WIRE BONDING OF MAGNETIC THIN FILM HEADS FOR DIGITAL RECORDING

Magnetic recording thin film heads used in the high density Winchester type technology must be wire bonded with termination bonding pads located in planes perpendicular to each other. This unusual three-dimensional configuration must also meet specific electrical and mechanical requirements.

The mechanical constraints occur because the interconnect wires become part of the magnetic head assembly which must accurately follow the surface of the recording disc. The flight height of the slider is in the 2500 + 500 Angstroms (10 + 2 microinches); it follows that the forces acting on the slider suspension assembly are critical and must be controlled accordingly.

Electrically bare aluminum or gold wires cannot be used because of a high probability of shorting on the substrate (Al_2O_3 - TiC is a conductor); furthermore a twisted pair of wires is preferable from an impedance matching viewpoint at the very low signal levels and frequencies involved. The preferred method of attachment at the other end to the flex circuit is soldering. The electrical connections must also be able to sustain the 100 ma current pulses which are required to write on the disc.

The scheme currently favored by magnetic head producers uses ultrasonically bonded copper magnet wire plated with a flash of gold over the copper. The insulation varnish is not removed before bonding. Instead the operator relies on sufficient ultrasonic energy and pressure being applied to the bonding tool to clearly separate the varnish from the wire. This must shake the insulator material debris loose; therefore permitting a bond uncontaminated by organic residues. The pressures and ultrasonic energies are larger than normally encountered in ultrasonic bonding.

The termination pads on the thin film head consist of a pair of electroplated copper studs, approximately one mil thick, embedded in, and level, with the top surface of a thick coating of sputtered aluminum oxide. The copper studs are covered by two tenth of a mil of electroplated gold. The copper is electroplated first using a dry photoresist process. It is then removed and over one mil of alumina is sputtered over the whole wafer to encase completely the heads. This is done for mechanical protection, particularly with respect to wear of the thin film head during normal operation start and stop cycles. Sputtering is followed by a lapping process to planarize the top surface and expose the copper studs end level with the alumina. The final step is electroplating of gold to facilitate bonding and prevent corrosion of the exposed copper.

The problem presented by this ultrasonic bonding scheme was to determine the optimal bond settings and gain as much knowledge of the process as possible to guide the development group which was unfamiliar with bonding.

There are three parameters of major interest, they are: bond power, bond force or pressure and bond dwell time. It is apparent that all three would be interactive and increasing one of the parameters increases the energy input into the formation of the bond. The obvious engineering approach would be to hold two parameters constant while the third is varied until the maximum bond strength is obtained. This process would then be repeated for each parameters until one is sure that all three are optimized. Again, to be certain, the entire process would probably be repeated. Unfortunately all interaction effects are lost in this type of scheme.

A statistical design method of experiments called a Central Composite Rotatable Design (CCRD) is preferable. It is a type of three level factorial experiment, in which each variables and levels set, so that the separation of effects and interactions can be done using very simple algebra, rather than needing the solution of full matrices.

Three variables at three levels result in 33 experiments, or 27 experiments in total. Each was replicated four times, for a total of 108 measurements. Each of the 27 conditions was different, and every possible condition of duration, power, and force was used. Two hundred and sixteen wire bonds were made, four of each of twenty seven different conditions. The bond was a measure of bond strength due to each of the three main interaction as well. As would be expected, the equation is parabolic, that is, there is a maximum for each effect, and each effect interacts with every other. It is easiest to visualize bond strength. The surface is actually in four dimensions, where three are the input variables, and the fourth the response. It is easier in the practical world to make three, three dimensional plots, where one variable is held constant in each, and the response is bond strength. The plot in each case resembles an elongated ellipsoid as would be expected. The operating areas were in actuality rather narrow, but once chosen, any of the three variables could be changed to continually optimize bond strength as a parameter. It was common for there to be slow drift in the settings of the wire bonder, and so any of the three parameters could be "tweaked" to bring it back in. It was however, very reassuring to know exactly where we were operating in the total experimental space.

It was our plan to extend the experiment to include a steepest ascent procedure for the development people to use, for the purpose of daily optimization of the equipment. This involves a procedure for varying the three parameters in a specified way, deepnding on the result of bond strength measurements, to optimize the three variables in an ongoing basis, without disrupting work. This was never implemented due to the pressures of implementing the process as soon as possible.

In summary, it was possible to quickly (two days) to implement a process which none of us was very familiar with, which resulted in bond trengths within 90 per cent of ultimate tensile strength of the bonding wire used.

An interconnect system based on a variation of the tape automated bonding was proposed several years ago but never fully implemented. This scheme becomes more attractive and will eventually be mandatory as arrays of heads and higher data transfer rates become feasible. Any wire bonding scheme becomes rapidly mechanically and elecrtically unmanageable as the number of wires and frequencies increase. The current bonding pads consist of approximately 20 to 25 microns of electroplated copper capped with 5 microns of electroplated gold over a sputtered titanium gold interface, but can quite readily be used for thermocompression if necessary. This particular bonding pad structure is partially dictated by other device requirements but thin film heads structures can be readily adapted to any tape automated bonding demands and chosen bonding technology. Appropriate tooling on current semiconductor type TAB equipment could handle the requirements particular to the flexure assembly.

JJH NECHE
OPTOMAG
212 Lester Lane
Los Gatos, CA, 95030
(408) 356-8065

PAUL SIMON
CENSTOR CORPORATION
150 Charcot Avenue
San Jose, CA, 95131
(408) 262-3416

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FOR DIGITAL RECORDING

MAGNETIC THIN FILM HEADS
INTERCONNECT PECULIARITIES

Bonding Pad:

*** Very complex underlayer stucture arising from steps in the head fabrication (Many layers have been omitted from the sketches for clarity)

*** Electroplated copper encapsulated in thick sputtered aluminum oxide (1 mil (25 um)).

*** A 1/4 um diamond polishing step to planarize the surface after sputtering the thick alumina.

*** Gold caps electrodeposited on the bonding pads.

Bonding Wire

*** Insulated copper wire : 1 mil (25 um) diameter with a thin gold film electrodeposited between the copper and the insulator.

*** Urethane insulation approximately 1/2 mil thick (12 um).

*** Process is sensitive to the properties of the urethane .

*** Leonische Drahtwerke AG, Nuremberg, Germany found to be a suitable manufacturer of wire.

OPTOMAG JJH RECHE (408) 356-5085
212 Lester Lane, Los Gatos, CA, 95030

Bonding equipment

*** Ultrasonic bonder

*** 3x3 mils tip size bonding tool.

*** Load on tool in the 75-100 grams range.

*** Ultrasonic power supply: 5 watts with a late design piezo-electric ceramic transducer.

*** A fine wire bonder slightly modified for heavier load on the tool can be used satisfactorily.

*** Bonders used successfully: West-Bond, Orange, (CA) and Mech-El Industries, Woburn, (MA).

Process parameters

*** Optimized by statistical design of experiments.

*** For detailed information on Central Composite Rotatable Design call:
Dr. Paul Simon, Censtor Corporation, San Jose, CA) (408) 263-3416.

*** Reference text for multilevel experiments with quantitative variables:
William J. Diamond "Practical Experiment Designs for Engineers and Scientists". Lifetime Learning Publications, Belmont, CA.