



## ReThink Non-Volatile Memory and Security

### CrossBar ReRAM: 100x lower read latency and 1000x faster write performance than Flash

CrossBar was founded in 2010 to commercialize a radically different approach to non-volatile memory called Resistive RAM (ReRAM). A unique memory technology that can be integrated inside a System-on-Chip on standard logic CMOS manufacturing lines, or produced as a standalone memory chip, CrossBar ReRAM is playing an important role in enabling a new world of electronics innovation. Compared to traditional Flash memory, CrossBar's High-Performance-Memory (1 transistor, 1 ReRAM memory cell) offers much faster, bit-alterable, erase-free operation. It can be architected with smaller pages to reduce read and write latencies, lower energy and increased lifetime of the storage solutions. In addition, CrossBar's High-Density Memory technology (1 transistor supporting up to thousands of ReRAM memory cells) has the potential to provide Giga-bits of memory embedded into standard CMOS semiconductors or NAND-flash class of standalone memory at read/write and endurance specifications exceeding that of NAND-flash memories. CrossBar's ReRAM technology can also be used for physical unclonable function (PUF) security keys which ensure secure computing and communications.

## ReThink Electronics Innovation

The light bulb. The telephone. The printing press. The iPhone. All of these inventions had profound impact on the world and people's lives. So what's next? Thinking machines, artificial intelligence, machine learning and neural networks, bringing yet another wave of invention that will shift the trajectory of society in stunning and positive ways. These systems will deliver instant, ubiquitous access to Data, which will become the "New Air," wherever, whenever in real-time. But to make data truly ubiquitous, inventors have to rethink the status quo. New technologies are needed to architect systems with low latency, high energy efficiency, high capacity and screaming fast performance. That's where CrossBar ReRAM comes in.

## Rethink Simplicity

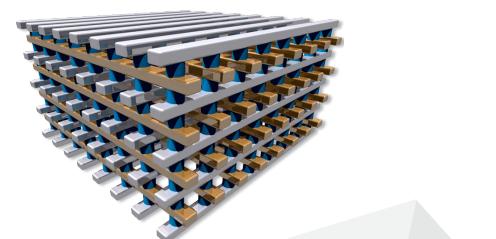
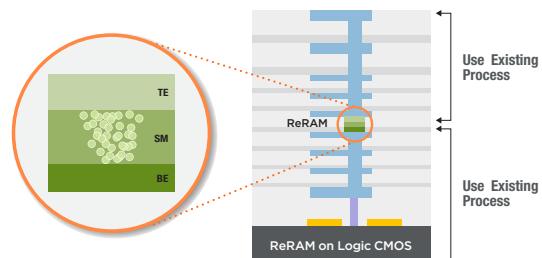
ReRAM is based on a simple three-layer structure comprising two electrodes and a switching medium between them. When a voltage is applied between the two electrodes, a nano-filament is formed. Because the resistance switching mechanism is based on an electric field, the CrossBar ReRAM cell is very stable, capable of withstanding temperature swings up to 125°C, with up to 100,000 cycles, and a retention of 10 years at 85°C.

CrossBar ReRAM technology can be stacked in 3D, delivering multiple terabytes of storage on a single chip. Its simplicity, stackability and CMOS compatibility enable logic and memory to be integrated onto a single chip at the latest technology node.

CrossBar's patented built-in selector allows various memory array configurations in which a single transistor can drive one or thousands of memory cells. This enables CrossBar cells to be organized in super dense 3D cross-point arrays, stackable with the capability to scale below 10nm, paving the way for terabytes on a single die.

## CrossBar KEY FACTS:

- Founded in 2010, headquarters in Santa Clara, California
- Leader in patented filament-based non-volatile ReRAM technology
- IP cores currently being licensed down to 12nm foundry nodes
- Licensed embedded memory IPs for SoC, MCU, FPGA from Kbytes, Mbytes to Gbytes
- Licensed storage memory IPs for standalone memory chips from Mbytes, Gbytes to Terabytes
- 193 patents issued worldwide
- Collaborative engagements in process to develop custom, ReRAM centric architectures
- Investors include: Artiman, Kleiner Perkins Caufield & Byers, Northern Light



## Product Highlights

CrossBar ReRAM is becoming available at various CMOS foundry process nodes, enabling even higher density and more tightly integrated devices. CrossBar licenses its technology to SoC and memory companies as off-the-shelf or custom IP cores. CrossBar is also actively growing its eco-system of hardware and software partners to help rethink how new ReRAM-centric architectures can usher in the next wave of innovation.

### HIGH-PERFORMANCE MEMORY

CrossBar High-Performance Memory IP cores are an ideal choice in embedded non-volatile memory applications such as Internet of Things (IoT), wearables, tablets, smartphones, consumer electronics, artificial intelligence, industrial, automotive and medical. These IP cores can be integrated at the same process nodes of micro-controllers (MCU), System-on-Chip (SoC) and Field Programmable Gate Arrays (FPGA) or used as stand-alone memory chips. Starting at 40nm and scaling below 10nm, CrossBar's High-Performance Memory enables cost effective, low latency, high speed and low energy code execution and data storage memory solutions.

CrossBar's High-Performance ReRAM memory technology can support numerous types of non-volatile memory including multiple-time programmable (MTP), few-time programmable (FTP) and one-time programmable (OTP) memories as well as physical unclonable function (PUF) capabilities. Since ReRAM MTP, FTP and OTP memories and PUF keys are able to share the same monolithic ReRAM manufacturing process and control circuitry, a single chip design can now be dynamically customized by re-sizing the different memory types during test time, offering CrossBar customers additional flexibility.

### HIGH-DENSITY MEMORY

CrossBar High-Density Memory IP cores are an ideal choice for high-capacity, low-latency memory applications such as data center storage, mobile computing, consumer electronics, and artificial intelligence. This technology offers high density, low latency, high performance and low power in a non-volatile memory solution. The data integrity and operational characteristics exceed current 3D NAND Flash. Depending on the business model, the IP cores can be provided to customers as hard macros that can be integrated into SoC or FPGA devices or used as stand-alone memory chips. Supported densities are from 8Gbits (1GBytes) to 1 Terabyte, or custom sizes.

### CUSTOM ReRAM

Based on our unique ReRAM technology IP portfolio, CrossBar offers pre-defined or custom IP cores with specific features, size and performance required by strategic partners. CrossBar is able to optimize the key attributes for specific requirements, such as endurance, retention, read/write speed and latency, operating voltages and current, memory size, etc.

### ReRAM PUF SECURITY KEYS

CrossBar's Resistive RAM technology has numerous uses for both non-volatile memory and security applications. The company is now exploiting the benefits of its unique ReRAM cell for MTP, FTP and OTP memories as well as physical unclonable function (PUF) security keys, providing superior protection, simpler implementations, higher speed processing and semiconductor fabrication synergy with embedded ReRAM memories.

## Memory is Everywhere



## TECHNOLOGY HIGHLIGHTS:

- Proven scalability below 10nm process node
- 100x lower read latency, 20x better energy efficiency and 1000x faster write performance than NAND Flash
- No erase needed, bit/byte level overwrite capability
- Manufactured on standard CMOS production lines
- Capacities of 1TB+/chip
- Dual use ReRAM cell for NVM memory and PUF security keys

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