NANOTHERM

Innovative Nano and Micro Technologies
for Advanced Thermo and Mechanical
Interfaces

September 2013 Newsletter #1

NANOTHERM is a European large-scale integrating project aiming at the development, integration and manufacturability of advanced interface technologies for superior thermal and thermo-mechanical design for heterogeneously integrated power systems on different technology platforms for different market segments in industry.

- The main principle common to all technologies is the exploitation of nano-effects to obtain outstanding interconnect properties by especially developed processes.

The project is completely organized in a top-down approach: all the activities are driven by the needs of the end-users, reflected in the specifications of the demonstrators.

WP 1 defines 6 project demonstrators in order to focus, test and validate the RTD work performed within the project. Each demonstrator will be specified in terms of applications, processes, materials, technologies and requirements. A second objective of this work package is to define suitable test samples and methods in order to perform the required characterization, verification and performance tests, thereby taking into account the key identified technologies and packaging concepts within the project.

The WP 2 is dedicated to the development and characterization of new enhanced nano-scaled, micro-scaled and mixtures of nano-scaled and micro-scaled materials for TIM and die attach, as well as to the design of the substrate material, needed to fulfil the demonstrators specifications.

The WP 3 is dedicated to the design with respect to electrical and thermal performance optimization as well as lifetime extension of the technology demonstrators. Critical interfaces of materials and weak spots of the proposed technologies need to be identified and countered by design solutions and guidelines to increase reliability and lifetime of the demonstrators on subsystem level in this workpage.

In WP4, a number of novel technologies will be developed based on the materials development from the WP2. The WP3 work will give us a guideline regarding the materials selection and guiding for the design and process selections. The new processing and technologies in the proposal include using graphene as heat spreader embedded into the thermal interface material system, nanosilver sintering and glueing for achieving high thermal conductivity of the die attach material as well as polymer infiltration into carbon nanotubes to form strong chemical bond and thin layer and high thermal conductivity TIMs.

WP 5 is the demonstrator work package. Here, partners will work together to show on system level the level of performance increase of the developed materials and technologies.

System characterisation with respect to electrical, thermal and reliability-related properties will be performed and benchmarked versus the state of the art and the objectives given in the project. Special attention will be given to manufacturability and integrability of the new technologies.

The project also includes a work package WP 6 devoted to dissemination and exploitation activities so as to ensure the dissemination of the project results toward the relevant industrial communities but overall to guarantee the industrial transfer of the developed technologies and to secure the corresponding supply chain.

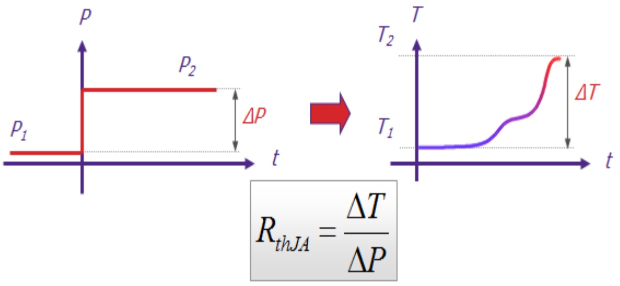
Finally, management activities are grouped into WP 7 and drive all types of activities: technical, administrative, organizational, etc.

Selected Progress in Characterization methods

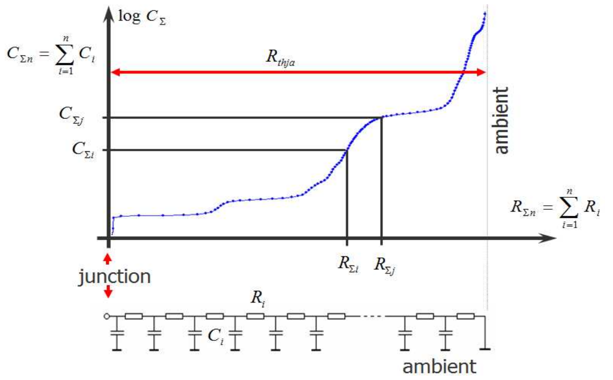
The main role of Budapest University of Technology and Economy (BME) in project Nanotherm is to aid the industrial partners to achieve the desired thermal performance of their thermal interface materials (TIM). For this purpose we mainly use the thermal transient test method.

The equipment that utilizes the mentioned measurement technique is the Thermal Transient Tester (T3Ster). Using this equipment the temperature inside a semiconductor device can be measured with 0.01℃ temperature and with 1 µs time resolution. After evaluation of the recorded transients the method gives structural information about the heat-flow path and helps to identify thermal metrics, structural defects, etc.

This is achieved by applying a power step on the semiconductor device inducing a temperature change in the structure. The recorded temperature change as a function of time (thermal transient) of the device is characteristic to its thermal network. Using appropriate evaluation algorithm the time-constant spectrum of the cooling (heating) curve can be extracted and turned into an equivalent one dimensional RC model.



Excitation and measured response

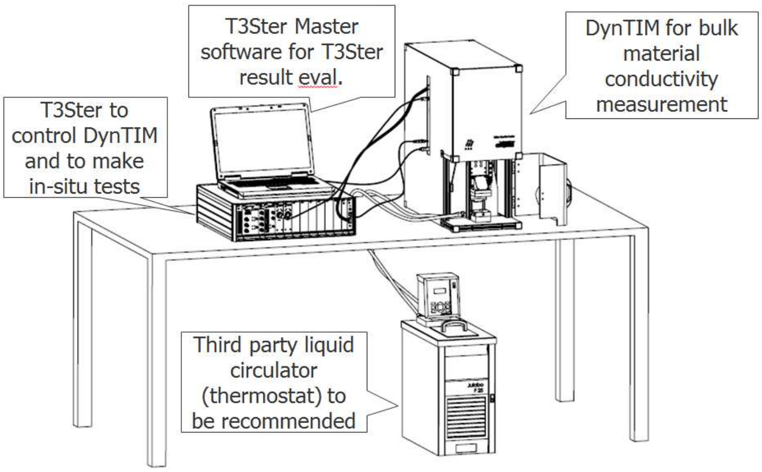


Cumulative structure function and Cauer equivalent circuit

This RC model not only describes the dynamic thermal behaviour of the device but certain structural information can also be calculated. A practical visualization of this model is the so called “structure function”. The structure function visualizes the characteristic thermal capacitances and thermal resistances of the measured structure in one plot. Actually the sums of partial thermal capacitances are plotted as a function of the sum of partial thermal resistances. By analysing the structure function the elements of the heat flow path can be identified, packaging defects can be detected. A steep section on the structure function corresponds to a section in the heat flow path with low thermal resistance and high thermal capacitance that means it is a conductive layer with high cross section and/or high thermal conductivity. Meanwhile a flat section on the structure function corresponds to a section in the heat flow path with low thermal capacitance and high thermal resistance i. e. a resistive layer.

Interpreting the results we always have to be prudent because preliminary knowledge is needed to distinguish if a section corresponds to a material with high conductivity or high cross section.

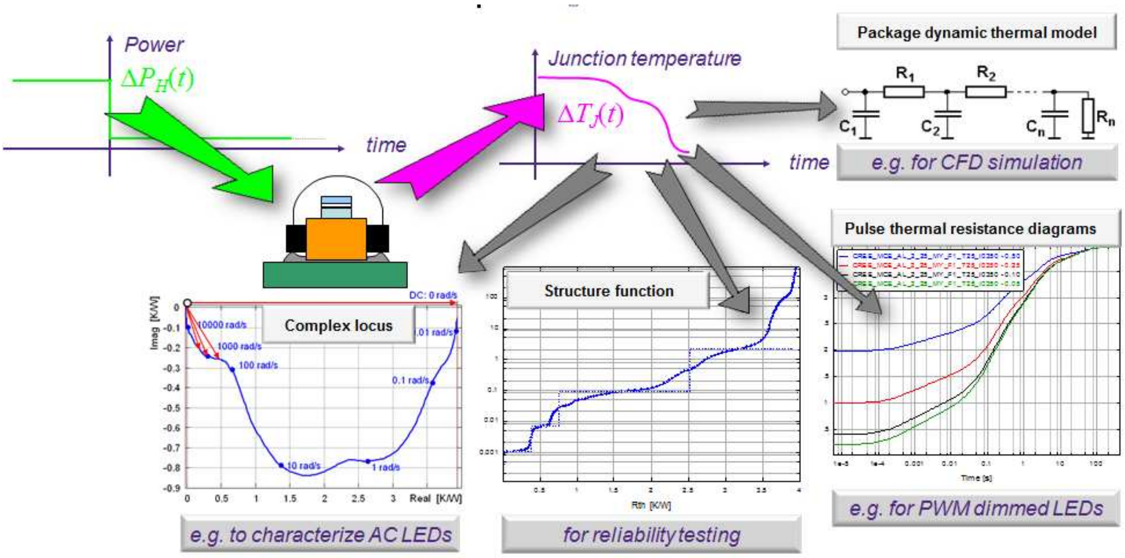
In workpackage 2 and 3 the Nanotherm partners are developing materials for the thermal interface layers. The thermal properties of these bulk materials have to be measured and compared in a consistent way. To guide the development at the partners, BME uses a high precision measurement environment for T3Ster – the so called DynTIM – to perform TIM conductivity tests. DynTIM is a stable test environment capable of changing important variable: TIM thickness. Making thermal transient tests – with T3Ster – at different TIM thickness allows us to calculate the materials' thermal conductivity accurately, because the environment stays constant, and only the TIM's thickness changes. See the complete environment on the following figure.



Complete test environment (T3Ster and DynTIM)

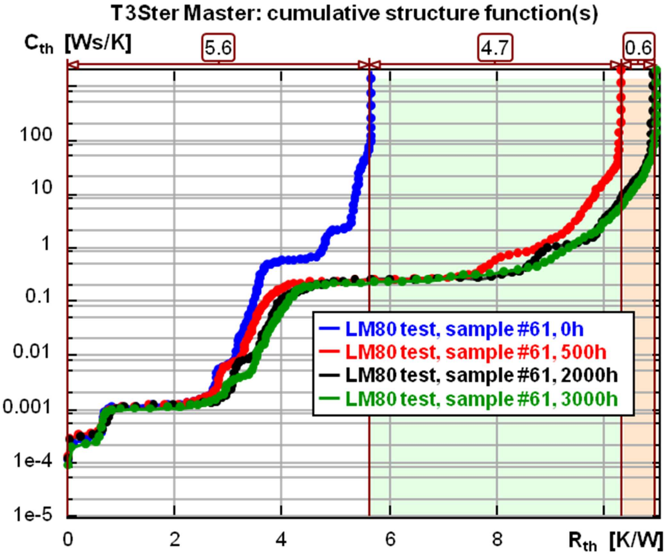
It is aimed at the test of compressible materials such as greases, pastes, soft pads, phase change materials, but it is also capable of measuring solid samples. The sample geometry can be taken into account at the evaluation phase, so with the measured thermal resistances, the thermal conductivity of the bulk material can be calculated.

In project Nanotherm, Viking is working in close co-operation with BME. Viking is developing a novel reliability test environment, in order to test and underline the applicability of the industrial demonstrators. The Viking reliability demonstrator utilizes some of the test and evaluation methods that BME also uses for determining the thermal performance of the TIMs developed by the partners. One of the forthcoming demonstrator tests is the reliability test of the newly developed Philips light emitting diodes (LED). The principle behind the LED reliability testing is to apply a sudden change of the power to a semiconductor device such as a PN-junction of a LED, so its junction temperature will also change. Under forced constant forward current the change of the forward voltage is directly proportional to the junction temperature. Thus, measuring the $\Delta VF(t)$ forward voltage – time function, the junction temperature transient of the device under test (e.g. a LED) can be measured. From this, the structure function can be evaluated for the device, which provides data on the thermal resistances and capacitances of the inner layers of the device. For the test a 4-wire access to the LED is needed. One pair of wires provides the power supply of the LED and another set of wires is needed for the measurement of the junction temperature response. This principle is used by commercial thermal transient testers, also widely used in the solid-state lighting industry. The figure below shows such a commercial test setup and the information that can be extracted from the measurements.



Principle of LED reliability testing

The reliability test is carried out with temperature, humidity and power-cycling. After numerous cycles, the devices under tests are measured with the thermal transient method, and the evaluated functions can be compared to identify the degradation.



Delamination from the substrate due to TIM aging

The two most typical degradations that can be seen on the structure function:

- LED package delamination from the MCPCB substrate
- TIM ageing

This test method is also feasible for all of the other demonstrators, using different semiconductor devices in their systems with several thermal interconnections. Therefore the wide industrial application range of the Viking reliability demonstrator will also be proven

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Further information at www.project-nanotherm.com