FUJITSU FRAM – NON-VOLATILE MEMORY OF THE FUTURE

Brendan Mc Kearney

President of Fujitsu Semiconductor Europe GmbH
fram.fseu@de.fujitsu.com

SUMMARY

This paper explains how the FRAM memory technology works and how the benefits and advantages help to develop smart and efficient meters.

ABSTRACT

Electrical meters and smart meters provide many new challenges to the memory technologies. On one hand the meters need to store usage data much more frequently than ever, ideally even in real time; on the other hand the metering systems need to operate reliably and ensure data integrity even in unstable power supply conditions. The increasing cost pressure also requires the meters to save energy and omit batteries, in order to keep operating cost and maintenance cost as low as possible.
Fujitsu FRAM technology provides the right answer to these challenges. The non-volatile Random Access Memory combines the advantages of SRAM/DRAM and conventional non-volatile memories. This paper shows how FRAM, with its outstanding features (fast writing, high endurance, low power consumption and non-volatility), enables reliable, simplified and efficient metering systems with long life time.

ÖZETÇE

Elektrik ölçerler ve akıllı ölçüm aletleri hafıza teknolojilerine birçok yeni zorluk getirmektedir. Bir yandan ölçüm aletleri kullanım verilerini her zamankinden daha sık bir şekilde, ideal haliyle gerçek zamanlı olarak saklamayı gerektirirken, diğer yandan ölçüm sistemlerinin güvenilir bir şekilde çalışması ve istikrarsız güç kaynağı koşullarında bile veri entegrasyonunu garanti altına alması gerekir. Artan masraf baskısı aynı zamanda ölçüm aletlerinin işletim masraflarını ve bakım masraflarını mümkün olduğunca düşük oranda tutabilmek için enerji tasarrufu yapmalarını ve bataryalarını çıkarmalarını gerektirir.Fujitsu FRAM teknolojisi bu zorluklara doğru çözümü sunar. Değişken olmayan Rastgele Erişimli Bellek SRAM/DRAM ve geleneksel değişken olmayan belleklerin avantajlarını bir arada sunar. Bu bildiri olağanüstü özellikleriyle (hızlı yazma, yüksek dayanıklılık, düşük güç tüketimi ve değişken olmamak) FRAM'ın güvenilir, basitleştirilmiş ve verimli ölçüm sistemlerini uzun ömürlü bir şekilde nasıl sunduğunu göstermektedir.

1. INTRODUCTION

The concept of a Smart Grid is being adopted in more and more countries. At the same time, the metering industry is confronted with a major challenge to build cost effective smart meters, which can communicate bi-directionally, maintain data integrity even in unstable power networks, and provide real-time logging data. These challenges require, at the end of the value chain, the semiconductor industry to provide smart memories to enable smart solutions. In this context, fast writing speed is needed for reliable data storage before a potential power outage. High endurance of the memory is required for real time logging for the whole life time of the meter without intermediate fast memory. Last but not least, low power consumption is a fundamental requirement for the IC components to reduce operation cost of the meters.

FRAM (Ferroelectric Random Access Memory), which has exactly these required features, is a perfect answer to the challenges of Smart Grid. It has the potential to become the non-volatile memory of the future and to supersede both Flash and E²PROM. With its non-volatility and random access, the technology combines the benefits of conventional non-volatile memories and rapid static RAM. FRAM"s additional features, such as low power consumption and high endurance allow this memory technology to fit perfectly into data logging and data storage applications like power meters.

2. FRAM TECHNOLOGY

The memory cell of FRAM, consisting of a transistor and a capacitor, has the same structure as a DRAM cell, giving it the same capabilities of high speed and random accesses. What makes FRAM special is that the FRAM cell contains a capacitor with a ferroelectric dielectric. The information – logically 0 or 1 – is contained in the polarization of this ferro-electric material Lead Zirconate Titanate, ($PbZrTiO_3$ or PZT). This material is placed between two electrodes in the form of a thin film, in a similar way to the structure of a capacitor.
By generating an electric field between the two electrodes, the ferroelectric film will be polarized (Fig.1) instead of moving charges from one electrode to the other. Because the polarization remains after the electric field is removed, the content of the FRAM is not deleted if the power is removed. This non-volatility represents the major advantage of FRAM compared to DRAM.

In contrast to the conventional non-volatile memories like Flash and E²PROM, the content of an FRAM cell is not stored in the form of charge carriers in a „floating gate", no large charge quantities have to be displaced. Therefore it is not necessary to generate large internal programming voltages to be able to write data. E²PROM and Flash technologies usually realize these voltages with internal charge pumps. As a result, FRAM technology is much more energy efficient than Flash or E²PROM.
FRAM supports direct immediate access to each address, so it is not only much faster than other non-volatile memories but also much more flexible.
It is not necessary to write whole blocks at once and waste significant time and therefore performance by waiting for a long write cycle to finish when only a small amount of data needs to be written. Neither is it necessary to delete the blocks

before they can be programmed. FRAM memory cells can be overwritten in both directions and there is no need to clear
whole blocks when only changing a few bits.

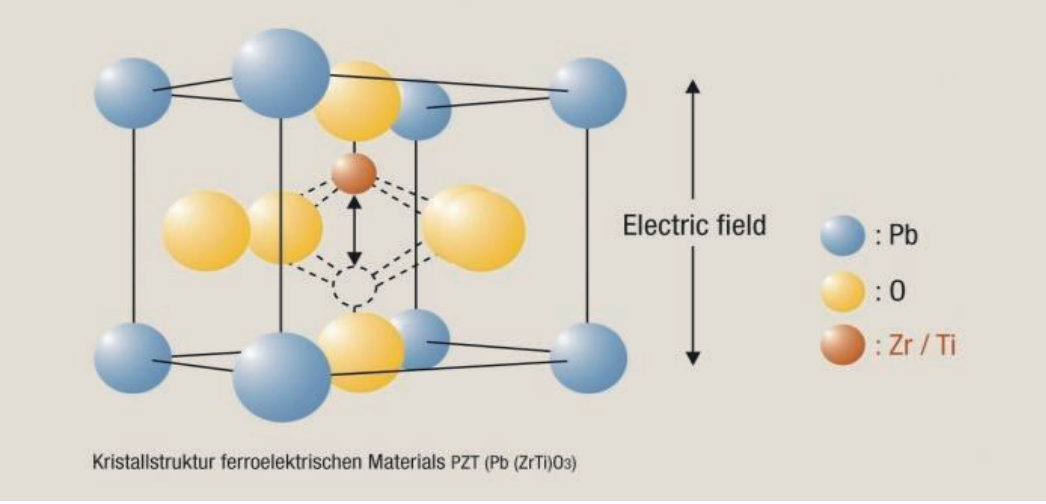

Figure 1: Crystal structure of ferroelectric material PZT

FRAM is a CMOS friendly technology. The FRAM layer islocated between the standard CMOS metal interconnect and the standard CMOS bulk layers.

Figure 2 shows the hysteresis curve of an FRAM. Applying a positive or a negative voltage ($+V_{CC}$ or $-V_{CC}$) creates an electric field that polarizes the ferroelectric film into one of two preferred states. When this voltage is removed, the polarization remains, represented by the two grey dots on the verticalmiddleaxis.

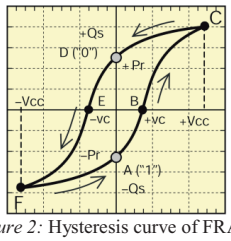

Figure 2: Hysteresis curve of FRAM

A read access to FRAM is performed by applying a reference voltage ($-V_{CC}$) and then measuring the voltage drop resulting from the change in polarization. A small change means the previous value is the same as the new value, a big change means the previous value was the opposite of the reference value. This type of read accesses is called a "destructive process", which means that the old value will be overwritten and of course re-written automatically if it was changed. Because of this reason a read access also results in a refresh of the memory cell, so by simply reading the memory the data retention of the cell is extended. Due to the fast writing feature of FRAM, such a "refresh" can be easily completed without data loss before a potential sudden power shutdown during an access.

Because of the almost unlimited number of possible write accesses it is extremely unlikely to find an application where the limits of FRAM are reached. An access to the same memory cell every 100ms would still be theoretically possible for over 30.000 years.

3. FRAM FEATURES AND BENEFITS

The non-volatility of FRAM permits data to be retained even in the absence of power, therefore battery deployment is rendered redundant. This compares favorably to the use of SRAM which, since it requires a current for data retention when the main power source is removed, requires a battery for back-up purposes. By eliminating the battery, FRAM helps to reduce the PCB size, material and maintenance cost as well as total power consumption of the target application.

Since FRAM operates based on random access, write processes can be completed without the delay which is usually inevitable with non-volatile memories. The write and read access times of FRAM are in the 2–3 digit nanosecond range, which is comparable with those of SRAM or DRAM. As a result, in case of a sudden power outage, FRAM is able to complete the writing process before the system shuts down, thus ensuring data integrity.

In addition FRAM is a very durable memory, capable of offering up to 10 trillion (10^{13}) read/write cycles. The maximum number of write/delete cycles for Flash and E^2PROM is between 100,000 and 1 Million. In comparison to that, the lifetime of FRAM memory is almost unlimited. With this FRAM feature, a true real-time logging application can be realized with one single memory product instead of having to use an intermediate solution like SRAM or DRAM. By simplifying the target system architecture FRAM can reduce potential sources of error and increase the reliability of the target system.

A by-product of this technology is a high resistance against radiation. Unlike the floating gate type memories, alpha, beta and gamma radiation cannot influence the data stored in FRAM. Therefore FRAM is very well suited for medical or space-science applications or in the food industry where radiation can be used for disinfection. Radiation is not only used for sterilization but – in smaller doses of course – it is a common tool to erase charge-based memories. Manipulation attempts based on radiation will therefore not succeed with FRAM.

4. METERING

A key basis for smart metering is a smart memory. With its superior characteristics over other non-volatile memories, FRAM is perfectly suited for frequent-logging applications such as metering.

The combination of the mentioned features enables the design of the smallest possible meters with minimal engineering effort, no requirement for additional components like fast intermediate memory or back-up battery and still supports the full set of capabilities required by metering applications. The ability to permanently store real-time information with exact time stamps in a very short period gives more precise data in unstable environments, allows more accuracy in billing and also a more detailed analysis of manipulation attempts.

5. FUJITSU FRAM

Fujitsu is the first company that has managed to bring FRAM technology successfully into mass production. Fujitsu has been producing FRAM products since 1999 and has to-date supplied over 2.58 billion pieces of FRAM products into the market which shows that the technology is very mature. Fujitsu"s reputation as a dependable supplier of high-quality products has been critical to the development of long-term customer partnerships.

Table 1: Comparison of FRAM with other memory devices

	FRAM	E^2PROM	Flash	SRAM
Type	Non volatile	Non volatile	Non volatile	Volatile
Method writing	Over-writing	Erase + write	Erase + write	Over-writing
Write cycle time	150ns	3ms	1s	55ns
Endurance	10^{13}	10^{6}	10^{6}	unlimited

6. Summary

The special requirements placed on metering equipment by the next generation of Smart Grids needs "smart" solutions at the component level. With its combination of non-volatility, fast access speeds, high durability and low power consumption, FRAM combines the best features of alternative memory technologies in one device. These specific characteristics of FRAM make it the ideal memory solution for smart meters.