The colourful history of magnetic recording

Just think what the world would be like today without magnetic recording, which certainly revolutionised the recording of sounds and music. Here's the story of how it developed, from primitive early machines to today's sophisticated technology.

by DR. FUKUZO ITOH*

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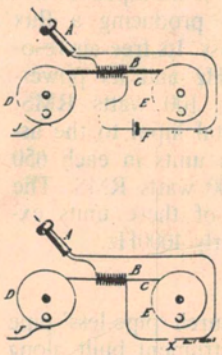
In 1944, Allied intelligence was confused. Hitler's voice could be heard day and night from radio stations all over Germany, and broadcasts of the Berlin Philharmonic Orchestra were airing in London in the wee hours. The US Army Signal Corps' Jack Mullin (who would contribute to tape recorder development after the war) was puzzled. Sure, Hitler was a dictator, but even he wouldn't force the Berlin Symphony to tune up at 3.00 am. Could it be that Germany had developed an all-new recording system? No one would learn the truth until after the Allied victory, since German magnetic recording technology was shrouded in (state) secrecy.

In fact, by 1941 a console-type AC bias tape recorder (the Magnetophon) was standard at all German radio stations. Hitler kept a portable close at hand to record speeches.

Today, 53 years have passed since production began on the first practical recording tape. But the groundwork for this achievement began some five decades earlier.

Valdemar Poulsen (1869-1942)



Circuitry diagram, found in Oberlin Smith's paper in The Electric World magazine.

Poulsen's Telegraphone is born

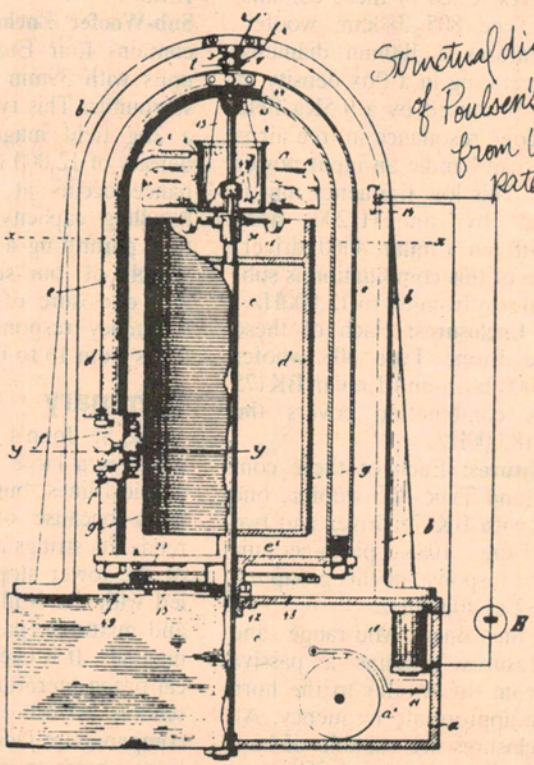
In 1898, Danish technician Valdemar Poulsen (1869-1942) developed the first magnetic recording machine based on the decade-old ideas of an American, Oberlin Smith.

Smith had proposed that a cotton or silk tape with steel dust embedded in its surface could magnetically record sound frequencies turned into audio currents, by a microphone. "Young lovers could record voice messages on the magnetic material, wind it on a small reel, and then send the messages to their sweethearts." said Smith.

Poulsen's first recorder — piano wire wound on a brass cylinder — had a recording time of only 30 seconds. In 1899, he developed a device which carried 0.01-inch steel wire past the recording head at better than two metres per second, achieving a recording time of several minutes.

In 1900, Poulsen took his "Telegraphone" to the Paris Exhibition, where it captured a Grand Prix — and the voice of Kaiser Franz Josef of Austria (the recording still exists today). *The Electric World* magazine heaped praise on the recorder's sound reproduction. In truth though, the voices were barely audible against a din that resembled buzzing mosquitoes.

Poulsen crossed the Atlantic in 1903 to form the American Telegraphone Company. Commercial production of his portable magnetic tape recorders (patented in 1907) failed, and the company folded. When Poulsen sold his patent rights and



Structural diagram of Poulsen's Telegraphone, from U.S. patent records.

turned to other forms of electrical research, it set back development of magnetic recording by almost 20 years.

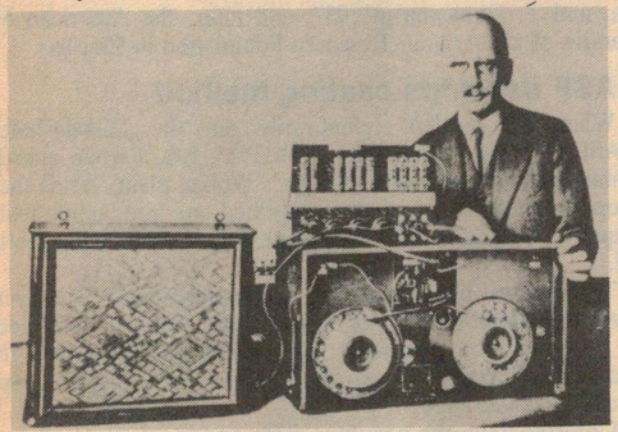
Until 1927, in fact. That's when machine technician Fritz Pfleumer, who had developed a material to replace the gold used on cigarette tips, hit on the idea of using cigarette gilding technology to develop inexpensive magnetic recording tape.

Pfleumer's golden opportunity

Pfleumer's first effort, in 1928, was a cellulose plastic film base coated with carbonyl iron powder. The rolled recording tape was 40 microns thick and 300 metres long, with 20 minutes of recording time. Production costs were low, but the coating tended to shed during testing and the sound quality was marred by noise, wow and flutter.

Pfleumer took his Sound Paper Machine to AEG, a major electrical equipment manufacturer. Quality considerations made the company balk, but AEG finally purchased Pfleumer's patent in 1932. AEG engineers knew that it would take major advances in chemical technology to make this method work. So, AEG Chairman Herman Bucher contacted his friend Carl Bosch, Chairman of E.G. Farben Chemical of Frankfurt, and the two companies pledged to undertake the project together. Finally, the wheel of tape recording history was beginning to pick up speed.

Hermann Bucher was also good friends with Wilhelm Guas, a physical chemist at BASF, which like Agfa was a subsidiary of I.G. Farben. In fact the two had a good work-



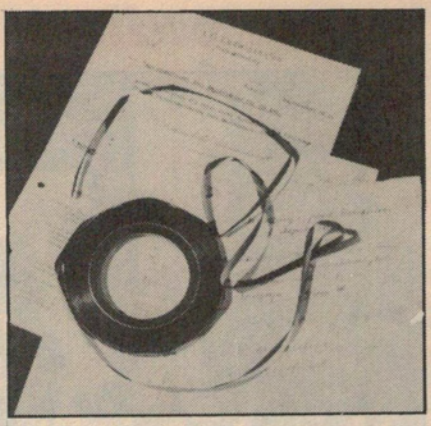
Fritz Pfleumer with his Sound Paper Machine of 1928.

ing relationship. After a series of joint experiments on carbonyl iron powder recording tape in Ludwigshafen during 1932-34, the first practical commercial recording tape was tested for production.

Originally, I.G. Farben/BASF had planned to produce recording tape solely for voice use. So when AEG produced a tape recorder in 1934, it ran at a speed of 1 metre/second and had a frequency range of up to 3kHz for recording and reproduction. That may have been good enough for recording speech, but even so, the sound quality needed work.

After consulting with AEG. BASF came up with a stronger tape with better electrical properties, which it called I.G. Farben Carbonyl Tape. Jusifiably proud, AEG eagerly prepared for the 1934 Berlin Radio Exhibition, comparing the quality of the new "Magnetophon" to that of disc recordings. Unfortunately a hitch with the tape's rewind mechanism meant production had to be stopped just one week before the exhibition. At the last minute, it was forced to pull out of the exhibition.

But the undefeated AEG engineers revised the tape recorder in October that year, and by the following summer,

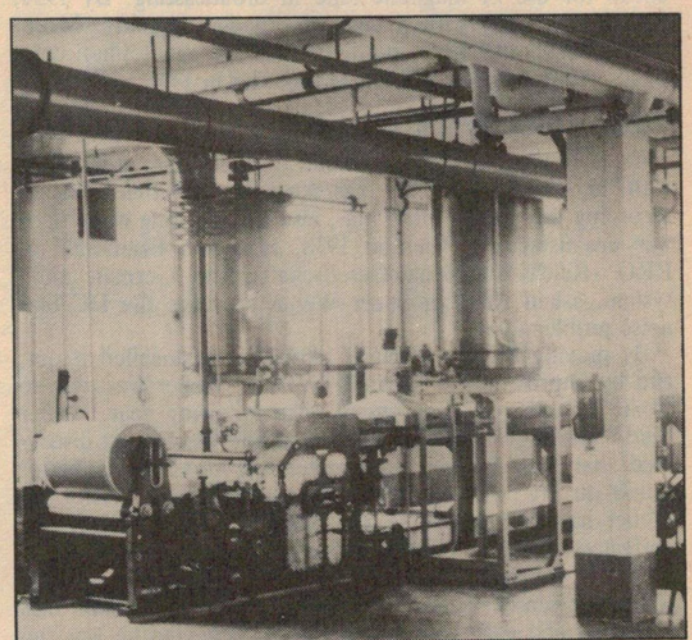


After a series of experiments in 1932, BASF was able to develop the first coated recording tape.

they were ready in plenty of time for the next Radio Exhibition, in August 1935. This time, the Magnetophon was a roaring success. One of the project members, Friedrich Matthias, said, "Dealers and the public literally stormed the demonstration room, so that we were forced to close the door temporarily." Within a few hours, the first eight recorders were sold. The tape recorder was on its way.

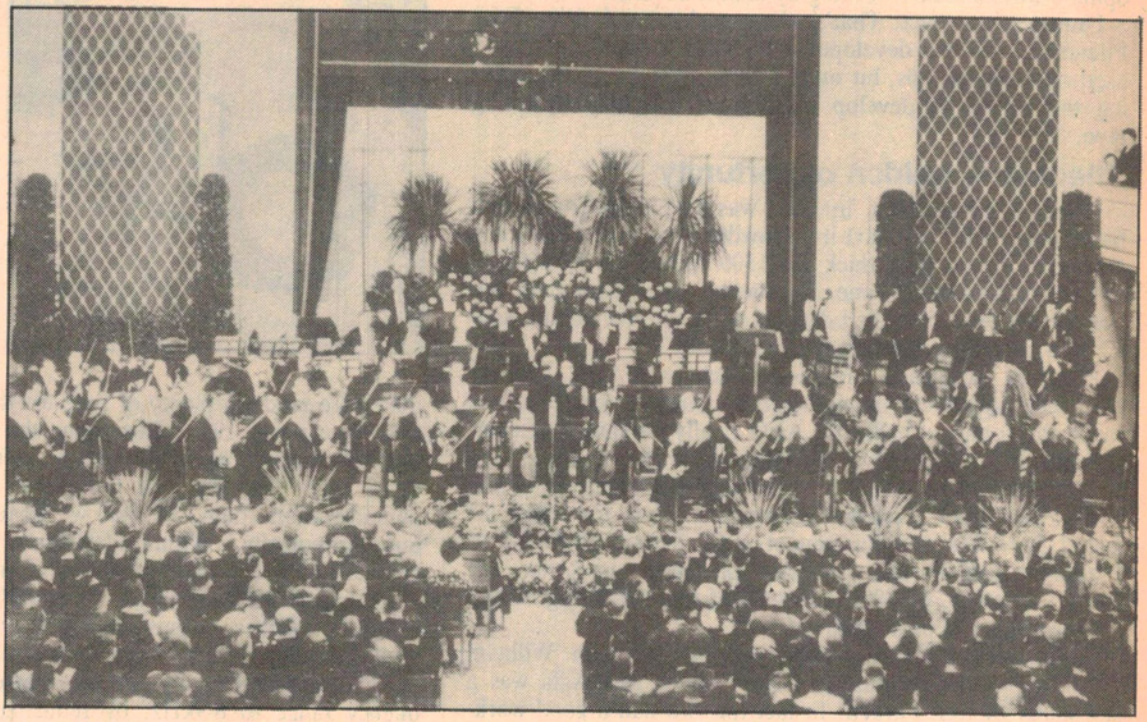
In August 1935, W. Gaus of BASF wrote a letter to his friend H. Bucher, suggesting that they might be able to extend recording time by reducing the tape speed from 1m/sec to 30-50cm/sec. He also proposed extending the upper frequency range to 8-9kHz, by reducing the diameter of the magnetic particles from 3-5um to 1um. This would permit the recording of music as well as voice.

The only problem was that carbonyl iron powder couldn't be produced that finely. Instead, he suggested, why not use a magnetic ferric oxide? This was magnetite, a black ferric oxide. Erwin Lehler of I.G. Farben had already proposed magnetite in 1934, but no one had listened to him at the time. I.G. Farben was already producing magnetite as a non-soluble electrode for electrolysis, and when they tried it for recording tape in 1936, the improvement was obvious. W. Gaus authorised its use, producing a vastly superior recording tape.



The first magnetic tape production plant, at BASF in Germany (1936).

Magnetic Recording



First recording of the London Symphony Orchestra on magnetic tape, at the BASF concert hall in 1936.

Recording the London Symphonic Orchestra

The new tape underwent a dramatic test when the London Symphonic Orchestra, conducted by Sir Thomas Beecham, was invited to play at BASF's own concert hall, where a recording was made. After the performance, Sir Thomas listened to the recording and was impressed, but not impressed enough to try it again soon. (He didn't attempt another tape recording until 1950.)

Another landmark event occurred in 1938, when the German Broadcast System (Deutsche Rundfunk) gave the go-ahead for use of magnetic tape in broadcasting. By 1939, BASF was ready with a tape of broadcast quality. Meanwhile, BASF and AFG jointly created a magnetophon company, with first sales of the tape recorder in 1936.

Weber discovers AC bias

Excess noise was still a problem, but help was on the way, with the discovery of AC bias recording. At this time, all recording was done on DC bias, and the resulting noise level was unsatisfactory. Then in 1938, H.J. von Brammuhl of RRG (Reichs-Rundfunk Gesellschaft), the German radio system, asked RRG engineer Weber so solve the DC bias noise problem.

By moving the noise phase 180°, which cancelled it out, and by improving the SN ratio by 3dB, Weber was able to create a noise reduction circuit. The following year, Weber tried recording voices as if they were sine waves, and discovered that high frequency characteristics produced a better sound quality, with reduced noise and harmonic distortion Weber had discovered the AC bias recording method, and perfected the method by the summer of 1940.

Weber was not alone. In the US and Japan, several independent researchers were conducting research into AC bias recording and each took out a patent, believing he was the first to discover it. They included Americans W.L. Carlson and T.W. Carpenter in 1928; Japan's T. Igarashi, M. Ishikawa, and T. Okuyama in 1937; and later, the American M. Camras of the Armour Research Foundation in Chicago.

BASF develops casting method

When an accident temporarily put the Ludwigshafen BASF plant out of commission in 1943, I.G. Farben quickly transferred all production to Agfa's Wolfen plant. When they reopened, it was with a new, simplified tape production technique developed by Karl Pfleumer, called the casting method.

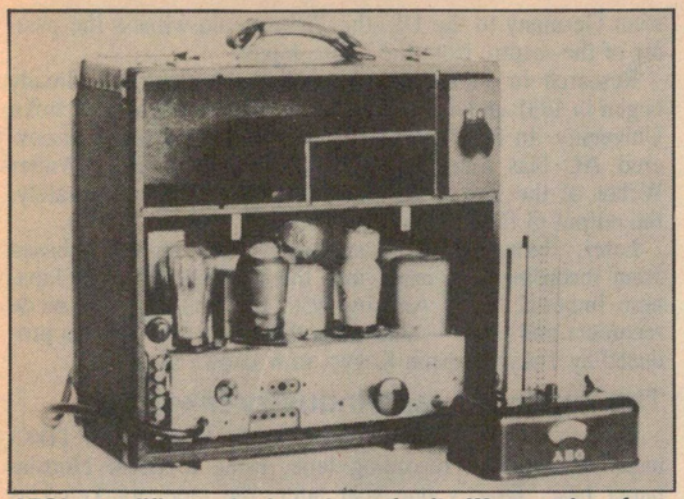
This method blended all the tape materials into one layer, creating a homogeneous or refined tape. Because both sides of the tape were the same, either side could be used for recording. Besides being stronger, it was not as hard on tape heads as coated tape.

Unfortunately, the new tape suffered loss of electrical performance, and was too thin to be practical for mechanical operation. BASF went back to coated tape in 1950.

Recording tape had now gone through three stages. Type C, the earliest tape, had two layers — a magnetic ferric oxide layer laid on an acetyl cellulose film base, using the casting method. Then came Type L, a one-layer tape of polyvinyl chloride film called Luvitherm. and finally, Type G: consisting of two layers, produced in the spring of 1945 in Germany.

Both mass production of tape and recording technology had made great strides under BASF and AEG, a fact which did not escape the notice of the Allied Occupation armies, who issued their first report on the Magnetophon in 1945. The PB Report, as it was called, referred to the BASF tape (played on an AEG Magnetophon) as having "excellent sound and very low noise." The next step in tape development would come in the United States.

As early as 1936, AEG had secretly demonstrated the Magnetophon K2 model for General Electric in the United States. But the K2 still used DC bias recording, and its sound quality was inferior to that of 78rpm disks, so GE wasn't interested.



AEG's amplifier and microphone for its K2 recorder of 1936 — portable, but not exactly lightweight!

Then when German engineer Walter Weber of the Reichs-Rundfunk Gesellschaft discovered the superior AC bias recording method, Germany made it a state secret. Cut off from German recording know-how during World War II, Americans continued their own work in recording development, concentrating on the magnetic wire recorder.

One of them was S.J. Begun, founder of the Brush Company. In 1944, he asked 3M (Minnesota Mining and Manufacturing) to develop a thin recording tape coated with ferric oxide. Two years later, Brush came out with America's first experimental tape recorders, the "Soundmirror".

Meanwhile in Europe in 1944-45, US army personnel discovered quantities of the new Type L tape, a one-layer polyvinyl chloride film called "Luvitherm". At the same time, Allied Intelligence discovered Magnetophons in use in radio stations all over Germany. A young member of the US Signal Corps, J. Herbert Orr, visited the BASF plant at Wald Michelbach, and obtained tape samples there. After returning to his Alabama home, he assembled a Magnetophon using components he had brought home with him from Germany, and went on to conduct demonstrations at radio stations along the East Coast. Later, he founded Orradio Industries, and produced both the Orr tape and the Irish tape.

Another Allied soldier impressed by the sound quality of BASF tape was J. Mullin, who listened to it on an AEG Magnetophon at the Frankfurt radio station. He sent components for two Magnetophon machines and 50 rolls of BASF tape to his San Francisco home. On his return to the US he conducted several demonstrations, both with William Palmer and at the IRE (IEEE) fair held in San Francisco on May 16, 1946 to an audience of 250 people.

By this time, research based on German tape technology was going on at 3M, Audio Devices, Reeves Soundcraft, and Orradio. 3M was the first to succeed and in 1947 under the direction of W.W. Wetzel, developed its own tape for use with the Soundmirror. This was the Scotch 100, a magnetite-coated paper-base tape. Soon after, 3M developed a plastic-based version of the tape, which they called the Scotch 110.

Meanwhile, Ampex developed America's first tape recorder for commercial use in 1946. The quality of 3M's tape was still not comparable to the BASF tape, and was not suitable for either the new Ampex machine or Mullin's Magnetophon. Moreover, 3M decided that its Soundmirror had no future as a commercial machine, and began concentrating its research efforts on producing a recording tape for the Ampex machine.

Milestones in the history of recording tape

1880s	Oberlin Smith proposes magnetic recording theory.
1898	Valdemar Poulsen's first magnetic recording machine.
1900	Poulsen's Telegraphone wins at Paris Exhibition.
1903	Poulsen starts unsuccessful bid to commercialize technology.
1907	The Telegraphone gains a patent.
1928	Fritz Pfleumer unveils Sound Paper Machine.
1932	AEG and I.G. Farben buy Pfleumer's patent, start R&D.
1934	AEG produces first Magnetophon and tests recording tape produced by BASF.
1935	Magnetophon sells out at Berlin Radio Exhibition.
1936	BASF manufactures recording tape on a large scale, and records London Symphony Orchestra. Soon after, Fe_2O_4 powder and Fe_2O_3 are used in producing magnetic tape.
1938	German Broadcast system allows use of recording tape in broadcasting.
1938	Researchers at Tohoka University independently discover AC bias recording.
1939	BASF produces practical recording tape.
1943	IG factory/Wolfen (Agfa) begins producing recording tape.
1943-1944	BASF develops casting method of tape production.
1946	Ampex develops America's first commercial tape recorder.
1947	3M develops Scotch III, a low-cost, long-playing tape.
1950	Sony introduces first Japanese tape recorder and recording tape.
1951	The first experimental cartridge tapes appear.
1953	The Magnetic Recording Industry Association is formed.
1954	Reeves Soundcraft reduces tape thickness, while increasing length by 50%.
1962	Philips announces the compact cassette recorder.
1968	TDK introduces Super Dynamic cassette.
1973	TDK develops Avilyn particle.

Recording was a time-consuming process in the 1950's.

Magnetic Recording

In 1962, Philips introduced the compact audio cassette.

In 1948, they succeeded, with the gamma ferric oxide-coated Scotch III. It soon became world renowned, and was to have a considerable effect on the Japanese recorder and tape industry. Meanwhile, Orradio merged with Ampex, giving Ampex an inhouse source of tape.

Both recorder and tape production began to pick up speed. In 1950, Concertone, Revere, Webcor, and Wilcox-Gay produced recorder models that would influence consumer product development in Japan, while small and simple tape recorders appeared for general use in Germany, Austria and other European countries.

Tapes were becoming thinner and longer, and playing longer too. In 1954, Reeves Soundcraft reduced base thickness from 36um to 25um and increased tape length by 50%. 3M also announced an acetate-based 25um-thin playing tape, while Audio Devices introduced a tape with a coloured reel. In 1955, Orradio announced a 12.5um mylar film tape which doubled recording time, calling it "Double Play". Later, they announced an even longer playing "Triple Play" tape.

Then in 1956, tape recorders and magnetic recording tape entered a new era. That March, Crosby Enterprises/RCA demonstrated a videotape recorder with a tape speed of 240"/sec, a tape width of 1/2", and a stationary head. This model was not commercialised, but in April, Ampex announced a videotape recorder at the Chicago NARTB (NAB) convention which caused a sensation. Its tape speed was 15"/sec, and it had a revolutionary rotary head. This was the VR1000, a model which would have a profound effect on the television industry and tape recording in general.

In 1957, Audio Devices announced a new type of reel as well as a low print through tape. 3M built the largest tape production plant to date, and started developing the technology that would eventually lead to a low-noise tape. By the end of 1957, 39 companies were producing over 650 different kinds of magnetic tape products, while the US Magnetic Recording Industry Association counted over 30 members.

The 1950s had seen the technical development of the new tape materials as well as a trend toward thinner, longer running tapes. In the 1960s, tapes incorporated newer, high-density recording materials and base film and became even thinner, eventually breaking through the 10um barrier to achieve the shortest recording wavelength at that time.

When Philips announced the compact cassette recorder in 1962, it changed sound recorders forever. In Japan in particular, tape recorders become synonymous with cassette recorders, and tape with compact cassettes. Just as the 1950s had seen the leadership in tape recording technology shift from Germany to the US, the 1960s would witness the passing of the sceptre from the US to Japan.

Research in Japan into magnetic recording had already begun in 1931 under the direction of Kenzo Nagai at Tohoku University. In fact, Nagai and his associates actually discovered AC bias independently of German engineer Walter Weber of the Reichs-Rundunk Gesellschaft. Unfortunately, the output of the tape they produced was barely audible.

Later, during WWII, samples of German paper-based 5mm recording tape came into the possession of the Japanese Imperial Navy. And by 1950, the first Japanese-made recorders and tapes — known as the KA series — were produced by Tokyo Tsushin Kogyo, now known as Sony.

The Japanese tape industry takes off

In October 1952, Tokyo Denki Kagaku Kogyo (now TDK) began research in recording tape, using a 3.5cm Honshu paper base. Exactly one year later, the tape, marketed as "Synchrotape" (TDK's original brand) was ready. Other

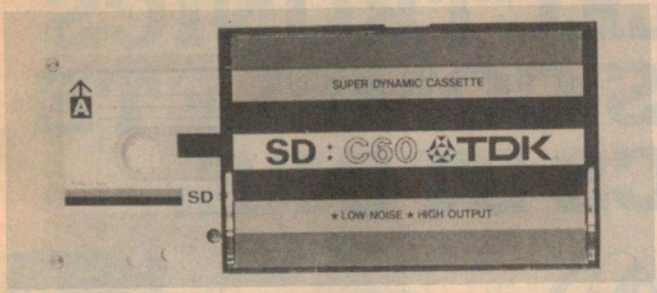
tapes also introduced around this time included Tohoku Konzoku Kogyo's "Talky Ribbon" and "Refined" (homogeneous) tape by Nitto Denki Kogyo (now Hitachi Maxell).

In August 1955, NHK (the Japanese national broadcasting network) selected the Scotch 111A tape, a gamma ferric oxide-coated tape, for use with its tape recorders, setting the magnetic recording standard for Japanese tape products. NHK officially shifted over to domestic tape in December 1956, and began using TDK and Sony tapes in its broadcasts.

In 1957, Japan first began producing domestic base film. Until this time, tape manufacturers had been importing base film, which often caused low-quality dispersion of magnetic particles. At first, diacetate film was used, but this was soon replaced by the more durable triacetate film, and then, by polyester film. Also that year, the home-use tape recorder market opened up and tape production began to pick up speed.

In 1962, Philips modified the RCA cartridge by reducing tape size for ease of use. The first compact cassette tape recorder, the EL 3300, was born. For the first two years, Philips limited test sales to Europe. But in 1965, the EL 3300 appeared at Mitsukoshi Department Store in Tokyo. One year later, the first Japanese cassette recorder, made by Aiwa, came on the market.

The first Philips cassette recorder of 1962.



TDK introduces the first Japanese cassette tape

With the advent of the cassette recorder and tape, Japan plunged into the world tape market. The first Japanese cassette tape was marketed in 1966 by TDK, followed closely by Matsushita Electric (OEM), Sony, Hitachi Maxell, and Fuji Film. With the advent of FM broadcasting in 1963, a new low-nose, low-transfer 6.3mm recording tape was needed.

Research into noise reduction continued, and in 1968, TDK introduced the SD cassette, which made high-fidelity music recording possible for the first time on cassette. The name "SD" was originally derived from "Single Domain", the code name for the project but eventually came to stand for "Super Dynamic". (Since that time, TDK recording tapes have always had a nickname as well as a brand name, a trend which has also influenced other tape manufacturers' products).

Realising that compact cassettes would have to become standardised before becoming popular, Japanese tape manufacturers negotiated with Philips to set a standard for cassette tape, with as low a patent compensation as possible. This created a much larger market for cassette tape than had ever been possible for open reel tape.

Low-speed cassette tapes demanded a higher tape coercivity in order to improve magnetic recording performance. In 1961, DuPont developed a new type of high-coercivity chromium dioxide tape called "chrolin tape". Japanese tape manufacturers could not ignore this important new development, but the high patent royalties were discouraging. So a search began for other materials that would also result in high coercivity.

The birth of "Avilyn" — the super particle

In 1968, W.P. Haller of 3M developed a magnetic particle with high coercivity, by adhesing a cobalt compound onto the surface of gamma ferric oxide. This was marketed as "High Energy" tape by 3M.

In 1973, Yasuo Imaoka of TDK succeeded in adhesing a cobalt compound onto the surface of ferric oxide. TDK called this magnetic material "Avilyn", and initially used it to produce videotape. This magnetic particle is superior to other cobalt ferric oxide particles, because it retains heat stability despite high coercivity. In 1975, TDK used Avilyn to create its "A" (audio) cassette tape, which it called "SA".

In recent years, we've seen astounding progress in tape technology, with the introduction of metal tapes, micro-cassettes, and most significantly, digital audio tape. These latest advances in recording will open the door to even more dramatic developments in days to come.

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