IMPRESS

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Today's challenges

The impact of the integration of micro- and nano- technologies to plastic component manufacturing by injection moulding has already been shown in some restricted areas such as the recording media industry (CD, DVD and Blue Ray) and more recently the anticounterfeiting holograms. To develop these new products, knowledge-based technologies do exist but only for very specific approaches (such as unlimited surfaces). But the industry lacks a generic way of developing new products and bringing them onto the market. Consequently, there is an urgent need to strengthen the injection moulding technology base of this important European industrial sector.

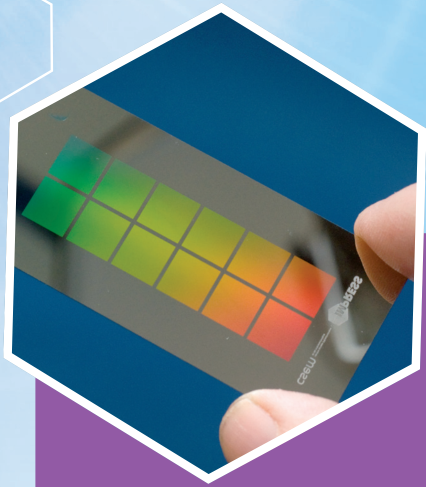


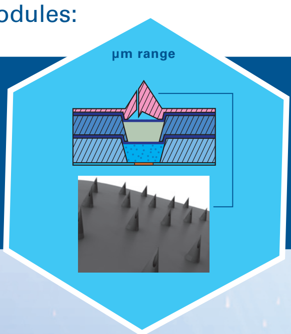
Figure 1 : Optical photograph of a nickel shim (wedge) patterned with submicrostructures, obtained by CSEM

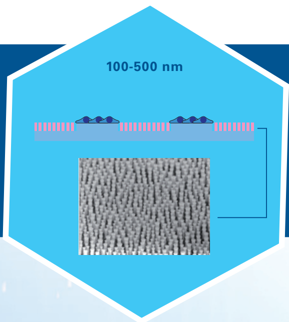
Objectives

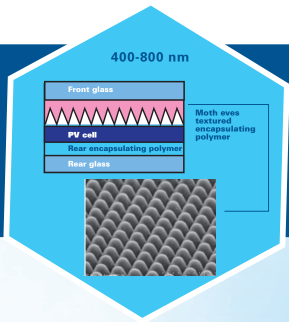
The objective of the IMPRESS project is to facilitate the development of new manufacturing routes of micro/nano-scale feature manufacturing by implementing a complete technology platform. IMPRESS targets the development of a technological injection moulding platform for serial production of plastic components incorporating micro or nano scale functional features.
The platform is based on most advanced facilities divided in three modules:

- tool manufacturing, involving different technologies of micro-nano direct manufacturing, from top-down to bottom-up such as self-assembling,
- injection moulding, including equipments fitted with innovative hardware technologies to improve replication quality and capability,
- intelligence, dedicated to advanced process control and online metrology integration.

Thanks to this set of modules, IMPRESS will offer new generation of technologies for the replication of micro/nano-scale features in plastic parts. The best potential processes will be validated through the production of different polymer demonstrators representing applications from different industrial sectors (Medical, Biotechnology, Energy).







1. Patchs of hollow micro needles for drug delivery

Micro needles with an overall length of 1000 µm and integrated channels (Ø50-120 µm) will be developed in order to penetrate the top layers of the skin and to deliver liquids underneath the top skin layer. Typical array sizes comprise 4 to 100 needles, on an area of up to 2,5 cm^2. By using micro needles no nerve endings are stimulated so no pain is experienced by the patient.

2. Patterned cell culture slide for genetic analysis

Micro-nanostructured cell-culture slides will be produced for cost effective cell-based diagnostic devices. The main challenge will be the fabrication of micropatterns of cell-repellent nanostructures to create spots of biological cells at predefined locations, each spot being an individual reaction site. The micro-pattern of cell-repellent nanostructures will have size ranging from 10 of 500 µm and the nanostructures will be in the range of 100-500 nm in diameters with heights of 100 nm-1 µm.

3. Anti-reflective Solar Cell Housing for photovoltaic modules

Solar cell efficiency is limited by internal and external reflection of incident photons. The major innovation proposed for this IMPRESS case study consists in using micro-injection moulding to realize a module architecture involving nanotexturation to eliminate reflexion losses between the encapsulating material and the solar cell. For solar application, the grating period should be less than 200 nm for an height of 2 µm.

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The IMPRESS platform at mid-term

During the first half of the project, significant results were obtained.

For the "Tool manufacturing module", micro-nano structured inserts have been realized by CSEM, Cardiff University and CEA LITEN (see following sections for more details). These inserts are integrated into a complex dedicated mould made by Compose and Moldetipo, which gives us the possibility to benchmark innovative replication technologies.

Concerning the "Replication module", the IMPRESS platform is now ready to produce, in an automatically way, plastic components with micro-nanofeatures. It includes:

- A two-shot full electric injection-compression moulding machine developed by Billion, with a maximum clamping force of 200T.

Figure 2: The IMPRESS platform at PEP plant

- A vacuum unit, using the Fondarex® technology: it first applies vacuum in a 20 L tank. Then, thanks to the signal from a sensor or the machine, the vacuum valve is switched to evacuate air from cavities and runner, in few milliseconds (i.e. without affect on the cycle time).
- Two rapid heat and cool technologies driven by the injection moulding machine :
- Roctool® induction technology: the tool surface is rapidly heated by induction thanks to internal inductors.
- GWK® technology: it combines internal ceramic heaters with optimized cooling channels made by strato-conception.

Regarding the "Intelligence and reliability module", innovative sensors have been provided by Kistler and integrated into the mould. The process monitoring equipment developed by IPA follows sensors and digital process signals. The objectives of the next months will be to establish predictive models that correlate machine parameters, online process data and product quality.

Two main technologies have been developed at partner plants and will be integrated in the IMPRESS platform within the next 6 months:

- The online cleaning technology, from ACP: it is based on a CO_2 snow jet cleaning process. ACP developed specific nozzles suitable for micro and nanostructures, and performed robot adaptation for future integration on the final process.
- The online metrology equipment, from Zeiss: within the metrology box, a light source is irradiated to the sample, and scattered in the direction of the detector. Thereby the scattered light is influenced by the nano and micro structure of the sample. After detection of the scattered light image processing is needed in order to analyze the sample surface.

Finally, the platform is now ready to launch the demonstration activities. Part and mould designs will be carried out beginning of 2012 to have the moulds ready to produce first prototypes in May 2012.

Focus on micro/nano-structuration of inserts

CSEM developed new cost efficient hybrid manufacturing chains for the fabrication of micro and nano-structured inserts for replication. In the approach proposed, self-assembly based structuring techniques and interference lithography have been used for the low cost fabrication surface nanopatterns. These nanopatterning techniques were combined with standard microfabrication to produce functional micro-nanostructures. The structures were tailored for both cell-growth (high aspect ratio to obtain cell repellency) and replication (tapered sidewalls for easy demolding). The final structures had diameters of 400 nm in average and a height of 1.2 micrometers.

To produce a durable insert, the structures fabricated have been replicated into a nickel shim via an electroforming step. These structured shims have been used for preliminary replication tests using hot embossing and injection molding, as shown on Figure 3.

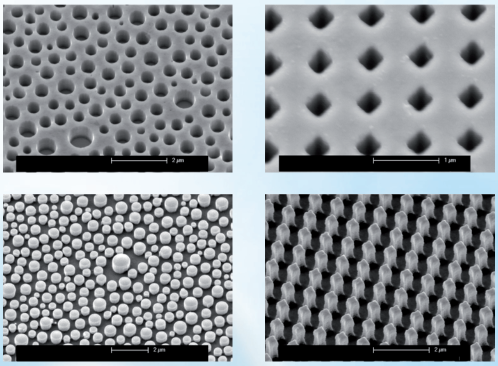

Figure 3: SEM images of nickel shims based on self assembly and interference lithography (top), and their replica in polycarbonate obtained by hot-embossing (bottom)

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Cardiff University investigated possible manufacturing process chains for producing steel mould inserts for serial replication of microneedles patches employing injection moulding. They studied the use of several manufacturing technologies for producing masters for replicating arrays of micro-needles, including: micro-milling, laser milling (or laser ablation) using nano (ns) and pico-second (ps) lasers, Electro Discharge Machining (EDM) and electro-plating.
Laser milling, and especially ultra short pulse laser ablation, like ps laser machining, was considered as a preferred technology for manufacturing the microneedles mould insert due to its capability to produce high resolution features/structures and its potential to fabricate the necessary cavities for replicating needles with sharp tips in comparison to the other micro-manufacturing processes. They investigated laser milling as a single process for the manufacturing of the cavities necessary for injection moulding microneedle patches. The microneedle cavities were successfully machined in stainless steel workpieces to a depth of 1mm using both ns and ps laser milling and the machining results were repeatable. Although they were not measured, a better feature resolution and surface roughness was obtained by ps laser milling, as shown in Figure 4. It is worth mentioning that further improvements should be obtained in regards to the draft angle of the microneedles cavities and the tip size by optimising further the ps laser milling process.

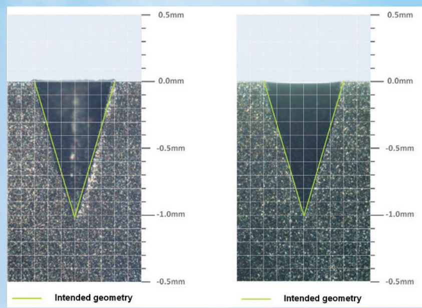

Figure 4: Microneedle machined using the ns (left) and ps laser milling (right, better resolution)

CEA LITEN worked on a solution based on the Linear Coating Device process, which enables to deposit a monolayer of micro- or nanoparticles in a compact arrangement; the obtained particles organisation is similar to the one resulting from the Langmuir-Blodgett technique; however, it offers a higher potential for industrial applications since it enables to coat larger surface areas and can be applied to a wide range of materials, as well as flexible or rigid substrates. This process presents many advantages to get low cost highly organised particles arrangement; nevertheless, a fine tuning of the process parameters is required to achieve long range compact arrays.

This technique is a new approach in the manufacturing of nanostructure inserts to mould with a high degree of feature.
The working can be cut up into 3 parts:

- A system responsible of the dispersion of the particles solution.
- A conveyor using a liquid to transport and transfer particles on a rigid or flexible substrate.
- A conveyor that makes the substrate (upon which particles have to be deposited) moving.

Therefore, the process consists in dispensing the particles on the carried liquid surface. The carried liquid transports the particles to the transfer area. The particles are stored in this area and then go back up on the sloping plane. Particles situated on this plane apply a pressure that force the ordering of particles situated in the transfer area. The scheme plan below described the general principle of the technique used. Thanks to this technique, nanostructured steel inserts (25 mm x 25 mm) were obtained (see Figure 5) using silicon oxide balls of 1 micron in diameter. The rate of layout is upper than 93 %.

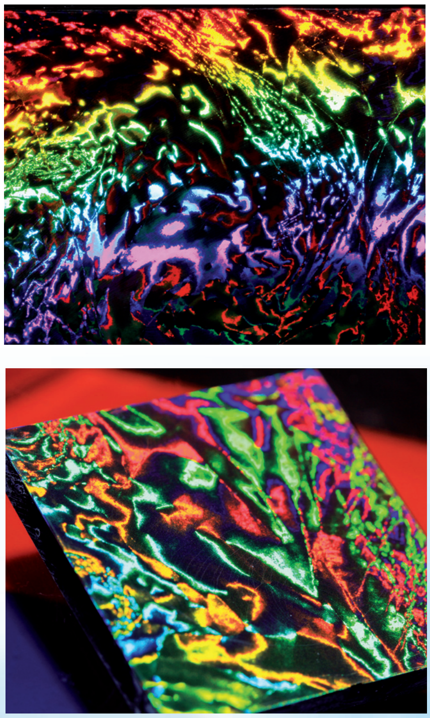

Figure 5 : Insert steel took with a top view in artificial lighting. (Before etching plasma treatment).

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ACP ADVANCED CLEAN PRODUCTION, SME, Germany
ACP is company manufacturing equipment for the semiconductor and PV-industry, primarily for single substrate wet processes (cleaning, developing, etching, stripping, lift-off) but also VUV surface conditioning.
www.acp-micron.com

BILLION, SME, France
BILLION is a company specialised in multi-components machines and manufacture injection molding machines for plastics in a range from 40 to 2500 tons. http://www.billion.fr/

CEA, RTD centre, France
CEA is an internationally recognized technological research organization in the domains of energy, information and health technologies and defense. http://www-liten.cea.fr/

COMPOSE TOOLS, SME, France
Compose is one of the largest French mouldmaker specialised in medium to large scaled moulds mostly for plastic and composite industry like injection, injection compression moulding, blowing extrusion, RTM, lay-up. http://www.compose-tools.com/

CARDIFF UNIVERSITY, University, United Kingdom
Cardiff University (CU) is recognized in independent government assessments as one of Britain's leading teaching and research universities. http://www.mec.engineering.cf.ac.uk/

Carl Zeiss, Large Company, Germany
The Carl Zeiss Group is a leading group in the optical and optoelectronic industries.
http://www.zeiss.de/

CROSPON LIMITED, SME, Ireland
CROSPON is a medical device company. www.crospon.com

CSEM, RTD centre, Switzerland
CSEM is a privately held research and development company active in applied research, product development, prototype and low-volume production and technology consulting.
http://www.csem.ch/site/

Fraunhofer IPA, RTD centre, Germany,
he Fraunhofer Institute for Manufacturing Engineering and Automation IPA is focused on solving organizational and technological problems faced by industrial companies active in the manufacturing field. http://www.ipa.fraunhofer.de/

KISTLER, Large Company, Switzerland,
Kistler Group is leading the global market for sensors and systems for pressure, force, torque and acceleration measurement. http://www.kistler.com

MOLDETIPO, SME, Portugal
Moldetipo is a tool shop specialized in the construction of serial moulds and prototypes for plastic industries such as automotive, electronics, medicine and house ware.
www.moldetipo.pt

PEP-centre technique de la plasturgie, RTD centre, France
PEP is the French plastic injection molding technical center. http://www.poleplasturgie.net/

PLASTIPOLIS, Cluster, France
Plastipolis is a SMEs cluster network including most of the leading plastic industry clusters in Europe and nanotechnology for Plastic. http://www.plastipolis.fr/

SILLIA, SME, France
SILLIA designs and manufactures solar photovoltaic modules and assembles these modules from the photovoltaic materials (cells, EVA, glass, ...) on a automated production line.www.sillia.com/

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