Perpendicular Recording: A Boon for Consumer Electronics

Kim Nguyen
Corporate Communications
kim.nguyen@hitachigst.com

Advancements to 100-year-old Recording Technology Open Doors for 10-fold Hard Drive Capacity Expansion

While the hard drive industry has been using longitudinal recording successfully for five decades, it is now within two product generations of reaching its practical limit.

For about the past decade, scientists and engineers have pondered the potential effects of a natural phenomenon called superparamagnetism and postulated when its presence might interfere with the progress of the hard disk drive (HDD) industry.

Since the first commercial hard drive was introduced in 1956, the industry has grown storage capacity exponentially by decreasing the size of the magnetic grains that make up data bits. In effect, the smaller the magnetic grain, the smaller the bit, the more data that can be stored on a disk. With longitudinal recording, we are getting close to the point where data integrity will be harmed if we continue to shrink the magnetic grains. This is due to the superparamagnetic effect.

Superparamagnetism occurs when the microscopic magnetic grains on the disk become so tiny that random thermal vibrations at room temperature cause them to lose their ability to hold their magnetic orientations. What results are "flipped bits" – bits whose magnetic north and south poles suddenly and spontaneously reverse – that corrupt data, rendering it and the storage device unreliable.

Today, the hard drive industry's ability to push out the superparamagnetic limit is more critical than ever as capacity requirements continue to grow dramatically. This is due, in large part, to the increasing use of hard drives in consumer electronic devices. Consumers wanting to store more music, photos and video are looking to the hard drive industry to pack more and more storage capacity on smaller devices. The superparamagnetic effect on current magnetic recording technologies will make that growth impossible within one to two years.

Thanks to renewed interest in a magnetic recording method first demonstrated more than 100 years ago, there's confidence at Hitachi Global Storage Technologies (Hitachi GST) and elsewhere in the storage industry that the natural effects of superparamagnetism can be further stalled. That method is called perpendicular recording, which when fully realized over the next 5-7 years is expected to enable a 10-fold increase in storage capacity over today's technology. This would enable, for example, a 60-GB one-inch Microdrive from Hitachi GST, which is used in MP3 players, personal media players, digital cameras, PDAs and other handheld devices.

Hitachi, earlier this month, demonstrated a perpendicular recording data density of 230 gigabits/square inch – twice that of today's density on longitudinal recording -- which could result in a 20 gigabyte Microdrive in 2007.

Perpendicular and Longitudinal Recording: How They Differ

For nearly 50 years, the disk drive industry has focused nearly exclusively on a method called longitudinal magnetic recording, in which the magnetization of each data bit is aligned horizontally in relation to the drive's spinning platter. In perpendicular recording, the magnetization of the bit is aligned vertically – or perpendicularly – in relation to the disk drive's platter.

Perpendicular recording was first demonstrated in the late 19th century by Danish scientist Valdemar Poulsen, the first person to demonstrate that sound could be recorded magnetically. Advances in perpendicular recording were sporadic until 1976 when Dr. Shun-ichi Iwasaki – president and chief director of the prestigious Tohoku Institute of Technology in Japan and generally considered the father of modern perpendicular recording – verified distinct density advantages in perpendicular recording. His work laid the foundation for more aggressive perpendicular recording research that continued even as the industry made advances in areal density using longitudinal recording.

Perpendicular Recording: A Boon for Consumer Electronics

To help understand how perpendicular recording works, consider the bits as small bar magnets. In conventional longitudinal recording, the magnets representing the bits are lined up end-to-end along circular tracks in the plane of the disk. If you consider the highest-density bit pattern of alternating ones and zeros, then the adjacent magnets end up head-to-head (north-pole to north pole) and tail-to-tail (south-pole to south-pole). In this scenario, they want to repel each other, making them unstable against thermal fluctuations. In perpendicular recording, the tiny magnets are standing up and down. Adjacent alternating bits stand with north pole next to south pole; thus, they want to attract each other and are more stable and can be packed more closely. This geometry is the key to making the bits smaller without superparamagnetism causing them to lose their memory.

Perpendicular recording allows hard drive manufacturers to put more bits of data on each square inch of disk space – called areal density or data density -- because of magnetic geometry. Moreover, perpendicular recording results in the improved ability of a bit to retain its magnetic charge, a property called coercivity.

Though it departs from the current method of recording, perpendicular recording is technically the closest alternative to longitudinal recording, thus enabling the industry to capitalize on current knowledge while delaying the superparamagnetic effect.

The exact areal density at which the superparamagnetic effect occurs has been a moving target, subject to much scientific and engineering debate. As early as the 1970's, scientists predicted that the limit would be reached when data densities reached 25 **megabits** per square inch. Such predictions were woefully inaccurate; they did not consider the ingenuity of scientists and engineers to skirt technical obstacles. Through innovations in laboratories at Hitachi GST and other companies, those limits have moved forward dramatically. Today, the highest areal density with longitudinal recording has surpassed 100 gigabits per square inch. However, researchers believe the technology will begin losing its ability to maintain data integrity at areal densities much beyond 120 gigabits per square inch, at which time, perpendicular recording will become the dominant magnetic recording technology.

The superparamagnetic barrier is drawing nearer, forcing the industry to slow the historically rapid pace of growth in disk drive capacity – a pace that, at its peak over the past decade, doubled capacity every 12 months. Using perpendicular recording, scientists at Hitachi GST and other companies believe that the effects of superparamagnetism can be further forestalled, which would create opportunities for continued robust growth in areal density at a rate of about 40 percent each year.

The geometry and coercivity advantages of perpendicular recording led scientists to believe in potential areal densities that are up to 10 times greater than the maximum possible with longitudinal recording. Given current estimates, that would suggest an areal density using perpendicular recording as great as one **terabit** per square inch -- making possible in two to three years a 3.5-inch disk drive capable of storing an entire terabyte of data.

Perpendicular Recording: Opportunity and Challenges

Perpendicular magnetic recording represents an important opportunity for Hitachi GST and others in the hard drive industry to continue to grow capacities at a reasonable pace. Such growth is needed to satisfy the burgeoning information requirements of society: A 2003 University of California-Berkeley study estimates that more than 4 million terabytes of information were produced and stored magnetically in 2002 – more than double the 1.7 million terabytes produced and stored in 2000. There are no signs that the requirements for hard-disk storage is ebbing. On the contrary, all signs indicate that the demand for hard drive storage will continue to grow at a staggering rate, fueled by IT applications and, increasingly, consumer electronics requirements.

Industry analysts have predicted that hard drives for consumer electronics will account for 40 percent of all hard drive shipments by 2008, up from 9 percent in 2003 and 15 percent in 2004. But unlike hard drives used in IT applications where performance is key, hard drives for consumer electronic applications have ultra-high storage capacity as their main requirement. More than ever, consumers are holding their entertainment and personal data in digital formats and have demonstrated an insatiable appetite for storing more music, photos, video and other personal documents. So much so, that Hitachi GST believes in the next 5-10 years, the average household will have 10-20 hard drives in various applications. This vision will require the successful adoption of perpendicular recording.

Even though perpendicular recording is technically akin to the current generation of longitudinal devices, a number of technical challenges remain. For example, engineers at Hitachi GST are engaged in research to invent new kinds of read/write heads; to experiment with new materials that have enhanced magnetic properties and improved surface finishes; to maintain signal-to-noise ratios as the magnetic bits and signals become smaller; and to detect and interpret the magnetic signals using ever more advanced algorithms.

Though large, all of these challenges are familiar – the same type of challenges that the industry has traditionally faced and overcome. But successfully meeting the new challenges will take time, engineering resources and ingenuity on a massive scale – the kind of scale most likely to come from Hitachi GST and other vertically-integrated companies who research and produce their own hard drive technologies.

Equally important, perpendicular recording is not a panacea for all storage requirements. Rather, it is a stepping stone that will give the disk drive industry breathing room to explore and invent new methods of extending magnetic recording. One method called patterned media, for example, may one day reduce the size of a bit to a single grain as compared to the 100 or so grains that comprise a bit today. The approach uses lithography to etch a pattern onto the platter. Once engineered, it is a technology that should be easily and economically replicated, adding no significant cost to the drive and potentially improving areal densities by another factor of 10. Significant research is being undertaken in Hitachi GST laboratories on this approach.

A fundamental challenge researchers are facing is that high media coercivity is normally associated with an increased difficulty in writing. Potential approaches to resolve this problem include thermally-assisted magnetic recording. The heat assist allows recording on improved media with a high coercivity. Another approach is tilted perpendicular recording. This approach sets the magnetization at a diagonal to theoretically improve the media's ability to hold magnetic charge while still being recordable.

Confidence for the Future

When the first five-megabyte drive was introduced 50 years ago, few if anyone could have predicted the current state of the industry. They would likely not believe that a read/write head could fly a hundred miles an hour over a spinning platter at a distance that is less 1/10,000th of a human hair. Or that drives the size of quarters would be capable of storing entire music libraries. This would all be in the realm of science fiction.

Yet they would likely understand the scientific concepts and physical laws that have made these advances possible. While there has been a great deal of invention, the basic science – like Valdemar Poulsen's discovery more than 100 years ago – has remained relatively constant.

Such constancy gives rise to confidence across the industry that the challenge of superparamagnetism will be met. Perpendicular recording is the most likely first technology bridge but it is by no means the last.

.

# # #

Hitachi Global Storage Technologies

Hitachi Global Storage Technologies
5600 Cottle Road
San Jose, CA 95193

Produced in the United States 4/05