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STREAMS

Smart **T**echnologies for ene**R**gy **E**fficient **A**ctive cooling in advanced **M**icroelectronic **S**ystems

Start date of the project: 01/01/2016
Duration: 42 months

D7.7

Standards Inventory and Recommendations Update

WP	7	Exploitation and Dissemination
Task	7.5	Standards and standardization as tools for the dissemination and implementation of research results

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[1] Dissemination level: **PU** = Public, **PP** = Restricted to other program participants (including the Commission services), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the Commission services).

[2] Nature of the deliverable: **R** = Report, **D** = Demonstrator, **O** = Other.

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[3] Creation, modification, final version for evaluation, revised version following evaluation, final.

Deliverable abstract

Standardization within STREAMS Task 7.5 aims at providing a bridge connecting research to industry by promoting innovation and commercialization through dissemination of new ideas and best practice. This deliverable analyses international standard organizations, consortia and documents that should be considered in the perspective of the fabrication and industrialization of a microfluidic cooling system for electronic devices. Binding regulations developed by the JEDEC committee JC15 are analyzed to identify any restrictions or constraints concerning microfluidics use in electronic components. In addition, SEMI standards are analyzed, especially the standards linked to the microfluidics task force initiated in the 2000's. A discussion with Carricool project partners is summarized. Further analysis of the landscape has allowed updating the first version of the deliverable (D7.4). DARPA and ASHRAE organizations, new collaborative projects on the microfluidic field are indeed included on this final version.

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1 – Introduction

According to the European Commission (2008), “standardization” is a voluntary cooperation among industry, consumers, public authorities and other interested parties for the development of technical specifications based on consensus. Standardization complements market-based competition, typically in order to achieve objectives such as the interoperability of complementary products/services, and to agree on test methods and on requirements for safety, health, organizational and environmental performance. Standardization also has a dimension of public interest, in particular whenever issues of safety, health, security and of the environment are at stake.

In the context of improving Europe's competitive performance through innovation, there are close links between standardization and research. Many research projects deal with issues such as interoperability of technologies, defining specific techniques that may need to be included in standards, etc. The results of research projects can be invaluable to standardizers, and, conversely, research projects need to have state-of-the-art information on standards that are available or that are under development. In some cases, the standards activity itself may generate the need for additional research, for instance into the appropriate test methods for a product.

Standardization within STREAMS Task 7.5 aims at providing a bridge connecting research to industry by promoting innovation and commercialization through dissemination of new ideas and best practice. This will comprise circulating of new measurement and evaluation methods, implementation of new processes and procedures created by bringing together all interested parties such as manufacturers, researchers, designers and regulators concerning products, raw materials, processes or services.

This deliverable first analyses the landscape of international standard organizations, consortia and documents that should be considered in the perspective of the fabrication and industrialization of a microfluidic cooling system for electronic devices.

Then, specific documents are described. Activities within JEDEC Committee JC-15 include the standardization of thermal characterization techniques, both testing and modelling, for electronic packages, components, and materials for semiconductor devices. But the embedded cooling of advanced Microelectronics devices is not addressed at this time. This dimension is actually found in SEMI standards that has benefited in 2003/2004 of a Microfluidic task force to determine the critical common needs in this area and develop technical standards. Further data are found in collaborative project developments and in industry /research specific consortia. For instance, a discussion with the Carricool project partners is summarized to give an external point of view on this standard topic.

2 – Worldwide standard organizations and consortia related to microelectronics and fluidics

2.1 – Joint Electron Device Engineering Council (JEDEC)

JEDEC is the global leader in developing open standards for the microelectronics industry, with more than 3,000 volunteers representing nearly 300 member companies. JEDEC brings manufacturers and suppliers together to participate in more than 50 committees and subcommittees, with the mission to create standards to meet the diverse technical and developmental needs of the industry. JEDEC publications and standards are accepted throughout the world, and are free and open to all. JEDEC is accredited by The American National Standards Institute and maintains liaisons with numerous standards bodies throughout the world. The JEDEC committees that can be relevant for STREAMS are:

JC-14, responsible for standardizing quality and reliability methodologies for solid state products used in commercial applications such as computers, automobiles, telecommunications equipment, etc. It also includes standards for board-level reliability of solid state products used in commercial equipment.
JC-15 scope includes the standardization of thermal characterization techniques, both testing and modeling, for electronic packages, components, and materials for semiconductor devices.
JC-63 defines standards for multichip package that address unique electrical, mechanical, test, and architecture issues relating to die-to-die design and manufacturing for commercial applications.

2.2 – Semiconductor Equipment and Materials International (SEMI)

SEMI is a not-for-profit global industry association, representing the suppliers of equipment and materials used to manufacture semiconductors and many high tech technologies (ASICS, MEMS, photovoltaic, flat panel display, etc.). SEMI is the global industry association serving the manufacturing supply chain for the micro- and nano-electronics industries, including Semiconductors, Photovoltaics (PV), High-Brightness LED, Flat Panel Display (FPD), Micro-electromechanical systems (MEMS), Printed and flexible electronics and related micro- and nano-electronics. For more than 40 years, SEMI has served its members and the industries it represents through programs, initiatives, and actions designed to advance business and market growth worldwide. SEMI brings together industry experts through a number of committees to develop globally accepted technical standards. These Standards Technical Committees provide the forum for the essential collaborations that must be achieved to move new and existing markets forward efficiently and profitably. Choose a committee below to learn more about activities including charter and scope where available in that area.

3D Packaging and Integration Committee develops standards for materials including prime silicon, glass wafers, temporary and permanent bonding material, materials for interconnection. Standards for heterogeneous and multi-chip packaging technologies and associated metrologies.

MEMS/NEMS Technical Committee works on unique requirements of standards for MEMS & NEMS devices that cannot be handled by existing technical committees. The integrating ability to interact with, or measure the properties of fluids, has created a new class of microfluidic products that create new sectors and applications. SEMI Standards Global MEMS Technical Committee received input from the Microfluidics Task Force in 2003/2004 to determine the critical common needs in this area and develop technical standards.

2.3 – European Committee for Standardization (CEN) & European Committee for Electrotechnical Standardization (CENELEC)

The European Committee for Standardization (CEN) is a business catalyst in Europe, removing trade barriers for European stakeholders such as industry, public administration, service providers, consumers and other stakeholders. Through its services CEN provides a platform for the development of European Standards and other specifications. More than 60.000 technical experts as well as business federations, consumer and other societal interest organizations are involved in the CEN network that reaches over 480 million people.

The European Committee for Electrotechnical Standardization (CENELEC) is officially responsible for standardization in the electrotechnical field. CENELEC fosters innovation and competitiveness, making technology available not only to major businesses but also to SMEs through the production of voluntary standards. Through the work of its 31 Members together with its experts, the industry federations and consumers, Electrotechnical European Standards are created in order to help shape the European Internal Market, to encourage technological development, to ensure interoperability and to guarantee the safety and health of consumers and provide environmental protection.

2.4 – ASHRAE (ASHRAE)

ASHRAE, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, is an American non-profit professional organization seeking to promote the design and construction of heating, ventilation, air conditioning and refrigeration (HVAC&R) systems. It has more than 50,000 members in 132 countries, from various backgrounds: academics, industry, consultants and end users. Its members are building services engineers, architects, mechanical contractors, building owners, employees of equipment manufacturers and others involved in the design and construction of HVAC and refrigeration systems. It is widely recognized in the industrial cooling sector as an impartial source of information. The company funds research projects, offers continuing education programs and develops and publishes technical standards to improve building services engineering, energy efficiency, indoor air quality and sustainable development. ASHRAE's thermal guidelines are particularly well documented in the field of data centers due to the many feedbacks from IT equipment manufacturers' working groups.

The technical expertise of ASHRAE is concentrated in its Technical Committees (TCs), Task Groups (TGs), and Technical Resource Groups (TRGs). Among the hundred or so technical committees that make up ASHRAE, some are in line with the themes explored in the STREAMS project:

- TC1.2 Instruments and Measurements

- TC1.3 Heat Transfer and Fluid Flow
- TC1.5 Computer Applications
- TC1.6 Terminology
- TC1.10 Combined Heat and Power Systems
- TC4.1 Load Calculation Data and Procedures
- TC4.7 Energy Calculations
- TC8.5 Liquid-to-Refrigerant Heat Exchangers
- TC8.7 Variable Refrigerant Flow
- TC9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment

ASHRAE has a Standards Committee that cooperates with other organizations and oversees the Company's participation in the development, preparation and adoption of codes, standards and guidelines. It proposes a procedure for requesting a new standard or guideline: requests may come from individuals, professional associations, or any source that perceives a need. If research is to be conducted, the Standards Committee will recommend to the appropriate Technical Committee that a research project on the subject be completed before forming a standards or guideline project committee. Proof of the need for a new standard or guideline is based in particular on the following points:

- the purpose of the document
- the need and potential impact associated with the creation of the document
- an investigation of other related standards or guidelines in the field
- if the matter requires a new document or can be resolved by revising an existing document
- who needs and will use the standard/guideline, and the consequences of not providing one
- if there are known negative aspects associated with the proposed document
- whether another group can produce the document more efficiently

2.5 – United States Defense Advanced Research Projects Agency (DARPA)

The Defense Advanced Research Projects Agency (DARPA) is an agency of the United States Department of Defense responsible for the research and development of new technologies for military use. DARPA's mission statement is to "make critical investments in revolutionary technologies for national security". DARPA subcontracts research and development to multiple contractors such as University laboratories and companies. Among the various programmes and projects launched and financed by this organisation, one in particular drew our attention because it includes objectives and resources that are in line with the developments of the STREAMS project.

In June 2012, DARPA has launched the Intrachip/Interchip Enhanced Cooling (ICECool) program to explore embedded thermal management. Proposals were invited for intra-/inter-chip thermal management solutions using dielectric liquids through microchannels, micropores and microchips, as well as heat transfer through thermal interconnections, to meet the thermal management needs of chips and high-performance chip stacks. The success of ICEcool was about bridging the gap between heat density generation at the chip level and heat removal density at the system level in high-performance electronic systems, such as computers, RF electronics and semiconductor lasers.

ICECool “Fundamentals” part has undertaken fundamental research on microfabrication and evaporative cooling techniques. The “Applications” part tried to demonstrate microfluidic cooling in monolithic microwave integrated circuits (MMICs) and integrated HPC modules. Microfluidic cooling for MMIC RF power amplifiers has the potential to significantly reduce the size, weight and power required for a variety of RF systems such as radar, communications and electronic warfare. Microfluidic cooling is also required for HPC systems such as computers and on-board data processing and fusion. The Agency hopes that the demonstration of new cooling methods will complement the development of integrated and energy-efficient computer devices and architectures under DARPA's Power Efficiency Revolution for Embedded Computing Technologies (PERFECT) program.

The objective of DARPA's Power Efficiency Revolution For Embedded Computing Technologies (PERFECT) program is to research revolutionary approaches and develop technologies and techniques that will provide the energy efficiency needed to enable embedded computing systems.

2.6 – Microfluidics Consortium

This Consortium brings together stakeholders in Microfluidics from across Europe and the USA to learn about state-of-the-art, recent applications, market dynamics as well as to collaborate to address key issues which are constraining growth and scale-up

3 – European collaborative projects related to microelectronics and fluidics

In this part we explore collaborative projects related to microelectronics and fluidics cooling. We do not mention projects related to microfluidics for biology, even if some common concerns could be found between them and STREAMS developments.

3.1 – Thermally Integrated Smart Photonics Systems (TIPS) project (ICT-02-2014)

The objective of the TIPS (Thermally Integrated Smart Photonics Systems) project was to demonstrate an integrated 3D optoelectronic platform that is scalable and thermally compatible and capable of responding to the explosion in data traffic. These strategies will facilitate future high bandwidth optical communications that are energy efficient, scalable, reliable and capable of monolithic 3D integration. The project integrates heterogeneously micro-thermoelectric (µTEC) and micro-fluidic (µFluidics) coolers with optoelectronic devices (lasers, modulators, etc.) in order to precisely control the temperature and therefore the wavelength of the devices in relation to the discrete technologies available on the market.

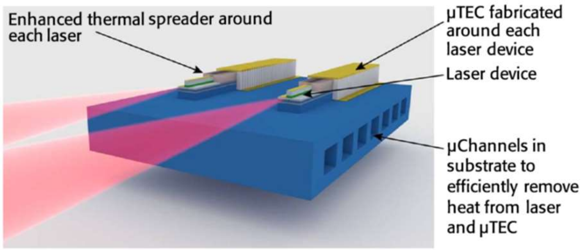


Figure 1: High-level schematic of the TIPS architecture

The TIPS consortium united eleven partners from global companies, European SMEs, institutes and academia across four European countries. The coordinator was National University of Ireland, Cork (Ireland).

3.2 – Carricool project (FP7-ICT)

Carricool is a european project with the objective of a modular interposer architecture providing scalable heat removal, power delivery and communication. In CarrICool, advanced More-than-Moore components required to scale to energy efficient ExaFLOP computing performance are developed and integrated into a modular and multifunctional interposer. Four critical packaging elements are implemented on the CarrICool interposer: i) Improved structural and electrical performance will be provided by expansion matching and high wiring density. ii) low thermal gradients for Beyond-CMOS and silicon photonic devices will be provided by integrated, single-phase, water-cooling cavities. iii) High granularity, distributed Buck-converters using integrated, high-quality power inductors will support energy-efficient power delivery to heterogeneous chip stacks. iv) Off-chip bandwidth will be enabled through low-cost and low-loss passive optical coupling to silicon photonic wave guides.

The CarrICool consortium units ten partners from global companies, European SMEs, institutes and academia across seven European countries. The coordinator is IBM Research GMBH (Switzerland).

The question of standards has been discussed with Carricool IBM researchers (T. Brunschwiler). Following suggestion and remarks have been expressed:

On the materials side IBM considered the moisture diffusivity as a crucial topic in Carricool, as there is obviously a moisture concern for the adhesive directly contacting the liquid interface. Existing standards are considered not sufficient enough at this time. They have developed their own test method for adhesive material screening. Corrosion was also considered as a strong matter, for example when solder joints made of SnAg or SnCu are in located close to the fluid. Again standards are not there yet, as the embedding of microfluidics transfer the corrosion problematic from the system level to the module level.

3.3 – MFManufacturing (ENIAC Project)

MFManufacturing is the European initiative for the standardization and manufacturability of complex micro-fluidic (MF) devices. The MFManufacturing project has been accepted by the ENIAC Joint Undertaking (JU), a public-private partnership focusing on nanoelectronics that brings together ENIAC Member/Dutch, French and United Kingdom States, the European Commission, and AENEAS (an association representing European R&D actors in this field).

The objective of the MFManufacturing project is to bring the manufacturing of microfluidic devices to the same level of maturity and industrialization of electronic devices, enabling them to address more widely in the healthcare needs. The anticipated standardization in the microfluidics field will focus on increasing maturity of both functional and fabrication process aspects:
- Gain of maturity in MF functions focusing both on novel functional modules and their interoperability,
- Gain of maturity in manufacturing process: focusing on a distributed pilot line, on novel hybrid integration processes and on increasing maturity of some selected manufacturing processes,

This will have an effect on availability, reliability as well as accessibility and will result in device cost reduction and improved time-to market. These conditions will enable large scale uptake of microfluidic devices in the markets identified.

4 – Review of standards and documents related to the field of STREAMS project

In this part we list and describe the existing standards found within JEDEC, SEMI and other database that are considered relevant in the context of STREAMS project. They include documents related to generic information, documents related to the thermal performance and finally documents related to the specific fluid co-existence with the electronic devices.

JEDEC - JESD69B: Information Requirements for the Qualification of Silicon Devices

This very generic standard defines a minimum set of data elements that describes the component. It includes quality, reliability, electrical and mechanical performance data, materials used within the component and general requirements:
- General information: technology & device type, package type (…)
- Die fabrication process, supplier, location, metallization, number of level, protective coating, UBM composition, die substrate material
- Package assembly : supplier, location, substrate type, die-to-die and/or die-to-package interconnect, die attach, terminal finish and solder ball material

Introducing microfluidics in the interposer will necessitate to establish a proper terminology in order to adequately define these data.

JEDEC - JESD51

This family of standards define methodology necessary for meaningful thermal measurements on packages containing single chip semiconductor devices

JEDEC - JESD51-13 – Glossary of Thermal Measurement Terms and Definitions

This document provides a unified collection of the commonly used terms and definitions in the area of semiconductor thermal measurements. The terms and definitions provided herein extend beyond those used in the JESD51 family of documents to include other often used terms and definitions in the area of semiconductor thermal measurements.

JEDEC - JESD51-12.01 – Guidelines for Reporting and Using Electronic Package Thermal Information

This document define electronic package thermal information to be reported consistently by suppliers. It serves end users to be able to understand, interpret and use the data reported, as well as compare the thermal performance of various packages under standardized test conditions. Standardized thermal values include:
- θ_{JA} chip junction-to-ambiant air thermal resistance
- θ_{JMA} chip junction-to-moving air thermal resistance
- $\theta_{JCx}/\theta_{JBx}$ conduction thermal resistances (top/bottom)
- Ψ_{JT} junction-to-top thermal characterization parameter
- Ψ_{JB} junction-to-board thermal characterization parameter

Temperature measurement locations used to determine these values are shown in Figure 2. The junction designation represents the location of the temperature sensitive device in the die used for the measurements. Finally this guide defines compact models construction.

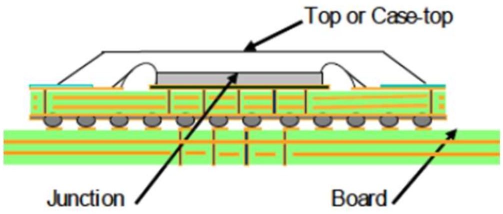


Figure 2: Typical temperature location designations

JEDEC - JESD51-32 – Extension to Thermal test Board Standards to Accommodate Multi-Chip Packages

This document addresses the need for extending the existing thermal test board standards to accommodate the potential of higher electrical connection needs of multi-chip packages (MCPs) and the associated wire routing to implement these connections.

JEDEC - JESD22-A120B – Test Method for the Measurement of Moisture Diffusivity and Water Solubility in Organic Materials Used in Electronic Devices

This standard provides a means for determining the moisture sorption properties of organic materials used in the packaging of electronic devices. It gives procedures for measurements of characteristic bulk material properties of moisture diffusivity and water solubility in organic materials used in packaging of electronic devices. Apparatus, test samples shape and procedures are detailed for absorption measurement, solubility and diffusivity calculation, desorption, calculation of functional fit for moisture diffusivity & solubility.

SEMI - MS6-0308: Guide for Design and Materials for Interfacing Microfluidic Systems

The Standard provides guidelines for general fluidic interface design and materials selection that can reduce redundant effort and lead to improved design, manufacturability and operation.

- Design guidelines: Basic criteria for µfluidic interconnections considering fluid type, pressure, flow rate, surface conditions, materials and compatibility. Scaling rule for dimensions.
- Materials Guidelines: Matrix of materials compatibility for commonly used materials and fluids.
- Interface guidelines provides example of design and materials of some fluidic interfaces, such as illustrated in Figure 3

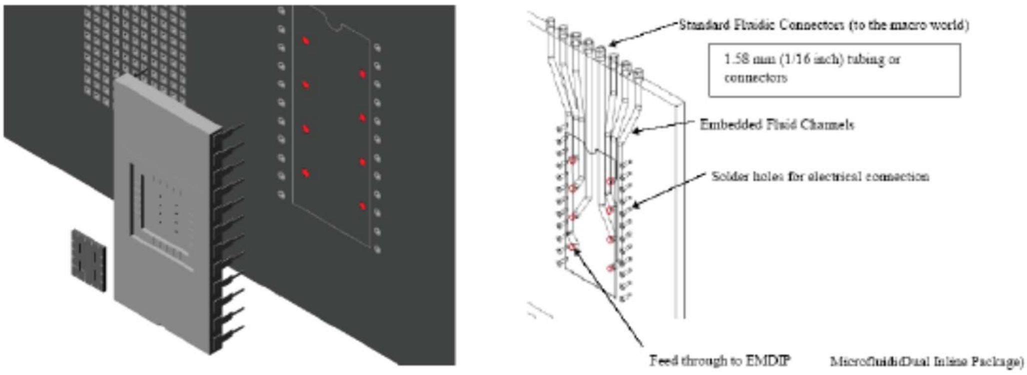


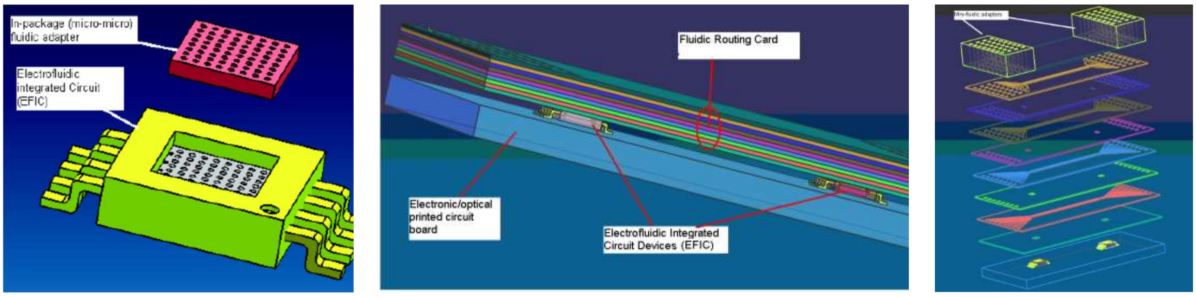
Figure 3: Fluidic Printed Wiring Board internal flow passages. Flow passages fan out to small fluidic connector ports (red), similar in size to RF electrical connectors. (Sandia National Laboratories)

SEMI - MS7-0708: Specification for Microfluidic Interfaces to Electronic Device Packages

The specification describes the connection attributes and interface requirements between Electro-Fluidic Integrated Circuits (EFICs) and macro-sized interface boards. The standard is intended as an enhanced capability to state-of-the-art electronic device technologies incorporating a combination of electronics and fluidics. It defines an industry-standard for fluidic interfaces with electronic devices.

Enable devices from different vendors to interconnect via an open architecture. The standard contains four mutually exclusive sections of requirements:
Part A – EFIC Fluidic I/O Design Constraints
Part B – In-package (micro-to-micro) Fluidic Adapter Design Constraints
Part C – Fluidic Routing Card Constraints
Part D – Mini-fluidic Adapter Constraints
Part E – Fluidic routing card dimensions

Design examples of one implementation adhering to all the constraints are shown in the Figure 4.



a) b) c)

Figure 4: (a) Exploded 3-D View of EFIC Package, (b) EFICs with Fluidic Routing Card & Printed Circuit Board, (c) assembly layout with mini to mini-fluidic adapters at top.The bottom layer (layer 1) is a printed circuit board with 2 EFIC's. Layers 2–10 are the fluidic routing card,and the two blocks at the top are mini fluidic adapters

Assembly of the fluidic device and test methods are finally discussed and example of manufacturing process sequences for an EFIC are given. Final assembly description is given in Figure 5.

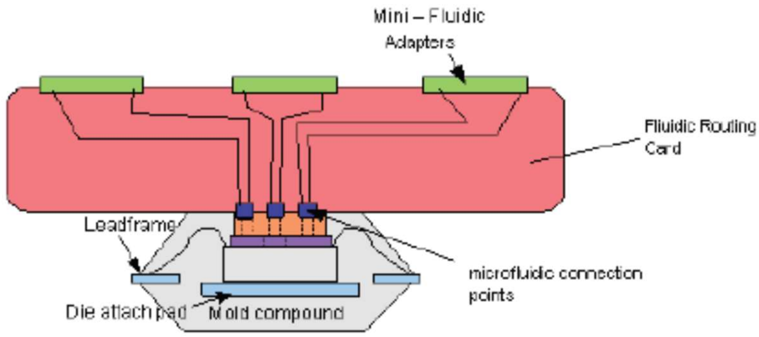


Figure 5: Functional description of Assembled Parts

SEMI - MS8-0309: Guide to evaluating hermeticity of mems packages
Hermeticity is primarily important to reliability of MEMS devices, similarly to integrated circuits. This document is intended to provide an overview of hermetic packaging with emphasis on the evaluation of hermeticity of the smaller internal volumes typical of MEMS. This guide is relevant for gyroscopes and accelerometers; RF MEMS switches; optical mirrors and switches; pressure sensors; resonators; filters; and microfluidics devices including valves and pumps. This guide defines reliability categories by application requirements, as illustrated in Table 1.

Category (see ¶ 6.2)	*Lifetime in Years*	*Temperature Range °C*	*Application*
R1A or R1B or R1C	>10	−55 to +150	Military, space, aviation
R2A or R2B or R2C	>10	−20 to +65	Telecommunications
R3A or R3B or R3C	5–10	−40 to +125	Automotive
R4A or R4B or R4C	2–5	−20 to +65	Industrial
R5A or R5B or R5C	0–2	0 to +50	Commercial, consumer

Table 1: reliability categories by application requirements
A indicates that the performance of the device is directly related to the package hermeticity
B indicates that package hermeticity is required only for general reliability
C indicates that hermeticity is only required to protect the MEMS during the assembly and surface mount

This guide explores the following fields :

- Hermetic sealing methods and materials description: bonding techniques etc.
- Seal integrity evaluation: acoustic microscopy, X-Ray inspection, integrated sensors, FTIR etc.
- Detection and measurement of hermetic Package Leakage: He leak, radioisotope, RGA etc.
- Test equipment, considerations and recommendations in Evaluating hermeticity

JEDEC – J-STD-020E (2014) – Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices

This standard applies to all nonhermetic SMDs in packages, which, because of absorbed moisture, could be sensitive to damage during solder reflow. This standard cannot address all of the possible component but it provides a test method and criteria for commonly used technologies. In particular, the bonding layers inside the STREAMS µfluidic cell may be source of failure during temperature cycling. In order to ensure proper co-integration of the µfluidics part with the electrical function of the interposer, hermeticity of the bonding has to be assessed. The criteria from J-STD-020E in terms of moisture sensitivity levbel (MSL) can then be considered (Table2). This standard also provides a logic flow diagram for the implementation of these criteria (Fig. 6).

			SOAK REQUIREMENTS[3]				
					ACCELERATED EQUIVALENT[1]		
	FLOOR LIFE[4]		STANDARD		eV 0.40-0.48	eV 0.30-0.39	
LEVEL	TIME	CONDITION	TIME (hours)	CONDITION	TIME (hours)	TIME (hours)	CONDITION
1	Unlimited	≤30 °C/85% RH	168 +5/-0	85 °C/85% RH	NA	NA	NA
2	1 year	≤30 °C/60% RH	168 +5/-0	85 °C/60% RH	NA	NA	NA
2a	4 weeks	≤30 °C/60% RH	696[2] +5/-0	30 °C/60% RH	120 +1/-0	168 +1/-0	60 °C/60% RH
3	168 hours	≤30 °C/60% RH	192[2] +5/-0	30 °C/60% RH	40 +1/-0	52 +1/-0	60 °C/60% RH
4	72 hours	≤30 °C/60% RH	96[2] +2/-0	30 °C/60% RH	20 +0.5/-0	24 +0.5/-0	60 °C/60% RH
5	48 hours	≤30 °C/60% RH	72[2] +2/-0	30 °C/60% RH	15 +0.5/-0	20 +0.5/-0	60 °C/60% RH
5a	24 hours	≤30 °C/60% RH	48[2] +2/-0	30 °C/60% RH	10 +0.5/-0	13 +0.5/-0	60 °C/60% RH
6	Time on Label (TOL)	≤30 °C/60% RH	TOL	30 °C/60% RH	NA	NA	NA

Table 2: Moisture sensitivity levels as defined in JEDEC J-STD-020E

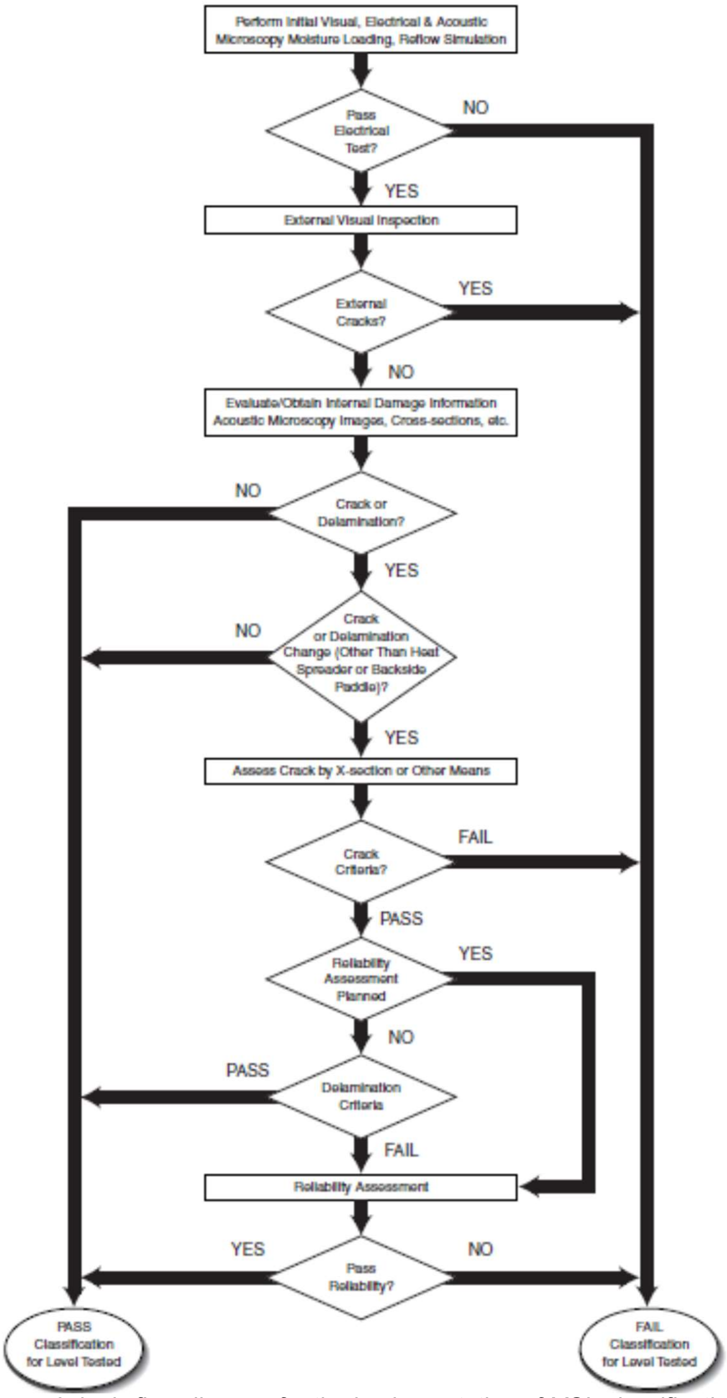


Figure 6: logic flow diagram for the implementation of MSL classification

MFM - Design Guideline for Microfluidic Device and Component Interfaces (Part1&2)
The goal of this document is to facilitate the process of designing new microfluidic sensors, actuators, connectors etc. by providing guidelines for the seamless integration with other microfluidic components and systems. Its purpose is to present developers a standard by which they will improve the chances of their device will be accepted by the marker / fits to other products. The paper is said to be "application, materials and production technology agnostic" and gives guidelines for:
- axes and reference point for chips,
- microfluidic ports,
- chip formats,
- exclusion zones for clamping or gluing chips,
- dimensions of sensor / Actuator building blocks,
- operational conditions / application classes,
- chip thicknesses,
- edge connectors,
- further miniaturization of chips and connectors.

5 – Conclusion & perspectives

This deliverable has presented a benchmark of standards organizations worldwide and research / industrial consortiums that are involved in the activity of standardization around the microfluidic topic. We have highlighted several documents relevant in the context of the STREAMS project. These documents include generic temperature-related standards but also more specific standards linked to the fluid co-integration. We are now using these data in in order to establish in which way they can be improved of completed. STREAMS partners may establish contacts with the cited organizations or consortia, as already initiated with Carricool project partners.