Documentation

The documentation required to implement an investment will normally comprise: a subscription and shareholders agreement; articles of association (the by-laws or rules setting out how the company is operated); share option schemes (allocating a pool of shares to reward employees and management team members); assignments and licences of intellectual property (if not already entered into); intellectual property pipeline agreements (which allow the company to take an assignment or licence of intellectual property created by the founders in the future whilst continuing to work in the university laboratory); and founders' employment or consultancy agreements.

The main document is the subscription and shareholders agreement. This sets out the terms upon which the investor will obtain shares in the company including the amount that will be paid for the shares and how many shares, and when and how the money will be paid to the company. It also includes the terms on which existing shareholders of the company (usually the investor, and the founders) will hold the shares and the way in which the company will be managed including the decision-making processes. In the case of STS the investors required a slightly more complicated document known as a convertible loan. The investment was lent to the company and the investors have rights to subscribe for shares in the company at any time or to require repayment of their loan.

Conclusion

Providing you identify the technology you wish to exploit and understand the steps involved, a spin-out is an effective model for the exploitation of technology. The key stages are developing the business plan, transferring the technology, finding investment and creating a business which has a good commercial basis. Expert professional advice, should be sought at each stage and is critical to getting it right. However, as with any new business, the time and effort required should not be underestimated.

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Competitive aspects of a probe storage technology

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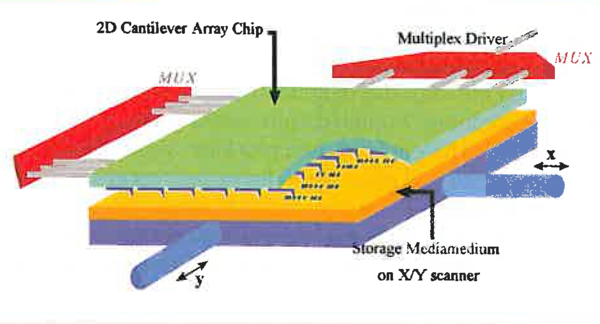
Probe storage technology has been pioneered by Gerd Binnig and Peter Vettiger who developed the concept based on AFM activities in IBM Zurich Research. The basic concept uses a matrix of micro-machined cantilevers to write and read indentations in a polymer material [1]. The cantilevers are bonded to a CMOS chip that holds an analogue sensing unit per cantilever and a multiplexer that transfers the data to the main sensor and control component. A magnetically actuated x/y scanner moves the storage media cantilevers relative to the cantilevers (see Figure 1). A mass-balanced design protects the media from shock in the x/y direction. In a single-lever test system the thermo-mechanical read/write mechanism has demonstrated a storage density of 641Gbit/in2 at raw bit-error rates of 10-4 [2,3]. Raw error rates of this order of magnitude are typical for magnetic recording. Standard error correction schemes can be used to get to the error rates required for today's applications. The system architecture, control and error correction codes are currently being developed to demonstrate a fully functional storage system. MEMS components have been fabricated and assembled and are incorporated into a first small-scale prototype that serves as a test platform for the channel and control electronics built on a dedicated printed circuit board. In parallel to the technical developments a commercial evaluation is performed to validate the competitiveness and market attractiveness of the technology against the most successful non-volatile memory technologies today: magnetic hard disc drive (HDD) and Flash. (We will use the term storage for any non-volatile memory)

Assessing a technology

The attractiveness of a technology can only be analysed by looking at the attractiveness of derived products for particular applications and markets. In a commercial enterprise the business case will be analysed to evaluate the attractiveness of any



▲ Fig. 1: Probe storage concept based on an array of cantilevers.

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investment in a new product. This analysis addresses the product, its cost and potential on the market but is driven by the strategic objectives of the organization and its capabilities such as the marketing and sales channels, the manufacturing expertise and capacity, and financial resources.

The basic analysis of the competitiveness of the technology can however be assessed to a large extent without addressing the company-specific issues. Figure 2 gives an overview of the key factors that drive this process. Application requirements are derived from the needs and wants of the end user. Video and still picture cameras, and mobile phones are the high volume applications in today's consumer electronics. Audio players and USB drives are emerging applications with important growth rates. Each one of these applications has its particular set of requirements on a storage device that are addressed in the market by various products: Flash cards and small HDDs are the two most important technologies that enable products for these applications.

The success of a storage product in the marketplace depends primarily on its fitness for a specific application. If multiple products are perceived to match the requirements of an application then the price is the most important buying criteria: the price per capacity ($/Gbyte) and price per unit. In the price sensitive consumer electronics market the maximum storage capacity of a device is often driven by the price of storage unit that must not be over a certain percentage of the overall cost of the device.

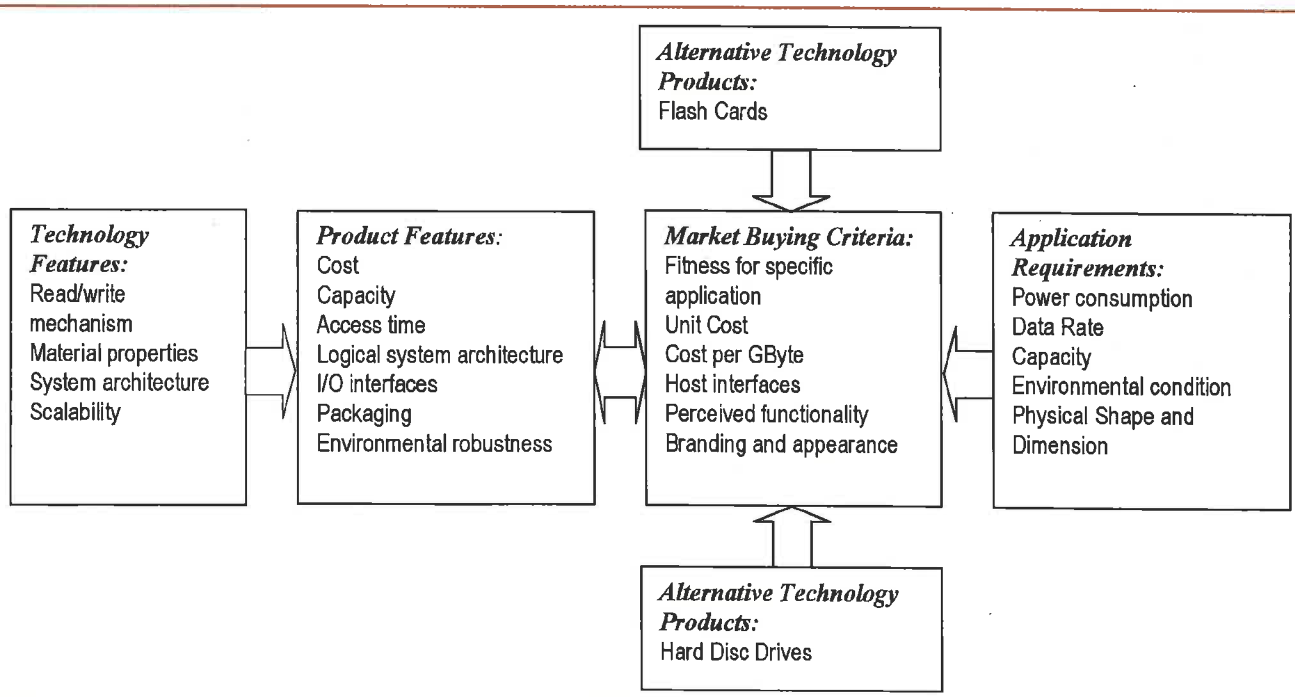
Flash vs Hard disc vs Probe storage

Flash is a semiconductor device that follows the scaling rules of this technology. Increasing densities provide lower cost per storage bit. The cost per bit is however relatively high because of the overhead of a sensor per bit. A high demand and consequently high investments in Flash drive the progress of the technology and decrease cost.

Magnetic storage in HDD takes advantage of a single but expensive sensor that is addressing a magnetic disc and provides low cost per bit. The unit costs are high because of the system overhead of the electronics and sensitive mechanics imposes a limit to the downscaling of the cost. In the next few years it is unlikely that another technology will compete with HDD in cost per GByte at high capacities, i.e. larger than 40GByte. However Flash products have the advantage of the best unit price for small and moderate storage capacity, i.e. <1GByte (see Table 1).

In the near future probe storage cannot compete with the high volume products in HDD and Flash. Even if there might be some technical challenges in the further development of these technologies over the next 5 years, it is likely that they will be overcome by the combined investment of these multibillion industries. Probe storage must therefore target niches not optimally addressed by Flash and HDD. One niche we have identified is mobile storage at capacities that are very costly for Flash and for HDD, between 5 and 40 GByte. The mobile storage market is attractive because of the high growth of mobile devices that are demanding ever increasing storage capacity. Analysts studies by Webfeet and IDC predict around 15B$ revenue in this market for Flash cards and 1B$ for small HDD (Microdrive or competing 1" devices) in 2006.

In mobile applications the environmental stress on a device is an important challenge. The most important factors are an operating temperature over a wide range (e.g. -20C to 85C) and shock resistance (e.g. 1 m drop of a host device on concrete). A permanent loss of data is not acceptable. Semiconductor storage has distinct advantages for these requirements. Probe storage due to the low mass of the MEMS components has a good potential to be advantageous over HDD devices that are very sensitive and are using accelerators to sense a fall and take preemptive measures to protect sensor head and magnetic disc. A detailed analysis with the developers, marketers, and users of the



▲ Fig. 2: Market situation for a new storage technology.

applications is required to identify additional usability requirements. An example of such a requirement, specific to mobile application, is the extreme low power requirement at moderate data rates when a device is used on battery power versus a high data rate and virtually no power limitations if a device is connected to the line-powered host. Differentiating factors that provide the user a noticeable advantage can help to position a product in a market niche beyond a price comparison.

Investment and Risk Management

The most effective allocation of resources is one of the imperatives of any business. Hence we must assess the technology also on the necessary investment and the associated risk.

Manufacturing investment: The downscaling of the feature size is a huge challenge to current semiconductor technologies. Current and future cost will be dominated by very expensive mask technologies and lithography tools. While the cost for mask sets will be several hundred thousand to millions of dollars, lithography tools will cost more than 10 million dollars per tool. Our current probe storage prototypes and potential future product do not require the latest lithography but can rely on established MEMS and CMOS manufacturing facilities. The initial manufacturing investment will therefore be significantly lower than for a new semiconductor generation. Unknown factors are in the yield of assembly and packaging of the components that require nanometer precision. This issue is however not directly related to a high one-off investment but can be addressed in a carefully planned engineering effort.

Scalability: Even though the investment in a product line must be amortized over a few years the opportunity costs could limit the attractiveness of a product investment if it cannot be demonstrated that the technology is competitive over multiple generations of products. The scalability of the technology becomes therefore another important parameter to be analyzed. It seems that the fundamental limitations of probe storage are reached if the indentations approach molecular dimensions. In current tests indentations are in a distance of around 30nm. Higher densities have been demonstrated and indicate room for further scaling. Improved coding and increasing storage area are additional means to develop multiple product generations with ever increasing storage capacity.

Summary

Thermo-mechanical probe storage has demonstrated record density. The technical and commercial feasibility of a product is currently being investigated. The viability of a technology must be analysed on specific products. We have identified mobile mass storage at capacities between 5 and 10GBytes as a potential first niche market. For a successful product the cost per unit and cost per GByte must be attractive. However, ideally additional parameters provide a perceived benefit for a user beyond price. An investment decision must take into account the mix of upfront investment for tooling and of controllable investment for development and engineering efforts. Scalability of a technology over generations of products provides the opportunity to amortize the investment over the longer term. In thermo-mechanical probe storage, potential physical limitations allow for multiple product generations that appropriate engineering efforts could bring to realisation.

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Hard Disc Drive	Flash (NAND)	Probe Storage
Magnetic	Electronic	Thermo mechanic
Rotating magnetic media	Semiconductor chip	Polymer substrate
High system overhead: Mechanical structure, servo, sensor, channel electronics low cost per bit	Low system overhead But high cost per bit cell	High system overhead: MEMS components and assembly, electronics Low cost per bit
high unit cost low $/MB wins at high end (high capacity > 40 GByte	low unit cost high $/MB wins at low end (low capacity < 1 GByte)	moderate unit cost moderate $/MB potentially attractive at moderate capacities
Sensitive to shock due to the moving parts and sensitivity of head and magnetic disc	Low shock sensitivity, no moving parts	Low shock sensitivity due to low masses

Table 1: Comparison HDD – Flash – Probe Storage