

March 22, 2004

*Appendix B: NVE's MRAM contribution claims are unfounded.*

The following report names the leading contributors to MRAM from the earliest theoretical work through the design and manufacturing of today's MRAM chips. It forms a dateline of inventions and manufacturing experiments leading to MRAM's recent commercial introduction. This MRAM historical outline is referred to in a separate report titled "**NVE fails to provide any support for its Motorola claims.**"

In 1856 British physicist **Lord William Thomson** discovered that metals change their resistance to electrical current when they are close to or are touched by a magnet. Later, after the development of quantum mechanics in the 1920s, this discovery was defined as **magnetoresistance**. But it was another British physicist, **Paul Dirac**, who is generally accepted as the father of spintronics. In 1928 Dirac proved that electrons possess a unique quantum-mechanical property other than their charge that is known today as "spin." Thomson and Dirac's work led directly to today's MRAM products.

By 1988, **Albert Fert**, a physicist at the University of Paris, was using magnets to magnify a metal's magnetoresistance by layering thin metal sheets together and then magnetizing the metals. His invention is called **Giant MagnetoResistance** ("GMR"). Fert's work was backed by Siemens, Thomson and Philips Electronics. He also worked with **Peter Grunberg** of the Institute of Solid State Research in Julich, Germany and Japan's Hitachi Ltd. invested heavily in this invention.

GMR was another area in which NVE claimed to be a leader. Unfortunately for NVE, Motorola's MRAM does not use GMR. Motorola uses an entirely different system called **Magnetic Tunnel Junction** ("MTJ"), which is far smaller and more effective than the layers of metals and magnetizing scheme.

Also in 1988 a fourth British physicist **Stuart Parkin** went to a meeting in Le Cresot, France. Parkin was 32 when he heard Fert speak about measuring the change of electrical resistance of a metal in the presence of a magnetic field. Within a few years Parkin had perfected the technology. IBM has built an \$8 billion hard disk drive business using GMR. Parkin received IBM's highest research and development award and prizes from the Industrial Application of Physics, American Physical Society and the European Physical Society.

Parkin worked on IBM's MRAM development. Many of the tools he used to create and test MRAM materials cost multiples of what NVE has raised in its entire lifetime. Other pioneers include **Gary Prinz** and **Mark Johnson**, both of the U.S. Naval Research Laboratory. Prinz worked on early MRAM fabrication schemes and Johnson has been credited with creating the **first spintronics transistor**.

The most recent significant discovery was made by the Russian-educated physicist **Leonid Savtchenko** of Motorola. Savtchenko, who died three years ago at the age of 35, invented what has come to be known as the "Savtchenko Switching," which led to the Motorola MRAM toggling feature that can flip a spin on one piece of the layered metal while protecting adjacent pieces of the layered metals from flipping by accident. This was a highly important development, which some believe allowed Motorola to have enough belief that they can manufacture MRAM chips, at least simple ones, cheaply enough to offer samples to customers for testing.

Distribution of samples from initial manufacturing batches to customers only marks the beginning of the commercial selling phase of a chip. The chip will be four corner tested and designed into new or improved versions of existing electronic products. Commercial developments that will make MRAM cost effective are only now beginning in earnest. Meanwhile, NVE has not shown a chip, chip design or chip component design to the industry, much less a sample.

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