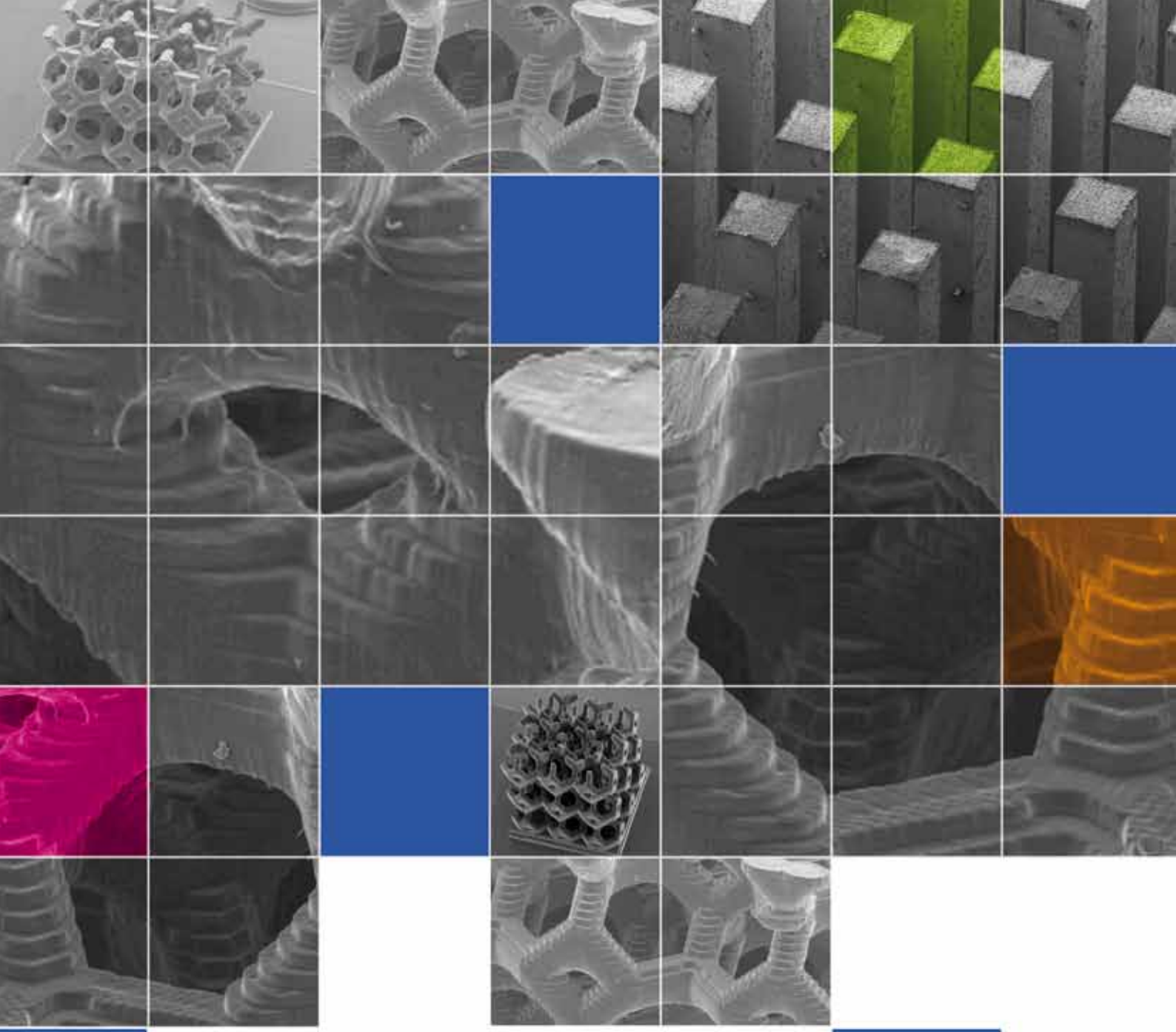
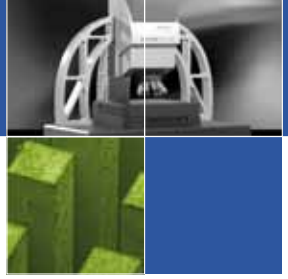
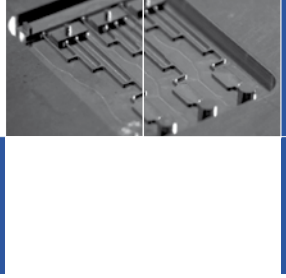
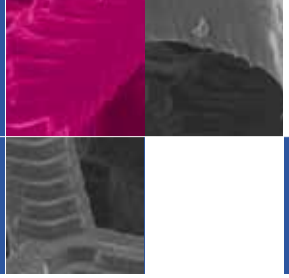


A global approach to micro manufacture
from materials to applications

COTECH
RESULTS

A European Large-Scale Project supported through the Seventh Framework Programme
for Research and Technological Development.

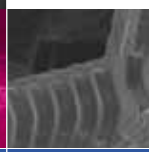
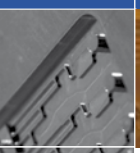
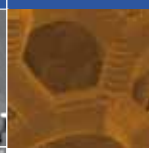
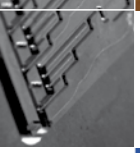
Todays challenges

The trend towards ever-smaller products showing ever-smaller features down in the range of sub-micron and even nanometer scale is continuously progressing and is continuously leading to a demand for polymer-based micro-mechanical systems, which will require complex shaped and even multi-material components which cannot be produced using the available techniques.

In order to support European manufacturers in this context, existing micro fabrication techniques and tools need to be adapted and modified, which means that micro replication technologies such as micro injection moulding and hot embossing have to be improved significantly. Furthermore, automated part-assembly and highly sophisticated quality control techniques need to be established.

The COTECH project was initiated in order to develop and demonstrate new approaches of converging technologies and hybrid solutions for the manufacturing of polymer-based micromechanical components and systems.

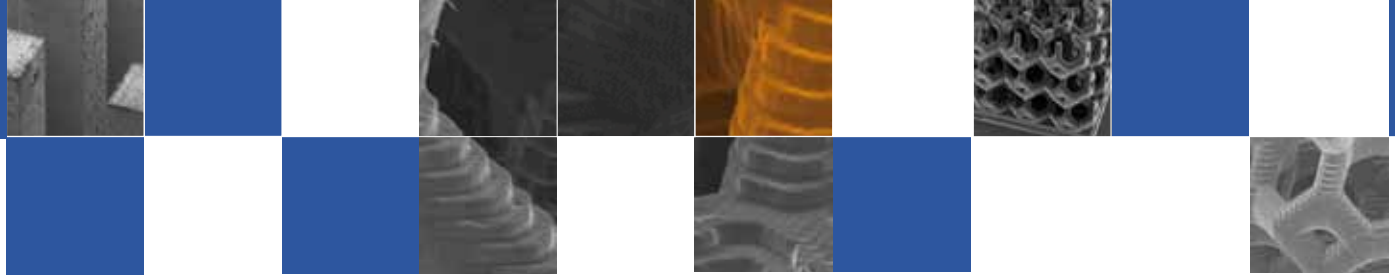










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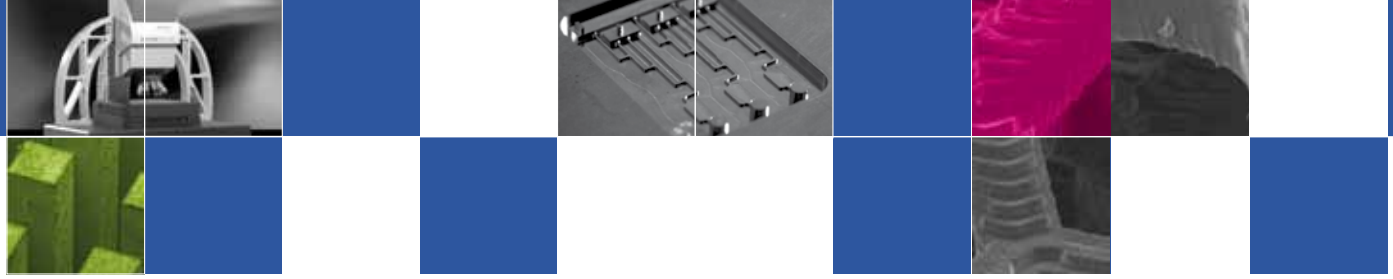


Preamble

Converging technologies

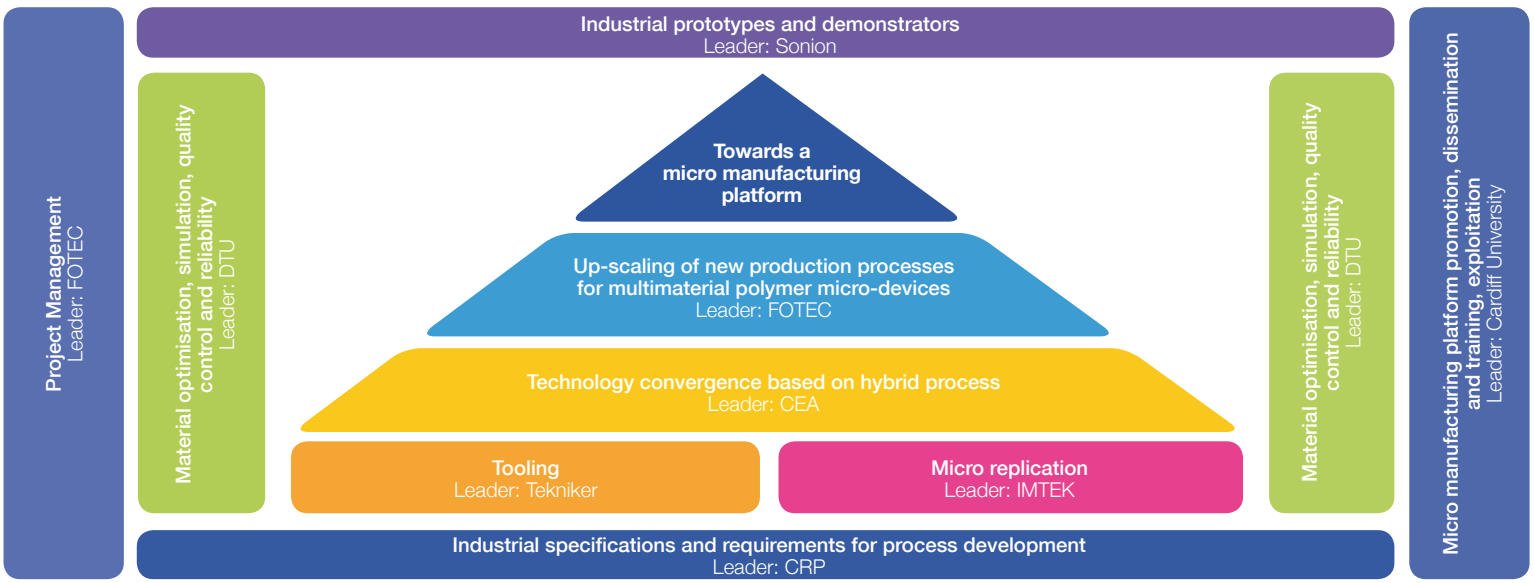
The COTECH project "**Converging technologies** for microsystems manufacturing" aimed at concentrating and combining **complementary techniques** by **converging technologies** and developing **hybrid solutions** in the full process chain of micro production.

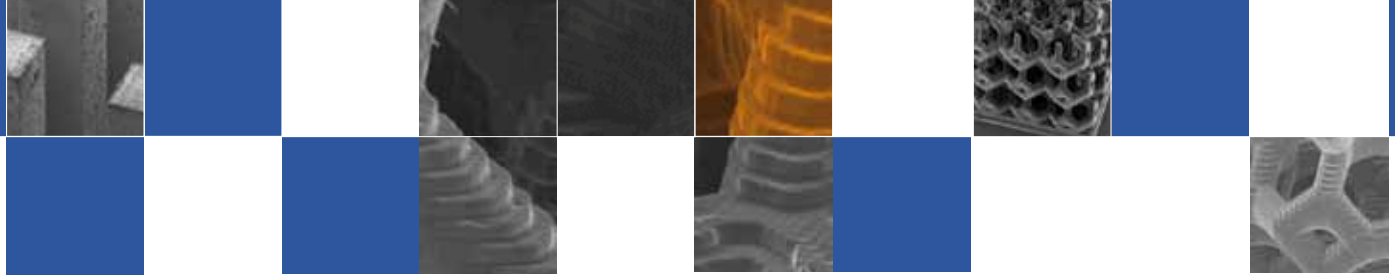
The following three approaches were investigated:

- Combination of process technologies enabling the production of multi-material and/or multi-form polymer-based micro-mechanical components and systems.
- Hybridisation of complementary replication technologies.
- Integration of different processes for master and tool production needed for the replication processes in the same tooling process chain.

COTECH objectives

- Development and demonstration of **new micro replication techniques** supported by **emerging tool-making technologies** for the manufacturing of polymer-based multi-material components.
- Introduction and demonstration of **new micro replication techniques** combining capabilities of different processes or techniques based on **micro injection moulding**.
- Implementation of **global process chains** for the manufacturing of polymer-based micro-mechanical components and systems, supported by the use of **new advanced simulation models** and **"in-line" non destructive quality control procedures**.
- Demonstration of the capability to produce **high added value micro devices** with advanced functionalities by means of realising **8 demonstrators** coming predominantly from the areas of **healthcare and automotive industry**.





Tooling

The objective was to develop **hybrid tooling techniques** for the fabrication of micro mould inserts and to supply **the necessary tools** for research and technological development as well as for demonstration activities.

For an optimal performance and better positioning accuracy, a new micro machining platform has been developed for the combination of two tooling processes in one high precision machine. The possible process combinations are:

- EDM roughing + EDM finishing
- HSM roughing + EDM finishing
- Laser ablation + EDM finishing

Advantages

- High performance micro-machining.
- High accuracy.
- «One Step Process» without removing the work piece.
- Micro machining of various materials (e.g. metals, ceramics).

Furthermore, another machine has been developed which can combine the following processes:

- EDM roughing + µ-EDM finishing
- Laser machining + µ-EDM finishing
- Laser drilling + µ-EDM machining

SX-MEC platform
(courtesy of Sarix SA)

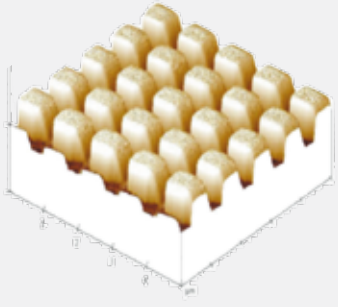
Aero machine
(courtesy of Sarix SA)

Micro replication

The objective was the improvement of the basic processes in **multi-material replication** (injection moulding, micro injection moulding and hot embossing) towards **better quality by lowest cycle times**. Based on advanced statistical process control, new process monitoring and modeling methods, a mapping of the relationship between process quality and process parameter has been obtained.

The following main results have been achieved:

- Determination of main influence parameters for advanced part weight and product quality control.
- Reduction of cycle time in hot embossing down to 2 min instead of typically 20 min.
- Improvement of the injection rate stability in micro injection moulding below 1 % instead of typically 4 %.
- Improvement of surface replication fidelity.
- Improvement of the packing cycle for micro and nano injection moulding.



Surface characterization
of a hot embossed part
(courtesy of KIT)

Material optimisation, simulation, quality control and reliability

The objective was to handle simulation, quality control and reliability of µ-replication processes. It also included the development of a new high-speed metrology system for in-line quality control and the generation of a new simulation tools.

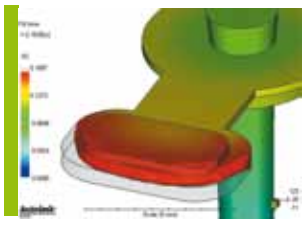
Material optimisation

A new polymer high speed rheology database suitable for micro injection moulding has been developed and is now available for high temperature polymers (PEEK) with glass fibers, optical polymer grades (COC, PMMA, PC, PS) and polymer nano-composites (PC with carbon nanotubes).

Process and product quality control

- The micro injection moulding process is now fully characterized by using temperature, speed, pressure and demoulding force sensors measurements. Methods and procedures for optimized micro injection moulding processing have been established.
- A new micro injection moulding process monitoring platform based on a fully monitored micro injection moulding machine with wireless connection for high speed process measurement sampling has been developed.
- A new micro injection moulding control method based on integral values instead of single-point peak values of pressure-based parameters has been established and validated. The new integral-based parameter provides a comprehensive representation of the process throughout its different phases (filling, packing, cooling, demoulding).
- A major advancement in terms of optical metrology for micro manufacture was achieved. A new method based on the soft replica technique for micro/nano dimensional metrology was established and validated for sub-µm roughness polymer and metal surfaces, as well as for sub-mm to µm geometrical features.
- The metrology framework for full traceability and process/product capability is now established from sub-mm to sub-µm dimensional range. Methods and procedures have been successfully applied to the COTECH demonstrators.

Process simulation



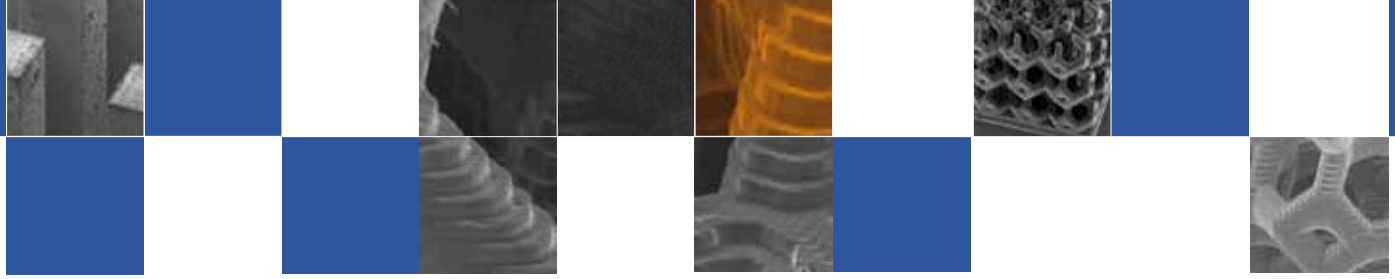
The Autodesk Moldflow software was validated for micro injection moulding simulations in relation to flow pattern shape, injection pressure, part weight, part dimensions and shrinkage. Methods and procedure for optimized micro injection moulding simulations have been established.
Autodesk Moldflow has developed a new software module for three-dimensional injection compression moulding simulations, which is now available to all Autodesk Moldflow customers.

New quality control techniques

A new high-speed metrology system for micro metrology has been developed with reduced dimension and weight suited for in-line applications in micro manufacture.

A new surface roughness standard has been developed for the calibration of micro/nano surface roughness optical instruments. The calibration uncertainty of the Alicona Infinite Focus using the new surface roughness standard is now of ± 20 nm for an Ra roughness of 500 nm.

(courtesy of Alicona Imaging GmbH)

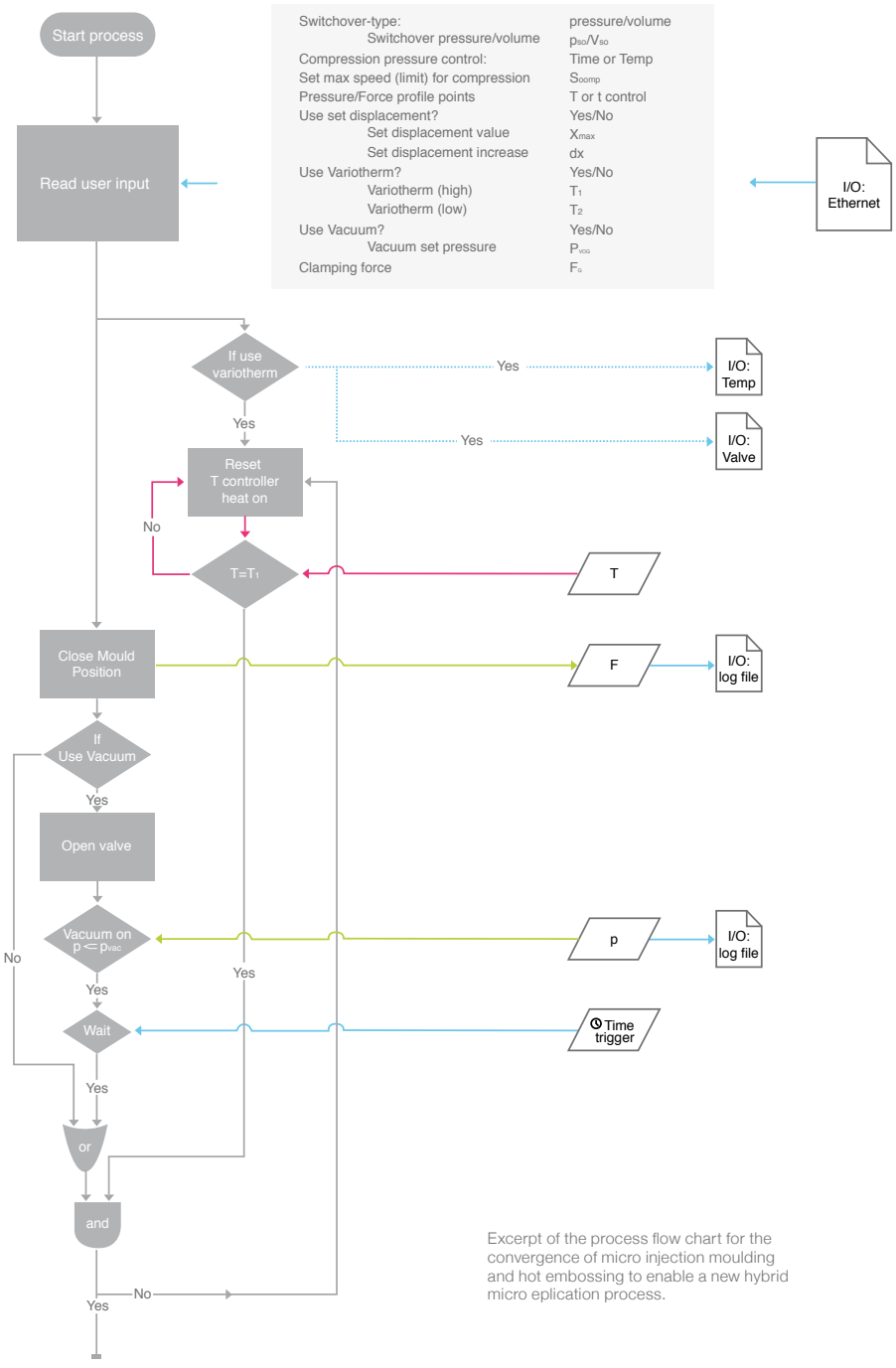


Technology convergence based on hydrid processes

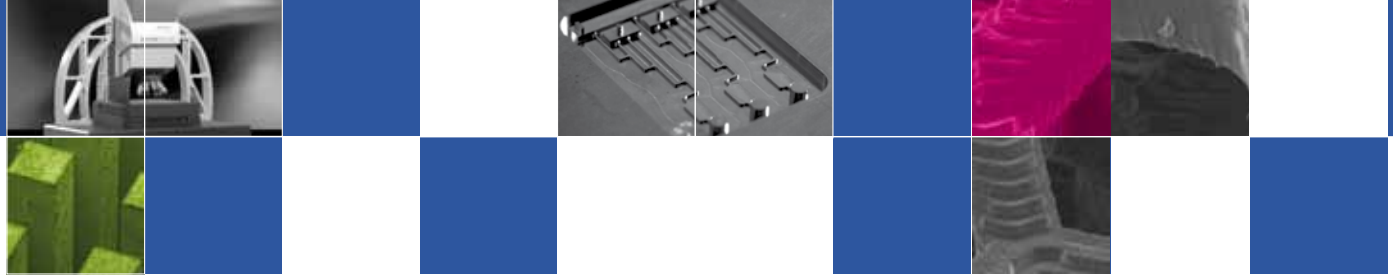
The objective was to investigate **technology convergence** based on the combination of different processing technologies for directly producing **functionalised** micro-devices with **reduced assembly steps**.

The following approaches have been investigated:

- Convergence of micro injection moulding and hot embossing.
- Convergence of micro injection moulding with insert moulding.
- Convergence of micro injection moulding with reel-to-reel moulding.
- Convergence of micro injection moulding with metal deposition.
- Convergence of micro injection moulding with localized surface treatment.



Excerpt of the process flow chart for the convergence of micro injection moulding and hot embossing to enable a new hybrid micro eplication process.



Up-scaling of new production processes for multi-material micro-devices

The objective was to **up-scale new production processes** for **multi-material micro-devices** based on micro injection moulding. In this context, **a new generation of micro injection moulding machinery** has been developed in order to generate a minimum necessary melt cushion, to avoid any kind of cold material slug and to realize a high accurate and reproducible injection to eliminate all disadvantages of existing micro injection moulding machinery.

New generation of micro injection moulding machinery

Based on the new generation of micro injection moulding machinery the following special processes have been up-scaled to enable the production of multi-material micro-devices:

- Insert micro injection moulding.
- Multi-component micro injection moulding.
- Reel-to-reel micro injection moulding.
- Micro injection moulding with localized surface treatment of moulded micro-devices.

Example of special process:
Three-component micro injection moulding machinery (courtesy of FOTEC Forschungs- und Technologietransfer GmbH and Wittmann Battenfeld GmbH).

MicroPower machine
(courtesy of Wittmann Battenfeld GmbH)

New hybrid micro replication process

For further improvement of micro replication accuracy and micro part quality, a new hybrid process has been developed and realized to combine advantages of micro injection moulding and hot embossing. This new hybrid process enables a compression with hot embossing pvT-characteristics during the packing phase of the micro injection moulding cycle. It has been realized on the MicroPower machine.

Industrial prototypes and demonstrators

The objective was to realize 8 industrial demonstrators in terms of design, manufacturing and characterization.

Micro-prismatic light-guide for automotive lighting application (CRP, Italy)

• The optical output of automotive tail light has been enhanced through an innovative design and integration of micro prismatic structures on the light guide (efficiency increased by 48%).

• A vacuum moulding system for a flawless production of the light guide has been developed which contributes to an optical output improvement of the overall system by 21%.

• A converged production technology based on insert moulding and the use of MID substrates as PCBs of the system has been developed.

Micro-lens for mobile phone flash light (Heptagon, Finland)

• The micro-structured lens consists of a mixture of refractive and total-internal reflection structures arranged in a sectored way in order to perform the beam shaping of an optical beam emitted by an LED.

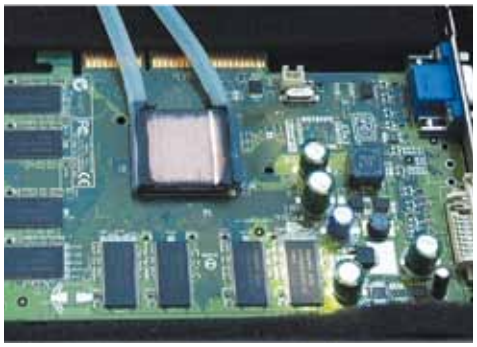
• The combination of both types of structures allow to have superior performances in terms of efficiency (and uniformity, to ensure an optimum illumination.

• The use of the new hybrid micro replication process enabled the production of this demonstrator with superior performance.

Cooling device for microelectronics applications (Atherm, France)

• Addition of carbon nanotubes increased the thermal conductivity of polymers (thermal conductivity 1W/mK).

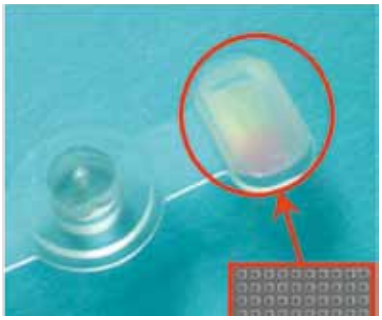
• Development of a converged production technology based on injection moulding in combination with surface treatment.

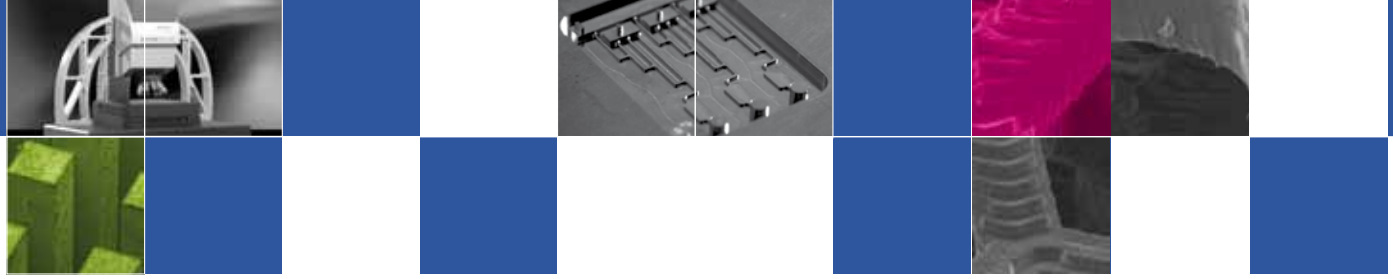


Nano-structured substrate plate for artificial skin production (Gema, Spain)

• The nano-structured surface of the substrate plate facilitates the possibility of cell growth for rapid skin tests.

• The use of the new hybrid micro replication process enabled the production of this demonstrator.





Innovative self-ligating dental bracket (Euroortodoncia, Spain)

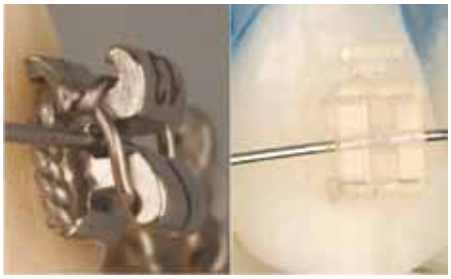
• Aesthetics of the brackets are significantly improved by the use of transparent polymers.

• Manufacturing constraints have been overcome by micro injection moulding in replacing slow and cost intensive machining techniques.

• The modular design concept consists of 4 covers which can be combined with 13 different bases to provide a complete set of dental brackets which can be adapted to the different phases of the treatment.

• The self-ligating dental brackets incorporate a tied arch mechanism to eliminate metal ligature improving comfort for the patient.

• Pressure control of the arch decreases friction and increases the effectiveness of the device resulting in shorter treatment times and fewer visits to the dentist.



8 pin RIC socket for hearing aids (Sonion, Denmark)

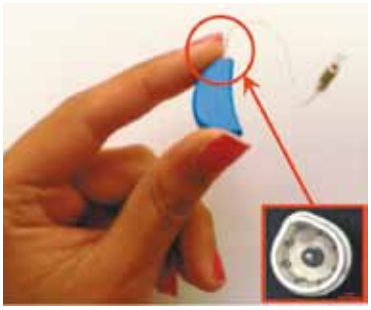
• This versatile new socket for hearing aids can combine the functions of a RIC socket and a programming socket to reduce the number of components in hearing aids.

• 8 contact pins provide the possibility of having two speakers in the same ear canal to give the precise directional indications of the incoming sound and also to give a stereo-effect to the listener.

• An innovative and simple lock/unlock mechanism based on the snap principal increases the user friendliness and life time of the RIC connector.

• Simultaneous programming of the hearing aid is enabled meaning that the programmer can program the hearing aid while it is sitting in the patient's ear and real time feedback from the patient can be taken into account.

• A converged and automated production process has been developed based on fully automated insert moulding with in-line quality control.



Accommodable intra-ocular lens (Be Innovative, Germany)

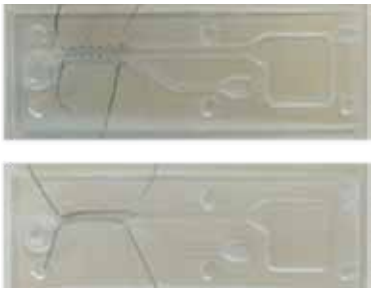
• An optical design for an accommodable intra-ocular lens has been developed.

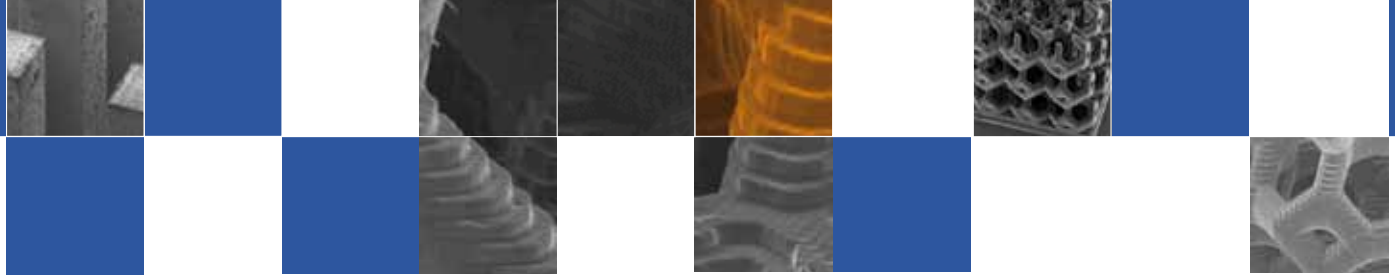
• Material optimization enabled a high-volume production of the lens by micro injection moulding.

Smart diagnostic chip for biomedical applications (GBO, Germany)

• The diagnostic chip comprises an application specific layout of micro-fluidic channels to separate DNAs from biological fluids by an electrical field.

• A converged production process has been developed in order to enable micro injection moulding with in-line atmospheric pressure plasma enhanced CVD process to integrate hydrophilic and hydrophobic sections in the micro-fluidic channels.





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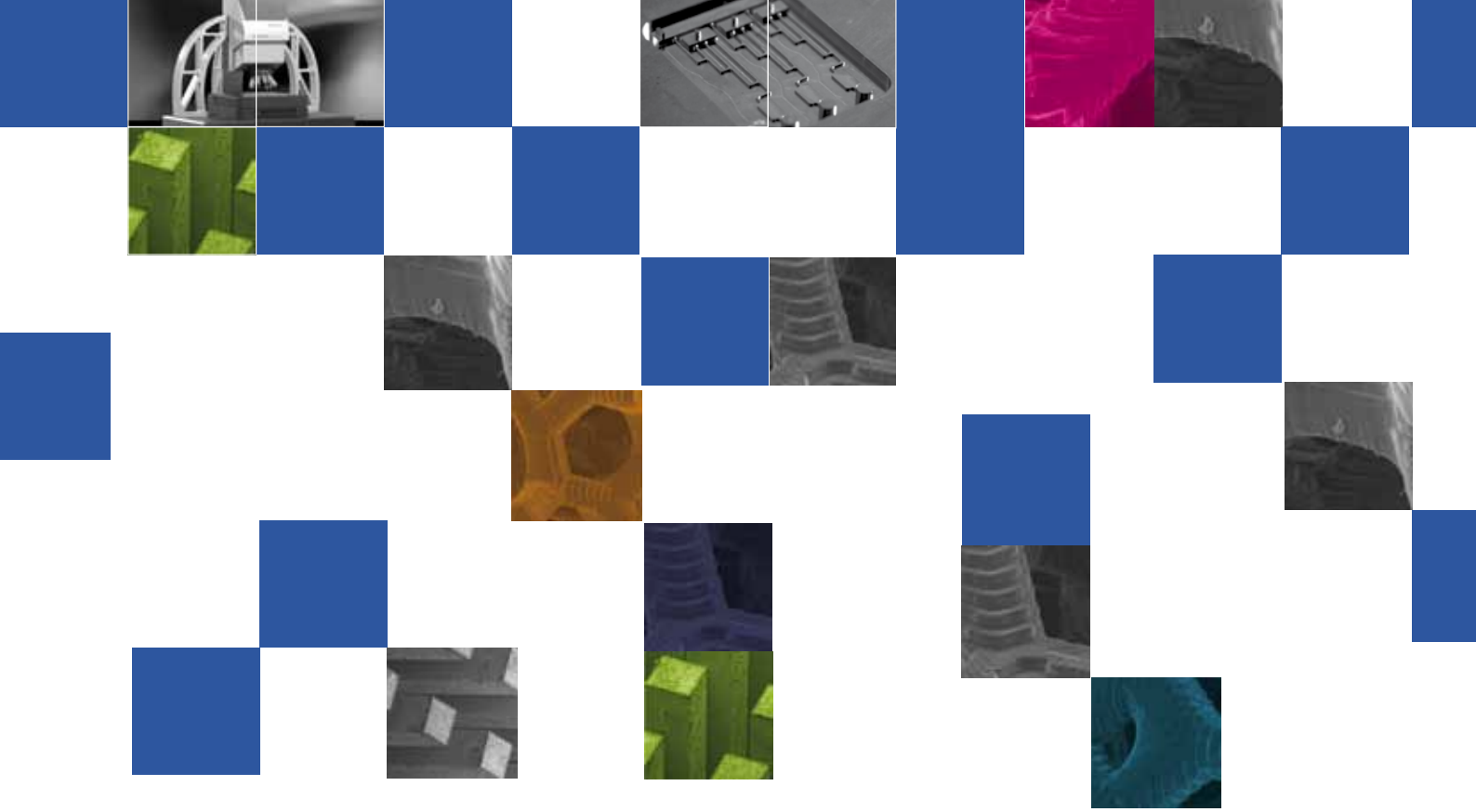

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