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MRAM: And the Winner is...

In an emerging field like nanotech, ups and downs are inevitable. There is always going to be hype, speculation, mystery, and promise. This is precisely the story of the development of spintronics-based MRAM— the fast, dense, non-volatile memory technology that remains poised to revolutionize computer memory and portable consumer electronics. Projected by some to become a $50 billion industry by 2010, nearly every major tech company now has a hand in MRAM, and much of it seems to center around one small but crucial player, **NVE Corporation** [NVEC], whose intellectual property portfolio may provide the basis for MRAM's development. The race to commercialize MRAM has entered the home stretch. Who's going to come in first, who's going to profit, and how is it all going to affect the landscape of nanotech investment? We remain confident of NVE's prospects despite some vocal detractors of NVEC, and a few investment firms are beginning to wake up to this potential.

Spintronics is a nanotechnology that utilizes a quantum property of electrons called spin rather than its electric charge. An electron can either be in a state of "spin up" or "spin down." If these states can be controlled, they can comprise a binary language capable of encoding information such as in computer memory. This is precisely the idea behind MRAM, magnetic random access memory, which uses magnetization to manipulate spin states.

MRAM is built of units called magnetic tunnel junctions, which consist of two ultra-thin magnetic metal layers separated by an insulator. Within a single magnetic layer, all the electrons' spins are aligned—all "up" or all "down." An electric current will have an easier time passing through the layers if the spins of the two magnetic layers are aligned parallel to one another. If their spins are "anti-parallel" they will resist the current—a phenomenon called magneto-resistance. Let's say layers with anti-parallel spin represent a 1. If this is the case, then the data can be read as a measure of magneto-resistance. Each magnetic tunnel junction is a memory cell and stores a single bit of data. To write data in such a cell, one need only apply a magnetic field to flip the spin orientation of one of the layers.

What's the significance of all of this? The advantages of storing information in magnetism rather than electrical charge are enormous. Today's forms of RAM, which use charge to represent data, need to be supplied with a constant flow of electricity. In fact, their memory cells need to be refreshed thousands of times per second, which uses up a significant amount of electrical power. Spin, on the other hand, is much more stable—once the spins are aligned, they stay that way unless you apply a magnetic field to flip them, so a computer running on MRAM uses much less power. What's more, in the event of a power outage or a system crash in a computer running regular RAM, the data is lost the second the electricity stops flowing. Spin orientation, on the other hand, stays put, so an MRAM computer doesn't lose data. This feature, called non-volatility, marks a tremendous improvement in computer memory design. MRAM also eliminates the boot-up process, yielding 'instant-on' computers that turn on and off as quickly and easily as a light switch.

MRAM has been called the holy grail of memory, because it promises more compact, more efficient, and more secure data storage than conventional RAM. It combines the density of DRAM, the speed of SRAM, and the data integrity of Flash—all of which translates to instant-on non-volatile computers, and super-fast, tiny, reliable portable devices like cell phones and MP3 players. It's no wonder that so many companies are scrambling to get their hands on it.

Minnesota-based NVE has been developing spintronic-based MRAM since 1989, working mainly off government research grants. They've built up an impressive intellectual property portfolio, consisting of 32 issued U.S. patents and over 100 patents worldwide, either issued, pending, or licensed—including the basic patents needed for a wide range of commercial MRAM applications both for the near and long term. It seems difficult to imagine that other companies could develop MRAM technology that doesn't in some way overlap with NVE's patents. The million dollar question is, just how crucial is NVE's intellectual property for MRAM commercialization?

As of now, NVE has licensed its IP to both **Motorola** [MOT] and **Cypress Semiconductor** [CY], two key players in the MRAM game. Motorola signed an agreement with NVE back in 1995—the agreement has never been made public, but Stephens Inc. speculates it grants NVE a 1% royalty on all sales of Motorola MRAM products that utilize NVE patents, a deal that seemed like a good idea to NVE a decade ago but isn't looking as good now that commercialization is pending. All of Motorola's MRAM develop-

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ment is controlled by its spin-off company **Freescale Semiconductor** [FSL], and at the moment nobody knows whether Freescale is using NVE IP in its MRAM designs. "Motorola/Freescale is coming very close to commercializing MRAM," says Marcus Mainord, a research analyst at Little Rock-based investment bank Stephens Inc., "which could hit the market in early 2005. As a result, there's a lot of speculation as to whether their MRAM uses NVE's patents."

NVE is optimistic about Motorola's use of its IP. "Motorola has made public presentations describing their approach and their MRAM designs and we have said that if those are indicative of what they put into production then we believe they'd be using our intellectual property," says NVE's CEO Daniel Baker. "The reason we can't be more direct about it is that currently they're not selling anything. So we can say what we've said, but we have to stop short of saying what will be in their production devices because that's predicting the future."

Mainord agrees. "It is hard to imagine that Motorola/Freescale's MRAM does not to some degree incorporate NVE's patents," he says. "Unfortunately we won't be certain until Motorola begins selling chips." That may be only a matter of months. The company is currently sampling a 4Mb MRAM chip which could be used for back-up memory in industrial and military environments. Says Freescale's MRAM Market Development Manager Michael Haight, "We expect this activity to lead us to a production ramp in 2005." The chip won't have the speed necessary for consumer products, but in settings where data loss cannot be afforded, the chip's non-volatility is in high demand. When they produce a 16Mb chip they will be able to penetrate the cell phone and PC markets.

Freescale has patented its own significant piece of IP—a device called the Savtchenko bit cell, which allows greater control and a reduction in accidental spin flips when writing data with magnetic fields. "The invention has moved us far past the conventional approach in making MRAM technology viable for production," Haight says. "It puts us in a good position to be the first to enter production with MRAM components."

While Motorola is currently the majority owner of Freescale, reports suggest it will likely be selling its shares by the end of the year. Should that happen, the NVE license will no longer apply, and one of two things will occur. If Freescale says that they are in fact using NVE's IP, then NVE will have the opportunity to renegotiate a new licensing agreement, one that would likely be significantly more lucrative than NVE's deal with Motorola. What's more, Freescale is in an alliance with the European electronics company **Philips** [PHG] and chipmaker **STMicroelectronics** [STM], which means that if Freescale uses NVE's patents, Philips and STMicro will have to negotiate with NVE as well. On the other hand, if Freescale claims that they are not using any of NVE's IP, a legal battle could ensue which, for a small company like NVE with just over $7 million in cash, could spell financial difficulties.

Luckily, NVE's deal with Cypress should come in handy with any potential litigation. The two companies joined forces in April 2002 in the form of a technology exchange agreement. In return for access to NVE's intellectual property and a 17% equity stake, Cypress invested $6.2 million in the company and committed to defending NVE's IP in patent litigation under certain circumstances. Cypress also agreed to manufacture a minimum of 500 wafers per quarter that NVE could package and sell under their own label. With large semiconductor backing and the ability to actually sell MRAM products without the high manufacturing costs, NVE seems to be in prime position.

There's no question that Cypress is using NVE's IP, and while there are no royalties in the mix, NVE could still benefit. Production by Cypress "will serve as validation that NVEC's technology know-how is an integral part of commercializing magnetic-based memory," says Mainord.

Cypress raised many an eyebrow, however, in September 2003 when they sold all of their shares in NVE—totaling $23 million—the same day that it announced delays in its MRAM development. We never like it when big "insider" shares are sold in any stocks we recommend and the sale prompted an attack from from one short-seller with a vested interest in the decline of NVE's stock who argued that the considerable insider trading was indicative of an exaggeration of NVE's valuation. Now, Cypress seems to be back on track with MRAM and, despite a 6-month delay, should move into commercialization of products based on NVE's IP in the very near future. "They've solved a number of very difficult problems," says Baker, "and they feel that once they design an error correction, they'll have designs they can sample." They are currently sampling a 265Kb chip and recently stated that they expect to begin commercial sales in the first quarter of 2005.

Cypress and Motorola/Freescale are the current frontrunners, but there are other companies in the race toward MRAM commercialization. "My guess is that **IBM** [IBM]/**Infineon** [IFX] is not too far behind these leaders," says Mainord. "Less than a year." IBM has a solid history in the field. The first mass-produced spintronic device was developed by IBM. And IBM recently joined with Stanford University to create the IBM-Stanford Spintronic Science and Applications Center. In addition to their own MRAM pursuits, IBM formed an alliance with Germany-based Infineon to commercialize MRAM through a new company called Altis Semiconductor. **NEC** [NIPNY] and Toshiba are also working on their own alliance. Going solo are **Hewlett-Packard** [HPQ], Samsung, **Sony** [SNE], Renaissance, and **Intel** [INTC]. "These are multi-billion dollar companies," says Mainord. "NVEC is the only small player out there."

NVE views every competitor as a potential licensee, which could be the case if, as I believe, its IP portfolio is truly comprehensive. As far as the magnetic tunnel junction is concerned, its patents seem to cover a broad range of key elements. "The spin-dependent tunnel junction, as well as the array, or configuration of the memory cells are central to achieving functioning magnetic memory," says Mainord, one of the most vocal analysts on the stock. "Thus far MRAM appears to be the conventional approach to potentially revolutionizing the semiconductor memory market. Given the substantial portfolio of MRAM IP that NVEC possesses, I think it's in a pretty good position."

The first commercial MRAM products are set to appear in the beginning of 2005 in lower-speed applications, and consumer electronics will be quick to follow. "I would ballpark it at two to three years before the cell phone market is penetrated and probably three to four years before the PC market is penetrated," Mainord says. The coming months will set the tone for the industry, and may cement NVE's position as an IP powerhouse. What remains clear is that MRAM will soon truly change the face of electronics, and the companies leading the revolution will reap the bounty of the information age's latest incarnation.