NANO TECHNOLOGY BASED DATA STORAGE

ABSTRACT

Storing data in the storage devices such as Magnetic Tape drives, Hard drives, Floppy drives, Compact-Disc, DRAM, SRAM, FLASH, etc, is important for the information technology world. But as this industry growing on the needs of storing data is increasing tremendously. We require high data capacity, high data transfer rates. Current trend storage devices can not meet this requirement. In this medley Nanotechnology is useful to design high data compression storage devices with higher data rates. In this regard Ultrahigh storage densities of up to 1 Tb/in2. or more can be achieved by using local-probes techniques to write, read back, and erase data in very thin polymer films. The thermomechanical scaning-probe-based data-storage concept, internally dubbed "millipede", combines ultrahigh density,, and high data rates. High data rates are achieved by parallel operation of large 2D arrays with thousands micro/nanomechanical cantilevers/tips that can be batch-fabricated by silicon surface-micromachining techniques. The inherent parallelism, the ultrahigh areal densities and the small form factor may open up new perspectives and opportunities for application in areas beyond those envisaged today.

NANO-TECHNOLOGY

The construction of materials whose physical constraints such as length, area, volume rang from 1nm to 100nm. The properties of materials such as physical, chemical, etc,. at this scale are different from at usual scale.

A physicist Richard P. Feynman in December 1959 introduced this concept and he said that "There's Plenty of Room at the Bottom - An Invitation to Enter a New Field of Physics." He notified the possibility of construction of a structure by atom-by-atom from individual atoms which are precisely joined by chemical forces. Finally this led to the a robotic device at nanoscale dimensions that could automatically assemble atoms to create molecules of the desired chemical compounds based on the new concept "universal assembler". For instance diamond can be formed from such a robot from basic carbon atoms with low cost and large size, light weight, highly hard.

NANOTECHNOLOGY APPLIED TO STORE DATA

Silicon-based semiconductor memory chips and magnetic hard drives have been dominating the data-storage market and they have their limitations as magnetic data storage can not exceed the areal density 250 Gbit/in2. At the same time DRAM, SRAM, FLASH Memory chips having the limitations no of Transistors per chip and difficulties in decreasing feature size(2λ). These limitations can be overcome through the new innovative technology namely NANO TECHNOLOGY. Applying nanotechnology to data storage will result in memory devices with high capacity of aeral density of 1 TeraByte/square inch. Techniques that use nanometer-sharp tips for imaging and investigating the structure of materials down to the atomic scale, such as the atomic force (AFM) is suitable for the development of ultrahigh-density storage devices. As the simple tip is a very reliable tool for the ultimate local confinement of interaction, tip-based storage techno-logies can be regarded as natural candidates for extending the physical limits that are being approached by conventional magnetic and semiconductor storage.

NANO-TIP

A sharp pointer type object having nano dimensions is a nano-tip are cantilever. Several of such tipscalled probe and large no.of such probes is used to write and read back data using thermomechanical method on a thin polymer film. The thermomechanical probe-based data-storage concept, millipede_, combines ultrahigh density, small form factor, and high data rates by means of highly parallel operation of a large number of probes. This device stores digital information in a completely different way from magnetic hard disks, optical disks, and transistor-based memory chips. The ultimate locality is provided by a tip, and high data rates result from the massively parallel operation of such tips.

PRINCIPLES OF OPERATION

In cantilever-array storage technique Information is stored as sequences of inden-tations. The presence and absence of indentations will also be referred to as logical marks. Each cantilever performs write/read/ erase operations within an individual storage field with an area on the order of 100%100 µm2. Write/read operations depend on a mechanical *x*/*y* scanning of either the entire cantilever array chip or the storage medium. The tip-medium spacing can be either controlled globally by a single *z*-actuation system for the entire array, or by simply assembling the device with a well-controlled *z*-position of the components such that the *z*-position of each tip falls within a predetermined range.

Efficient parallel operations of large 2D arrays can be achieved by a row/column time-multiplexed addressing scheme similar to that implemented in DRAMs. In our device, the multiplexing scheme could be used to address the array column by column with full parallel write/read operation within one column. The time between two pulses being applied to the cantilevers of the same column corresponds to the time it takes for a cantilever to move from one logical-mark position to the next. An alternative approach is to access all or a subset of the cantilevers simultaneously without resorting to the row/column multiplexing scheme. Clearly, the latter solution yields higher data rates, whereas the former leads to a lower implementation complexity of the electronics.

WRITING AND READING OF DATA

Thermomechanical writing is achieved by applying a local force through the cantilever/tip to the polymer layer and simultaneously softening the polymer layer by local heating. The tip is heated by application of a current pulse to a resistive heater integrated in the cantilever directly above the tip. Initially, the heat transfer from the tip to the polymer through the small contact area is very poor, but it improves as the contact area increases. This means that the tip must be heated to a relatively high temperature of about 400ºC to initiate softening. Once softening has been initiated, the tip is pressed into the polymer, and hence the indentation size is increased.

Imaging and reading are done using a thermomechanical sensing concept. To read the written information, the heater cantilever originally used for writing is given the additional function of a thermal read back sensor by exploiting its temperature-dependent resistance. For read-back sensing, the resistor is operated at a temperature in the range of 150_300ºC, which is not high enough to soften the polymer as in the case of writing. The principle of thermal sensing is based on the fact that the thermal conductance between heater platform and storage sub-strate changes as a function of the distance between them. The medium between the heater platform and the storage substrate, in our case air, transports heat from the cantilever to the substrate. When the distance between cantilever and substrate decreases as the tip moves into a bit indentation, the heat transport through the air becomes more efficient. As a result, the evolution of the heater temperature differs in response to a pulse being applied to the cantilever. In particular, the maximum value achieved by the temperature is higher in the absence of an indentation. As the value of the variable resistance depends on the temperature of the cantilever, the maximum value achieved by the resistance will be lower as the tip moves into an indentation: During the read process, the cantilever resistance reaches different values, depending on whether the tip moves into an indentation (logical bit _1_) or over a region without an indentation (logical bit _0_). Under typical operating conditions, the sensitivity of thermomechanical sensing exceeds that of piezoresistive-strain sensing, which is not surprising because in semiconductors thermal effects are stronger than strain effects.

SYSTEM ASPECTS

Each cantilever can write data to and read data from a dedicated area of the polymer substrate, called a storage field. As mentioned above, in each storage field the presence (absence) of an indentation corresponds to a logical _1_ (_0_). All indentations are nominally of equal depth and size. The logical marks are placed at a fixed horizontal distance from each other along a data track. We refer to this distance, measured from one logical mark center to the next, as the bit pitch (BP). The vertical (cross-track) distance between logical mark centers, the track pitch (TP), is also fixed. To read and write data the polymer medium is moved under the (stationary) cantilever array at a constant velocity in the *x*-direction by the micro-scanner under the control of a servo system.

THE SERVO MECHANISM FOR X-Y POSITION OF CANTILIVER ARRAY

In general, the servo system in a scanning-probe data-storage device has two functions. First, it locates the track where information is to be written or from which information is to be read, starting from an arbitrary initial scanner position. This is achieved by the so-called seek and settle procedures. During seek, the scanner is rapidly moved with the help of thermal position sensors so that the read/write probes are at a position close to the beginning of the target track. A smaller further move in the cross-track direction from that position to the center of the target track is achieved during the settle mode. As the actuation distances during the seek and settle modes are very small, i.e., on the order of 100 µm, the average data-access time is expected to be on the order of 4 ms. The second function of the servo system is to maintain the position of the read/write probe on the center of the target track during normal read/write operation. This is achieved by the so-called track-follow procedure. Track following controls the fine positioning of the read/write probe in the cross-track direction and is critical for reliable storage and retrieval of user data. It is typically performed in a feedback loop driven by a position-error signal, which indicates the deviation of the current position from the track center line. A robust way to achieve synchronization and servo control in an x/y-actuated large 2D array is by reserving a small number of storage fields exclusively for timing recovery and servo-control purposes.

ADVANTAGE OF SCANNING-PROBE STORAGE

Important characteristic of a storage device is the sustained data rate for storing or retrieving information. Scanning-probe storage is inherently slow in storing or reading back information with only a single probe or sensor. Figure 6 shows the user data rate as a function of the total number of cantilevers accessed simultaneously. In this diagram, T denotes the time it takes for a probe to move from the center of a logical mark to the center of the next logical mark. Equivalently, $1/T$ represents the symbol rate per probe. In this scenario a (d =1, k = _)-constrained coding scheme is assumed. For example, for a 64×64 cantilever array, a system designed to access a maximum of only 256 cantilevers every $T = 5\ \mu s$ yields a user data rate of 34.1 Mb/s.

CONCLUSION

A very large 2D array of AFM probes has been operated for the first time in a multiplexed/parallel fashion, and write/read/erase operations in a thin polymer medium have been successfully demonstrated at densities significantly higher than those achieved with current magnetic storage systems.

The _millipede_ array has the potential to achieve ultrahigh areal storage densities on the order of 1 Tbit/in.2 or higher. The high areal storage density, small form factor, and low power consumption render the _millipede_ concept a very attractive candidate as a future storage technology for mobile applications because it offers several gigabytes of capacity at data rates of several megabytes per second.

Although several of the basic building blocks of _millipede_ technology have been demonstrated (high-density thermomechanical writing and reading), there are a number of issues that need further investigation, such as overall system reliability, including long-term stability of written indentations, tip and media wear, limits of data rates, array and cantilever size as well as tradeoffs between data rate and power consumption.