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# APPROACHES TO 100 Gbit/in$^2$ RECORDING DENSITY

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A recording density of 10 Gbit/sq. in. is being pursued by a number of companies and universities in the National Storage Industry Consortium. It is widely accepted that this goal will be achieved in the laboratory within a few years. In this paper approaches to achieving 100 Gbit/sq. in. storage densities are considered.

A major obstacle to continued scaling of magnetic recording to higher densities is that as the bit size is reduced, the grain size in the magnetic media must be reduced in order that media noise does not become so large that the signal to noise ratio (SNR) degrades sufficiently to make detection impossible (1). At 100 Gbit/sq. in., the bit size is only 0.006 square micrometers, which, in order to achieve 30 dB SNR, requires a grain size of about 2.5 nm. Such small grains are subject to thermal instability, and the recorded information will degrade over time unless the magnetic anisotropy of the materials used is increased significantly, or the media thickness is made much larger than expected on the basis of scaling today's longitudinal media thickness.

Perpendicular recording may enable one to use larger media thicknesses and therefore increase the volume of the grains, making it possible to overcome the thermal stability issues. However to record at such high densities onto perpendicular media will require that contact recording be used. Probe heads such as the Micro Flexhead(TM) components proposed by Censtor may provide a solution to this problem (2).

Another solution may be to use structured media in which the bit cells are defined by lithographic or otherwise created structure in the recording media. If the bit cells are defined, then each bit can be stored on a single particle, and instead of requiring 1000 grains per bit, it is possible that 1 grain per bit would be adequate. In this case recording densities as high as 10 Tbit/sq. in. would theoretically be thermally stable with today's materials.

Alternatively, bits could be recorded in the form of cylindrical domains in perpendicularly oriented, exchange-coupled magnetic media, like those used for magneto-optic recording today. With careful design of the magnetic parameters of such media, it is possible to balance the inward directed force of the domain wall surface tension against the outward directed force of the demagnetizing field. This produces a magnetic domain which is easily stabilized by moderate coercivity. Using near-field magneto-optic recording, domains have already been written and readback at a density of 45 GBit/sq. in. in such media (3). These domains have been shown to be thermally stable for several years in these media.

Whatever form of recording media is utilized, it is likely that some form of near-field magnetic or optical probe head will be required to record and playback the data. In order to achieve the desired resolution, the head will likely have to operate with a head-media spacing of less than 10 nm. Although it is too early to say for sure that such heads could not be "flown" above the media surface on a slider, it currently appears more likely that either the probe head would be run in contact with the media, or that some form of active feedback would need to be used to keep the probe head in close proximity to the media similarly to how feedback is used to control the head- media spacing in atomic force microscopes (AFM) today. If the AFM approach is used, then some means must be found to enable an adequate data rate. Theory and experiment indicate that, if a probe head is used with feedback, the data rate from a single head will be limited to a few megahertz (4).

One approach to achieving higher data rates would be to use an array of probe heads. L. R. Carley, et al. have been micromachining arrays of probe heads, actuators and control electronics for head positioning on a silicon wafer (5). This offers one approach to achieving the high data rates that are required.

In conclusion, storage densities of 10 Gbit/sq. in. are likely to be achieved with longitudinal recording; however, densities of 100 Gbit/sq. in. appear to require some changes in approach. Perpendicular recording, structured media and exchange coupled media all offer possible solutions to the thermal instability which is expected to result from too small a grain size. Because of resolution requirements, some form of probe head spaced less than 10 nm from the media is anticipated to be required.

1. Pu-Ling Lu and Stanley H. Charap, *IEEE Trans. Magnet.*, **30** (1994) 4230.
2. H. Hamilton, R. Anderson and K. Goodson, *IEEE Trans. Magnet.*, **27** (1991) 4921
3. R.E. Betzig, J.K. Trautman, R. Wolfe, E.M. Gyorgy, P.L. Finn, M.H. Kryder and C-H. Chang, *Appl. Phys. Lett.*, **61** (1992) 142
4. H.J. Mamin, L.S. Fan, S. Hoen and D. Rugar, "Micromechanical Data Storage with Ultra Low-Mass Cantilevers", Technical Digest of Solid State Sensor & Actuator Workshop, June 13-16, 1994, p. 17.
5. L.R. Carley, "Data Storage System Based on an Array of MEMS-Activated STM Tips" 1992-1993 DSSC Annual Report for Industry, Data Storage Systems Center, Carnegie Mellon University, 1993.