12. High Density Magnetic Recording. Recent Developments in Magnetic Tapes, Discs and Heads

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Magnetic recording technology, i.e. electrical signals recorded onto a magnetic medium in the form of magnetic remanence signals produced by a magnetic head, was primarily invented by Poulsen at the end of the 19th century. He recorded audio signals on a steel wire by a pole-type electromagnet. Present day audio-tape recorders (ATR) were completed and put into practical use just after the invention of magnetic tapes and ring-type magnetic heads in the 1930s. In the 1950s, video-tape recorders (VTR) and magnetic disc drives (MDD) used as computer peripherals were invented and used widely in industry. Today VTR and MDD have become popular and are widely used consumer products. In many fields of social activities, one has to appreciate the convenient tools arising from magnetic recording technology such as magnetic cards for various vending machines, tickets, certificates, magnetic scales for NC-machines, as well as the ATR, VTR and MDD mentioned above.

Magnetic recording technologies are superior to other recording or memory technologies with respect to (1) the simplicity of recording, reading and erasing operations and to (2) the non-volatility of stored memories without any energy consumption. In Fig. 12.1, the basic principles of magnetic recording are shown.

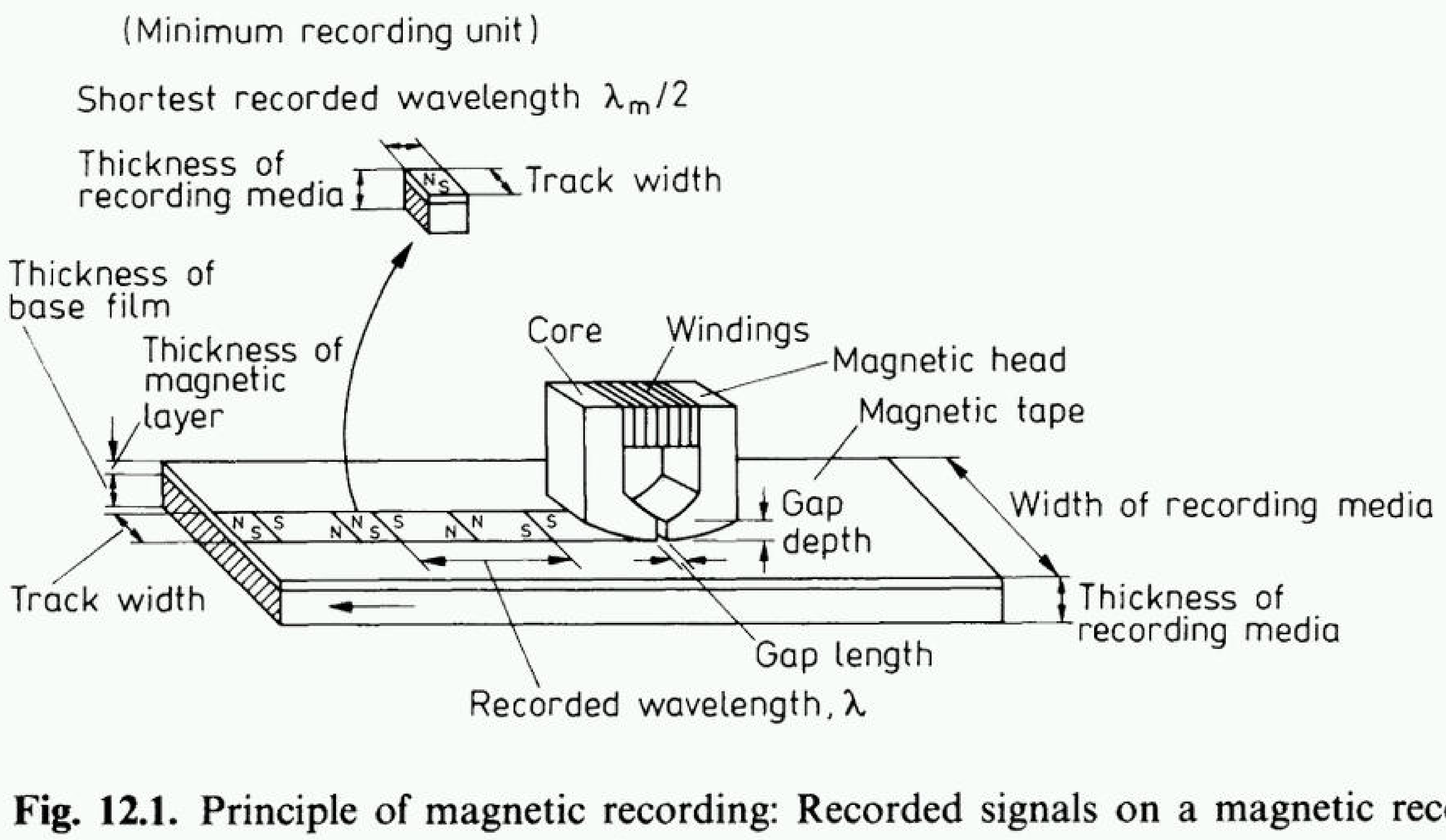

Fig. 12.1. Principle of magnetic recording: Recorded signals on a magnetic recording media written by a magnetic head

High density magnetic recording depends entirely on how to shorten the shortest recording wavelength λ_m and also how to narrow the recording track width w. The highest density in practice is realized by VTR's of which the λ_m and the w are about 1 μm and 20 μm, respectively. Using these, the maximum video-recording time can be extended up to 8 hours using a standard magnetic tape 1/2″ wide and about 250 m long. This VTR has been implemented after numerous improvements in materials and fabrication processes for magnetic tapes and heads, together with practical solutions for the tribological problem of tape-head contact.

The progress in recording density is shown in Fig. 12.2. In this century the density has become 1000 times higher than that of Poulsen's recorder. This progress has in part been realized by advances in magnetic media, i.e. the invention of magnetic tape and the improvement of magnetic fine powders with large coercivity H_c and remanence B_r. The isotropic iron oxide powders (Fe_3O_4 and γ-Fe_2O_3) of the early days were replaced by the needle-like iron oxide powders invented by Camras in the 1950s when the first generation of magnetic recording technology was assumed to be completed as far as ATRs were concerned. In the 1960s, DuPont reported that CrO_2-tape shows excellent high

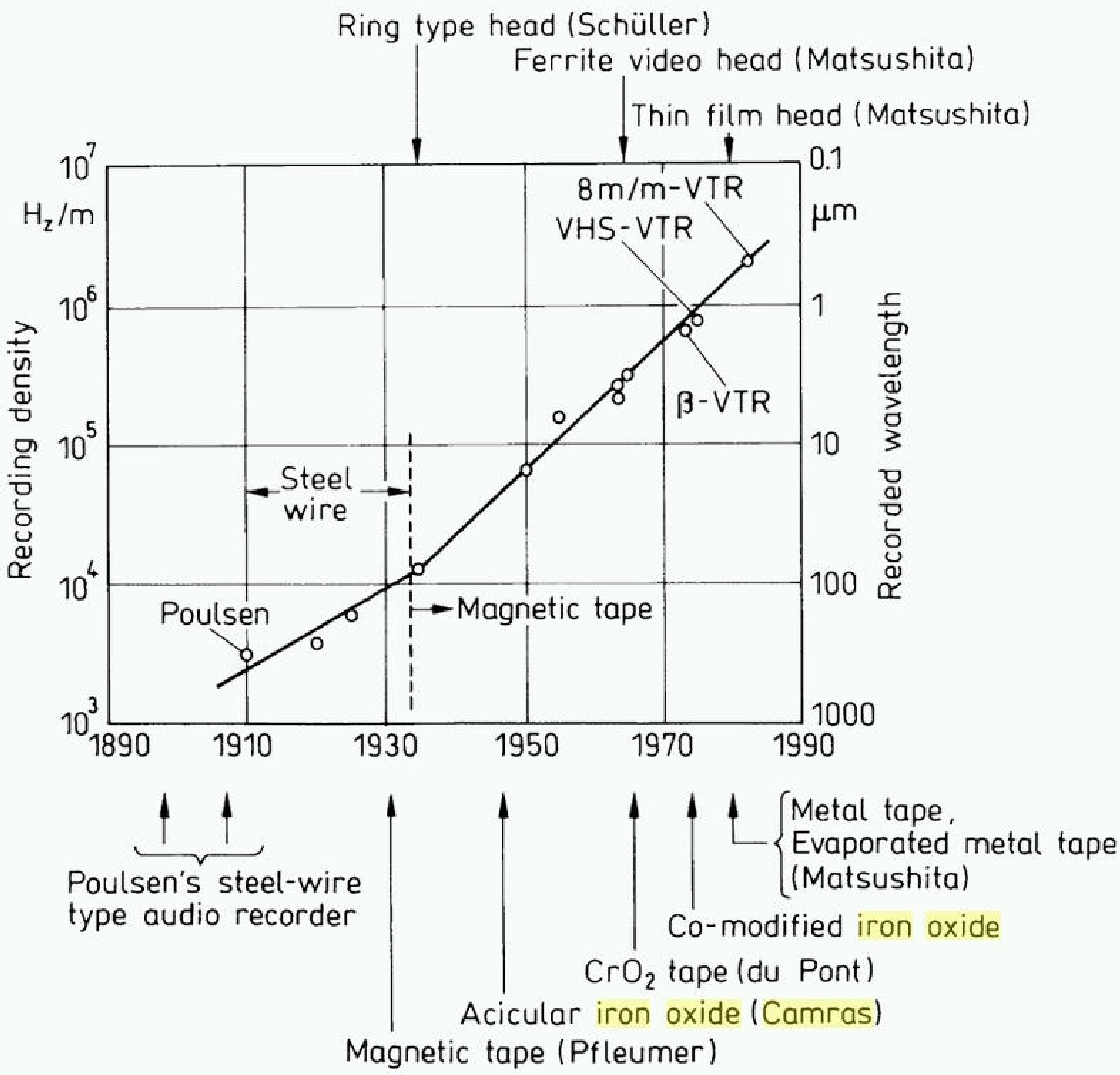

Fig. 12.2. Progress of magnetic recording technology, magnetic tapes, heads and recording density

density recording characteristics due to the well-aligned crystalline CrO_2 powders with higher H_c and higher B_r than Camras's iron oxide powder. With the stimulus of these high energy tapes (i.e. high H_c and high B_r tapes), much work was carried out on various types of Co-modified iron oxide powders in the 1970s. The great success of VTRs, β- or VHS-type (Appendix A.3) on the consumer market today, is partially due to the development of the high energy Co-modified iron oxide tapes. In the 1980's Fe or Fe–Co alloy powders with even higher H_c and B_r have been introduced and are generally known as "metal tapes". Other types of metal tapes, such as continuously evaporated Co–Ni alloy thin film tapes are assumed to be the super high density recording tapes of the next generation and have been developed for application to the compact VTR such as the 8 m/m-VTR. Research on these thin film magnetic media is being carried out quite intensively all over the world with the clear indication that λ_m is now heading into the submicron region.

Magnetic heads have also been continuously improved. For the ATR, magnetic head cores are fabricated by stacking thin Fe–Ni alloy sheets of high permeability. The alloy is modified with Nb, Ti or other metal additives which harden the alloy and improve the wear resistance of the metal heads. The wear of VTR heads is even worse since the relative speed of tape and head is several meters per second and faster by 100 times than that of ATRs. In order to improve this wear problem and also the high frequency characteristics, the VTR heads are made of single crystal Mn–Zn ferrites which have sufficiently high mechanical hardness H_v and electrical resistivity ρ. However, the saturation magnetization B_s of the ferrites is not large enough to fully magnetize the high H_c metal tapes described above. There have already been heads developed for this purpose, fabricated by stacking thin films of an Fe–Al–Si alloy or an amorphous Co–Nb–Zr alloy with satisfactory hardness and B_s.

The head signals reproduced from magnetic tapes decrease if there is a space between tapes and heads, as described below (the spacing loss). In practice the space d between tape and head must be less than 1/20 of the λ_m. Also the magnetic gap length g of the heads must be about 1/3 of the λ_m. Precise machining technologies with a tolerance of less than 0.1 μm are used for the farbrication of these heads. Furthermore, in future sub-micron recording, a machining tolerance of the order of 100 Å is required for the gap length g and also for the space d. Thus a better understanding of the tribology of the head-tape interface is very important to improve tape and head materials.

Figure 12.3 shows the progress of MDDs, mainly IBM's disc systems for computers. Magnetic discs consist generally of magnetic particulate layers of about 1 μm thick on an aluminum disc and are called hard discs. Magnetic layers are applied to an Al-disc by spin-coating of acicular γ-Fe_2O_3 powders dispersed in a dilute solution of resins and drying. For computer use, a very high reliability for recorded data is required and the bit error rate (BER; a probability to make errors in one cycle of the read and write of one bit signal) is assumed to be less than 10^{-12}. The read-write operation is made by the flying magnetic heads which glide over a disc with a constant space between head and disc,

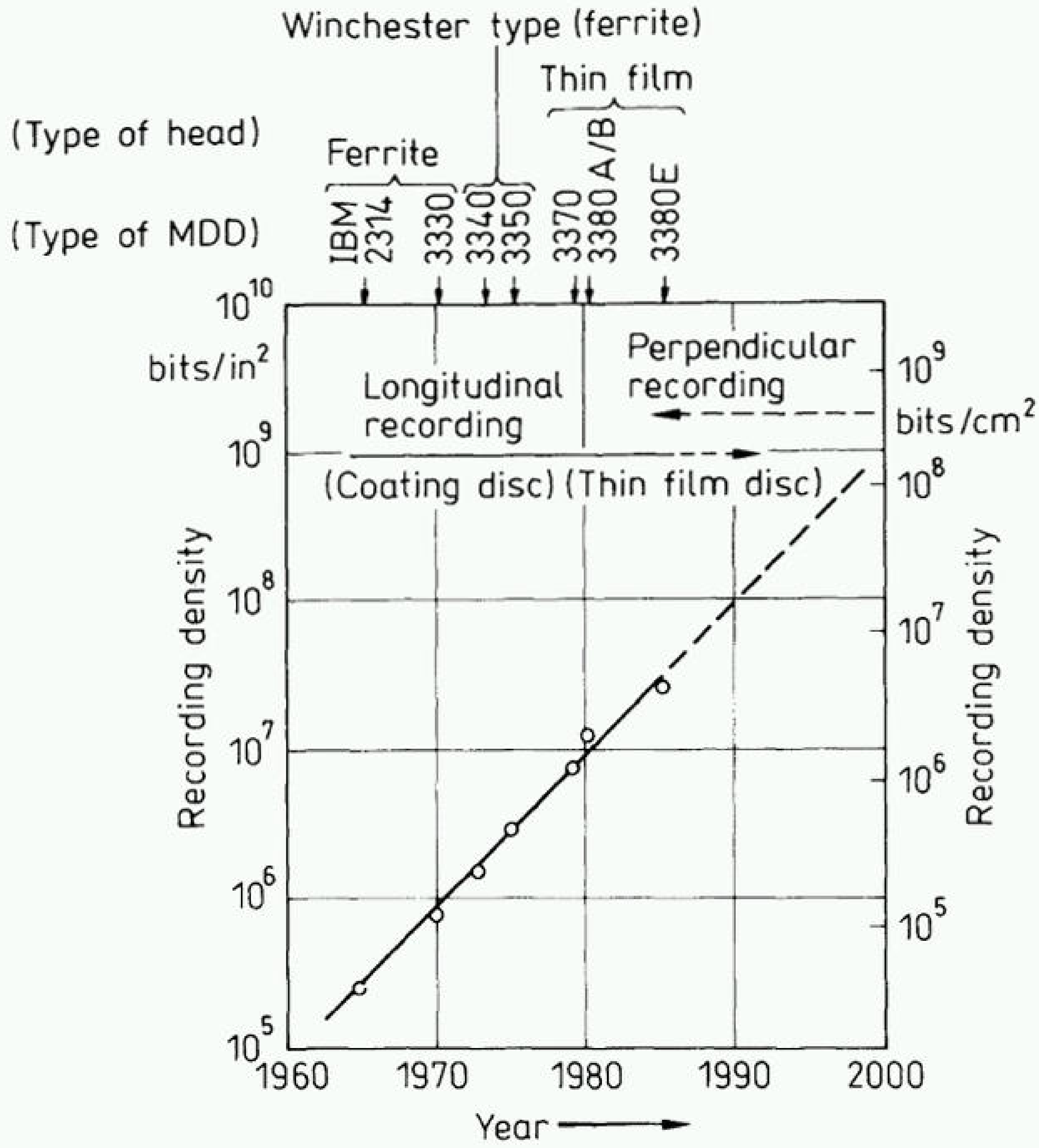

Fig. 12.3. Progress of recording density in magnetic discs

namely, the flying height h_d. The recording densities are about 1/10 of those of the ATRs and VTRs described above and yet they are constantly improved by about 10 times every 10 year period. To realize the higher density recording in the MDD various thin film discs have been intensively studied. Reported so far are a plated film of Co–P alloys, an evaporated film of Co–Ni alloys and a reactive-sputtered film of iron oxides. Although today's flying heads consist of ferrites, thin film heads have been introduced recently for increasing the recording density.

Various types of floppy discs are currently used as memory devices for personal computers, word processors and so on. These discs are made of particulate media consisting of flexible plastic films and coated magnetic layers. Contrary to hard discs, the floppy disc makes intimate contact with the floppy heads during recording and reading data signals. Also with this application, intensive research efforts are being made to miniaturize the memory devices, namely, to realize higher recording density. Recently increased interest and work have been reported on the development of so-called perpendicular recording technology where the recorded signals are the magnetic remanences perpendicular to the magnetic media. Since sputtered or evaporated Co–Cr alloy thin films have a large magnetic anisotropy perpendicular to the film, these alloy films have been studied as typical media for perpendicular recording. In normal