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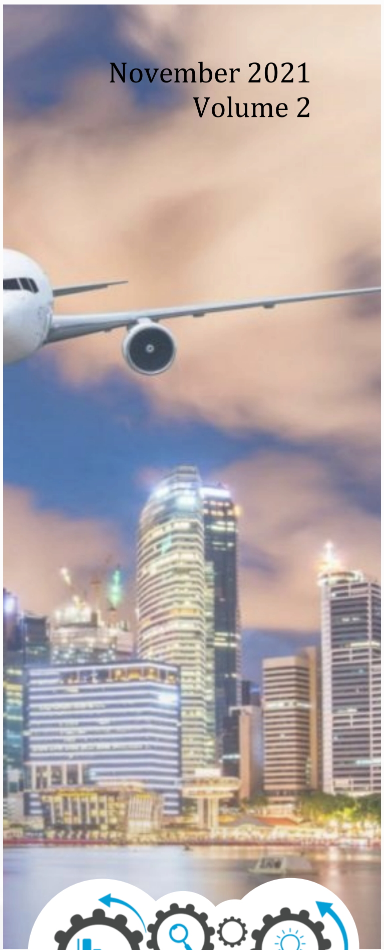


iRel40

Intelligent Reliability 4.0

Newsletter M18

"Intelligent Reliability 4.0" (iRel40) has the ultimate goal of improving reliability of electronic components and systems by reducing failure rates along the entire value chain.

Welcome to the second newsletter from the project "Intelligent Reliability 4.0" (iRel40), which aims to improve the reliability of electronic systems and micro(nano)electronic components. Coordinated by Infineon Technologies AG, 75 research and industrial partners from 13 countries are joining their forces to achieve this goal.

Quality and Reliability are key differentiators of electronic components and systems made in Europe! iRel40 improves the Reliability of electronic components and systems along the value chain wafer/chip-package-board/system, throughout the whole lifecycle in the domains of Transport and Smart Mobility, Energy and Digital Industry. Experts from science and industry in Europe are working together to find solutions to cope with the ever-increasing complexity of reliability topics. Their effort is supported by the newest insights and methods in material research, failure analysis, including modelling and simulation, as well as artificial intelligence.

This newsletter presents selected results obtained during the first 18 months of the iRel40 project.

Inside this issue

Facts & Figures

Partners: 75

Countries: 13

Budget: 101.8 Mio €

JU Funding: 24.5 Mio €

Project Start: May 1st, 2020

Duration: 36 months

Coordinator: Infineon Technologies AG

ABOUT THE iRel40 PROJECT

Project budget

Partners plan to spend costs of more than € 100 Mio. requesting roughly € 24.5 Mio. of European and national funding each. Additionally, partners cumulative contributions make up more than 50% of the overall project budget clearly demonstrating their very high commitment to the iRel40 project.

Project characteristics

8 Work Packages

16 Application Use Cases

18 Industrial Pilots

Project Objectives

iRel40 has one primary objective:

Improve the reliability by reducing the failure rate. Hence, iRel40 will be the nucleus for a new European reliability expert community, enabling differentiation in the ECS Industry.

The strategically measurable objectives:

Objective 1: Define needs and requirements for future ECS applicants to drive improvements and prediction of reliability along with the value chain chip, package, board/system - to foster Europe's competitiveness in ECS.

Objective 2: Implement data value chains and cross-component data analytics to speed up the learning curves by 30%.

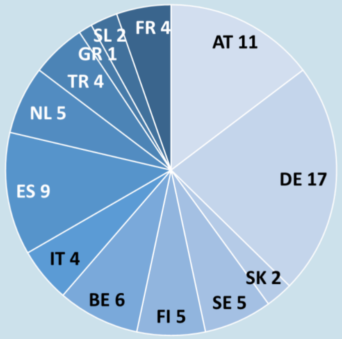
Objective 3: Double the predicted lifetime for specific materials and load conditions for ECS applications.

Objective 4: Early detection of unexpected quality relevant events along the ECS value chain by advanced and innovative control concepts.

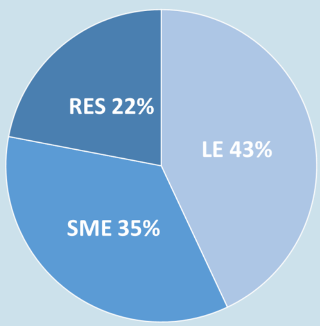
Objective 5: Reduce the failure rates by 30% and enable lifetime prediction with connected and new test concepts along the ECS value chain.

The iRel40 has the ultimate goal of improving the reliability of electronic components and systems by reducing failure rates along the entire value chain.

iRel40 consortium (# of partners for each country)



Partner structure



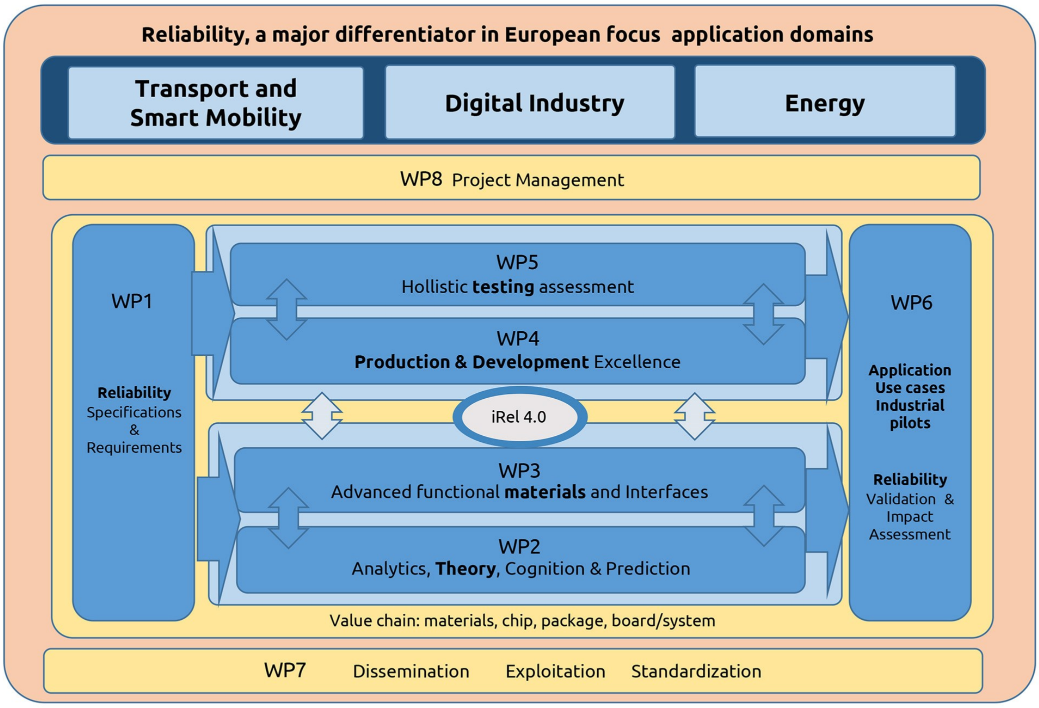
Project Organisation

The project is organized in 8 work packages, 6 of which focus on the technical content. In addition, iRel40 includes 34 use cases, which are worked out horizontally in the six technical work packages. WP1, which includes specifications and requirements, and WP6, where reliability results are worked out and use cases are evaluated in respect to impact, are the frame of the project. In WP2 and WP3 important innovative technology bricks (the iRel40 test vehicles) are developed. WP2 focuses on data quality and management, WP3 focuses on material, interfaces, processes and methods. These test vehicles are the enablers for the two groups of use cases.

Industrial pilots IP (related to WP4 and WP5): they are examples of reliability-related improvement achieved by the development of better processes in fabs, new test methods, advanced test procedures and AI-supported control concepts.

Application use cases (related to WP6): they are examples of demonstrators where reliability improvements related to an application are worked out. These application-related use cases, which are supported by the outcome of the technical work packages WP2 to WP5, are managed and evaluated within WP6.

ABOUT THE iRel40 PROJECT



iRel40 Project organization diagram

Newsletter introduction — 10 highlight results

In this second newsletter, we present the first three highlighted results on test vehicles, which support the 18 industrial pilots (IP) and the 16 application-driven use cases. Then we present the first results related to industrial pilots and application-related use cases.

Example results #1 to #3 related to test vehicles, which support industrial pilots and application-driven use cases

#1 *Framework for the determination of realistic usage profiles for automated shuttle pods* (supports DI-2)

#2 *Modelling & simulation applied to prototyping: material characterization of a ferrite ceramic used in power electronics for reliability simulation* (supports IP-11)

#3 *Precise temperature control of power transistors, which are subjected to power cycling* (supports test infrastructure of use cases)

Example results #4 to #8 related to industrial pilots (IP)

#4 *IP-6: Conditional burn-in*

#5 *IP-2: Handling of unbalanced datasets*

#6 *IP-16: MEMS-sensor package development with help of stress sensors*

#7 *IP-17: Simulation-driven investigation of mechanical failure risks in an SO16 current sensor test vehicle*

#8 *IP-3: Investigation of component health condition based on ML and using data from an after-sales report*

Example results #9 and #10 related to application-driven use cases

#9 *DI-3: Development of a smart/reliable LED driver system with a new solder material*

#10 *T-8: Polymer protection study for GaN HEMT in SiP packaging: from chemistry to microelectronic devices*

#1. Framework for the determination of realistic usage profiles for automated shuttle pods

For automated vehicles, especially Levels 4 and 5 where there are no measurements of real-world operation available, testing of new sensors and components is challenging. Realistic test profiles (including route information, operation time, weather influences etc.) are needed to verify the reliability and estimate the lifetime.

Therefore, ViF proposes a framework for the design of novel 24h usage profiles, especially for Level 4 (L4) shuttle pods. Representing one year of operation, not only driving routes are considered, but also weather conditions are taken into account. Due to the lack of data, artificially generated driving data is required. Hence, public transport routes in Graz are chosen to create driving profiles. Since these routes are already in operation, it is reasonable to assume that buses and tramways can be replaced by L4 shuttle pods in the future.

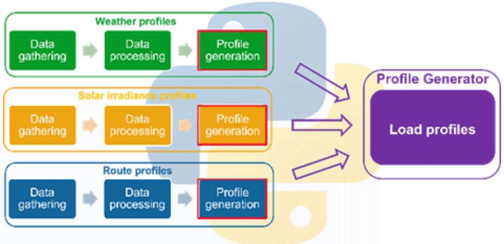


Fig. 1: Software approach for Profile Generator.

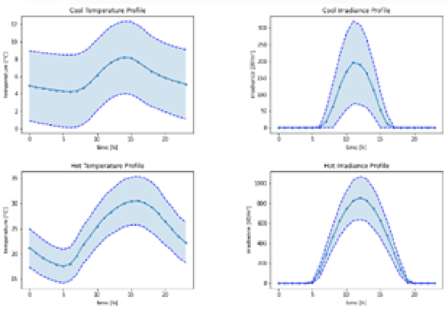


Fig. 2: Temperature and irradiance profiles for cool and warm environmental conditions. The profiles are represented by the mean values (dotted line) as well as the standard deviation (dashed lines).

The software design approach for the usage profile generation is represented in Fig. 1 and shows a Python module called Profile Generator. First, weather, solar irradiance and route profiles are created out of historical data respectively. After data gathering, processing and profile generation, the results are provided to the Profile Generator, which determines the required usage profiles in the next step.

Fig. 3: Map of representative 24h route profile.

Route profile weights

	Cluster	Profile weight	Category weight
Main profiles	Bus31	36.9%	89.5%
	Bus52	21.0%	
	Bus61	15.8%	
	Bus48	5.3%	
	Tram6	10.5%	
Extreme profiles	Bus1	5.25%	10.5%
	Bus40	5.25%	

Weather and Irradiance profile weights

	Cluster	Profile weight	Category weight
Main profiles	Warm	31.08%	73.34%
	Mild	26.09%	
	Cool	16.17%	
Extreme profiles	Hot	10.64%	26.66%
	Cold	16.02%	

Tab. 1: Weather and irradiance profile weights.

For a realistic representation of different climates in Europe, historical weather data containing the ambient temperature and solar irradiance of different locations representing the three most common climate regions in Europe were chosen. To form realistic seasonal profiles, the data was analyzed and combined accordingly to form 5 daily profiles for temperature and irradiance respectively (see Fig. 2). Artificial driving data is created by simulation, using an optimization tool to determine the driving speed for different routes in a certain area. Each specific route is used to produce seven 24h profiles containing the vehicle's speed, acceleration and power consumption in order to represent one week in operation. A Principal Component Analysis for reducing the dimension of the route attributes (e.g. duration of time when the ignition is on) is performed. On the transformed data set, a cluster analysis is carried out. The evaluated seven clusters represent 24h route profiles (see Fig. 3), in detail five main and two extreme routes.

Finally, all-weather, irradiance and route profiles can be combined to determine annual 24h usage profiles. All profiles correlate to a probability of occurrence (see profile weight in Tab. 1). Permutation of all route and weather profiles results in 35 daily usage profiles. Considering the occurrence probability, a simulation of the 35 usage profiles provides sufficient data for an annual vehicle simulation. For more details on the method, the interested reader is referred to the upcoming paper, which will be submitted to the ICCVE22.

SELECTED TECHNICAL INNOVATIONS

#2. Modelling & simulation applied to prototyping: material characterization of a ferrite ceramic used in power electronics for reliability simulation

Fig. 1: Specimens prepared from the bulk ferrite ceramic.

When embedding ferrite ceramics into the inner layers of printed circuit boards, cracks and shattering of the components are a common failure mechanism often occurring during reliability testing of the final packages. Therefore, as part of the AT&S VirtualLabs approach developed within the scope of iRel40, full characterization of the material behavior of a commonly used ferrite ceramic allows to model these packages for use in virtual reliability testing and lifetime prediction simulation.

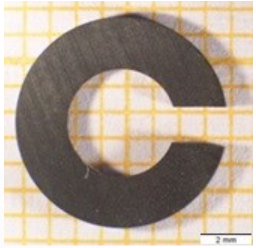


Fig. 2: Ferrite ceramic component used for material characterization.

Tab. 1 shows a summary of the measured properties at room temperature. Specimens were prepared from both the original bulk plates (Fig. 1) and the actual components (Fig. 2) and were analyzed in order to identify differences in porosity and subsequently extrapolate density values accordingly. The elastic constants were determined both statically and dynamically. A 4-point bending test setup was used to obtain the bending stiffness by measuring the eigenfrequencies using the resonant beam method. The dynamic moduli and the Poisson's ratio were calculated. Measuring the temperature-dependent specific heat capacity and thermal diffusivity allowed the calculation of the thermal conductivity of the ferrite ceramic. The determination of the thermal expansion coefficient not only provided the dimensional changes due to thermal loading but also revealed the changes in material behavior when reaching the Curie temperature of the ferrite.

In addition to mechanical and thermal material properties, fracture toughness and strength of the specimens were measured as well. In combination, these characteristics can be used to model failure criteria for simulation and finally allow the prediction of crack growth and damage of the material. The biaxial Ball-on-3-Balls (B3B) test was used to determine the strength of the brittle ceramic specimens, which in many cases (e.g. thermal shock) provides more realistic values than the conventional bending test realizing a uniaxial stress state within the specimens. The principle of the B3B test and the correlation between subcritical crack growth and strength of the specimens in wet and dry testing environment are shown in Fig. 3 and Fig. 4. Finally, all these measurement results were used to set up a material model for use in simulation, comprising the full temperature-dependent mechanical, thermal and fracture behavior of the ferrite ceramic.

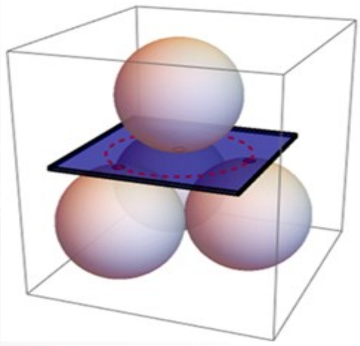


Fig. 3: Principle of biaxial B3B test.

Measurements		Ferrite
Density	[kg/m³]	4592
Porosity	[%]	11,2
Hardness HV0.5kg	[-]	531
Fracture toughness	[MPa √m]	1,08
Young´s modulus, static	[GPa]	125
Young´s modulus, dynamic	[GPa]	127
Shear modulus, dynamic	[GPa]	49
Poisson´s ratio, dynamic	[-]	0,3
Heat capacity	[J/kgK]	686
Thermal conductivity	[W/mK]	3,6
Thermal expansion	[ppm/K]	10
Characteristic Strength (B3B)	[MPa]	106 [104 – 107]
Weibull modulus	[-]	16,3 [13.5 – 18.8]

Tab. 1: Properties of the ferrite ceramic measured at room temperature.

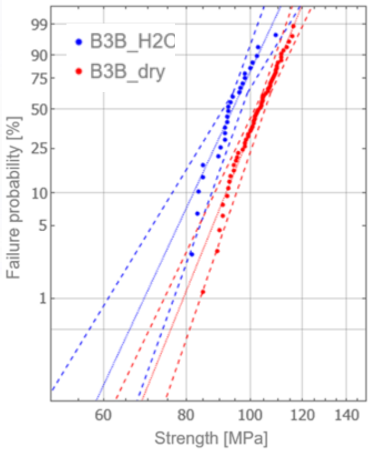


Fig. 4: B3B strength test of ceramic in wet and dry state.

#3. Precise temperature control of power transistors, which are subjected to power cycling

Semiconductor lifetime is a key factor for the economical and sustainable use of power electronics. Manufacturers invest much money and effort into the optimization of the product's reliability. Thus, power cycling is a state-of-the-art method to assess the reliability of power semiconductors.

For more than 15 years, KAI has been developing life test systems for the assessment and evaluation of power semiconductors. The current generation of KAI-developed lifetime test systems is based on one common modular test architecture. Its key property is the clear separation of local, distributed control entities from the actual test circuit. The significant advantage of this architecture is the reusability of the control entities as well as the likewise KAI-developed software framework to run the stress tests fully automated. The control part of the test system is also implemented in the here described task.

The demand for a new method is indicated, as the modelling of real application-specific temperature profiles is getting increasingly complex. Thus, this task focuses on the development of a test system to conduct power cycling and at the same time control the DUT's (device under test) temperature precisely. The novelty of the system is that it enables arbitrarily settable temperature rises in the range from -30°C up to +200°C. Thus, all expectable temperature rise combinations demanded by the target application can be emulated by this system. Previously developed test systems also enable power cycling, where many DUTs are operated within a climate chamber. The drawback of this solution is that the temperature among the DUTs is unevenly distributed and that the temperature rise is not arbitrarily settable.

In this approach, the temperature is controlled by liquid cooling. The DUTs are mounted on a cool plate. The DUT's temperature is measured and controlled precisely. The high temperature is achieved by actively turning on the DUT, which is a power transistor, with a high current. The low temperature is attained by the liquid cooling through the cool plate. This method increases the repetition rate of the temperature cycles compared to the traditional method with the climate chamber by a factor of six. Hence, the temperature cycles can be set as fast as possible by this method and at the same time secure that the DUT has uniformly reached the target temperature.

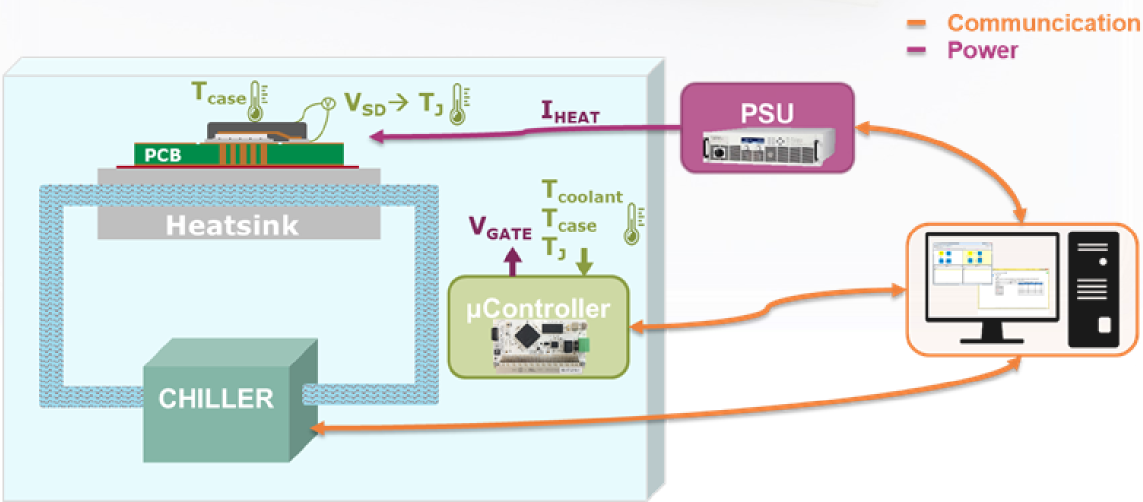


Fig. 1: Test system

SELECTED TECHNICAL INNOVATIONS

#4. IP-6: Conditional burn-in

Due to the defect density in production, early failures are inherent in semiconductor devices with an early life failure rate (ELFR) decreasing over time, see Fig. 1. Burn-in (BI) is a state-of-the-art technique to screen out early failures. For this objective, the electronic devices are operated under accelerated stress conditions that simulate their early life.

Industrial Pilot IP-6 aims to reduce the burn-in costs of semiconductor devices with the help of AI-methods. AI can support identifying the specific burn-in requirements per lot. Furthermore, we still need to guarantee the pre-defined quality target for early failures $\pi_{target} \in [0, 1]$.

In detail, AI models are used to correlate data retrieved during the production process and from electrical tests with the production quality of individual lots. Thus, lots can be classified according to their need for burn-in, resulting in a burn-in reduction. Each classifier can have classification errors, see the confusion matrix in Table 1. A decision-theoretical concept combining the uncertainties in AI predictions and resulting possible classification errors with interval estimates of π is under development. This is a necessary step to still ensure the quality target for early failures.

In experiments with simulated data, Gaussian process regression turned out to be a promising candidate for an AI method to determine the burn-in requirements per lot. Further AI models are also under investigation, like models based on Poisson and negative binomial regression and support vector machines.

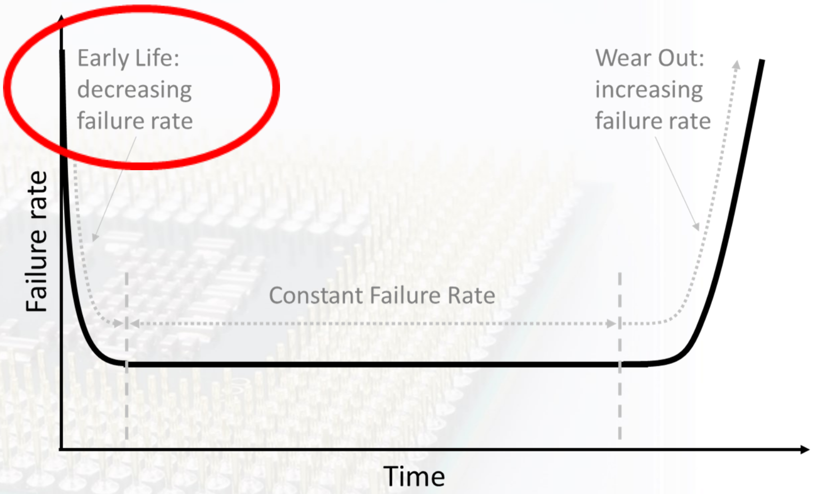


Fig.1: Bathtub curve.

Confusion Matrix		AI Classification	
		positive	negative
Ground Truth	positive	true positive	false negative
	negative	false positive	true negative

Table 1: Confusion matrix.

#5. IP-2: Handling of unbalanced datasets

Unbalanced datasets are very common in real world-domains because the appearance of different events is naturally not uniformly distributed, i.e. some events happen more often than others. Under such assumptions, careful statistical, Machine Learning and Deep Learning modelling has to be performed because models trained on unbalanced datasets tend to perform better on the majority classes compared to the minority classes, which are classes with abundant or only a few samples, respectively.

A way to tackle this problem is to apply data-level class balancing to the dataset by random sampling. Oversampling randomly adds samples, whereas undersampling randomly removes samples from a class and a hybrid of both is also possible. Simple oversampling, however, increases the likelihood of overfitting the data, since the minority classes are filled up with copies.

To avoid overfitting and hence, running into misleading results, data augmentation is usually applied on oversampled datasets. Data augmentation is a technique to increase the diversity of the dataset by generating new samples through modifying the original input data. Typical modifications, e.g. for images, are geometric transformations such as, flipping, height and width shifting, shearing, zooming, and rotating. This modified dataset is then used for model training.

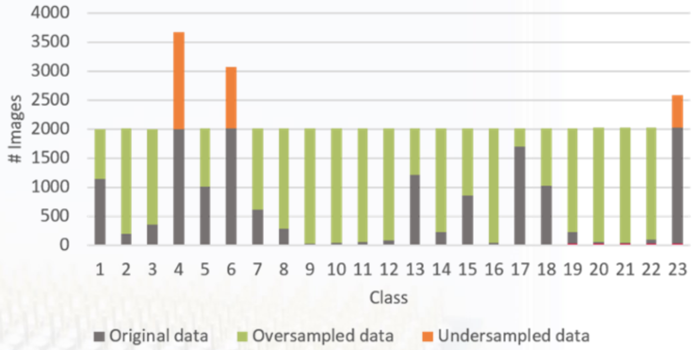


Fig. 1: Hybrid sampling for IP-2 dataset.

The application scenario for IP-2:

The IP-2 partners KAI, IFAT and UCLM deal with data which are images from the defect density inspection in the semiconductor front end production. With the help of AI, each image showing a defect is automatically classified into its corresponding defect class like scratch or particle. Here, the number of images (samples) varies greatly between the different defect classes, as some defects naturally occur more frequently than others.

Fig. 1 illustrates the handling of initially unbalanced data by applying hybrid data-level balancing, combined with data augmentation (see Fig. 2), to balance the training dataset.

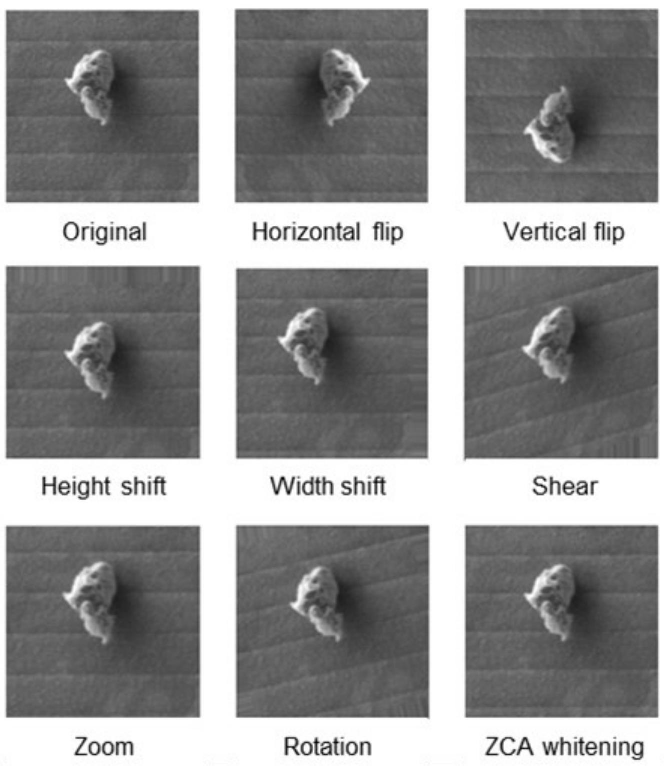


Fig. 2: Data augmentation for IP-2 dataset.

#6. IP-16: MEMS-sensor package development with help of stress sensors

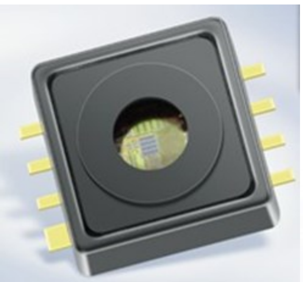


Fig. 1: Example Infineon Side air bag sensor.

Sensor chips, e.g. Infineon´s MEMS-based pressure sensors or magnetic Hall sensors, typically suffer from mechanical stress effects. Major critical influences thereby are long-term changes of mechanical tensions in the package, which causes signal drifts over the product lifetime.

Necessary stress decoupling requires specific package solutions, e.g. cavities, globe tops or elastic glues. Hence it is important to understand the package specific stress causes precisely to ensure stable stress decoupled products over their lifetime, but prevent over-engineering resulting in high costs.

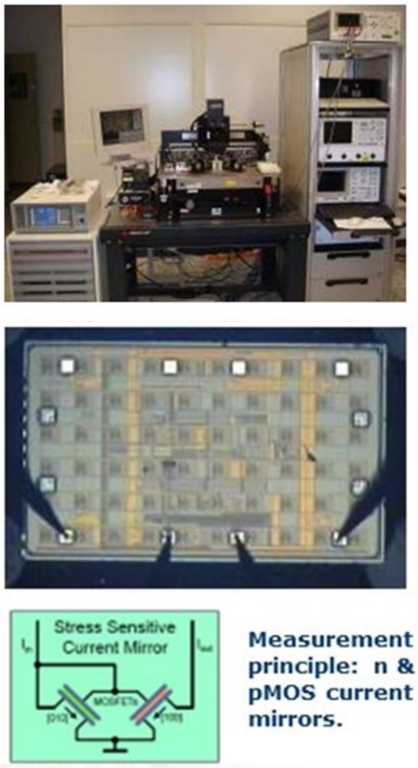


Fig. 2: Stress-test chip based on stress sensitive current mirrors and test infrastructure .

Infineon Regensburg, therefore, uses in its package development department in-house developed and manufactured stress test chips for learning of package specific stress effects. Based on a plurality of systematic material and process variations the impact of the resulting package stress on the assembled stress test chip is determined. This enables early learning and systematic exclusion of combinations that lead in the wrong direction upfront a time consuming complete characterization of the finished pressure sensor development samples.

The following picture shows an assembled stress-test chip in a DSOF-cavity package as used for e.g. for the side airbag pressure sensor in Fig. 1. Differential stress distribution over the chip surface is visualized with help of colors. Additional arrows indicate the direction and strength of the mechanical forces. Further performed measurements with help of a profilometer show a very good correlation. The learning out of these studies helps in several ways:

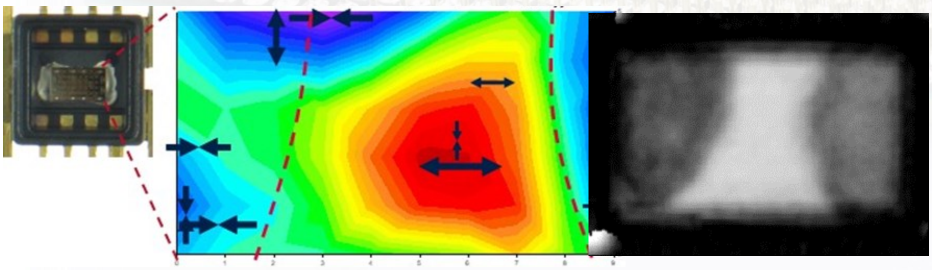


Fig. 3: Test chip in DSOF package (left), visualized stress distribution measurement result (middle) and profilometer measurement of resulting height profile (right).

- The impact of material specific properties as e.g., glues or protection gels can be directly compared.
- Additional the influence of process parameters is determined.
- As a consequence additional parameters as e.g. glue patterns between chip and package can be adjusted.
- Further on early reliability studies as e.g. temperature or humidity impact can be also performed with help of these stress test chips.

All these aspects together lead already in an early state towards the design of optimum MEMS-based pressure sensor packages. Choice of the right material, geometries and processes are supported with help of this time-saving development methodology.

#7. IP-17 Simulation-driven investigation of mechanical failure risks in an SO16 current sensor test vehicle

The SO16 Current Sensor Device (CSD) is an important part of a Current Measurement Module (CMM) developed by Sensitec. The SO16 current sensor test vehicle itself is a moulded System-In-Package and includes an AMR sensor, two magnets and one ASIC (see Fig. 1). Along the production chain the whole sensor device is exposed to different temperature loads at each process step like post mould cure or soldering (see Fig. 2). Due to different thermal expansions of the package materials (CTE mismatch) and expected curing induced shrinkage of the mould material several different thermo-mechanical load situations will occur. A better understanding of their relationship to certain failure modes in the plastic package will lead to a more robust and reliable product.

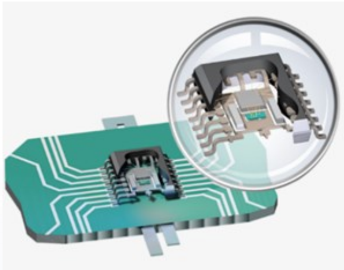


Fig. 1: Current Sensor test vehicle in SO16 package.

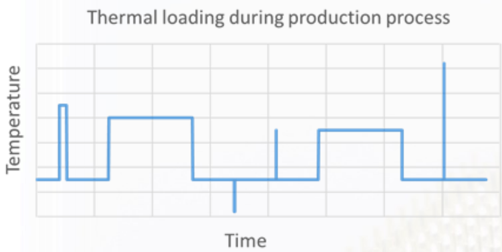


Fig. 2: Temperature time regime during production.

Fraunhofer ENAS has developed a FE model of the test vehicle package to simulate stress effects along the whole process chain. For a good virtual representation of the real model behavior, the relevant nonlinear and temperature-dependent material descriptions like metal plasticity and visco-elasticity were included. The consideration of intrinsic stresses induced by chemical mould shrinkage and thermal mismatch is essential for evaluating the possible failure risks of the SO16 package. Especially the inner architecture of the sensor package with a comb-like structure and the generation of a non-trivial stress distribution near the surface of the AMR sensor die came into focus of the investigation (see Fig. 3). The change of this stress distribution during the assembly process especially after the calibration step can lead to a certain measurement deviation of the device – a so-called offset drift.

Besides model uncertainties regarding available data for the specific materials, the properties can fluctuate naturally due to several reasons like different batch qualities, changed ingredients etc. Additionally, the separate sensor components normally have a process-related quality range such as e.g. geometric dimensions/ shape. This all can have an impact on the resulting intrinsic stresses and therefore to the manifestation of a calibration error. To take all these facts into account an extensive DoE study with 20-30 free parameters at process and component level was started. As a result, a reduction of the parameter space is expected whereby the development of a prognostic model for the resulting stresses at the AMR sensor will then be possible. Furthermore, a newly developed methodology of in-situ measurements based on Stress Measurement Chips (SMC) combined with an advanced online data evaluation routine will enhance the simulation-based investigations with experimental field data.

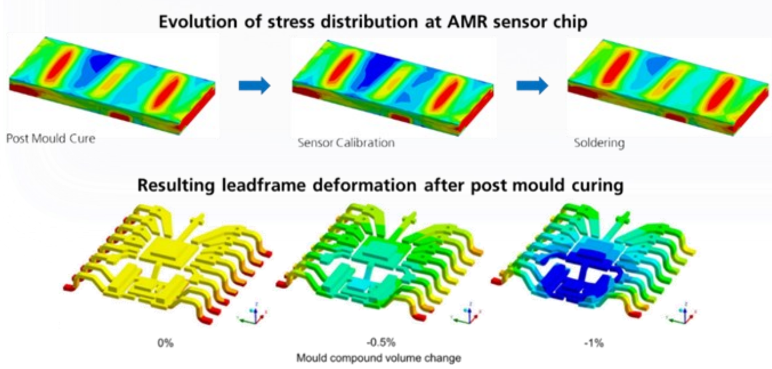


Fig. 3: Stress distribution at the AMR sensor caused by intrinsic stresses, leadframe deformation caused by mould shrinkage.

SELECTED TECHNICAL INNOVATIONS

#8. IP-3: Investigation of component health condition based on ML and using data from an after-sales reports

The appearance of quality defects after a product is sold to a client may result in liability costs, lost customer sales, complaint investigation, etc. Minimizing such “after-sales” defects is, therefore, a strategic issue, in particular, for the home appliances sector. To address this, the data generated from reparation reports of the after-sales services are very valuable but, at the same time, they are currently not sufficiently well exploited. These data and others from different sources are nowadays not fully linked to each other and therefore it is not possible to establish correlations or to define decision processes that are automated and taking into consideration all those variables.

In this context, BSH has worked on merging market reparation reports with production databases, to investigate component health condition based on machine learning (ML) technics. As a leading home appliances manufacturer, it has vast amounts of information from after-sales services worldwide at its disposal. This provides the opportunity to use artificial intelligence to label defects from the different markets and obtain a score card of them and track them to the causes that provoked them in the production process. The result will be a tool which during production will take decisions basing on the historical data that has trained the ML.

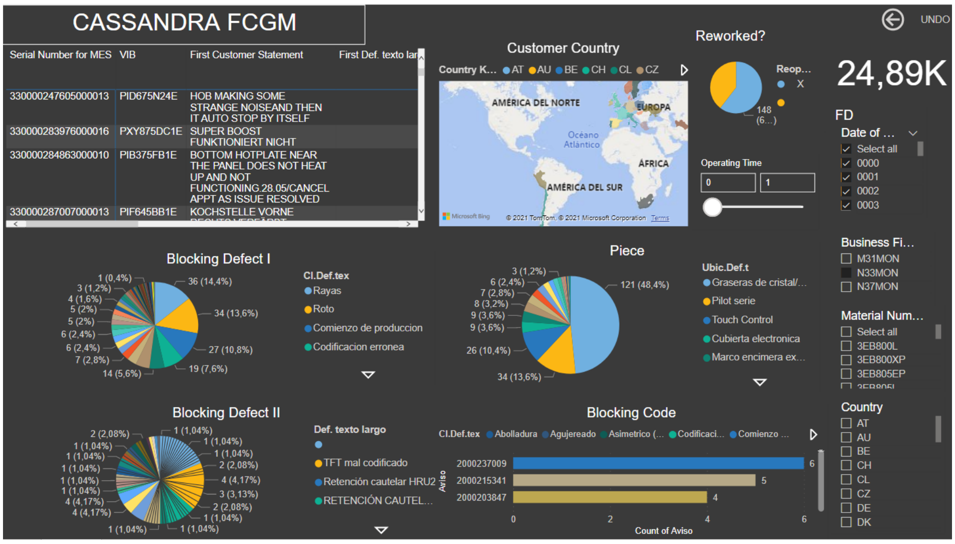


Fig. 1: Example of dashboard showing the different types of defects, the free text which is used for the ml training, location per country, among other parameters

Before training the ML, it is necessary to process the data. One of the most relevant aspects to achieve this is the data treatment of the free text. This is known as Natural Language Processing (NLP) in data science. For each of the free text fields ("Customer Statement", "Defect Found" and "Work Executed"), the text is standardized, and for each value of “General 1”·the table is filtered, the number of times that each word appears is counted and the most frequent words, kept. Then, in the table, a new column is created for the most relevant words, and the column is given the value “1” if the word is present in the free text (this is known as transformation in “unigrams”). Thus, the information of the free texts is processed so that an ML algorithm can interpret it. The ML algorithm that BSH has used is "Light Gradient Boosting Machine" (LightGBM), which is based on a collection of decision trees ("ensemble") each of which is built from the previous ones, solving their errors (“boosting”). This is repeated in a number of steps that is fixed a priori.

This LightGBM ML algorithm has been executed in files that BSH generates monthly in an Amazon Web Services (AWS) server. After being trained, the ML algorithm will be put into production (ML inference). Nevertheless, it will be subjected to further training to adjust the algorithm. In the picture can be seen an example of the dashboard which shows results of the ML inference. This dashboard is visualized in Power BI.

#9. DI-3: Development of a smart/reliable LED driver system with a new solder material

Driver failure is one of the top limiting factors to the reliability of LED lighting systems, especially when reliability requirements are getting more challenging: requesting a lifetime of more than 10 years. One of the weakest links in this system, e.g., the solder interconnects, are challenging to meet the needs in critical applications (temperature changes from -40°C to 80°C). To improve the reliability of LED drivers under these critical conditions, our intention is to improve the solder interconnects by using advanced materials and physics of failure-based modelling techniques.

During the operation of electronic products, solder joints experience harsh environmental conditions in terms of cyclic change of temperature and vibration and exposure to moisture and chemicals. Due to the cyclic application of loads and higher operational temperature, solder joints fail primarily through creep and fatigue behavior. Therefore, we firstly carried out creep tests to get the creep properties of the solder materials. Fig. 1 shows the Instron 5948 Micro-mechanical tester, which is utilized to perform creep tests at elevated temperatures. We get the creep data of solder materials under three temperature levels (25°C, 75°C, 125°C) as shown in Fig. 2. It is demonstrated that the creep rate of the new material is lower than SAC305 at 25°C, which indicates that the solder joints made by the new materials will be better to avoid creep-damage during application.

In the next step, we will study the effect of the solder materials exposed to thermal-mechanical loading in an LED driver. Several types of materials including both solder and potting materials will be considered and finally, we will propose a DOE optimization by varying input parameters to obtain design rules for industrial applications of LED drivers.

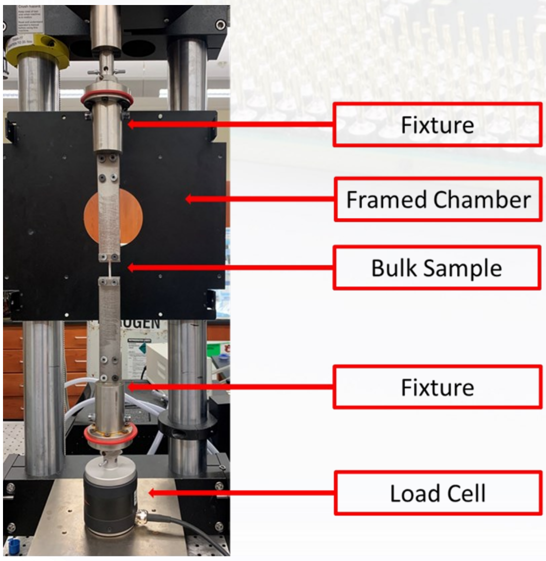


Fig. 1: Instron 5948 micro-mechanical tester.

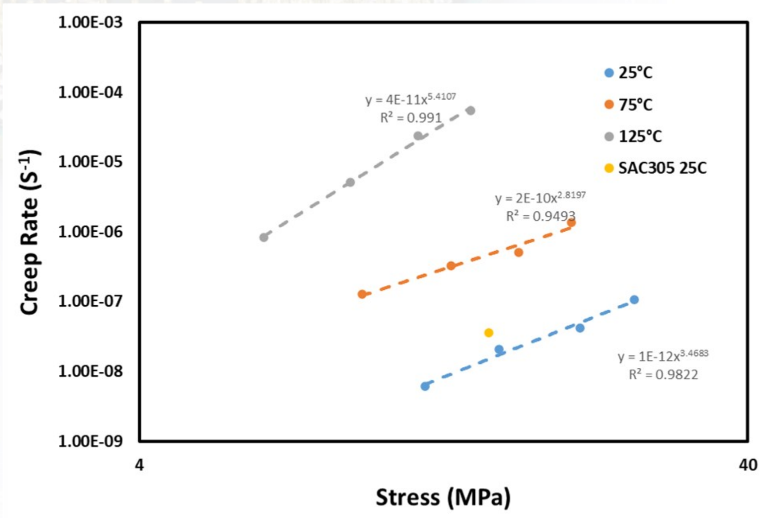


Fig. 2: Creep rate versus stress and temperature.

SELECTED TECHNICAL INNOVATIONS

#10. T-8: Polymer protection study for GaN HEMT in SiP packaging: from chemistry to microelectronic devices

Protection of GaN circuits to be integrated into System-in-Package (SiP) is challenging since this type of packaging technique does not provide full humidity protection and offers a priori limited thermal conduction. GaN-based High Electron Mobility Transistors (HEMT) are prone to corrosion in presence of water and it is important to address the demanding reliability specifications required for all the high tech markets. Moreover, power dissipation density is quite high in microwave amplifiers for telecom applications, since they are using continuous wave signals. The several dissipated watts, expected in reduced size packages, add constraints on the properties of the “thick” polymer protection material.

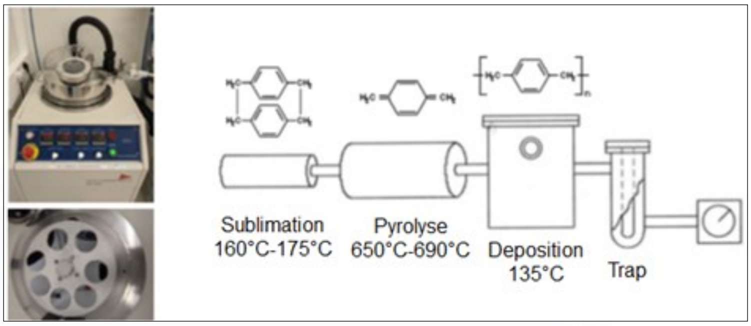


Fig. 1: Example of Parylene deposition set-up (UCBL).

UCBL, III-VLab and UMS have launched a study on the selection of appropriate polymers to address the issue of the secondary passivation protection of the III-N HEMT chips. UMS brings their expertise in the current dice protection approach and appraise progresses obtained. This study includes many aspects of the polymer materials; in particular, the sensitivity of the polymer to humidity, in terms of voltage breakdown and robustness, induced mechanical stress, RF losses, and protection of the interconnections. Selected polymers, currently under study, include Parylene “N” and “C”, polyimide, BCB and silicones. This selection can be further extended if other promising candidates are identified. Polymer basic materials are supplied on the commercial market, and thin films (5 - 30 µm) are deposited by UCBL by techniques optimized for each case (spin-coating, CVD, etc.). Dielectric tests are first performed at mm and cm scales by UCBL. III-V Lab brings its micro pattern and device processing and characterization capabilities. In order to determine the efficiency of polymer protection, Ti/Ge couple was proposed and validated as an efficient passive humidity sensor, out of several candidates. To evaluate the global quality of the protection, 1000 hrs in 85% humidity at 85°C oven ageing tests are currently ongoing and expected to be completed at the end of November 2021.

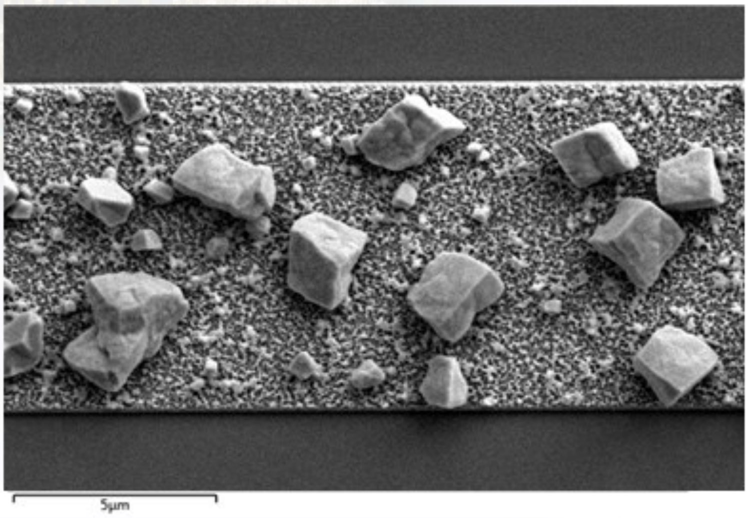


Fig. 2: Scanning electron microscopy of Ti/Ge test films after 48 h ageing in 85°C and 85% humidity environment (III-V Lab). Crystallites mostly contain Ge and planar stripe shows Ti.

DISSEMINATION

Scientific results of the project were published in journals, book chapters and presented at international conferences

Journal Articles & Books

2 book chapters with the titles "Reliability and failures in solid state lighting systems" and "Outlook: from physics-of-failure to physics-of-degradation" published by Springer

3 journal papers published in "IEEE Transactions on Electron Devices" and "IEEE Transactions Journal"

Conference Contributions

15 conference contributions presented at "31st European Safety and Reliability Conference", "WiPDA, the IEEE Wide Bandgap Power Devices and Applications workshop", "IEEE International Electron Device Meeting (IEDM)", "IEEE International Integrated Reliability Workshop (IIRW)", "IEEE International Conference on Connected Vehicles and Expo 2022", and others.

Advanced Reliability is key differentiator of electronic components and systems made in Europe.

PARTNERS

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