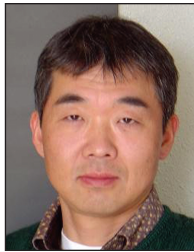


# Magnetic Tape Developments for HDV Recording with MPEG-2 Compression

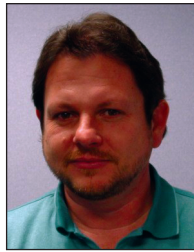
By Wayne Desmond, Hideki Kikuchi, and Steve Tice



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***Current innovations in compression technology allow for the storage of high-definition format video on the same format cassette that is used for standard definition. This is done using MPEG-2 compression. To achieve high rates of compression, MPEG-2 uses a groups of pictures (GOP) method with a single intra-frame (I frame), complete picture information, predictive (P frames), and bidirectional frames (B frames) that are dependent on context to create a complete image. Bit for bit, this MPEG-2 stream puts greater demands on data transfer integrity during playback in order to decode and reconstruct each and every frame in the GOP as they were originally encoded. This requires a technologically advanced tape media. In this paper, the methods for making metal-evaporated tape media capable of meeting this need will be discussed.***

**W**hile digital video acquisition storage requirements grow, the form factor of the storage media tends to remain the same. How is it that the same mini-sized DV cassette that stores 60 min of standard-definition video is also able to store 60 min of high-definition in HDV? The answer lies in the use of MPEG-2 compression employed with the HDV format, but this type of compression puts greater demands on the media for lower error and dropout rates, thus requiring higher performance tape media. This paper will explain developments made in metal evaporated technology that raise the performance level of the media to one where the added benefits of HDV recording can be more consistently realized.

## **Tape Manufacturing: Metal Particle and Metal Evaporated**

In today's consumer, broadcast, and data recording tape markets there are generally two types of tapes in use: metal particle (MP) and metal evaporated (ME). Metal particle tape uses what is commonly referred to as conventionally-coated tape manufacturing. With this process, a jumbo roll of substrate material, the base-film, is coated with a durable and flexible polyurethane-type paint containing, among other things, suspended metal particles. This solution is like household paint in that the magnetic metal particles are analogous to the pigment, or color. For the pigment or magnetic particles to adhere to the base, it must contain an adhesive or binder. This binding function is provided by the polyurethane part of the magnetic paint that is applied to the substrate.

The metal particles consist of needle-shaped iron, or ferric cores, which have been processed to enhance their magnetic capabilities and chemical stability. Immediately after coating, they are oriented in the same

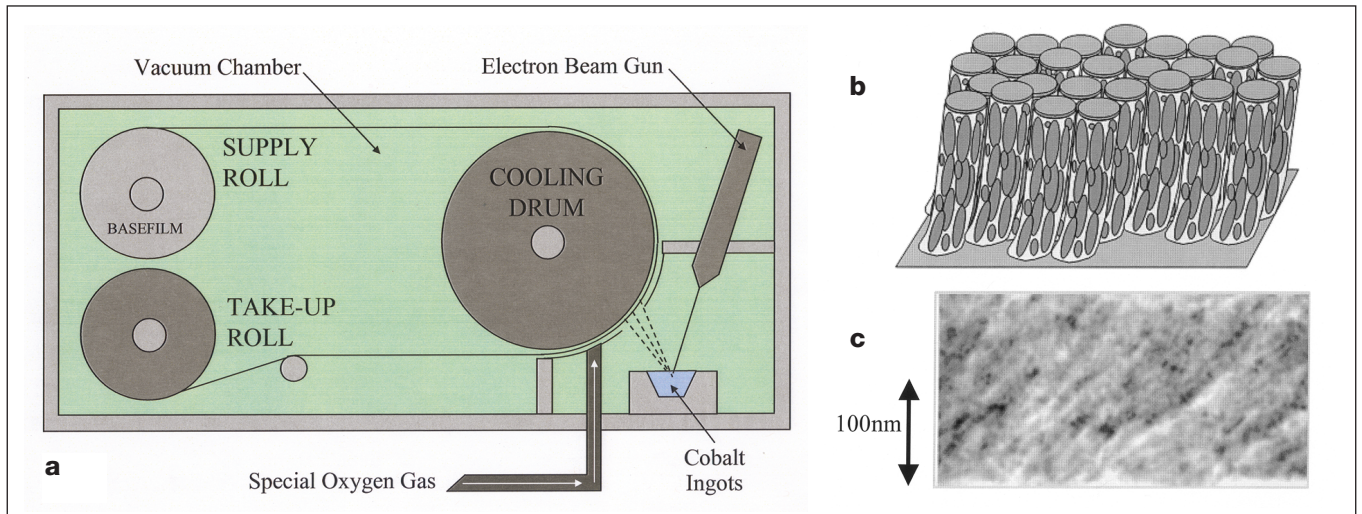


Figure 1. (a) Metal evaporation vacuum chamber. (b) Graphic representation of vertical column-like structures. (c) Resulting metal evaporated cobalt layer as viewed under electron microscope.

polar direction by a strong magnetic field while the paint is still in liquid form. This results in high squareness values in the direction of recording reducing tape noise while increasing output and packing (aerial) density of the particles. This process yields a coating that is less than 100% active magnetic material. The size and shape of the metal particles and other additives give the polyurethane paint, or coating, the desired magnetic, electrical, and physical characteristics needed to record and play back a particular format. A backcoating is then applied to the reverse side of the substrate to control friction and aid in the runnability of the tape. Metal particle tape is used with such formats as Betacam SP,\* Betacam SX,\* Digital Betacam,\* MPEG IMX,\* HDCAM,\* and HDCAM SR.\*

The other type of manufacturing process is the focus of this paper. Metal evaporated, the tape used for smaller form factor formats such as DVC (consumer DV), DVCAM,\* and HDV, uses a significantly different manufacturing process. Unlike conventionally coated tape, metal evaporation takes place in a vacuum chamber. A specially treated jumbo roll of basefilm material is fed around a cooling drum that passes by a shutter area. Cobalt ingots are fed into a crucible and vaporized by a scanning electron beam gun (Fig. 1). The ingots are vaporized at approximately 2000°C. The metal vapor is allowed to contact the basefilm and molecularly bond to it at the shutter area. Hence, there is no

need for the binder in the manufacture of metal particle tape. The coating is nearly 100% active magnetic material to store the data.

A special oxygen gas is mixed with the vapor at the shutter area. A cooling drum is chilled to approximately -40°C to prevent the basefilm from melting at the shutter area from the intense heat of the vapor. The vapor and gas mixture deposits vertical column-like structures on the basefilm. The incident angle of these columns, containing oxygen and cobalt, is at an angle consistent with the magnetic field that will emanate from the heads on the helical scanning drum inside the recorder. The shutter, which controls the angle of the columns, coupled with variations in the oxygen-cobalt mixture, determines the overall electromagnetic characteristics of the tape.

The surface of this tape is dense with very fine magnetic particles that are referred to as grains. This very high aerial density makes ME tapes suitable for small form factor formats.

The ME process also results in a tape with an extremely smooth surface. This enables the record/playback heads to make very close contact with the tape surface, resulting in a significant reduction in errors and dropouts caused by a loss of contact between the tape and the head. There is improved head-to-tape contact over metal particle technology.

### Carbon Layer

Following the metal evaporation process, a carbon layer is applied to increase the tape's durability (Fig. 2).

\*Betacam SP®, Betacam SX®, Digital Betacam™, MPEG IMX®, HDCAM™, HDCAM SR™, DVCAM™, and Digital Master™ are trademarks of Sony Corp.

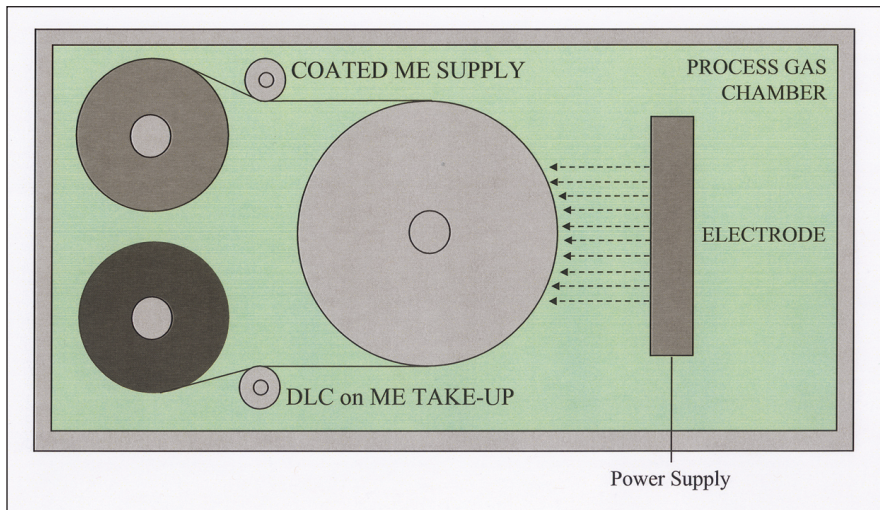


Figure 2. Carbon layer applied to ME coated jumbo roll.

This takes place in a chamber containing process gas. An electrode is placed on the opposite side of a transfer drum as the coated ME tape runs over it. Power is supplied to the electrode, and the protective carbon layer is formulated onto the metal layer as it passes over the drum. After the carbon layer, additional layers such as lubricant and backcoating are applied. The jumbo roll is then slit longitudinally to the width of 6.35mm, for DVC, DVCAM, and HDV, and loaded into cassettes.

Unlike MP tape, the layering process employed in ME manufacturing increases the risk of debris generation as a result of handling during manufacturing. The process is simply more complex than the metal particle process. Greater care and control is employed throughout the process to minimize debris generation when manufacturing higher grade ME tape used with these formats. Debris typically occur during the slitting process. Once in use, environmental factors such as encountered in a smoky bar, beach, or ball field are more likely contributors of debris. Dropout occurs when debris come in between the tape and the head during record/playback, compromising the head-to-tape contact. This results in a loss of signal that typically manifests itself visually as freeze frame with blocks (mosaic)

that move through the screen, or an audio dropout.

### Developments in Metal Evaporation: AME-II Technology

Since the release of metal-evaporated Hi-8 tape, in 1989, with an original magnetic layer consisting of 80% cobalt and 20% nickel, Sony's metal evaporated tape has evolved to a 100% cobalt magnetic layer, referred to as advanced metal evaporated (AME) tape.

Improvements to the AME process were realized in 2004 with the release of the AME-II formulation currently used with a 6mm high-end Digital Master\* tape, recommended for HDV camcorders, and AIT-4 (Advanced Intelligent Tape), a data storage format capable of 200 Gbyte native capacity in a 8mm cassette.

AME-II technology uses a new evaporation method supported by the development of high-density/high-performance Hyper Evaticle IV magnetic grains with smaller magnetic domain structure. Grain diameters were reduced from approximately 8~10 nm to 5~7 nm, AME to AME-II, respectively. Advanced controls are used to reduce the formation of nonmagnetic oxidation grains on the surface of the tape while allowing those with greater magnetic energy to condense closer to the surface of the tape. This brings a higher energy magnetic surface closer to the record/playback head gap. The effects are evidenced in increased electromagnetic properties (Table 1).

These manufacturing developments increase the tapes' output and lower the noise. This improvement in carrier-to-noise ratio (CNR of the output signal level during playback and the noise level) results in significantly reduced error rates.

Table 1—Comparison of AME and AME-II Electromagnetic Properties

Tape	Coercivity (Hc) kA/m	Retentivity (Br) mT	Squareness (Rs) %
AME	105	500	78
AME-II	125	550	82

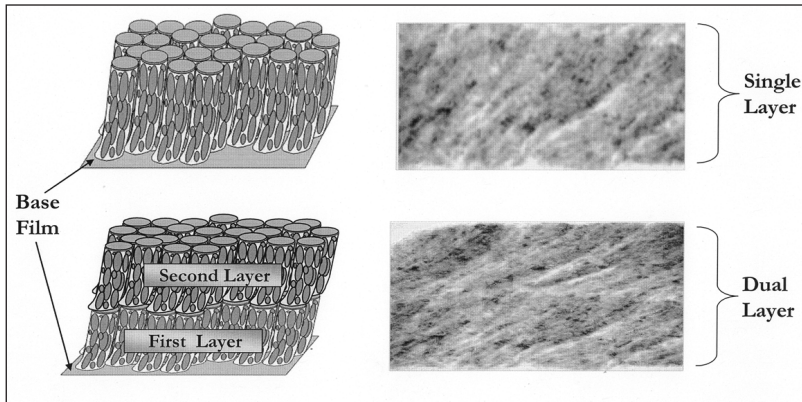


Figure 3. Cross-section of single and dual layer ME tape.

### Advantage of Dual-Layer

Inherent in the ME process is the formation of a non-magnetic oxidation layer that is proportional to the magnetic layer thickness but does not contribute to the signal strength. This layer creates a space between the tape and the head, resulting in a reduction in signal transfer during record/playback. Coupled with AME-II manufacturing developments, the application of two magnetic layers, each approximately half the thickness of a single layer, minimizes the thickness of the oxidation layer while moving the active magnetic cobalt grains closer to the head. This also positively impacts the CNR.

In digital video, data errors can occur within the noise or noise floor during playback, because the data may be masked or misinterpreted by the playback head. Less noise reduces the chance of misinterpreted data/errors, while a higher output enables more signal to be played back from the tape. Together they result in

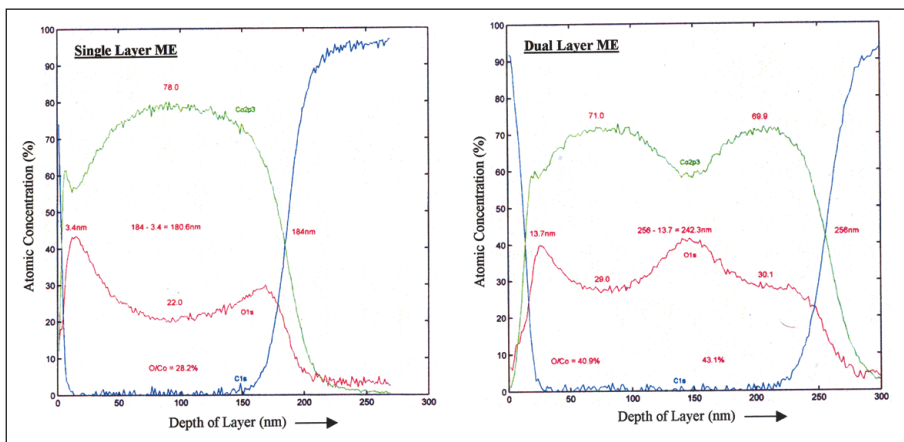


Figure 4. ESCA graphs compare examples of single-layer and double-layer metal evaporation.

a cleaner, more powerful, signal transfer during both record and playback. The total thickness of the dual ME layer is the same as that of a single layer (Fig. 3).

Consider the column-like angular structure of the ME layer discussed earlier. To maintain the same angle when applying the second ME layer, the jumbo roll must be rewound after the first ME layer, so when the second layer is evaporated onto the first, they both have the same incident angle.

This angular consistency is so powerful that if the second layer were applied at the inverse angle (herringbone-like), recording would occur on only one of the two layers, depending on the direction of the tape. This tape design is employed with a digital micro recorder in which half the width of the tape is recorded in one direction (side A) using the first layer, while the other half of the tape is recorded when the tape is in the reverse direction (side B) using the second layer.

An added advantage of dual layer ME can be found in Electron Spectroscopy for Chemical Analysis (ESCA) data. These measurements study the surface composition and electronic state of the evaporated layer. Performed in a vacuum, the tape is bombarded with X-rays that penetrate the layer 1 nm at a time. A chemical analysis is conducted as the X-ray “burns” through a layer at a time. The evaporation of two layers as opposed to only one layer reflects an increase from 28.2% to 40.9% in the oxygen to cobalt ratio (O/Co) (Fig. 4). This affects the electromagnetic properties of

the record layer in that the magnetization is proportional to the amount of metallic cobalt (Co), which in turn affects the output. The magnetic layer is composed of very fine metallic, cobalt grains that are magnetic and oxidation cobalt (CoO) grains that are non-magnetic.

### MPEG-2 Compression

The developments in AME-II technology and the application of a dual-layer of magnetic cobalt satisfy the more demanding

**Table 2—Three Types of Coded Frames Contained in an MPEG-2 GOP (Group of Pictures/Frames)**

I	Intra-frame	Contains all the data. There is only one of these per GOP
P	Predictive frame	Uses the preceding frame for reconstruction.
B	Bi-directional frame	Needs the frame before and after to be reconstructed.

needs that MPEG-2 compression places on the recording media.

Defined by the HDV format specification, video is transferred to and from the tape at video bit rates of either 19 Mbits/sec or 25 Mbits/sec, less than or equal to that of standard-definition DVC and DVCAM formats. The intraframe compression used with these formats only requires the information contained in each frame to reconstruct, or decode the frame during playback. On the other hand, HDV starts with this type of compression but then adds another level, MPEG-2 compression, which is an interframe compression. The signal is compressed further by comparing a series of frames, known as a GOP (group of pictures/frames), which contain three types of frames (Table 2).

The reliance on the I frame in the GOP is significant because it contains all the picture information captured; hence, it can be displayed by itself without degradation. MPEG-2 exploits temporal redundancy within the GOP in that the P and B frames that follow contain only the differences, or changes, when compared to the I frame. The interdependency of all the frames in the GOP, to successfully reconstruct the GOP in its entirety, means that errors and/or dropouts on any single frame not only compromise the reconstruction of that frame, but can affect the decoding of other frames as well. A dropout occurring on the I-frame, for example, can potentially have an impact on the entire GOP.

## Conclusion

A technologically advanced compression codec like MPEG-2 may be better served by a technologically advanced media, especially when employed by a small-format HD acquisition format such as HDV. Developments inherent in AME-II tape coupled with dual-layer technology improve the carrier-to-noise ratio, a specific electromagnetic tape property that helps to reduce dropouts and errors. Considering a mini-sized DV tape that traditionally stores 60 min of standard definition is now able to store 60 min of high definition at or lower than the standard-definition bit

rate, it becomes quite obvious that although the bit rates are similar, the importance of each recorded bit is not. Bit for bit, the interframe compression used with the MPEG-2 stream puts greater demands on data transfer integrity during playback, in order to decode and reconstruct each and every frame in the GOP as they were originally encoded.

## Acknowledgments

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