INLINETEST NEWSLETTER 2020

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December 31st 2020 - 3rd issue

The annual newsletter of the INLINETEST European project

Introduction

Dear Reader,

This is the third and will be the last newsletter to be published within the regular terms of project ***INLINE**TEST*. Although, the project will continue, to polish the last deliverables, this 3rd issue of the annual newsletter concludes an extraordinarily successful and enlightening joint research project that has brought lots of innovation, strengthened European technological partnerships and has proven viability of several novel approaches to quality testing.

Project ***INLINE**TEST* is a European, trilateral project, **funded by the European Union** under the Horizon 2020 Framework Research and Innovation Programme H2020-EU.2.1.1. in topic ICT-31-2017, grant number 780832. The funding is gratefully acknowledged.

Also you, dear reader, are appreciated for taking your time reading about our progress, our findings and achievements; our passed milestones. If you missed the last annual newsletters, please feel free to visit

[inlinetest.eu/#dissemination]

where you find these for download and other information about dissemination and publications.

As in the years before, this newsletter will not cover too many details already discussed in the previous issues, but provides a brief overview of the progress since. As this is the last newsletter to come in the terms of this projects, we will also give a more detailed look into the future of in-line testing and which impact the project ***INLINE**TEST* made in that regard.

For any remarks, questions or inquiry of miscellaneous nature, please do not hesitate to contact us. Contact details provided at the end of the document.

— *The Editor*

This is the end. Is it?

On January 18th 2018 project ***INLINE****TEST* officially kicked-off with an equally promising as challenging road map. The key measures to ensure success of the (still ongoing) endeavor is a consortium of key experts from all technological and scientific areas related to the project - in-line manufacturing, manufacturing equipment, electronics reliability, failure analysis methodology and measurement system manufacturing.

Moreover, with a university, three SME's and one large industry partner, the consortium provides a healthy mix that involves all economical perspectives but keeps a high degree of freedom to operate. To further link the project to the industry and to ensure feasibility of results, an Industrial Advisory Board (IAB) was acquired, that partook in project meetings on a regular basis and is still linked closely to the project.

On November 12th 2020, the 3rd Review Meeting was hosted in Berlin but held remotely, due to the SARS-CoV-2 pandemic. In this meeting, four technological milestones were demonstrated by video. They are fully functional and provide great potential for quality assessment in a production environment. This newsletter will showcase these demonstrators later.

Due to the pandemic, meetings in person and traveling across boarders, even inner-European, have become either restricted or at least problematic from an epidemiological perspective. Among other technical challenges, especially this situation has caused delays regarding the in-line integration of testing equipment. Due to that, a cost-neutral 9-months extension has been granted by the project officers.

As of today, the original end of project ***INLINE****TEST*, all work packages have been successfully completed, with exception of the integration of an inspection and failure detection functionality into a full production line system and, consequentially, the demonstration of such. Regardless of the delay, ***INLINE****TEST* has been extraordinarily successful. The great potential for innovation has become reality and led to novel failure analysis systems with a considerably high TRL (technology readiness level).

Is it the end? Absolutely not. It is the beginning of thinking production management anew. 100% in-line inspection has never been as close as now and can bring great advancements in resource management and process quality optimization. Admittedly, - project ***INLINE****TEST* has provided proof of concept, shown reliable results in scientific tests and - in the near future will have shown the feasibility in in-line production systems.

We cannot foresee what change may come to production in the future and how products will change. The results of ***INLINE****TEST* provide us with the tools to establish 100% in-line inspection of state-of-the-art products. If and how this toolset needs to evolve to keep up the technological progress, is written in the stars.

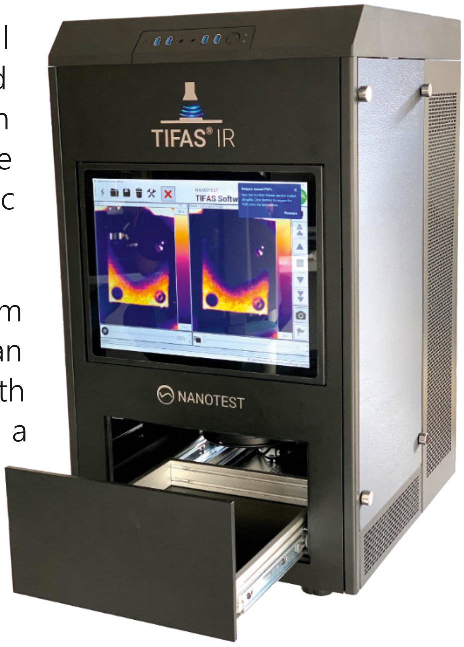
Results

TIFAS IR

TIFAS stands for Thermal Imaging-based Failure Analysis System and the extension IR stands for infrared thermography. TIFAS is the first compact and all-in-one system to offer a fully capable infrared thermography failure analysis as ready-to-use benchtop solution.

TIFAS IR incorporates all required hard- and software to perform pulse- and pulse-phase infrared thermographic failure analyses.

Centerpiece of the system is a coaxial assembly of an infrared camera with small form factor and a ring flash light, comparable with those used in photo equipment, for thermal excitation.

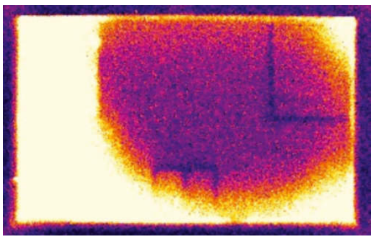


This simplistic all-in-one architecture is novel and allows to build a system much more compact than typical setups, that combine flash and camera on separately

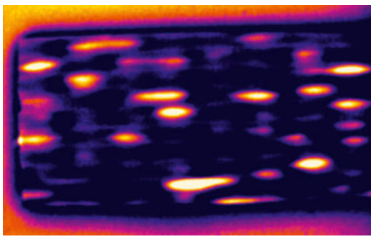
Samples are placed underneath the flash/ camera assembly into a drawer, that shuts the case to keep the user's eyes safe from the flash light.

A demonstration video is available on the ***INLINE**TEST* website: inlinetest.eu/#tifasir

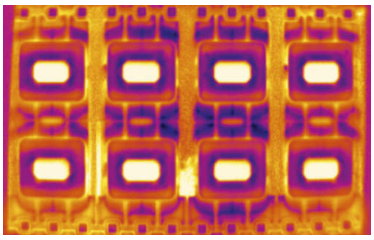
The examples below show the great versatility that comes with pulse-phase infrared thermography. Different defects are detectable and localizable at good resolution. The spatial resolution of TIFAS IR reaches down to 20 µm with defects of down to 500 µm diameter already being visible through thermal image reconstruction (TSR), an advanced image enhancement algorithm. The variety of detectable defects includes **voids**, **cracks**, **delamination** and **inclusions** (and more).



This IR image shows a large-area **delamination** in the sinterd silver layer under a DCB substrate. Already a **delamination** of less than 1 mm diameter is clearly visible.



The **entrapped air** in a carbon fiber reinforced polymer caused by insufficient evacuation are visible as they affect the thermal performance. The **voids** sizes range between 0.5 and 2 mm.



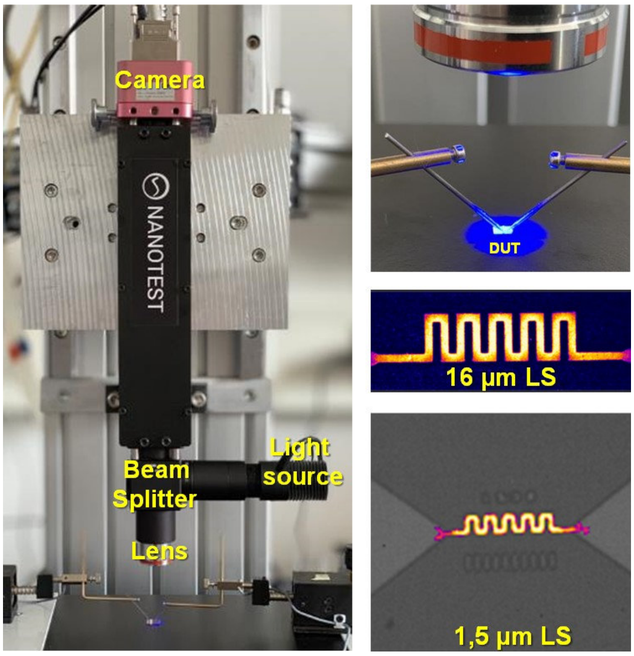
The investigation of **multiple components** at once can massively accelerate quality assessment. Visible defect sizes start at 500 µm, depending on their vertical position.

A large touch panel allows full direct review of the results, precisely control measurements settings and analyze the image data with various algorithms. Overall, the system is designed to be maximum user-friendly and convenient, yet, comprehensive in functionality. Still, the system is considerably low-cost, in comparison with laboratory setups and still providing a competitive resolution of defect sizes.

TIFAS IR is planned to launch as **product** in Q1/2021.

TIFAS TR

The name suggests that this system is a part of a family - the TIFAS family. Also being a system for failure analysis based on thermal image acquisition, only the extension TR is different from TIFAS IR. The difference lies in the kind of thermography that is utilized for failure analysis. **TR stands for thermoreflectance**.



Thermoreflectance thermography is an approach to maneuver around the limitations that infrared thermography brings: Examined surfaces must be highly emissive. Where IR thermography senses the emitted infrared radiation, TR thermography senses reflected light. The reflected portion of incoming light is dependent on the surface temperature. Though, with a temperature coefficient of only 10^{-5} to 10^{-4} per Kelvin.

The low coefficient induces the necessity of **lock-in amplification**. To make this possible, the surface of interest is optically excited using a high quality light source. The selected wavelength defines the spatial resolution and the temperature coefficient. Considering ultraviolet light - which is not suited for all surfaces - down to **250nm of resolution** are possible.

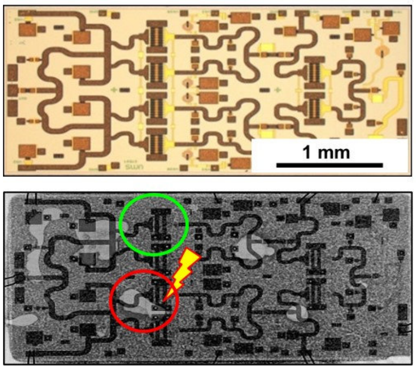
TIFAS TR is a lightweight custom implementation of such a TR thermography-based measurement system. It incorporates a very sensitive CMOS camera and a selection of diodes (460 to 780 nm wavelength). These light sources allow the examination of samples with various surface materials which, amongst others, mainly are gold, aluminum, copper, nickel, titanium and chromium.

The advantages of thermoreflectance thermography don't outnumber those if its infrared sibling, however, there are significant characteristics that oblige further efforts in the utilization of this methodology.

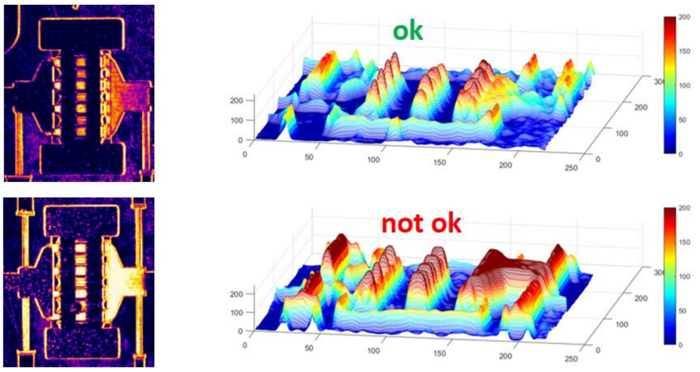
(1) Reflective surfaces are, by no means, measurable using infrared thermography without surface treatment. Thermoreflectance, in contrary, allows thermographic studies of such samples without further treatment, like surface coating.

(2) The resolution is limited by the Abbe limit. By the laws of physics, it is impossible to depict at a higher resolution than the observed wavelength. Given that infrared wavelengths roughly range from 1 to 20 µm wavelength and that camera optics as well as the sensors take their toll on the original image quality, about 3 to 5 µm spatial resolution is what some of the best off-the-shelf laboratory infrared cameras can do. Exciting with 500 nm wavelength and taking into account, that lock-in amplification may be slow but can inprove image quality, sub-micron resolution is easily possible as the images of two meander structures above prove.

(3) The lightweight character of a thermo-reflectance system is a great aspect, as it requires not many components to work flawlessly. This allows such systems to be designed to be affordable and easy to integrate into production line equipment. Moreover, its simplicity leaves flexibility in adaptation to certain application scenarios or to specific samples types and surface materials.



Thermo-reflectance imaging was used to locate hot spots in an HPA module. These hot spots can be caused by voids or cracks in the attach.



The right hand graphs show the results of the TR measurement on the HPA module. Two adjacent transistors show clearly different operating temperatures while operating with the same power dissipation. The cause of the temperature difference is a void in the attach beneath one of the transistors, which is clearly shown by an X-Ray analysis (bottom left image).

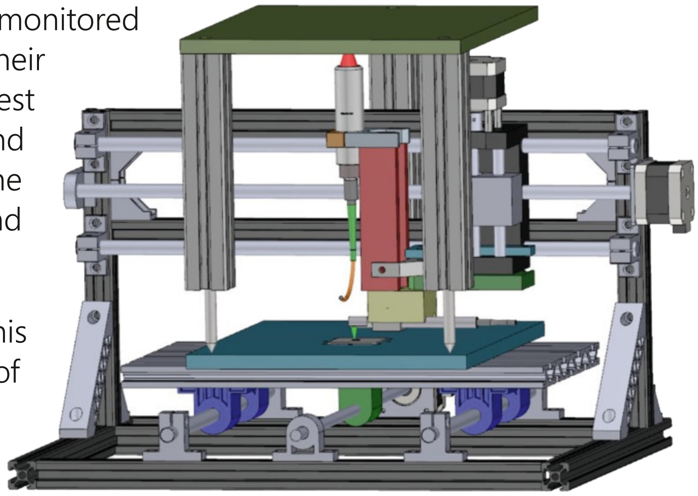
INFAS

The faithful follower of the project may remind that INFAS was already adressed in the ***INLINE****TEST* newsletter issue № 2. The production line demonstrator has already been described in the newsletter and published on exhibitions. Furthermore, its feasibility could be proven with various industry samples from partners and members of the IAB. Therefore, the potential for news regarding this demonstrator is rather sparse.

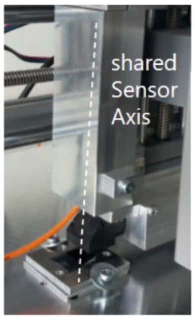
However, the idea of INFAS is on the verge of being implemented in a real production environment. The decendant of INFAS - the benchtop system TIFAS IR, is being set up at project partners in the Netherlands to be tested under real production conditions and to allow for a larger volume of samples to be tested.

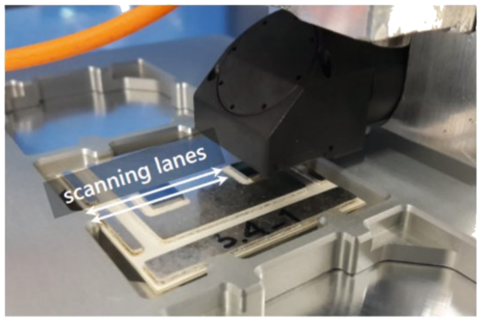
Tiltscanner

As the demonstrators and analysis system presented, so far, focus on detection of defects that significantly affect thermal behavior and therefore are sensitive to such failures only, other quality criteria, e.g. being of mechanical nature, cannot be monitored using these systems and their methods. Thus, a fourth test apparatus has been developed and realized that allows the measurement of sample heights and to detect and quantify tilt.

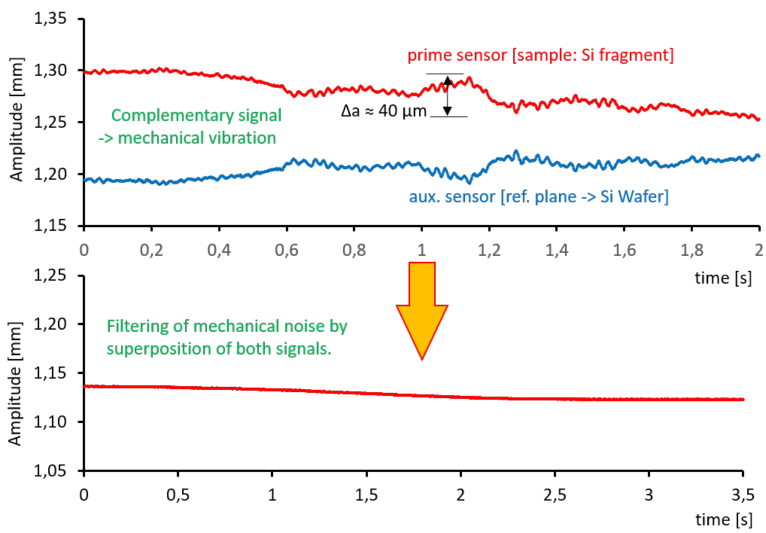


The important aspect of this implementation is the realization of a fully contact-less method, that could seamlessly be integrated into a production line. Tilt and variance in height can be an indicator for bad production quality and the need for readjustment of production parameters. Bad soldering, erroneous molding or various different flaws may occur during assembly processing.





A non-destructive, fast and reliable test method could prevent such flawed components from further being processed, possibly resulting in nothing but financial loss and waste of resources.



The graphs depict the functionality of the coaxial dual-sensor setup.

By scanning a plane Si-chunk with considerable flatness, only vibration occurs and is visible in the sensor readings.

This can be observed in the top graph, where both (coaxial but opposed) sensors show the same but complementary signal.

By adding both signals, as shown in the bottom graph, the noise can be filtered out to improve the resolution up to 1µm.

A demonstration video is online at inlinetest.eu/#heighttilt

The in-line capable test stand, set up in ***INLINE****TEST*, builds on a dual-confocal sensor setup that uses the second sensor as reference signal to substract noise from the original measurement signal. Using this approach, an ideal depth resolution of less than 1 µm can be reached. The X-Y-scanning unit creates a spatially resolved image of 50 µm pixel size.

A program was written, that can automatically detect the chip / object surface and conducts a level adjustment to accurately measure the flank height of the chip or object.

The table below summarizes some major characteristics of the test stand:

System	Parameter	Typical	Maximal	Unit
Confocal sensor	Sampling rate	1000	70 000	Hz
	Spot size	50		µm
	Z resolution	<< 2	0.06	µm
Scanning unit	XY travel	100	300	mm
	Speed	2	10	mm/s
	XY resolution	50	20	µm

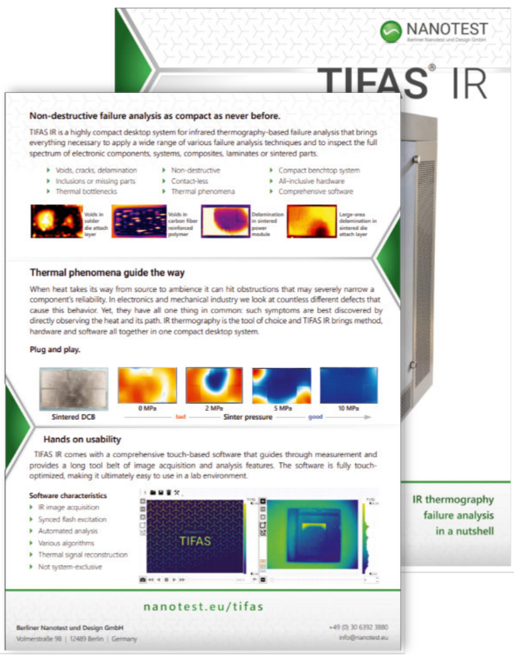
Dissemination activities

Exhibitions

Due to the SARS-CoV-2 pandemic, no exhibition could take place in 2020. This was a loss for dissemination of the developed test stands. Especially TIFAS IR needs a stage, which hopefully will be possible in 2021.

Brochure

In 2019, a brochure for INFAS had been published, also downloadable on the ***INLINE****TEST* homepage. This year, a similar brochure for TIFAS IR has been published, to be well-prepared for upcoming exploitation activities.



Publications

Despite the missing opportunities to meet in person and to practically demonstrate the project results, scientific dissemination has continued as usual in the context of virtual conferences. In the course of the past year, the following publications were made:

D. R. Wargulski et al., *Inspection of silver-sinter die attaches by pulsed and lock-in infrared thermography with flash lamp and laser excitation*, QIRT 2020, online

D. R. Wargulski et al., *Inline failure analysis of electronic components by infrared thermography without high-emissivity spray coatings*, ESTC 2020, online

D. R. Wargulski et al., *Pulsed Infrared Thermography Failure Analysis of low-emissivity Specimens without contaminations caused by high-emissivity coatings*, Therminic 2020, online

D. May et al., *Thermal Characterization and Failure Analysis of MMIC Components by Thermo-Reflectance Imaging*, Therminic 2020, online

T. von Essen et al., *IR based Failure Analysis of low-emissivity Specimens without sureface coatings*, EuWoRel 2020, online

Conclusion

During the past year of ***INLINE****TEST*, nearly all ongoing developments could be finalized to result in fully functional systems at the desired TRL. Although the in-line demonstration in a real production environment could not yet been conducted, this is merely a last step on a long road. This road was starting at fundamental scientific method development and went on through the process of evaluation, loops of testing and reworking, debugging and patching. Eventually, it led us to harvest the fruits of three years of efficient collaboration, collective innovation and text book-alike team work through seamless communication.

The project structure has proven the right choice from the very beginning. Involving an industrial advisory board brought essential directives and prevented the project progress from dead ends and false leads. As well scientifically as technically, the IAB was a beacon of orientation and provided a close relationship with the real target audience for the project results.

Overall, and despite the ongoing extension, ***INLINE****TEST* was already a complete success. The first product release based on the project results is planned for Q1 2021 and the technically challenging methodology of thermoreflectance has never been as close to real industrial application as now. The project consortium and the IAB are confident, that ***INLINE****TEST* will positively impact the future of electronics production.

For more updated information, please stay tuned on inlinetest.eu/#dissemination

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