MEDEA+

Failure mechanism driven qualification for reliability and analysis (FDQ)

Boosting reliability in cars and planes

Boosting reliability

Development of new failure-analysis techniques and qualification methodologies for semiconductor components in the A407 FDQ project makes it possible to predict the reliability of complex new chips and system-in-package devices for the automotive and avionics industries. With these techniques, it should be possible to meet stringent reliability conditions with advanced technologies without having to wait for market feedback. The new qualification techniques will thus provide European car and plane makers with faster access to components, while boosting overall competitiveness and employment.

in cars and planes

Reliability is crucial in safety-critical applications such as automotive or avionics electronics. Progress in semiconductor technologies over the past 20 years has led to tremendous increases in the number of electronic systems in cars with 80% of innovations in the automotive industry now influenced or even only made possible by electronics. Moreover, the automotive sector and its suppliers are faced with the highest demands on quality in the semiconductor industry in terms of performance requirements, harsh environmental conditions and a short time-to-market business that also poses the longest term obligations to supply spare parts.

An ability to offer innovative, qualified and cost-optimised products on time is more than ever a prerequisite to preserve competitiveness within the semiconductor and automotive industries. But, as complexity has increased, improving quality and minimising failure rates are creating demanding challenges. As a result, carmakers are hesitating to use new innovative components or to continue increasing the share of electronics in cars. Indeed, it is becoming ever more difficult to provide the quality level expected despite effective qualification methodology existing and being applied by most suppliers.

The MEDEA+ A407 FDQ project therefore set out to define and develop new qualification methodology that would make it possible to select only devices that meet customer requirements. It was intended to implement failure-driven methodologies and to obtain much more knowledge about conditions for failures so that it would be possible to predict accurately when failures would occur – depending on application conditions and the environment within the car – and what the failure rate would be.

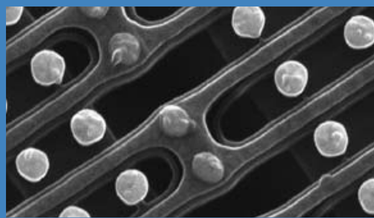
Focus on failure mechanisms

Failure mechanisms were the principal focus; one of the first conditions is to get failure-analysis techniques that would make it possible to have a good knowledge of potential failure mechanisms even for the most advanced technologies. The main concern was related to recent technologies from 90 down to 45 nm for which conventional techniques were becoming incapable of detecting most physical root causes of problems.

Automotive qualification based on stress-test methodology was no longer sufficient to ensure the lower than one ppm failure rate specified by the industry. Building a qualification system that could be used with complex techniques could be quite difficult. FDQ gave the opportunity to exchange extensive reliability experience as well as experiences in failure-analysis techniques and technologies.

While there was a clear need for a new approach, it would be impossible to change policies implemented for many years if there were no co-operation and no consensus. So collaboration within MEDEA+ was crucial to ensure widespread acceptance of the results. FDQ was centred around chipmakers, research institutes and avionics companies from Belgium, France and the Netherlands.

He-ion picture of 65 nm SRAM cells

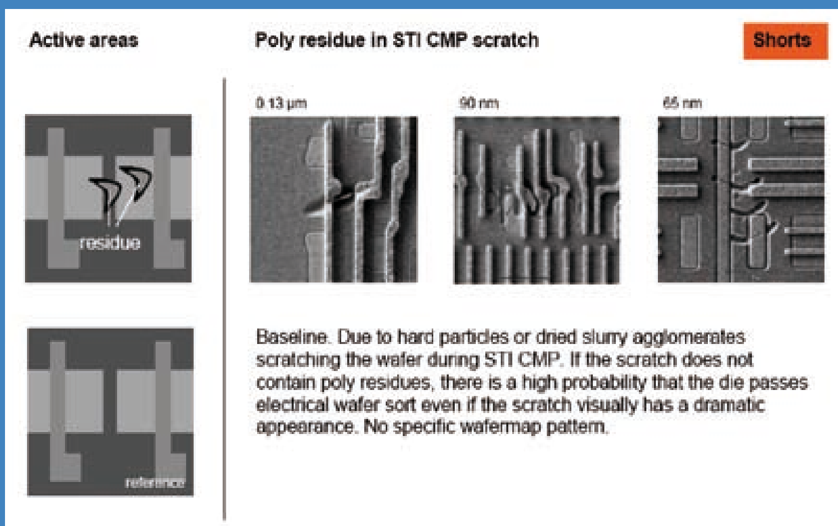


Extending failure analysis to 45 nm

The quality assurance (QA) methodological approach in the FDQ project was supported by a technological element to develop failure-analysis techniques that bring enough understanding of failure root causes down to 45 nm technologies.

This covered not only components but also packaging, system-in-package (SiP) or multi-chip-module (MCM) devices, and flip chips. As a consequence, it was necessary to define diagnostics and preparation techniques and failure-analysis flows that make it possible to manage failure analysis properly for either sub-micron technologies or complex assembly techniques.

Submicron failure-mechanism catalogue



Potential silicon and package failure modes were investigated either through prototype reliability testing or simulation. Project activities also lead to a better understanding of copper electromigration, tin whiskers, solder joint cracks, thermo-mechanical creep, chip cracks under mechanical impacts, oxide aging in non-volatile memories, wire bonding or moulding compound degradation under thermal and thermo-mechanical stresses and others in less depth.

New methodology defined

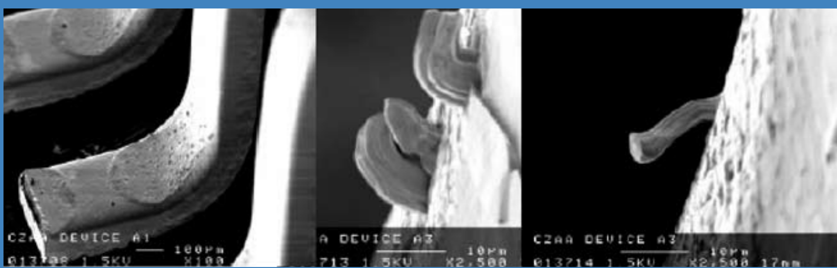
The project successfully defined a new qualification methodology based on a failure-prevention approach, and developed diagnostic and preparation techniques for nanotechnologies.

On the quality-assurance side, FDQ prepared a document and a set of tools that make it possible to implement qualification according to the failure-driven approach. The intention was to have such a document accepted by a standardisation body – and this has been submitted to the Automotive Electronics Council (AEC). Discussions also started with the French Automotive Equipment Industries Association (FIEV), which has similar objectives; several partners are continuing to work with FIEV to prepare a new document.

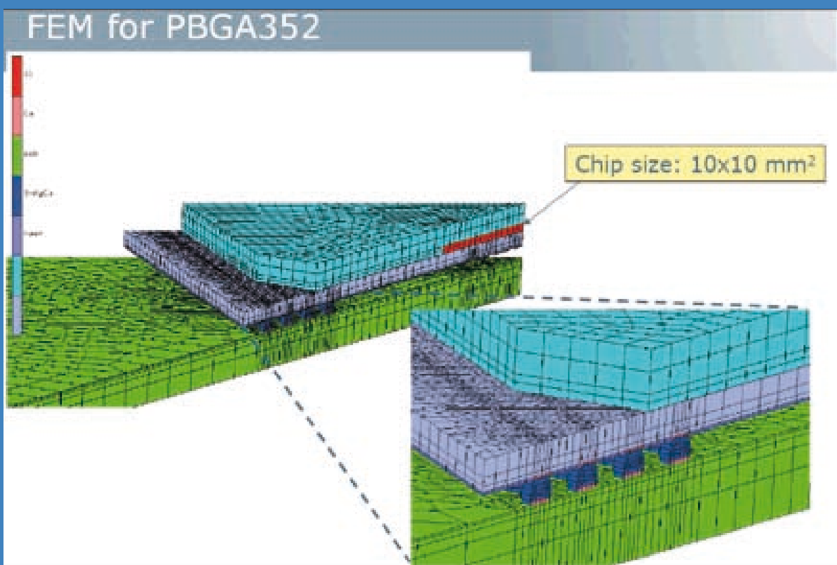
FDQ identified the requirements for future automotive and avionics applications. Typical mission profiles were considered – see flap – and potential use limitations estimated based on reliability models obtained from prototypes experimentation. Results were compiled in a common matrix to facilitate comparisons between automotive and avionic applications.

FDQ also provided an opportunity to share experiences and develop something that can be easily implemented, complementing other emerging initiatives. The German Electrical and Electronic Manufacturers' Association ZVEI is working with the Society of Automotive Engineers (SAE) in the USA to prepare a reliability handbook that supports a failure-driven approach. While this offers recommendations, the FDQ project document is a 'cook book' that focuses much more on implementation of qualification techniques.

Tin whiskers analysis



Finite-element method (FEM) analysis



Improving competitiveness

Project results are already being implemented by the partners, making it possible to evaluate and qualify complex devices and applications in harsh environments. For example, Atmel has been able to extend qualification of an eight-bit microcontroller from 125° to 150°C, putting it a year ahead of its global competitors.

NXP and STMicroelectronics have built models to determine whether components can meet customer demands in terms of reliability. This enables them to tackle markets they would not have done otherwise – normally it is necessary to wait two or three years for market feedback and evidence that a device is reliable before implementing it in the automotive sector.

AMIS, in co-operation with IMEC, has developed a new qualification test for mechanical impact on the IC package. It also presented a new alternative qualification on its non-volatile memory product family that has been proposed as a failure-driven alternative to the AEC-Q100-005.

For the future, a new MEDEA+ project – ELIAS – is focusing on design for reliability, with a group of reliability experts looking at basic structures within advanced technologies.

in cars and planes

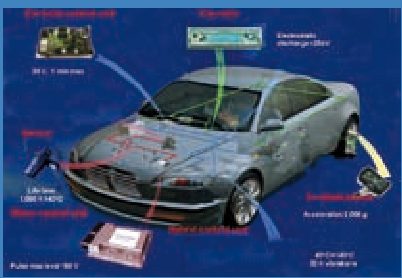
Application case studies

The FDQ project identified the requirements for many future automotive and avionics applications. Six typical applications were identified for automotive applications, covering a wide range of environmental constraints, comfort (radio), car body control unit, tyre pressure sensor, under-bonnet actuator, hybrid control unit and engine control unit.

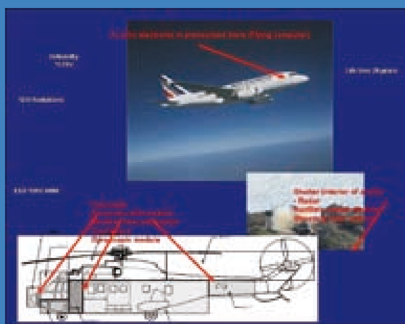
Three typical application areas were identified for avionics applications,:

1. A flying computer in a pressurised store;
2. A shelter – the interior of a tank: radar, auxiliary power module, shooting radar antenna; and
3. A helicopter: automatic pilot module, weather forecast module, dashboard and gyroscopic module.

Automotive applications case studies

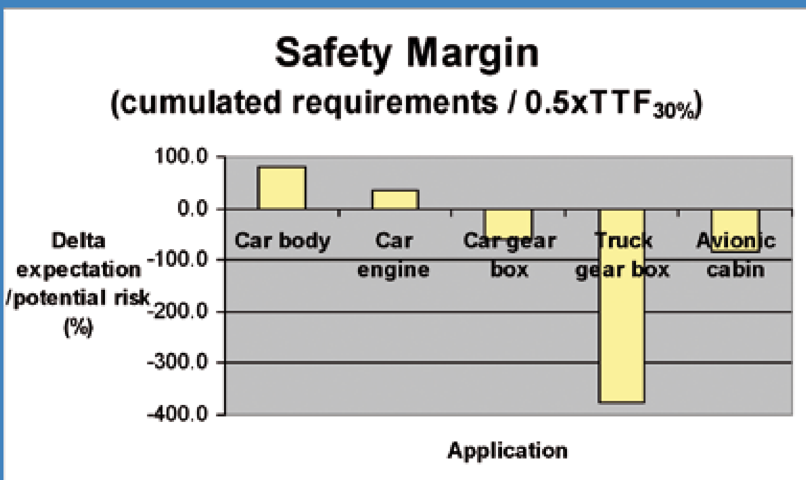


Avionics applications case studies



As a result of the new qualification approach, safety margin indicators could be provided for various application case studies.

Safety margin estimation for dominant silicon and package potential failure mechanisms – electro migration (EOM), non-volatile memory cell oxide leakage, non-volatile memory cell high voltage degradation, Kirkendall voids, resin stress on balls and silicon fracture



Automotive electronics

A407: Failure mechanism driven qualification for reliability and analysis (FDQ)

PARTNERS:

AMI Semiconductor
Atmel
EADS CCR
IMEC
Infineon
NXP (formerly Philips)
Siemens VDO
STMicroelectronics

PROJECT LEADER:

Pascal Lecuyer
Atmel

KEY PROJECT DATES:

Start: March 2004
End: March 2007

COUNTRIES INVOLVED:

Belgium
France
Germany
The Netherlands

EUREKA Σ!

MEDEA+ Office
140bis, Rue de Rennes
F-75006 Paris
France
Tel.: +33 1 40 64 45 60
Fax: +33 1 40 64 45 89
Email: medeaplus@medeaplus.org
http://www.medeaplus.org

MEDEA+ Σ!2365 is the industry-driven pan-European programme for advanced co-operative R&D in microelectronics to ensure Europe's technological and industrial competitiveness in this sector on a worldwide basis.

MEDEA+ focuses on enabling technologies for the Information Society and aims to make Europe a leader in system innovation on silicon.