FRAM technology puts intelligence in smart airbag systems

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Automotive airbag technology is getting increasingly smart. A variety of important sensor inputs allows purposive acting of the airbag controller and makes data available for storing. FRAM technology provides the "intelligence" for smart airbag systems and associated crash event data recorders.

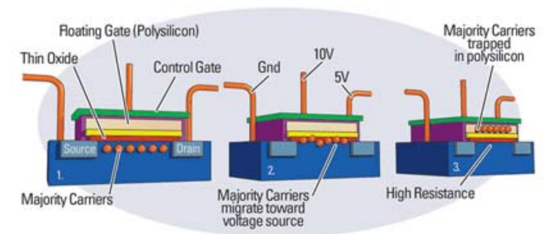

Figure 1. To program floating gate devices, a high voltage is generated on the control gate to accelerate the electrons.

■ In new airbag systems intelligence is being added so that instead of deploying in a standard way as if all accidents are the same, deployment force is determined by accident event parameters such as the severity of the crash, the weight of the occupant and the interaction with other safety systems within a vehicle. Vehicles are also increasingly being fitted with associated event data recorders (EDRs) that collect crash information similar to an airplane black box. The EDR function is normally included in the airbag electronic control unit (ECU). This is a natural grouping because the EDR does not have the survivability requirements of an airplane black box and because the airbag controller is the primary recipient of a variety of important sensor inputs.

The recent decision by Hyundai Autonet to utilise non-volatile ferroelectric random access memory (FRAM) devices in its next-generation smart airbag systems, is further evidence of the growing acceptance of the benefits of FRAM technology amongst leading automotive systems suppliers for use in such safety-critical applications. In this respect, Hyundai Autonet joins eight other automotive manufacturers across the United States, Asia, Japan and Europe who have opted for FRAM technology to provide the intelligence for smart airbag systems and associated crash event data recorders. The parametric data that is sent to a vehicle's ECU is generated by sensors throughout a vehicle's interior including sensors built into the seats that send data to the ECU so the airbag can deploy intelligently. As more and more sensors like this are added to cars, more data needs to be collected. FRAM allows automotive manufacturers to collect this data at higher frequencies enabling a vehicle's systems to store and act on the timeliest information available.

FRAM possesses key features for smart airbag systems that competitive memory technologies cannot easily provide. Its non-volatility and high write endurance coupled with its fast data collection capability make it a suitable memory technology for today's sophisticated airbag systems. Currently Ramtron's 16 Kbit FM25C160 is a popular choice among smart airbag developers due to its 5 V operating power and SPI interface. Non-volatility is important as crashes often result in a power outage, so at some point during the event it is assumed that the ECU will lose connection to battery. High endurance is desirable as the systems are required to collect a rolling window of data that is continuously overwritten with more current data. In addition to the EDR function it is desirable to continuously record a history data from occupant sensors for smart airbags. A fast write capability is essential. As the data requirements increase, the write speed becomes critical as power will fail after a short time. Previously, the predominant non-volatile memory technologies used in automotive applications were floating gate devices such as EEPROM or flash. Floating gate devices have polysilicon gates isolated from the channel by a thin SiO_2 layer. To program a device, a high voltage is generated on the control gate to accelerate the electrons (N-channel device) towards the source. As a result, the electrons gain sufficient kinetic energy to penetrate the insulating layer and are trapped in the polysilicon material (see figure 1). A depletion region is formed in the channel such that, at a particular gate voltage, a device that is programmed is "off" (higher resistance) and a device that is not programmed or erased is "on" (lower resistance).

As the complexity of automotive design requirements has increased, the restrictive nature of floating gate memory technology has become more apparent. For example, the programming process takes several milliseconds, which is an inordinately long time for safety-critical applications. The programming process is also destructive to the insulating layer and such devices consequently have limited write endurance of typically 100K to 1000K writes. In an occupant sensor, for example, data is frequently updated. If the requirement is to write the data once per second, a floating gate device would wear out in less then twelve days of operation. To overcome this, it is possible to use a

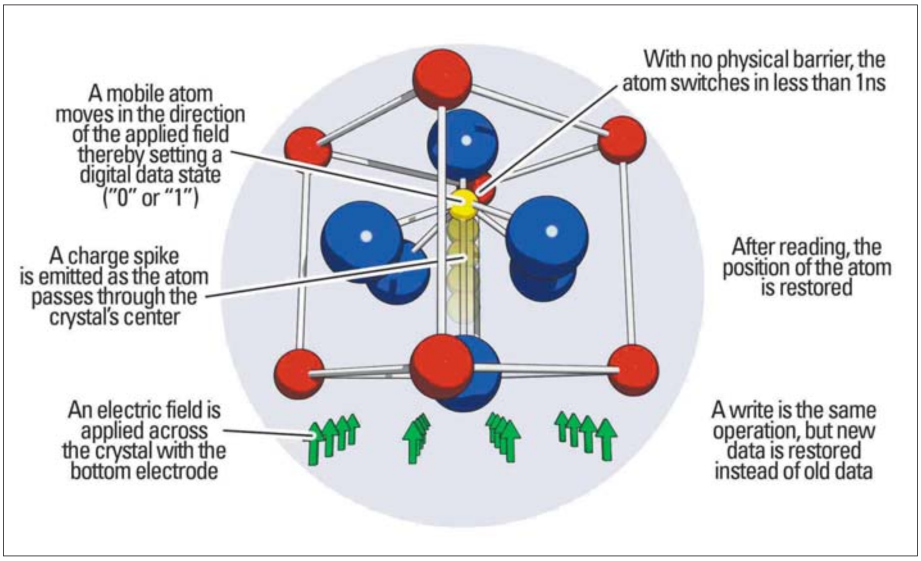

Figure 2. FRAM stores data within the ferroelectric crystal.

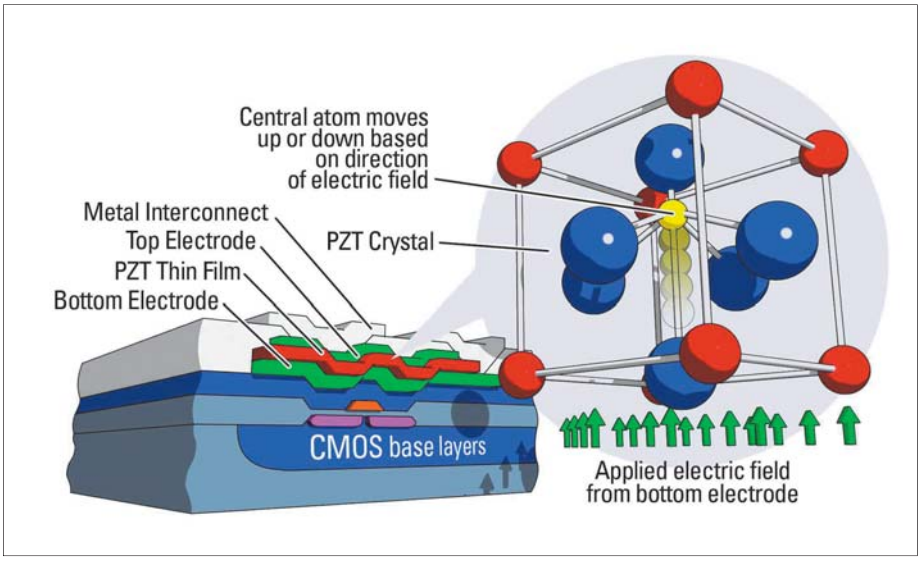

Figure 3. The ferroelectric thin film is placed over CMOS base layers and sandwiched between two electrodes.

buffer and only write the data to non-volatile memory during power down or if there is an event. However, this requires resources from the CPU sensor input in order to signal the occurrence of an event and also a possible alternative power supply to ensure there is sufficient energy to write the floating gate device reliably.

In smart airbag systems it is not only necessary to store data in the event of a crash, but also desirable to store pre-crash data prior to an event. To store pre-crash data, a rolling log would be used but endurance is again problematic for floating gate memory devices. Since airbag modules have large capacitors which store sufficient energy to fire the airbag, there may be sufficient residual energy to write the data from a buffer after the squib has fired. The amount of data that can be written is limited by the energy available, that is to say the residual energy in the capacitor and the speed with which the memory can be written. A typical 2 KB floating gate memory device can write approximately 4 bytes/5 ms. To write an entire floating gate memory device, therefore, can take more than a second.

Using FRAM is less problematic. Its endurance is high (1E12 and more) and its power requirement is significantly lower. Ramtron's FRAM technology integrates ferroelectric materials with standard semiconductor chip design and fabrication technology to provide non-volatile memory and analog/mixed-signal products. These products combine the high-speed read-write performance, unlimited write endurance, and low power consumption of DRAM and static RAM (SRAM) with secure storage of data in the event of power loss, which is unavailable from standard RAM technologies. A FRAM cell is fabricated with an industry-standard complementary metal oxide semiconductor (CMOS) process, with a ferroelectric crystal between two electrode plates to form a capacitor, similar in construction to a DRAM capacitor. Rather than storing data as a charge on the capacitor as volatile memories do, FRAM stores data within the ferroelectric crystal.

When an electric field is applied to a ferroelectric crystal the central atom moves in the direction of the field. As the atom moves within the crystal, it passes through an energy barrier, causing a charge spike. Internal circuits sense the charge spike and set the memory. If the electric field is removed from the crystal, the central atom stays in position, preserving the state of the memory (see figure 2). The ferroelectric thin film is placed over CMOS base layers and sandwiched between two electrodes. Metal interconnect and passivation complete the process (see figure 3).

Therefore, the FRAM memory needs no periodic refresh and when power fails, it retains its data. It is fast, and to all intents and purposes it doesn't wear out. In automotive safety systems applications that require data updates once per second, a FRAM memory would have an operating life of more then 31,000 years. It is therefore adequate to write the data at intervals of sufficient granularity to ensure the proper state is saved. FRAM memory can be updated 10,000 (1 write per 100 µs) times per second for a 25,000 hour operating life (1,000,000 miles at 40 mph). If it is desirable to write data quickly and on a limited power budget after an event is detected, as may be the case in an airbag application, FRAM offers noteworthy advantages. A 16 Kbit (2 KB) device can be written in 3.3 ms with a significantly lower power overhead. ■