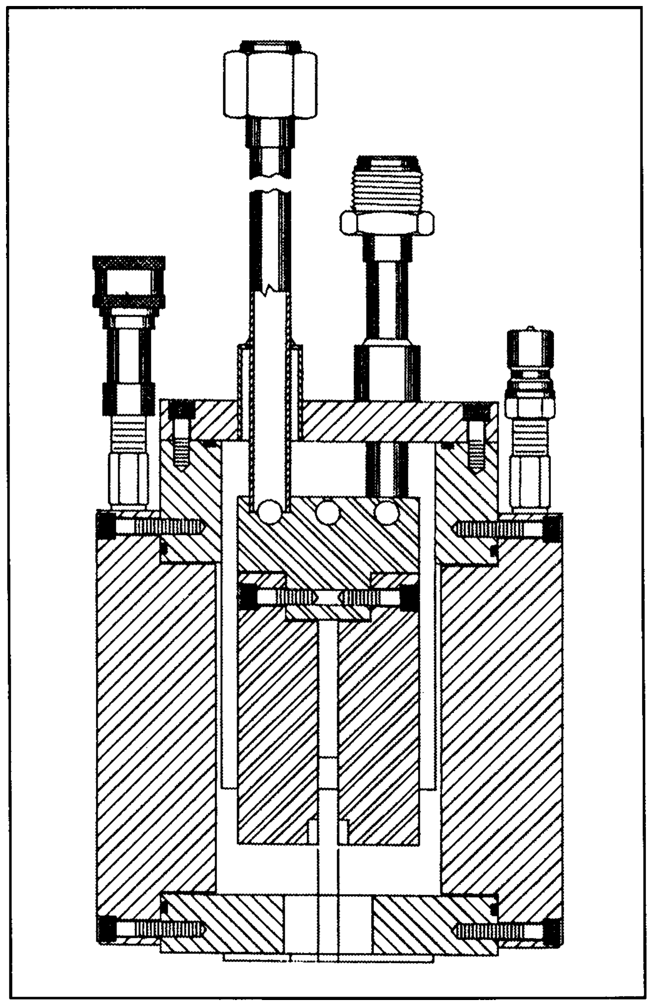

Figure 6 Cross section of cooling chamber

Operator Interface

A color display unit and a keyboard located in the clean room enable an operator or engineer to access the computer program to control deposition or other processes through appropriate menu choices, to monitor deposition data, or to call up certain access-protected service mode subroutines. The operator interface program runs on a 486 based computer which presents a hierarchical series of menus for operator selection. The three main menu options are as follows:

Run Process Mode

This mode allows the operator to select previously stored parameters for the process to be run, set the number of disks to be run, etc., and initiate a disk coating operation. Tolerance bands for system voltage, power and coil current are also provided that warn if any of these parameters being out of bounds. Out-of-tolerance conditions are indicated by both an audible alarm and blinking color change on the screen, so that the operator need not constantly scan all parameters.

Operator Service Mode

This mode allows an operator or an engineer to define process variables, store that information on the hard drive, and perform routine maintenance tasks.

Engineering Service Mode

This mode allows an engineer to troubleshoot process or system problems. The engineer can control operation of individual system sub-units, manipulate data in memory, call up operation subroutines, or operate the system automatically.

Process Specifications

The parameters for up to 25 separate processes, stored on the hard disk can be specified and entered into memory from the Operator Service menu. Additional processes can be specified on other floppy disks. The process variables include following:

- Heating time: 0 to 99.9 seconds (Software interlocked with heater power and substrate thickness)
- Deposition time: 0 to 99.9 seconds
- Deposition power: 0 to 5.00 kw
- Electromagnet current: 0 to 5.00 amps
- Argon flow rate: 0 to 60.0 sccm
- Substrate bias voltage: 0 to 600V
- Process voltage tolerance percent
- Process power tolerance percent
- Coil current tolerance percent
- Desired target voltage and electromagnet control loop enable

Data Logging Option

An optional data logging software package, which sends process data to a user-supplied personal computer, can be provided.

System Monitoring

A number of sensors provide data to the programmable controller which can alert the operator of a faulty condition or shut down the system, if desired. These sensors monitor the following conditions:

- Air line pressure
- Process gas line pressures (first, and optional second and third)
- Nitrogen line pressure
- Water flow
- Vacuum Pump Status

Process Monitoring

In the Run Process mode, the control system monitors and displays deviations from operator set tolerance values at the time of occurrence, including the following process conditions:

- Target voltage
- Target power
- Electromagnet current
- Number of kilowatt-hours usage for each sputtering target
- Argon flow rate
- Optional second gas flow rate
- Substrate bias voltage and current

Conclusion

A special purpose system has been designed to meet the demands of hard disk media producers today, and to provide the flexibility to meet the increasingly more complicated process requirements which may be required in the near future, as hard disk drives steadily increase in storage density, while they simultaneously are being designed to be physically smaller and lighter. As shown in Fig 7, the 250A can produce media with the high magnetic coercivity, and uniformity, required for advanced drives.

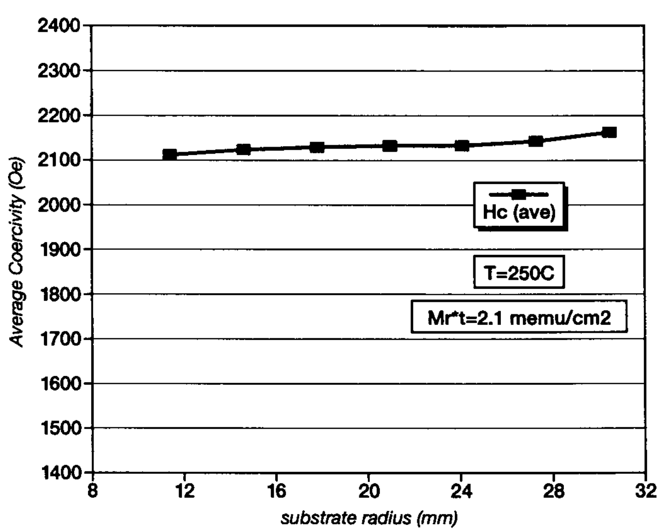

Figure 7 MDP-250 NiP/Al (textured) Media 750Å Cr/400Å Col2Cr4Ta/200Å C (no bias)