Electrodeposited Magnetic Thin Film Heads: A Quantum Jump For Magnetic Storage; Immense Impact on Development of Electrochemical Technology

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In 1957, when IBM introduced the RAMAC 305 hard disk drive system, the magnetic read-write heads were ferrite horse shoe magnets individually wound with thin insulated copper wire. The introduction of electroplated thin film batch fabricated heads in 1979 in the IBM 3380 disk storage system represented the **first major paradigm shift in the commercial fabrication of inductive read-write heads**. The process made possible fabrication of a large number of three dimensional head structures on planar surfaces and resulted in one order of magnitude increase of bit density, faster data access, and smaller, less expensive systems. In 1989 a **second paradigm shift was introduced** when the integrated MR-read, inductive-write heads replaced the inductive read-write heads. The larger MR and subsequently GMR signals, which were independent of the relative speed between head and disk, enabled even more rapid increases in density and access speed while at the same time allowing continued drastic decreases in disk diameter and in the size and cost of storage systems.

Since the introduction of the thin film heads in 1979 in DASD, the bit density has increased more than 4 orders of magnitude. Commercial systems are available today with 70 Gigabits/square inch, and there are experimental systems with >150 Gigabits/ square inch density. The cost of the system has decreased by 4 orders of magnitude to <$1.00 per Gigabits and disk size has shrunk from 12 to 1 inch diameter. The lighter, and much less expensive disk systems, with much higher density and substantially higher capacity per disk made possible desk and lap top computers, have been a very powerful enabler of the Internet, and are now making their way into digital audio, video recording and other consumer areas.

Electrochemistry gives a quantum jump to DASD

The processes for the mass fabricated, thin film magnetic read-write heads which enabled these dramatic advances in magnetic storage are based on a combination of thin sputtered seed layers, high aspect ratio lithography and novel concepts in electrochemical technology. This plated thin film head technology, along with the ability to fly the heads closer to the disk surface, gave a real quantum jump to DASD and drew the attention of the electronics industry and of electrochemical technology practitioners both in industry and in academia.

Thin film head fabrication has an immense impact on electrochemical technology

Before plated thin film heads were introduced, electrodeposition was thought of as an art suitable for decorating jewelry and household goods, and for providing wear resistance and corrosion protection in the automotive industry. The somewhat unexpected success achieved by making use of the functional intrinsic properties in the first heads opened new horizons to electrochemical technology; now the functional properties and 3 D structures became the key. To fabricate heads it was necessary to tailor the properties to device requirements. Additionally three dimensional structures had to be produced on planar surfaces with a high degree of reproducibility, precision, and uniformity.

The NiFe plating solution showed anomalous behavior in which alloy composition strongly depends on the rate of supply of iron and on the current density. Highly specific tools with new agitation techniques had to be invented and developed to achieve uniform agitation over the entire wafer. A correlation had to be developed between the chemistry of the solution, the structure of the NiFe deposit, the intrinsic magnetic properties and the performance of the heads. To build functional heads, the yokes and the pole tips of the magnetic elements had to be very smooth despite stepping over 10 to 20um steps to avoid Barkhausen noise. The copper coils had to be very closely packed inside the magnetic horseshoe. The yokes, the pole tips and the conductor had to have vertical walls.

Chemical and electrochemical etching could not produce smooth vertical walls in 2 to 3 um thick NiFe or 2 um spaces between 3 um high conductors. To satisfy the needs “plating through mask” and “frame plating” was invented. This opened an entirely new approach to metal patterning capable of achieving extremely high height-to-width aspect ratios and mask replication down to atomic dimensions. The “frame plating” technique solved several problems. It provided excellent current density uniformity and hence good thickness and alloy composition uniformity; it allowed good magnetic anisotropy to be achieved with only a very small applied magnetic field; and it gave extremely well defined vertical walls in NiFe. Fine adjustment of the magnetic properties was achieved by introducing thermal magnetic annealing of the structures. A hard baked thermosetting Novolac type resist was demonstrated to be a good filler/insulator which provided good leveling over the copper conductors and gentle slopes for the yoke and the pole tips.

The combination of electrochemical technology with through mask plating onto thin seed layers has withstood the test of time now for 30 years. The flurry of the activity which started in the late 1970’s at various companies , government and university laboratories has been providing steady stream of technical and fundamental information on material properties and electrochemistry needed to build devices for improved and new applications. Electrodeposition, which was once accepted by electronic industry with great reluctance, now is a desirable low cost technology capable of fabrication of very high aspect ratio structures down to nano dimensions. It now found it’s way into thin film chip carriers, C-4 solder connections, BEOL interconnects and MEMS.

Today the longitudinal magnetic recording, in which the electrochemical technology made its debut, is approaching the physical limits. To achieve the Terabit per square inch density, it will be necessary to switch to perpendicular recording, which will require new heads and new disks. We stand on the verge of the **third paradigm shift.** There is every reason to believe that electrochemical technology here, as in the longitudinal recording, can play an equally important role in the new and more demanding nano structures and devices.