Memorex®

Micro Drives

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From cave walls to stone tablets to papyrus to photographic film to laser devices, storage technology has always come up with new ways to hold and preserve information. We often overlook the fact that sometimes older methods coexist with the latest innovations simply because the older methods have advantages that cannot be ignored. In the electronic age, paper is in greater use than ever before in human history. For digital storage, magnetic recording—considered by many to be dying with tape—still leads the way in the greatest advances in storage capacity. The new Memorex Mega TravelDrive takes advantage of these latest advances to offer capacities beyond flash drives in a more affordable package.

PIONEERS OF MAGNETIC RECORDING

Thomas Edison was the first to record sound, using wax cylinders and a recorder patented in 1877. Oberlin Smith, a mechanical engineer from New Jersey, visited Edison the following year and that same year proposed the first methods of magnetic recording on undefined media. Valdemar Poulsen of Denmark actually produced a magnetic audio recorder in 1893 using steel wire as the medium, and in 1934 German engineers began making magnetic tape, the most commonly recognized form of magnetic media. Edison's wax cylinders waned in the face of Emil Berliner's flat platters, the shape copied by vinyl records, CDs, and DVDs. This platter shape was also used for magnetic media; but these media were hidden from view in vinyl jackets (diskettes), plastic cases (micro diskettes), and sealed cases (hard drives and disk packs). Optical discs have now replaced diskettes and tape in common use. In time they, too, will yield to new challengers from the future—holographic storage for optical storage, solid-state for electronic storage, and advanced hard discs for magnetic storage using the same principles proposed by Oberlin Smith.

PRINCIPLES OF MAGNETIC RECORDING

The basic principles behind magnetic recording are simple: all magnets have two poles--one with a positive charge and one with a negative charge.[1] The charges are best defined when the poles are separated from each other as far as possible, as in a long, thin bar. When the "bar" is a microscopic crystal with a single magnetic domain, it is impossible to eliminate or reduce the magnetic charge on the crystal. It is magnetic forever. It is possible, however, to reverse the charge so that the negative pole of the crystal becomes the positive pole and the positive pole becomes negative. A powerful magnetic field can force or coerce the poles to switch. The stronger the charge on the crystal, the harder it is to coerce the change in polarity; and the measurement of the

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[1] The ancient Greeks rubbed amber, fossilized sap, to put a static charge on it. Small rods of statically charged amber floating on water worked as magnets in early compasses. The Greek word for amber is *electrum,* and the association between magnetism and static charges led to our word "electricity."

strength required to switch the poles is the crystal's "coercivity." Oberlin Smith realized he could draw magnetic patterns in material coated with millions of tiny magnetic particles by arranging their poles under a coercive force. A magnetic "writer" creating varying magnetic fields will leave a record of those variations in magnetic material pulled past the writer, just as a moving pen writes on paper pulled under it in a lie detector. This remains the basic design used today.

The writers are electromagnet heads that have a gap between their poles. As varying amounts of current run through the head, a varying magnetic field spreads from the gap. When blank magnetic tape is pulled across the head during recording, the billions of microscopic magnetic particles that make up the pigment coating[2] magnetically rearrange themselves to match the magnetic field above them as they pass below the gap in the head (Figure 1). The particles do not move physically; they are frozen in position within the coating. They merely rearrange the polarity of their magnetic poles to simulate the field under the gap as they passed below as if the head were "magnetically

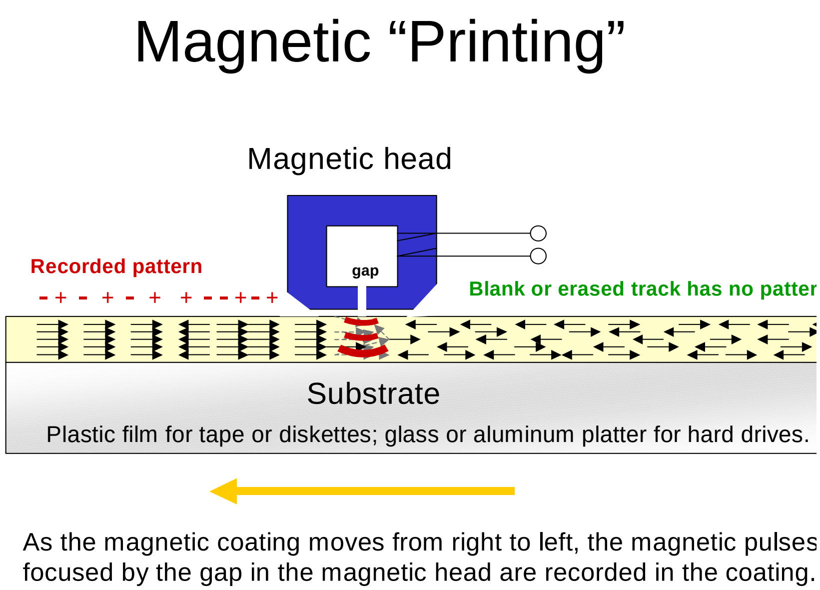

Figure 1

printing" a pattern in the pigment. When recorded tape is pulled across the head, the magnetic pattern on the tape passing below the gap creates a small varying current in the head that matches the original current that made the recording. The head now "reads" the pattern on the magnetic coating. The pattern can be rewritten by recording over the coating again. Erasing the pattern is easy: the head creates magnetic fields that change too fast for the particles to react uniformly. Half the particles in any area are magnetized

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[2] The term "pigment" is used for tape-based media because the coating on the plastic film substrate acts as "magnetic paint." Magnetic particles make up 40-50% of the coating thickness and the rest is resins, dispersing agents, and other chemicals. Gamma ferric oxide crystals were the first common magnetic particles, and they gave the tape a distinctive color. The same type of oxide is also used as the pigment in inexpensive, stable paint used for barns and railroad boxcars. That's why both are often a brownish red.

one way while the other half are magnetized the other way in a completely random way. No pattern exists, and the coating is “blank.”

THE INTRODUCTION OF THE HARD DRIVE

Tape is an excellent magnetic medium for recording, but it has two weaknesses: 1) it is a contact medium that must rub against the magnetic head for the transfer of the magnetic field to and from the head, and 2) it is a longitudinal medium—it takes a much longer time to access a spot on the tape. The first weakness results in both tape and head wear over time. The second makes it difficult to retrieve information quickly--it’s easier and faster to find a track on an LP record than it is on a cassette. IBM engineers in the early 1950s decided to combine the advantages of magnetic recording with the advantages of the vinyl record. In 1956 they introduced the IBM 305 RAMAC (Random Access Method of Accounting and Control). It stored a mere 4.4 megabytes of information spread over 50 discs, each of which was 2 feet (0.6 meters) in diameter.

RAMAC’s 50 platters

The innovative part of the design was that the head did not contact the discs but sat in a robotic access arm that positioned itself just above the discs in order to avoid touching them and to prolong the life of both discs and head. By 1962 IBM had designed heads that literally flew over hard discs by riding a cushion of air. When a computer “crashed,” it usually described exactly what the magnetic head physically did. Figure 2 shows relative sizes of the types of debris that can cause head crashes.

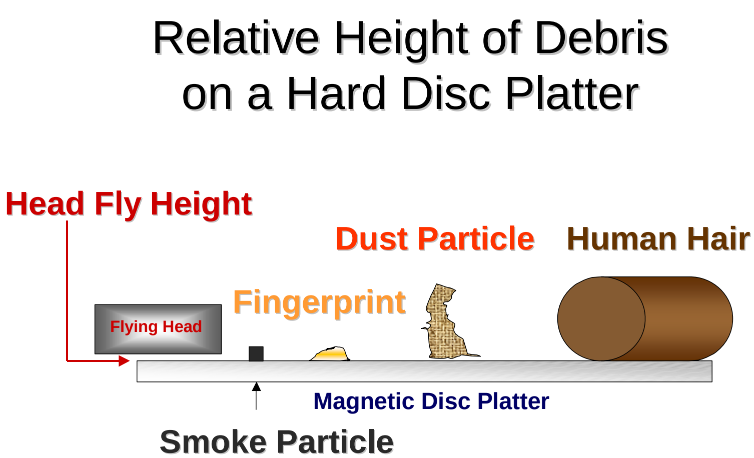


Figure 2

Design goals for magnetic recording have always included increasing the density of magnetic recording and shrinking the size of the media and the recorders. The huge disc arrays and disc packs of the 1950s have given way to small, then mini, and now micro hard drives that hold a thousand times more data in a form factor not much larger than a control button on the earliest drives. The size, speed, and materials have changed; but the principles behind even the most advanced micro hard drives are those Oberlin Smith outlined over a hundred years ago.

MICRO DRIVES: TECHNOLOGY GOES TINY

Figure 3 is a picture of a micro hard drive. The aerodynamic electromagnetic head lies at the end of a lightweight access arm that can position the head anywhere on the hard disc platter in thousands of a second. Instead of multiple 2-foot (0.6-meter) platters, the micro hard drive discs measure a mere 0.85, 1, or 1.8 inches (38.8, 45.7, or 25.4 mm) in diameter. The disc spins at speeds of 3,200 to 4,200 rpm; and in some large-capacity versions of these tiny drives, there are two discs in each drive. A very thin coating of cobalt/chromium/platinum alloy deposited on the platter gives the disc its magnetic properties. The design of the micro drives is nearly identical to that of standard hard drives used in all computers today except that all the parts are smaller and the speeds are somewhat slower. These drives lack the IDE or SATA cable connectors of their larger brothers because they are often designed to transfer data through other interfaces such as Compact Flash or USB connections. In many cases, the drives are permanently embedded in a device and as in the Apple iPods. Figure 3 is an example of such an embedded drive with its ribbon cable connector.

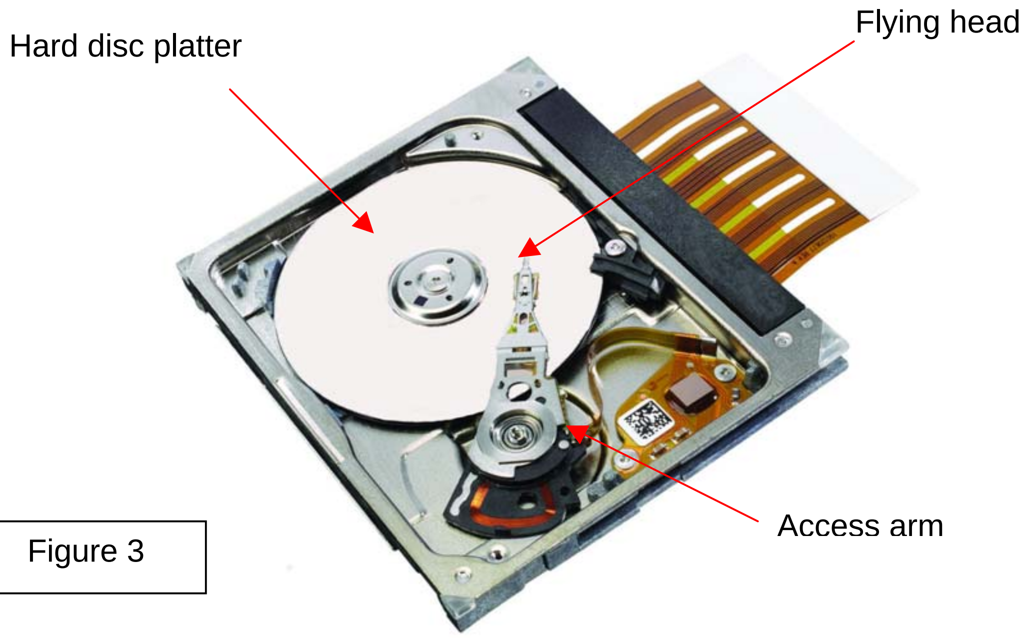


Figure 3

Although the design of micro hard drives is amazingly miniaturized, the concept of magnetic recording in the laser age seems rather crude. Laser light does not wear out the medium any more than flying heads would, and lasers are so much more “high-tech” than modifications to devices dating from the 1950s. The laws of physics, however, are immune to fashion. The fact is that thousands of magnetic particles laid end to end can fit in a wavelength of light—even blue laser light. That means there is much greater storage density potential in magnetic materials than in optical discs.

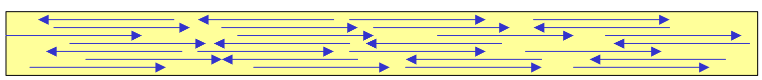
One problem has been that when these tiny particles, each of which is a single magnetic domain, lie end to end, there is some cancellation of magnetic flux (energy) where positive poles lie directly next to negative poles. That cancellation can lead to self-erasure when the magnetic material cannot sustain the smallest magnetic patterns that a record head is capable of producing.

PERPENDICULAR RECORDING—AN OLD THEORY BECOMES REALITY

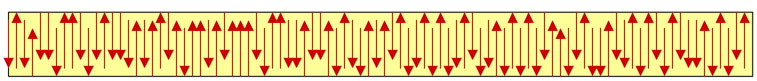
One solution to the problem of self-erasure has been to align the particles vertically in the coating rather than end to end so that more magnetic domains can be packed in the coating. Poles of opposite polarity attract each other, so positive poles next to negative poles can reinforce each other. Since the morphology (shape) of the domain is perpendicular rather than horizontal, there is less self-erasure and sharper delineation of the flux patterns that can be recorded on the vertical tips of the magnetic particles than on their ends. See Figure 4.

This new arrangement of magnetic domains allows "perpendicular recording," a goal of magnetic media manufacturers for some time because of the dramatic increase in flux density allowed by magnetic domains standing head to toe instead of lying end to end. Hard drive manufacturers are just now moving to perpendicular recording as a means to increase storage capacity without increasing the size of the drives or media. Optical recording will only see such a dramatic leap in density when it moves to holographic recording instead of using single wavelengths of light in molded pits. [3]

Greater Flux Density of
Perpendicular Recording



End to end distribution of single magnetic domains



Greater flux density with perpendicular alignment

Less self-erasure of magnetic domains

Figure 4

MAGNETIC RECORDING VERSUS SOLID STATE

There are factors other than recording density that determine which medium is best suited for storage. Two of the most significant factors are cost and reliability. Cost is generally calculated as the cost per gigabyte of capacity. Magnetic media, including tape products, generally have held a significant advantage simply because the storage density of such media is so large per unit. Despite their complexity, micro hard drives maintain that advantage over less complex devices such flash media. The costs of flash media continue to decrease as memory chips become less expensive and production

[3] Critics of optical recording can liken today's methods of using light patterns bounced off molded pits as a "more advanced method of IBM's old punch-card technology."

yield rates improve; but with the leap in density provided by perpendicular recording, micro drives are likely to keep their cost advantage for the rest of the decade. Figure 5 is an estimate of costs per gigabyte of NAND flash compared to the estimates for the 1-inch HDD (hard disc drive) for the next few years. The trend in more capacity at lower cost for both media continues as it has for years.

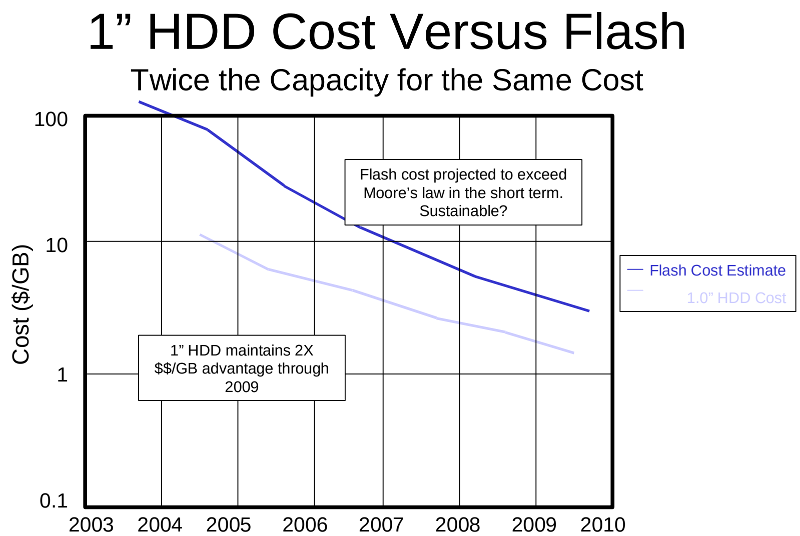


Figure 5

Mini HDD Cost per GB will continue to be ½ of that for Flash Memory

The real advantage flash media have over most other storage media is that they are solid-state—no moving parts. There are no alignment problems; no motors to act up; no bearings that need lubrication. Flash media fall and withstand shocks up to 2,000 Gs of force without damage. Micro drives can actually withstand the same shock forces lasting as long as 1 millisecond—as long as they are not operating. They are far more delicate when spinning their discs: the shock rating drops to 200 Gs for a period of 2 milliseconds.

Micro Drive vs. UFD

	Micro USB Hard Drive	USB Flash Drive (UFD)

Advantages	▪ **50% lower cost per GB**
	▪ Larger capacities up to 8GB
	  ▪ 15GB by late 2006
	▪ Perpendicular recording will increase cost/GB advantage
	▪ Best for high capacity users
	▪ Stable cost due to technology
		▪ **No moving parts**
		  ▪ More reliable—2000G shock resistance even when operating
		  ▪ Less power consumption
		▪ More portable
		  ▪ Smaller, lighter construction
		▪ Availability in capacities up to 4GB
		▪ Increasing affordability
		▪ Rapid popularity in mass market

Disadvantages	▪ **More susceptible to damage**
	  ▪ 200G shock resistance (operating)
	  ▪ 2000G shock resistance (non-operating)
	▪ Less portable
	  ▪ greater size and weight
	▪ Greater power consumption
	▪ Requires standard air pressure
		▪ **Higher price per GB**
		▪ Capacities over 4GB are expensive and impractical
		▪ Availability issues due to NAND shortage

Some new designs actually incorporate “drop sensors” that stop a drive, park the head, and lock the head arm within 140 milliseconds (the amount of time it takes for anything to fall about four inches) so that the “operating shock” rating is very close to that of the “non-operating shock.” Shock absorbent materials cushion tiny hard drives further to reduce the damage from impacts. The fact that the devices are so small and the parts have such low mass is part of the reason why they can sustain much more abuse than their bigger brothers.

A surprise threat for hard drives comes from an unsuspected source. Because the head is actually flying over a cushion of air, it needs air to maintain its flight properly. Hard drives have small, well-filtered vents in them to balance internal air pressure with the outside air pressure. At altitudes greater than 10,000 feet or 200 feet below sea level in unpressurized environments there is insufficient air pressure to maintain the head’s proper flight characteristics. These are unusual circumstances for most people, but they do pose a real threat to hard drives used in harsh environments.

WHAT’S NEXT FOR MICRO DRIVES

What were once electronic “gadgets” have fast become essential parts of modern lives. Cell phones are becoming digital cameras, audio and video players, GPS devices, and even TV sets. Video and photo storage is now commonplace in the most popular MP3 audio players. These changes in portable devices and demands for even better quality photos and high definition video in advanced cameras require more storage capacity than ever before—capacity that must remain small, light, and portable for “digital on the go.” These requirements are precisely the greatest strength of micro drives—lowest cost per gigabyte. New developments will make the drives even thinner than today’s while boosting capacity to 15GB—3,500 times greater capacity than the enormous IBM RAMAC disc array! Micro drives are the best solution to satisfy consumers’ inexorable desire for greater functionality and better quality at reasonable cost.

CONCLUSION

There is no perfect storage medium yet. Stone lasts a long time, but it is heavy and expensive with very limited capacity. The same could be said for paper—one DVD can hold as much as eight file cabinets full of paper. Flash memory is the latest advance in storage, but it is still expensive. Magnetic recording remains the biggest bang for the buck, and perpendicular recording breathes new life into its inherent advantages. Regular hard drives, though, are fragile; and tape is a contact medium that wears over use. Micro hard drives, including the new Memorex Mega TravelDrive, use a sophisticated combination of methods to increase their durability to nearly that of flash memory and still maintain a cost advantage for the near future. They are 125-year old technology wrapped in a 50-year old format with the latest innovations—and they are here to stay.