

## Sony, metal particle and A3MP tape: Nanoscale technology for terabyte storage

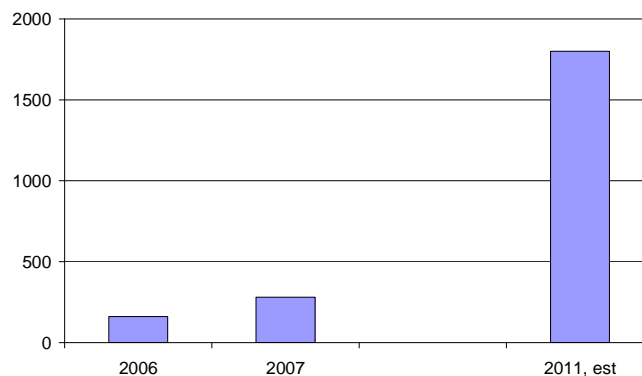
As the need for backup storage grows at double-digit rates, reliable storage technology has never been more important. A key tool in today's data centers is metal particle tape. This document will explore the explosive growth in data storage, the ways in which Sony metal particle tape meets the most stringent user requirements, and the nanoscale technology behind Sony Advanced Alloy Armored Metal Particle (A3MP) technology, as featured in Sony LTO™ 4 data cartridges

### ***The need for "areal density"***

Since 1965, Information Technology professionals have worked under the imperatives of Moore's Law, the prediction by Gordon E. Moore that the number of transistors on an integrated circuit would double every two years. As the prediction has proven out, the constant doubling and re-doubling of processor power has enabled computers to handle ever-more sophisticated forms of data.

From the relatively simple customer account data of the 1950s, the world of IT has grown to embrace word processing, desktop publishing, digital music, email backup/archiving, web assets, high-resolution digital imaging and high definition video, etc. As a result, the relentless growth in processor power has been matched by a staggering explosion in digital information. IDC estimates that 281 exabytes (281 billion gigabytes) of digital information was created in 2007, up 75% over 2006. As an example, IDC reports that Wal-Mart's data warehouse holds 600 terabytes, while Chevron's oil exploration activities accumulate 2 terabytes of new data every day. For the future, IDC estimates that nearly 1,800 exabytes of digital information will be created annually by 2011. This equates to roughly 60% compounded annual growth rate. Not only is data being created at ever increasing rates, but new regulatory mandates also require the data to be accessible for much longer retention periods.

Digital information created, Exabytes



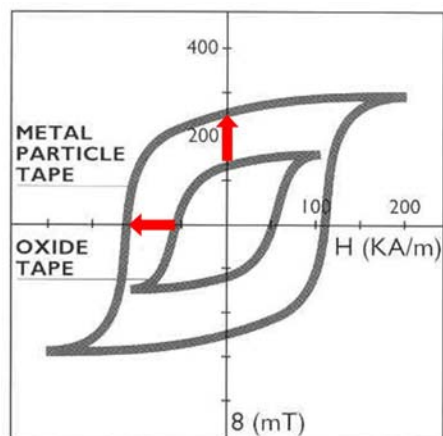
*The creation of digital information is exploding. (IDC, March 2008.)*

Behind Moore's Law have been well-publicized advances in micron-scale and sub-micron integrated circuit manufacturing processes. These enable more and more transistors to be manufactured on each square inch of silicon. Less heralded, but no less important has been intense research and development in magnetic and optical storage. The microscopically fine

metal particles that store digital 1s and 0s have gotten progressively smaller—into the nanoscale. This progress has enabled more and more bits to be stored on each square inch of storage media. The parameter of bits per square inch, which storage technologists call "areal density," is one of the key factors fueling progress in Information Technology.

### ***Metal particles and areal density***

The essential parameters of data tape recording are two magnetic properties that almost never come up in cocktail party conversation: "coercivity" and "retentivity." The first governs areal density, which is essential for greater capacity per area of tape. The second controls carrier-to-noise ratio, which is essential for reliable reading of digital 1s and 0s. Multiplying the two numbers gives the "magnetic energy" of a tape. In a very real sense, the history of tape recording has been a constant search for materials that maximize this magnetic energy.



*Sony introduced the world's first metal particle tape in 1978. Compared to oxide tape, metal effectively doubles both coercivity (left pointing arrow) and retentivity (upward pointing arrow) for a fourfold increase in magnetic energy.*

From the dawn of magnetic recording, the active ingredient in tape has traditionally been some form of metal oxide—such as rusted iron. If you've ever recorded or played a VHS tape, you've used metal oxide technology. Unfortunately, metal oxides are extremely limited in both of these two magnetic properties.

Early on, Sony engineers understood the potential of pure, unoxidized metal particles—"metal particle tape." As early as 1959, Sony was producing MP tape in their labs. Unfortunately, the metal particles of the time suffered from chronic instability—they oxidized suddenly (and violently) when in contact with air. Other obstacles to commercialization included lack of particle uniformity and the challenge of creating compatible read/write heads.

Fortunately, Sony engineers persisted. And in 1978, they marked a stunning success with the launch of the world's first metal particle tape: the MC-90 dictation microcassette. In a single stroke, MC-90 doubled *both* coercivity and retentivity of the tape. With four times the magnetic energy of previous tapes, the Sony MC-90 inaugurated a new era in tape recording.

The Sony MC-90 was soon followed by Sony "Metallic" audio cassettes in 1979, Sony 8mm videocassettes in 1985, and Sony BCT-MA series Betacam SP broadcast videocassettes in 1986. BCT-MA made such a profound difference in broadcasting, that Sony's metal particle tape technology was honored with a 1990 Emmy Award for Technical Excellence.

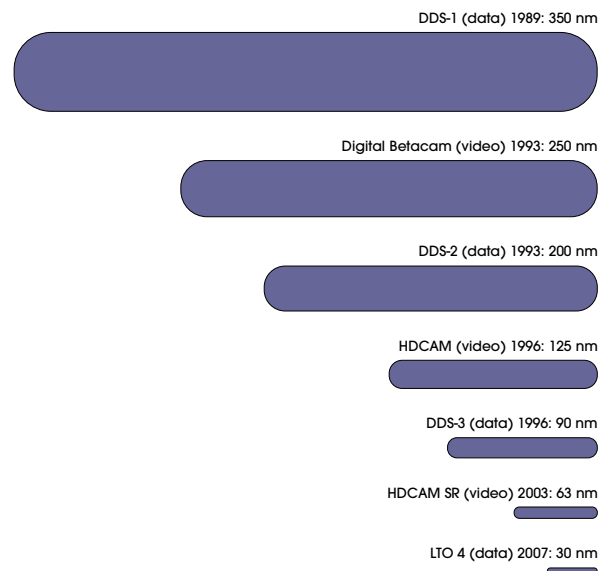


*Sony metal particle tape technology was recognized with an Emmy Award for Technical Excellence in 1990.*

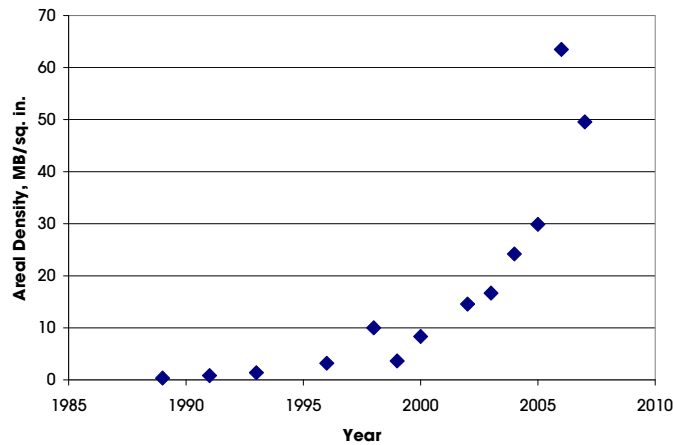
Up to the late 1980s, all data cartridges were still using the older, oxide tape. But it was inevitable that the advantages of metal particle tape would enter the data world. In 1989, Sony and Hewlett Packard introduced DDS data cartridges with MP technology. Since that time, metal particle data cartridges have gone from the exception to the rule. From DLT™ to LTO™, most of today's major data cartridge formats use some form of metal particle tape.

### ***Metal particle tape and Moore's Law***

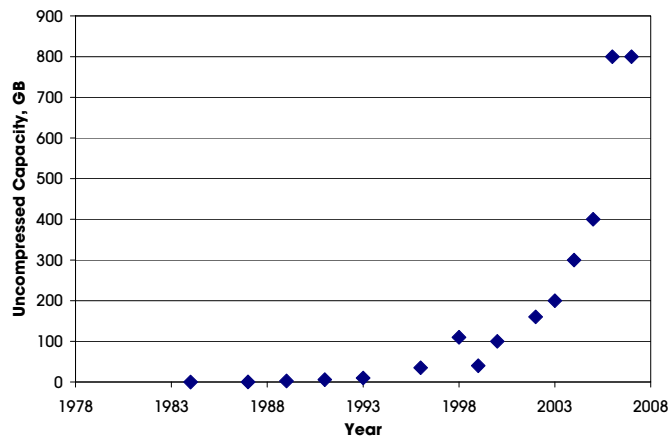
If metal particle were simply superior to 1978-vintage oxide tape, the story might have ended decades ago. But MP has also had enormous potential for additional development. Succeeding generations of metal particles have been smaller and smaller, enabling higher and higher storage capacities per area of tape. In this way, the rapid increase in computing power predicted by Moore's Law has been met with an equally vigorous growth in data tape storage capacity.



*The metal particle sizes for selected Sony tapes demonstrate the unrelenting pursuit of ever smaller particles—for ever higher capacity. The measurements are in billionths of a millimeter—nanometers (nm). For comparison, the average human hair is 75,000 nm thick!*



*Smaller metal particles have led directly to higher areal density. This chart tracks the uncompressed areal density of half-inch data cartridges, arranged by date of introduction. Starting at 360 KB per square inch in 1989, today's cartridges hold up to 63 MB/sq. in.*



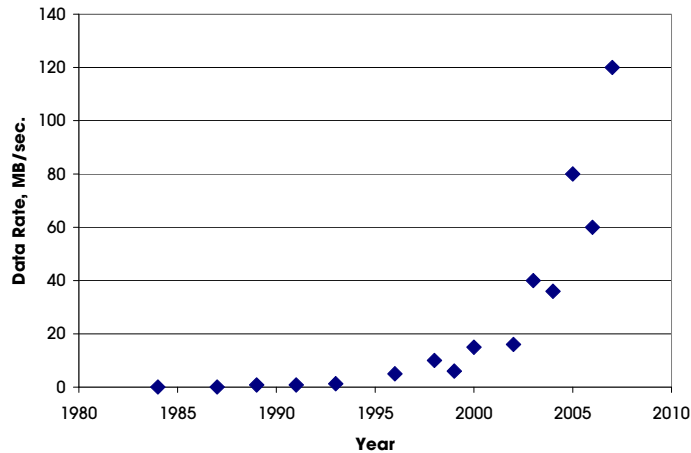
*Density means capacity. Here is the storage capacity of half-inch data cartridges. While the cartridge form factor have not changed, uncompressed capacity has boomed from 100 MB (native capacity) in 1984 to 800 GB in 2006—an 8,000-fold increase.*

Other things being equal, high density and high capacity also deliver important, tangible benefits:

- Smaller, less expensive data libraries, because each individual cartridge holds more data.
- Easier data portability. As high definition and multimedia files get bigger and bigger, the high storage capacity of metal particle tapes can keep shipping and cartridge storage costs in line.

### **Metal Particles and performance**

Increased capacity is only the most obvious benefit of the staggering areal density of today's metal particle tape. High density goes hand-in-hand with high performance, because less tape needs to be moved past the read/write heads to transfer a file.



*Metal particle tape technology has been instrumental in boosting half-inch cartridge drive performance from 45 KB/second in 1984 to 120 MB/second today. That's a 2,600-fold increase.*

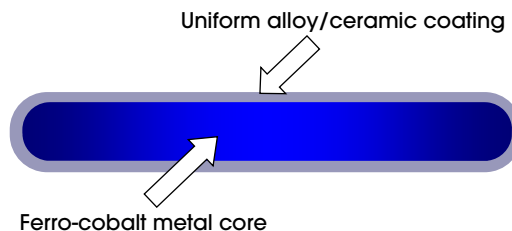
High performance makes a huge practical difference in the real world.

- Faster and reliable data backup. So backup jobs that are "supposed" to happen overnight actually do.
- Less time lost to cartridge interchange because each cartridge holds more.
- Faster data restoration. A single lost hour on a large network can cost tens of thousands of dollars. Faster reading and faster access can speed restoration—and save you money.

### **Beyond particle size: Sony A3MP Technology and LTO 4**

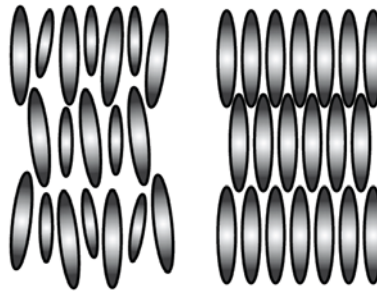
Sony's latest generation of LTO (Linear Tape Open) technology, LTO-4 takes advantage of the smallest metal particle size yet: a mere 30 nanometers long. Such small particles lend themselves naturally to the high recording densities that the LTO 4 format requires. But small particles alone are not enough. Ensuring high performance and high reliability required an entire system of technologies that Sony calls Advanced Alloy Armored Metal Particles, or A3MP.

**Protective Encapsulation.** As the A3MP name implies, Sony's ultra fine 30 nanometer particles are armored, completely encapsulated in an alloy/ceramic coating. This coating protects each particle from unwanted oxidation—and protects your data from premature loss. As a result, Sony LTO 4 cartridges deliver outstanding archival life.



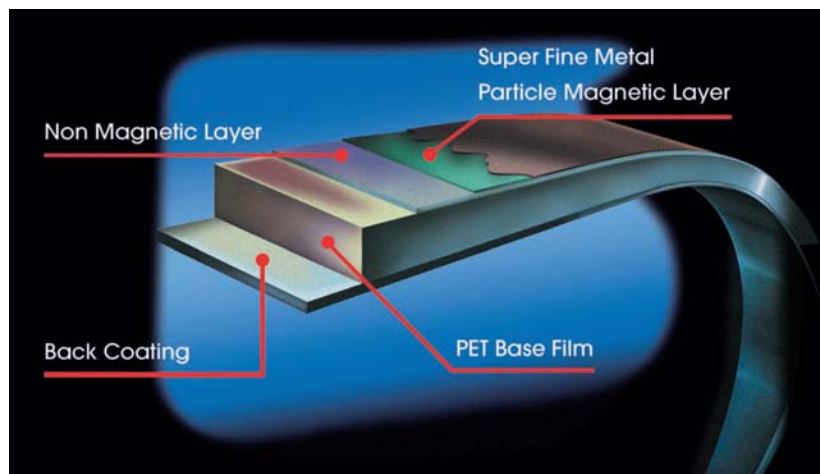
*Each Sony A3MP particle is armored with a protective alloy/ceramic coating.*

**Superb uniformity.** Variations in particle size—and variations in particle orientation—can degrade carrier-to-noise ratio. That makes it harder for the drive to reliably detect the difference between data 1s and 0s. To maintain consistent size, Sony exercises amazingly tight process control. To maintain consistent orientation, Sony subjects freshly-coated tapes to powerful and highly precise magnetic orientation. The result is a measurable improvement in carrier-to-noise.



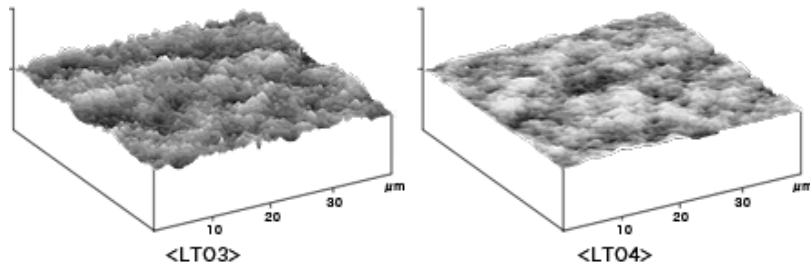
*Schematic view of conventional magnetic particles (left) and Sony's highly uniform A3MP (right)*

**Ultra-thin coating.** You might imagine that thicker coatings of magnetic material are better than thinner coatings. But at the incredibly high areal density of LTO 4, thick coatings trigger a phenomenon called "self demagnetization." This actually weakens the recorded signal. To combat this problem, LTO 4 data cartridges require ultra-thin coatings of just 200 nanometers. To better visualize such thin coatings, imagine painting a car. At 200 nanometers thickness, you could cover the entire car with less than one teaspoon of paint! The 200 nanometer coating corresponds to a layer just three metal particles thick. Sony coating technologies succeed in applying the active metal particle layer with supreme consistency.

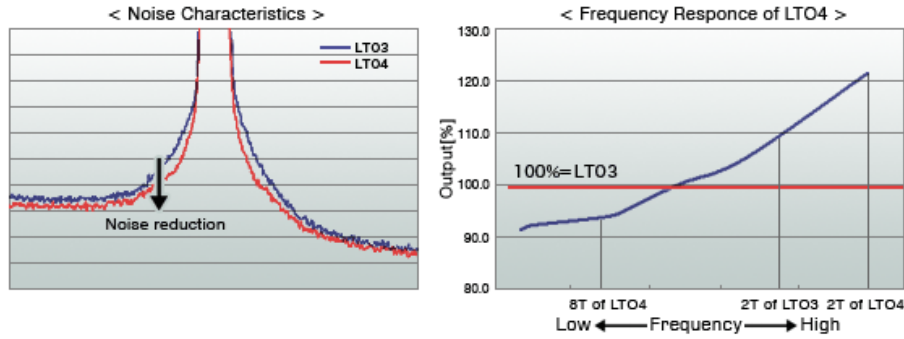


*Instead of a single, thick coating of active magnetic particles, Sony LTO 4 media incorporates a super fine 200 nm coating of metal particles, backed by a non-magnetic layer.*

**Surface smoothness.** Sony is the only data media manufacturer that is also a primary manufacturer of data drives. From this extensive, hands-on experience, they understand that the extremely sensitive interplay required between magnetic media and the magneto resistive read/write heads of LTO 4 drives. Excessive irregularity in the tape surface can cause premature head wear and generate static electricity that can degrade carrier-to-noise ratio. Careful process control in Sony's tape manufacturing maintains optimum surface smoothness, for best drive operation even during multiple read/write cycles.

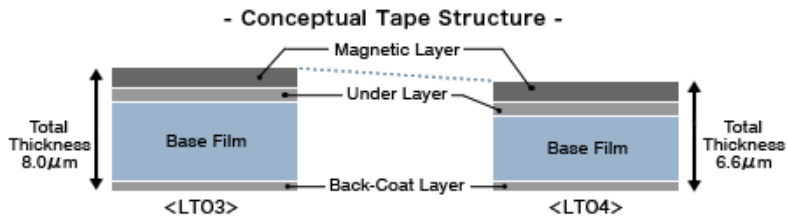


Actual measured smoothness of Sony LTO 4 tape (right) far exceeds Sony LTO 3 tape (left).

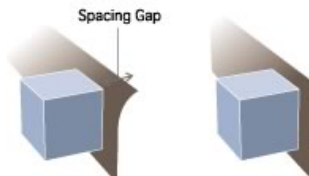


The incredible surface smoothness of Sony LTO 4 tape simultaneously improves carrier-to-noise ratio (left) and increases high-frequency output (right) compared to Sony LTO 3 tape.

**Dimensional stability.** While LTO 3 data cartridges hold 680 meters of tape, the LTO 4 cartridge design calls for 820 meters with no increase in cartridge size. For this reason, LTO 4 tape must be somewhat thinner (6.6 micrometers as compared to 8.0 micrometers) using a thinner base film. Ironically, the ultra-small read/write heads of LTO 4 drives require this film to be stronger than ever! Sony solves the problem with a polymer alloy hybrid base film. It reduces dimensional changes by 60% and increases lateral strength by 45%.



The LTO 4 cartridge design requires a thinner base film than LTO 3. Yet the LTO 4 base film is required to perform even better.



Unwanted spacing gaps (left) between the read/write head and the tape degrade performance and cause errors. While a weak base film might allow spacing gaps, Sony's polymer alloy hybrid base film prevents them.

**Ultra-precise servo track.** Because LTO 4 uses 896 data tracks compared to 704 tracks for LTO 3, proper alignment between the record/playback head and the recorded tracks is crucially important. These tracks are pre-written on the media as part of the manufacturing process. Sony's experience with hardware and media manufacturing allowed it to develop a proprietary servo track recording system that maintains the microscopically small servo track width to a tolerance of 0.14%. To appreciate the precision, imagine that the servo track were the width of a train track (4 feet 7 inches). Variation would be held to less than 0.1 inch! This results in superior writing and reading accuracy.

**Improved cartridge.** Along with Sony A3MP innovations, the LTO 4 cartridge itself is upgraded with an ultra-precise high-roundness hub and an improved flange shape to protect the tape edges. In accordance with the LTO 4 specifications, the cartridge also incorporates a non-contact IC memory for file access metadata that offers twice the capacity of previous generations.

### ***Into the future***

As a world leader in metal particle tape products—and as the world's number one recording media manufacturer—Sony is committed to the future. Not only are they already hard at work on the development of LTO 5 tapes, they are also working on the materials and manufacturing processes that will take data media beyond the next level of storage capacity.

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