IMPRESS

Flexible Compression Injection Moulding Platform for Multi-Scale Surface Structures

SEPTIEME PROGRAMME-CADRE

A European project supported through the Seventh Framework Programme under the Public-Private-Partnership 'Factories of the Future' initiative.

www.impress-fp7.eu

Today's challenges

Plastic component manufacturing has become the workhorse of a number of industrial sectors since the mid of 20th century because they have intrinsic feature of flexibility, high throughput and costless complexity. Due to the high potential of micro/nano-features, the 21st century looks forward to the adoption of micro/nano- technologies (MNT) to this plastic industry. To develop these new products, technologies providing functionality and intelligence to plastic parts (optics, mechanics, biomedical applications, etc…) do exist but only for very specific approaches (such as unlimited surfaces): the industry lacks a cost effective and reliable manufacturing process. As a consequence, long duration of the development cycles, high costs and high risks, very often prevent the industry to "move to micro/nano-". To succeed in this emerging global micro/nano-functional features market place it is required to broaden the range of products offered and at the same time to reduce time to market, development costs and create high added value plastic parts.

Introduction

Goals and objectives

The IMPRESS project targeted **the development of a technological injection moulding platform** for serial production of plastic components incorporating micro/nano-scale functional features. New manufacturing routes of micro/nano-scale features were developed by implementing a full integrated technology platform. The platform enables fast development of complex and high functional micro/nano-features on plastic parts. In order to achieve these objectives, the technical challenges were solved:

- Micro/nano-machining with high aspect ratio
- Innovative self-assembly technologies for low-cost manufacturing of nanostructured mould inserts
- High aspect ratio replication of micro/nano-features by injection compression moulding
- Ejection of plastic parts without damaging the nano-features
- Online control of the quality of micro/nano-features

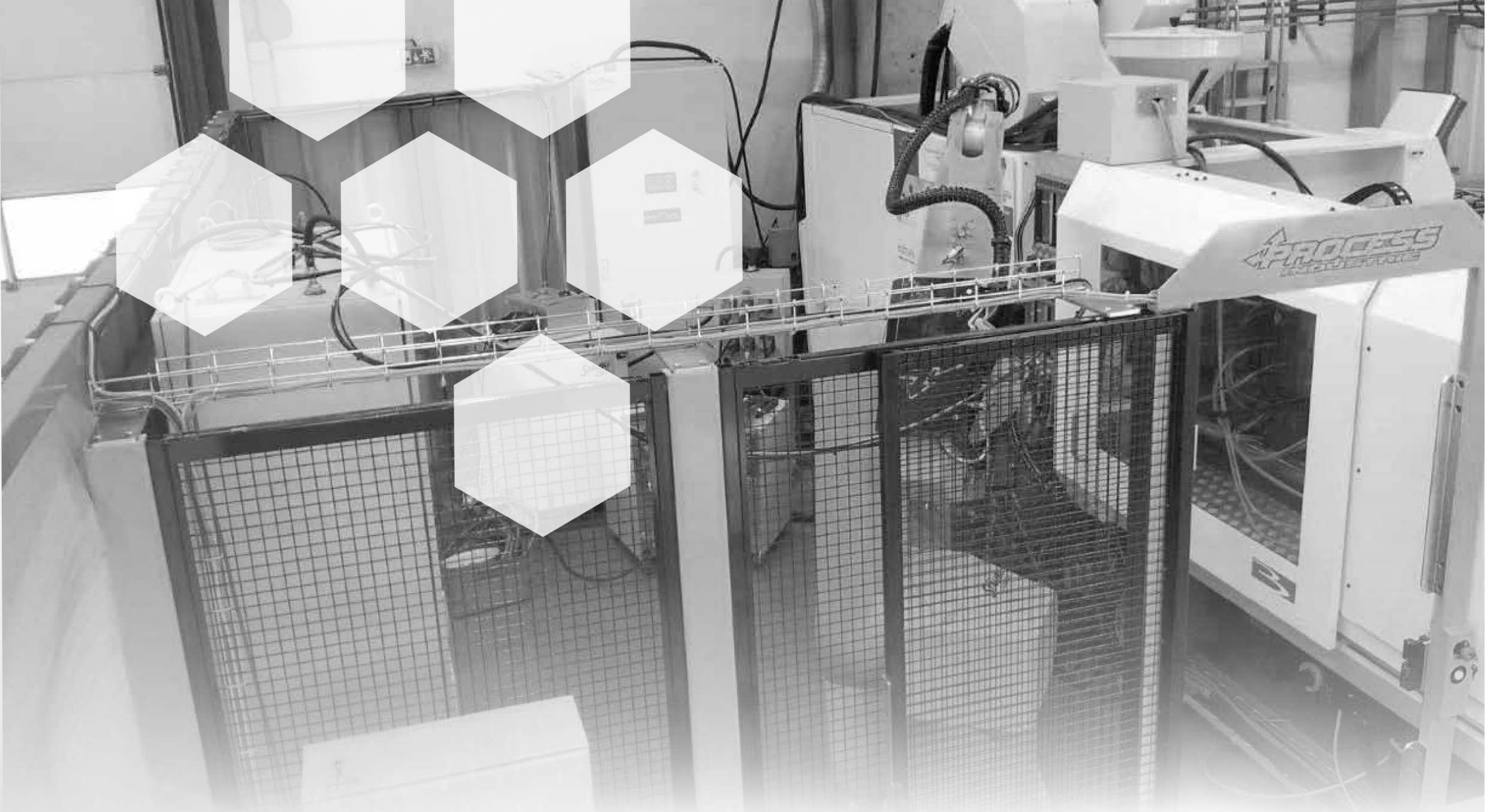
Impact

IMPRESS will accelerate the production and reduce time to market of micro/nano-scale functional features on multi-component devices. IMPRESS meets the industrial needs of the European Manufacturing Industry as it corresponds to the key evolution drivers for sustainable manufacturing systems in the plastic industry:

- Cost efficiency with extensive adoption of standards in production
- Low time-to-market
- Quick and easy convertibility/re-configurability
- Higher, stable product quality / high performance manufacturing
- Better reusability of systems and applications towards global interoperable factories
- Global knowledge merging for a "seamless knowledgeable factory of the future"

IMPRESS enabled the development and promotion of new technologies such as rapid heat and cool of mould cavities, and showed that nanostructurated plastic parts with complex shapes can be manufactured by injection moulding.

IMPRESS project paves the ground for new applications using these highly functional plastic parts. The replicated micro/nano-features obtained in IMPRESS offer many new perspectives in health and biotechnologies, optics, security and anti-counterfeiting, energy and micro-electronics, etc.



Platform

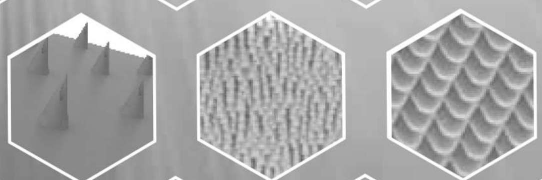
IMPRESS is a technology platform that gathers facilities for:

- tool-making for micro/nano-structuring of replication masters
- innovative plastic injection moulding cell
- metrology and process intelligence

Impress platform is fully integrated at PEP plant (Oyonnax-France). All technologies required for micro/nano-features replication are available.

- Electrical injection moulding machine (Billion)
- In line optical control system (Zeiss)
- CO_2 snow jet cleaning technology (ACP)
- In line process monitoring system (IPA)
- Heat & cool technologies based on induction, ceramic heaters, and high pressurized water
- 6 axis robot from Staübli
- Vacuum system from Fondarex

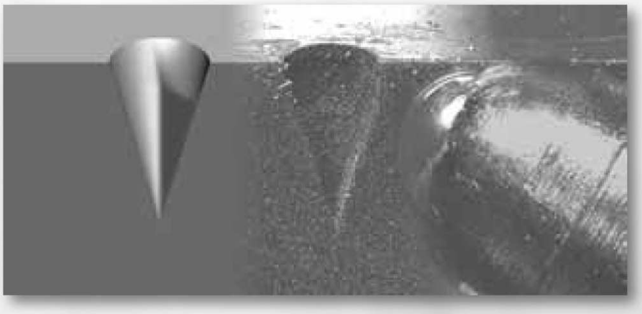
The tools and facilities are electrically connected in order to design complex cycles. As a consequence, cycle time is not time-dependent but it's linked to thermal data (for example, mould opening is driven by heat&cool equipments). After moulding, parts are sorted by the robot thanks to in line quality analysis.



Tool manufacturing module

Self-assembly process (CSEM)

CSEM has developed a process chain for the fabrication of micro/nano-structured inserts optimized for nanoreplication by injection moulding. The core of the process chain identified is nanosphere lithography, a bottom up process using the self-assembly of micro/nano-particles. This allowed the cost effective fabrication of micro/nano-structures over large areas (hundreds of cm^2). Special attention was paid to tailor the micro/nano-structures for both the final application (high aspect ratio required) as well as the replication process (draft angle).



Microneedle stainless steel moulding insert cavity (1mm length, 0.6mm base diameter)
Left to right: microneedle CAD model, microneedle laser machined cavity and Bic ball pen tip

Milling process (Cardiff University)

Cardiff University produced some microneedles stainless steel injection moulding inserts using nano second and pico second laser milling. These inserts were used to compare the two laser technologies, investigate the quality of the cavities produced using the moulded replicas and evaluate the suitability of these processes for producing sharp, high aspect ratio features.The inserts produced using pico second laser milling have a better feature resolution and surface finish than the ones produced using nano second laser milling, resulting in sharper microneedle tips but longer machining times.

Linear Coating Device process (CEA)

The technique used is called «colloidal lithography» The principle is to deposit a hard mask composed of a compact assembly of microspheres on the sample surface then, to perform a step of etching by RIE or plasma. After etching of the substrate through the mask of particles, the particles remaining are removed by simply wiping or by immersion in an ultrasonic bath. In the framework of IMPRESS project, inserts to structure are composed of a steel substrate coated with a layer of DLC. Gas content can selectively etch the particle mask or the DLC layer. It is thus possible to change the size and the shape of the particles during the process and to achieve in the DLC layer, microstructures with columnar or pyramidal shape.

Insert steel took with a top view in artificial lighting. (Before etching plasma treatment)

Injection moulding module

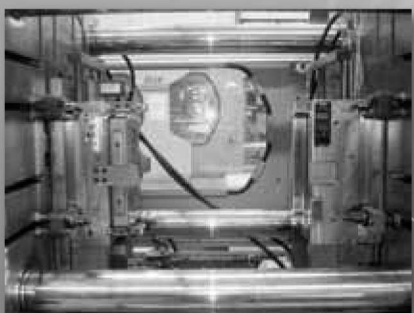
For filling accurately the micro-nano features (MNF), several technologies have been implemented:

- Injection moulding machine
- Rapid heat & cool mould technologies
- Injection compression moulding
- Vacuum of mould cavity
- New pressure sensors
- CO_2 mould cleaning system

Influences of these innovative technologies on MNF replication quality have been studied in order to determine the optimized process.
The injection moulding machine is a full electric & multi-material machine (2 injection units) from BILLION company.

- Full electric bi-material injection moulding machine
- High precision & repeatability
- Energy efficient
- High versatility: Mono-shot moulding / Multi-shot moulding / Rotative mould / Quickly removable barrels
- New control system "Dixit 3" : easy access and user-friendly for machine settings
- Specific compression option: a complete module with many possibilities in compression settings

High performance injection moulds (Compose and Moldetipo)
Toolmakers had to design 4 moulds with several technical requirements. They had to implement advanced technologies in the tools: integration of the micro/nano-inserts, injection/compression, heat and cool technologies and vacuum.

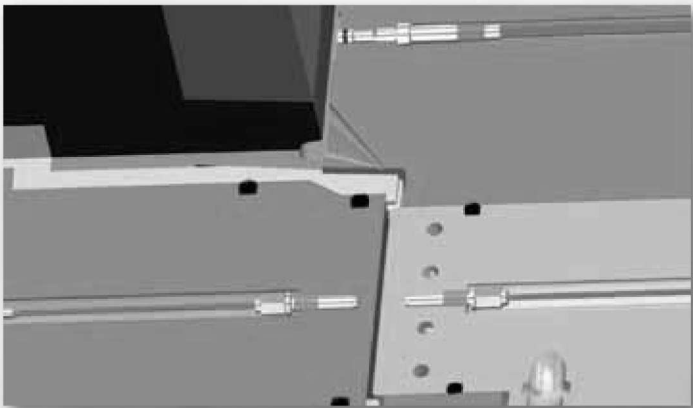


Intelligence and reliability module

Contact-free sensor (Kistler)

Cavity pressure is the basis for optimizing, monitoring and controlling of the injection moulding process. Cavity pressure measurement is the best option to have a high reproduction accuracy of structures during process. Due to the restriction of having no witness marks on the part, a new **contact free sensor** has been introduced. Together with standard combined pressure-temperature sensors the new measuring method makes it possible to improve the quality of micro structured parts.

Contact-free sensor



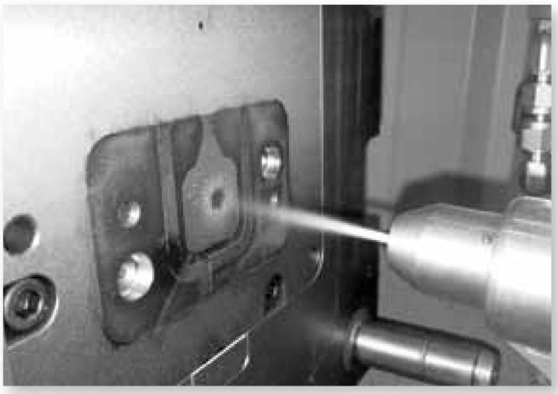
On the top: standard P/T sensor under the sprew
On the Bottom: 2 contact free sensors placed on both sides of the cavity

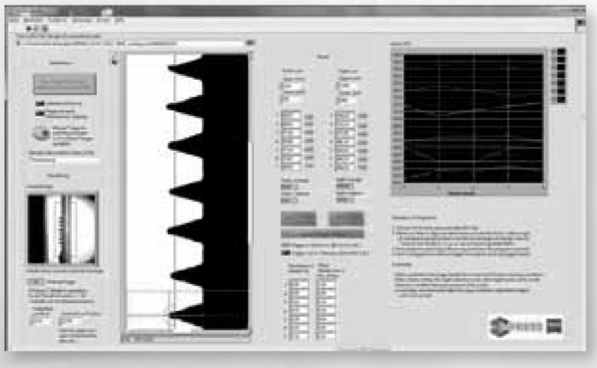
Process control (IPA)

The Advanced Process Control system developed by Fraunhofer IPA identifies defective work pieces by analyzing all relevant machine and sensor data that are available during a production cycle. For the demonstrators, e.g. for the microneedle array, a prediction rate of up to 98% has been reached. Moreover, the system assists in optimizing ramp-up times and production qualities during a production run (run-to-run control) by correlation based methods.

CO_2 snow jet cleaning technology (ACP)

The cleanliness of an injection mould plays a decisive role regarding the quality of the finished product. Therefore, the injection moulds/inserts have to be cleaned in order to ensure the flawless moulding of ultra-precise structures. Within the scope of the IMPRESS project, the cleaning process must fulfill two main requirements.These are the effective but gentle removal of particulate and filmy micro/nano-sized contamination from the structured inserts or moulds and the possibility of integrating the IMPRESS platform.



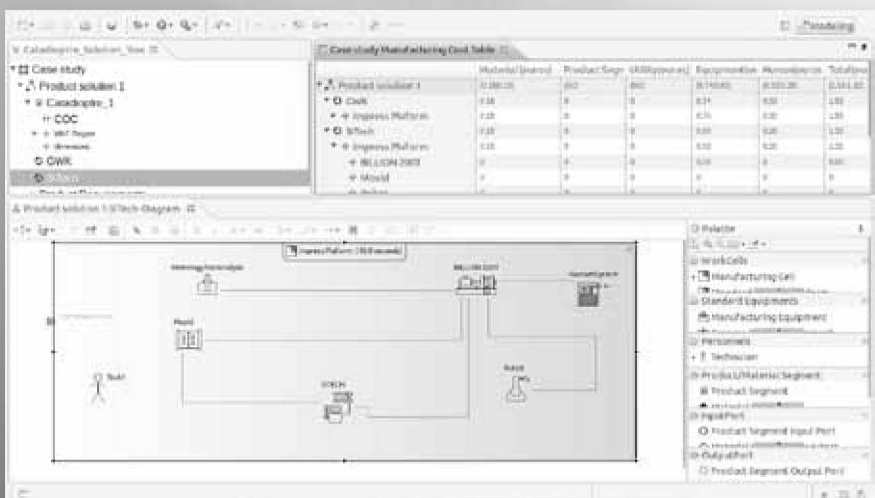


Metrology equipment (ZEISS)

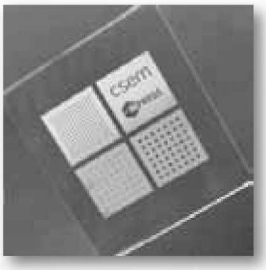
The inspection of the fabricated microstructures is performed by an advanced optical metrology system especially developed by Carl Zeiss for plastic part micro-metrology. The system provides a full surface characterization, real-time visualization and direct quality measurement. For a convenient process control and automated customization, the system is accessed by a user software interface that can be adapted to the produced parts.

Interactive software (PEP)

IMPRESS expert system tool allows engineers to specify collaboratively products with micro and nano-features. It provides interfaces to describe the product, to associate several manufacturing processes, and then to compare these processes regarding costs and cycle time. Expert system is based on design and recommendation rules, and it assists the user throughout process specifications. The software is also considered as a tool to save knowledge and to share experiences.

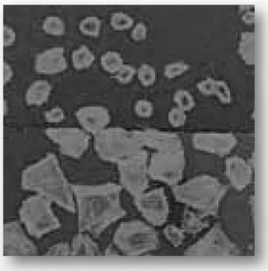


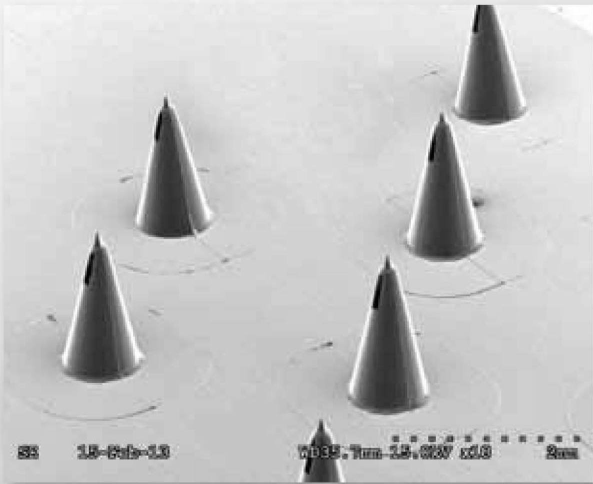
Demonstrators



Cell-repellent surfaces (CSEM)

Micro-nanostructured plastic parts have been manufactured to control the growth of biological cells. More especially, high aspect ratio nanostructures have been optimized to control the adhesion of biological cells. The presence of nanostructure significantly affects the morphology of the cells and their adhesion to the surface. By fabricating patterns of nanostructures and using a tailored cell-growth protocol, the location of biological cells can be controlled. Potential application for cell-based diagnostic devices are envisioned.





Micro-needle array (CROSPON)

Crospon's drug delivery technology enables painless, controlled intradermal medication delivery of one or more liquid drugs from a single patch applied to the skin. The device is controlled by an on-board microprocessor and is wirelessly programmable. The programmability of the device uniquely enables "programmable pharmacokinetics" whereby the pharmacokinetic profile of the injected drug can be tailored to a particular desired model.

The technology uses microneedles, created on the IMPRESS platform, that penetrate the stratum corneum to create a channel for drug delivery. The microneedles have an extremely sharp tip and reduce the discomfort compared to traditional hypodermic needles. The microneedle geometry enables the delivery system to be worn for extended periods of time as the nerve receptors in the dermis are not stimulated at the resulting shallow penetration depths.

Overmolded photovoltaic cells with polycarbonate

Anti-reflective housing (SILLIA)

The photovoltaic case study proposed in IMPRESS aims to develop a new and cost effective approach involving "moth eyes" nano-texturation to eliminate these reflexion losses.

Moreover, the encapsulation polymer is polycarbonate, suitable for nano-texturation by replication making this approach probably less costly than deposition of multilayer's or sol-gel films. Samples was characterized by scanning electron microscopy (SEM) and showed an efficient replication of nanostructures.

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