



EUMINAfab – a European Research Infrastructure on
multimaterial micro- and nanotechnologies

Mastermaking and Structuring Facilities @ Cardiff


Manufacturing Engineering Centre - Cardiff University

Steffen G. Scholz

14.09.2010

36 Installations




 **MEC** **4** **CrossBeamXB1540**

Mastermaking **Laserprocessing**


1 **NPL-MeasLab** **Micro&Nanoimprinting**

NanoMetrology


 **Noble metal** **e-beam**

MiPlaza **LTPS line** **Etching**

4

 **CHARPAN Tool**


IMS-CHARPAN **1**

 **Surface nanotexturation**

LTF **PVD** **CVD** **XPEEM**

6 **HRTEM TITAN** **PVD/CVD**



 **KNM F** **11**


Auger Nanoprobe **Abberation corrected TEM**

Laser processing **DPN** **VB6**

HSPC Micromech **μIM**


P&n imprint **PVD-Cluster**

dLIGA **In situ NANO BL**

 **ULTRA LAB** **METRO LAB**

TMM **REPLICATION LAB**

4 **NIL LAB**

 **PHOTOPOL** **SelfAss**

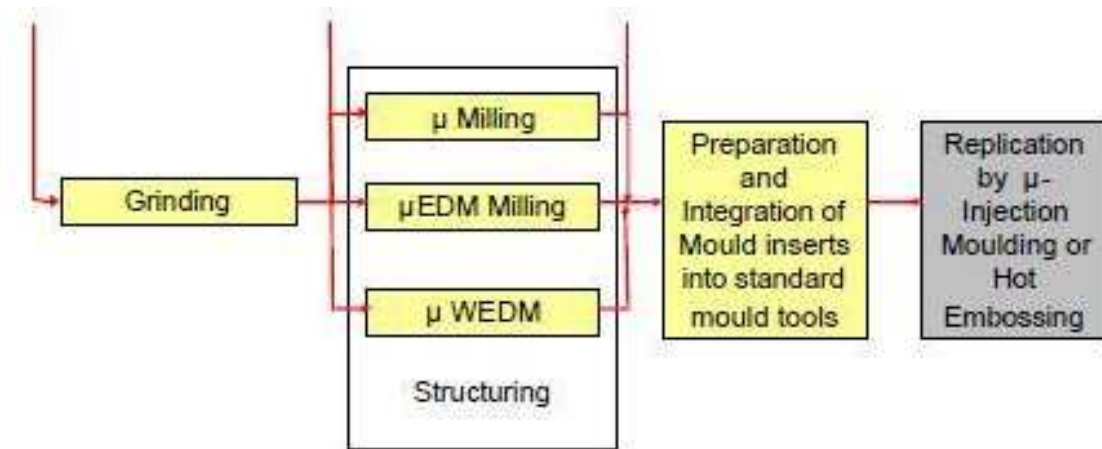
CRF-MN **ScreenP** **PVD-Org** **EO**

5

Installation

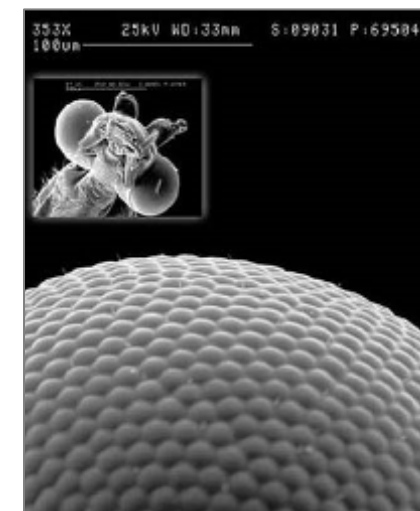
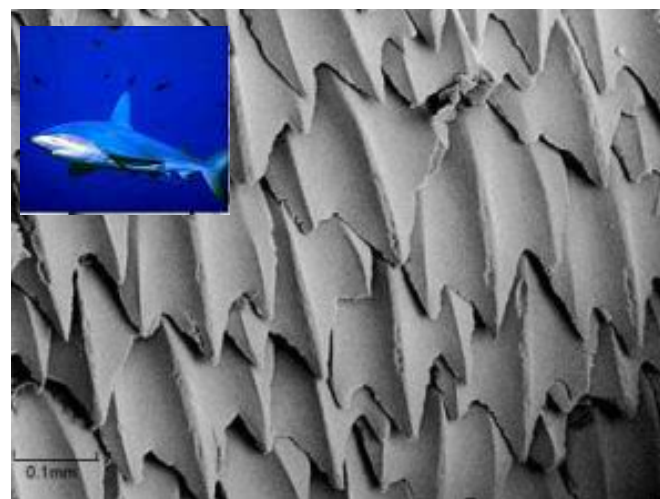
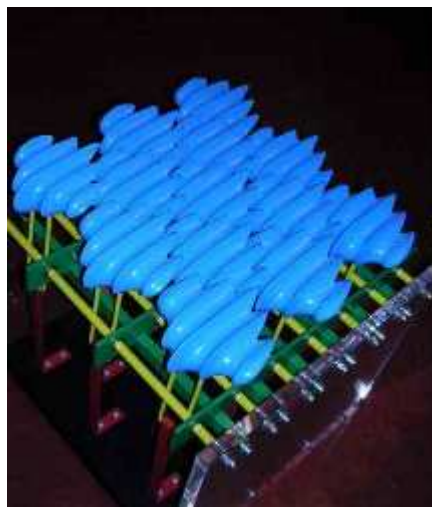
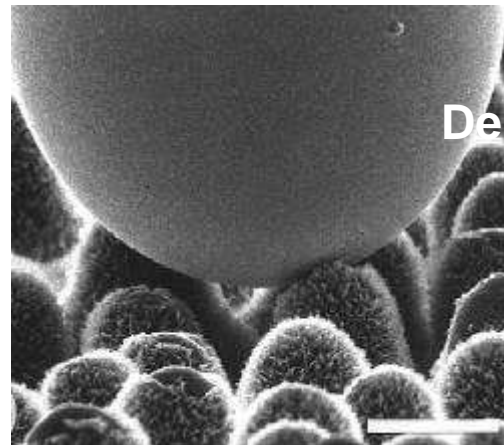
Short name of infrastructure

Mastermaking and Structuring of Mould inserts

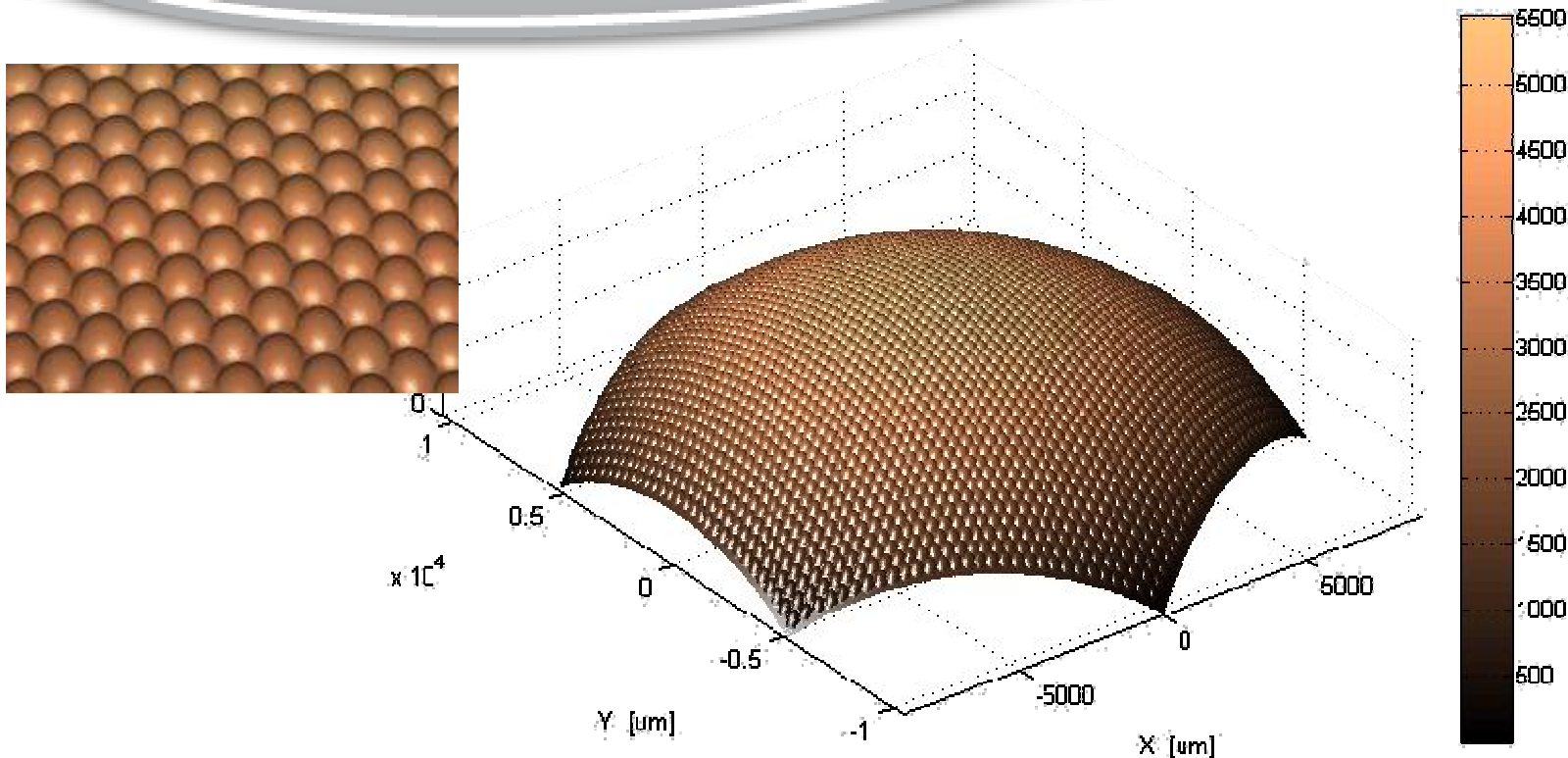


- ✧ Micro Milling, Kern HSPC 2216
- ✧ Micro-EDM, AGIE Comp.
- ✧ Micro & Vertex machines
- ✧ Micro EDM Milling system SARIX SX-100-HPM 3D
- ✧ Grinding
- ✧ Micro SLA

Oppotunity: Functional micro and nano structured surfaces

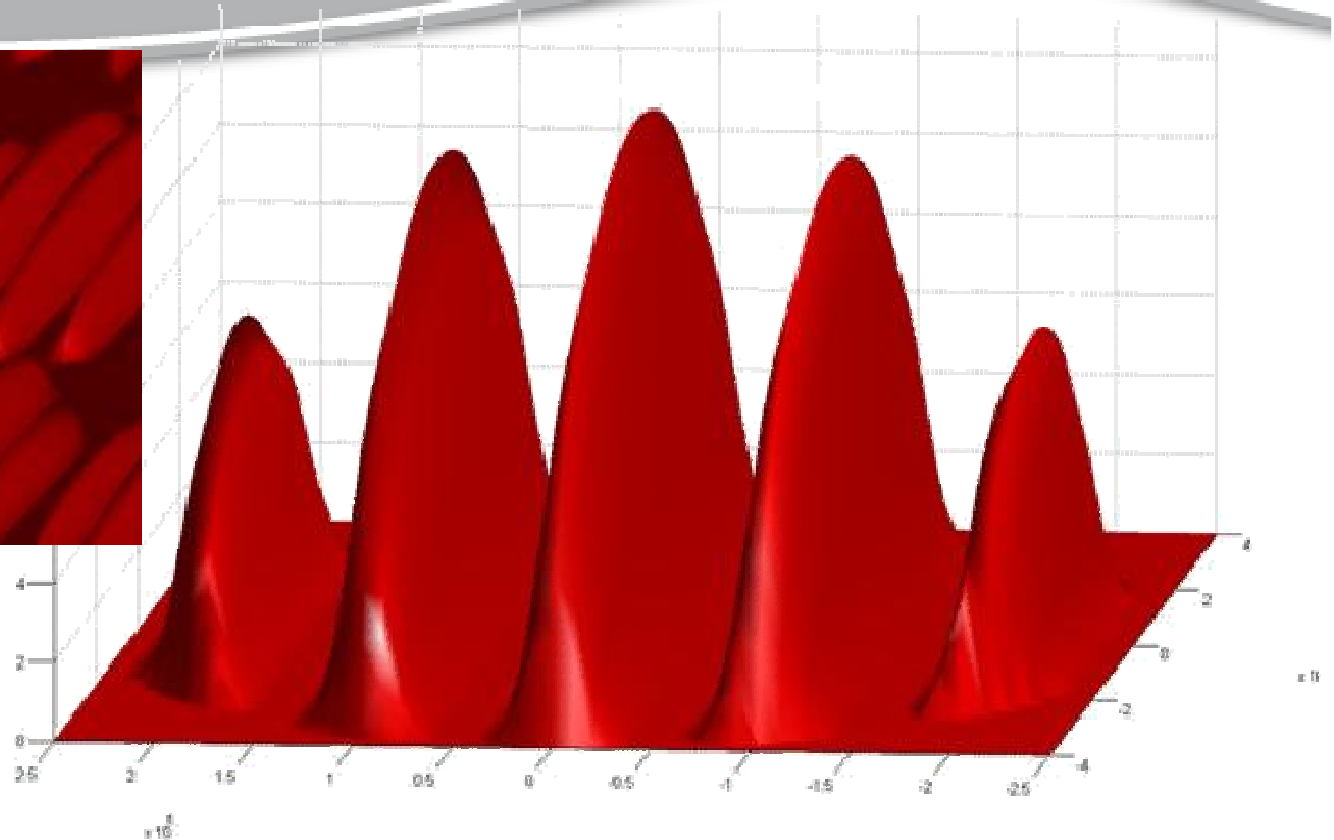


Bio-mimetic modelling: household fly eye like surface



- ✧ Hexagonal design for Ommatidia and protuberances: 3D on 3D
- ✧ Ommatidium: 9 μm in height and 21 μm in diameter
- ✧ Protuberances on top of the ommatidia: Ø 350 nm and 120 nm in height
- ✧ Dimensions of protuberances in range of wave length of optical light

Bio-mimetic modelling: shark skin like surface

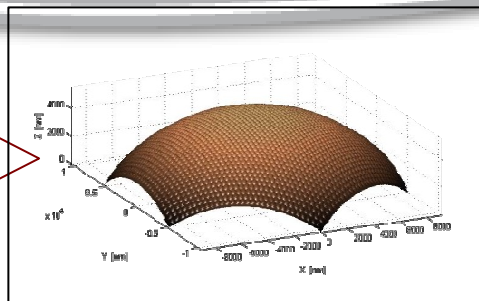


- ✧ Ellipsoid design with gaps: height up to 130 μm , distance between peaks 100 μm , length up to 500 μm
- ✧ Hexagonal design of functional elements (denticles) to achieve optimal spacing
- ✧ Functional elements on both planar and 3D freeform surfaces

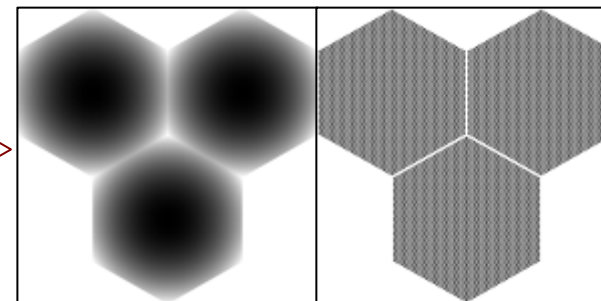
Process chain: replication of moth's eye like surface



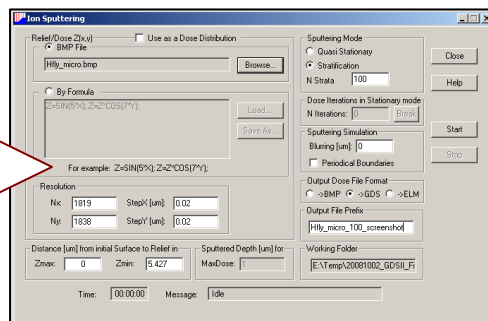
1) Bio-mimetic modelling



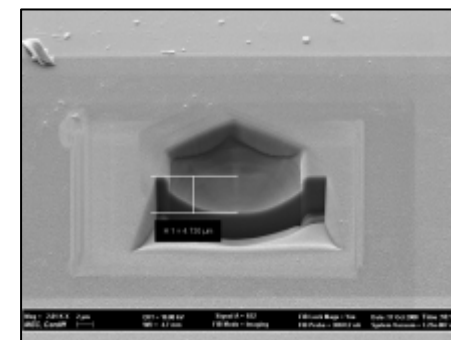
2) CAM solutions



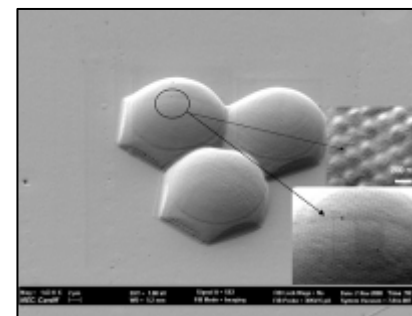
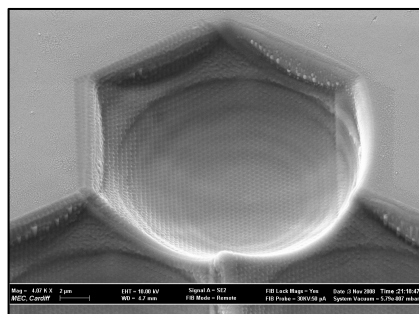
3) Generation of GDSII files



4) FIB machining



5) IM replication

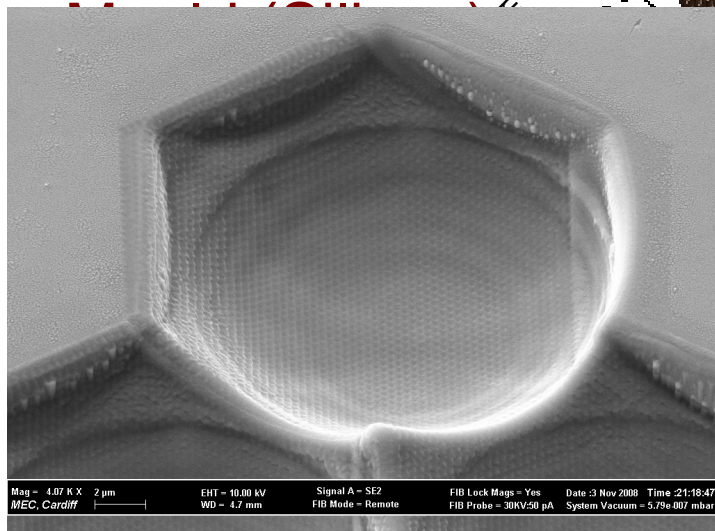
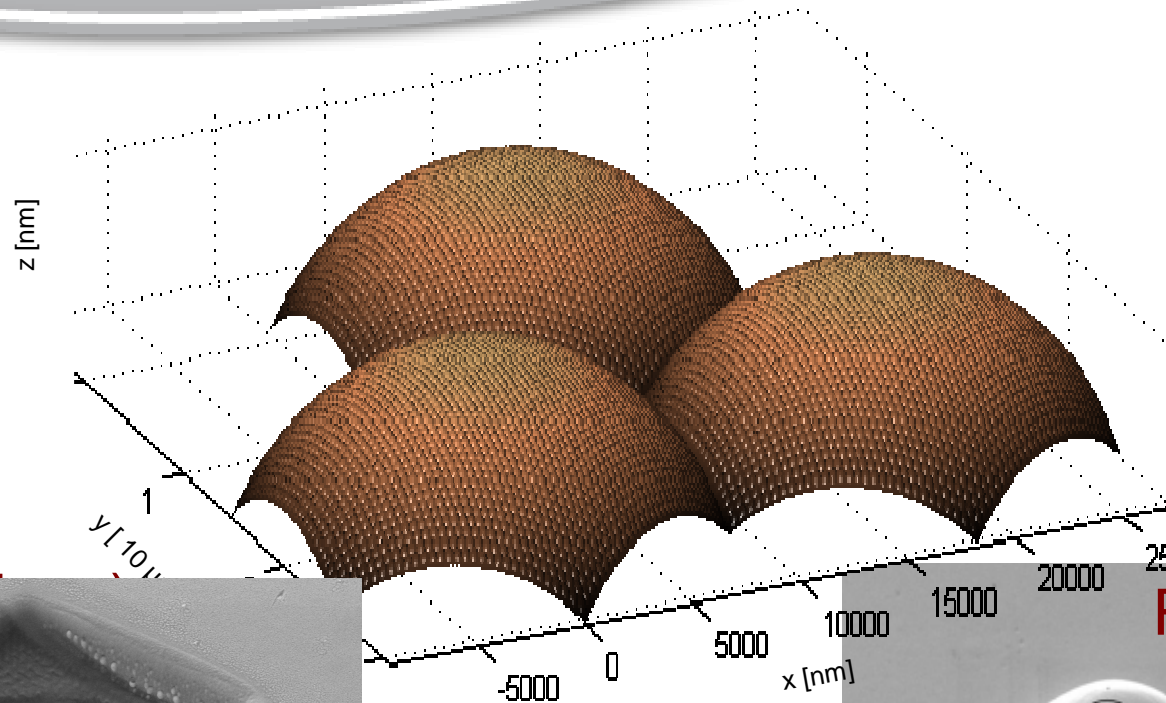


Scholz, S., Griffiths, C. A., Dimov, S. S., Brousseau, E. B., Lalev, G. and Petkov, P. *New process chains for replicating micro and nano structured surface with bio-mimetic applications*. ANTEC 2009 - Proceedings of the 67th Annual Technical Conference & Exhibition. Chicago, IL, June 22 - 24.

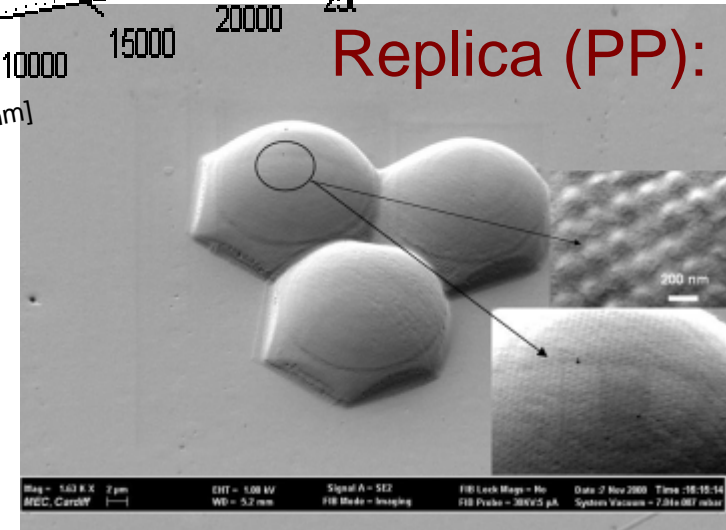
Results: replication of moth's eye like surfaces



Model:



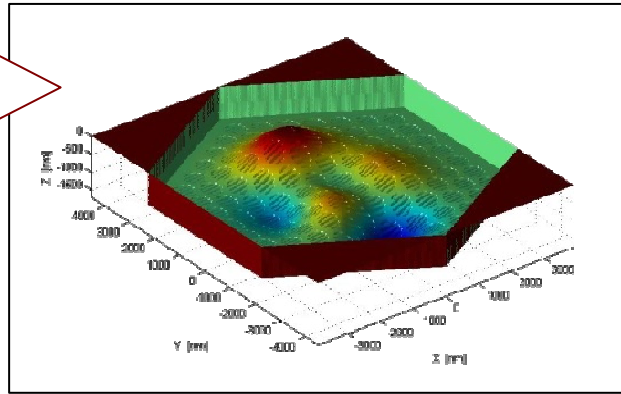
Replica (PP):



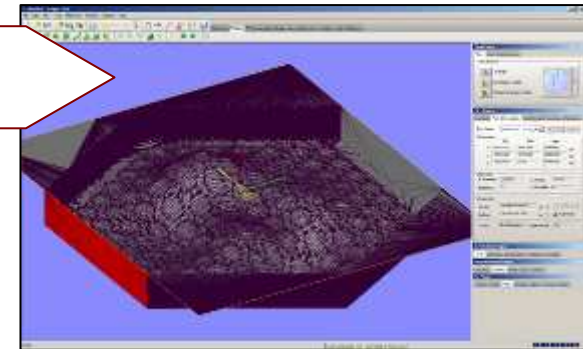
Scholz, S., Griffiths, C. A., Dimov, S. S., Brousseau, E. B., Lalev, G. and Petkov, P. *New process chains for replicating micro and nano structured surface with bio-mimetic applications*. ANTEC 2009 - Proceedings of the 67th Annual Technical Conference & Exhibition. Chicago, IL, June 22 - 24.

Process chain: replication of shark skin like structures on 3D freeform surfaces

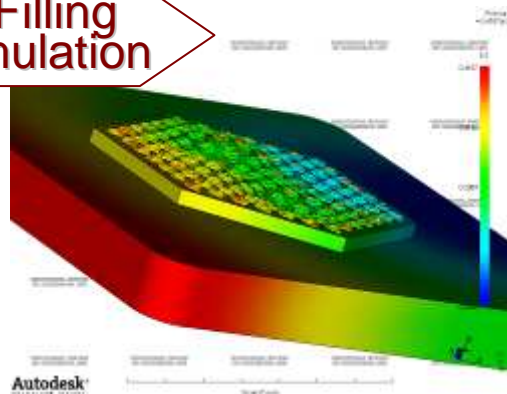
1) Bio-mimetic modelling



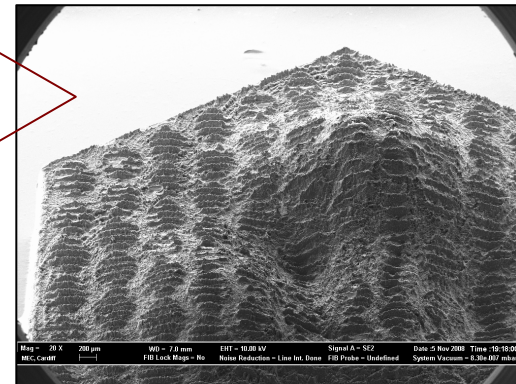
2) CAM solutions



3) Filling simulation



5) IM replication

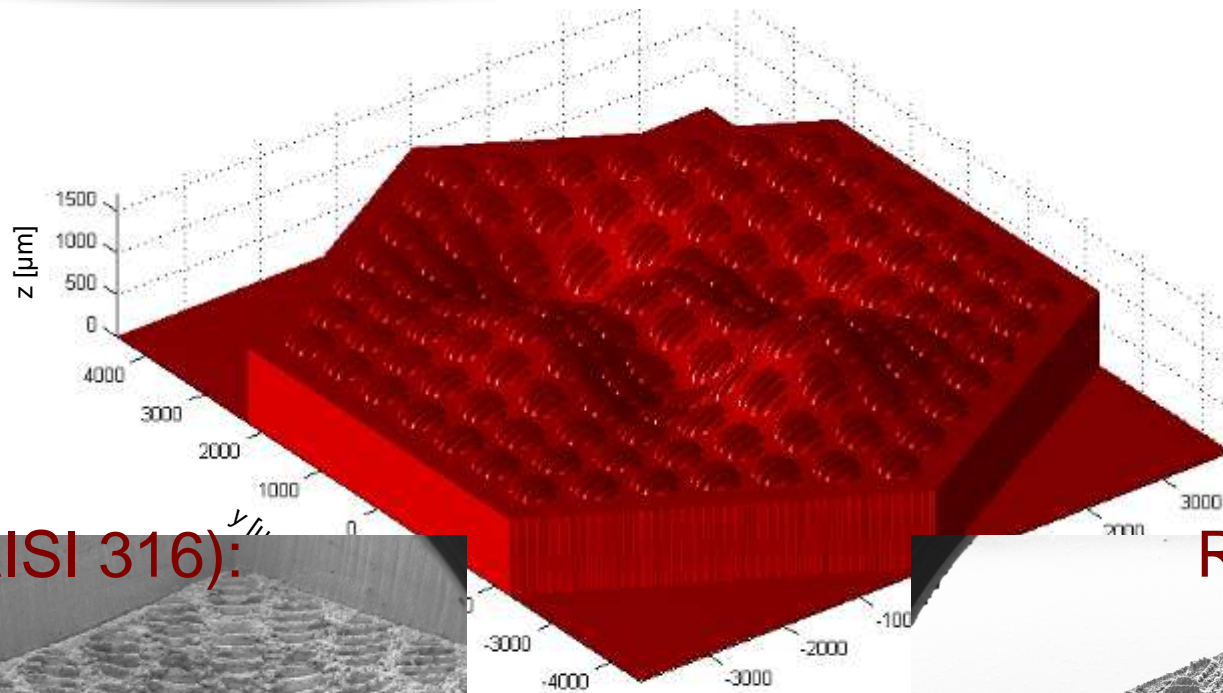


4) Laser milling

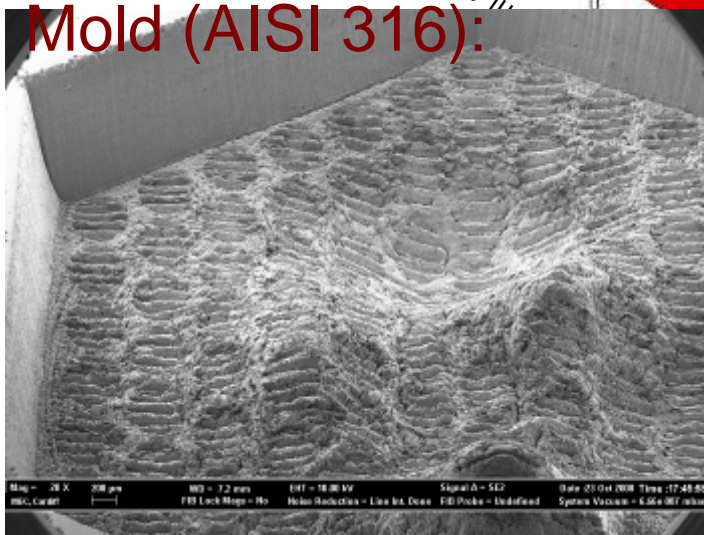


Shark skin like texturing on 3D freeform surface

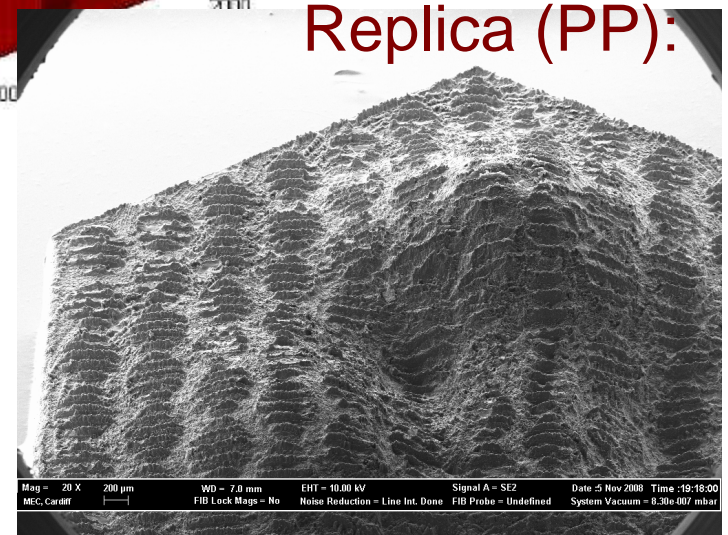
Model:



Mold (AISI 316):



Replica (PP):



Scholz, S., Petkov, P., Brousseau, E., Griffiths, C., Hirshy, H. and Dimov, S. *Process chain for replicating bio inspired micro structured surfaces*. 4M/ICOMM 2009 - The Global Conference on Micro Manufacture. Karlsruhe, Germany, September 2009.

Shark skin like texturing on 3D freeform surface

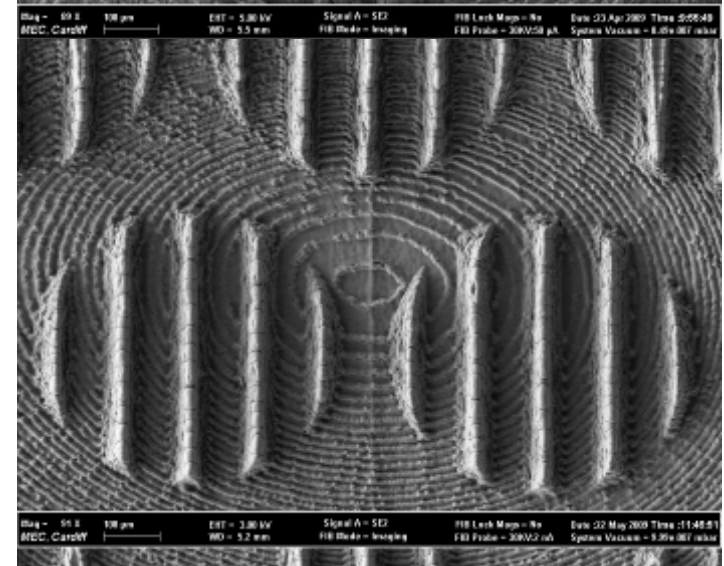
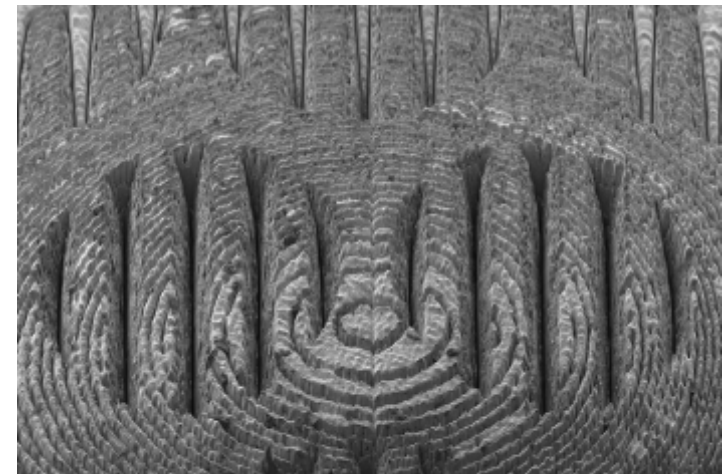
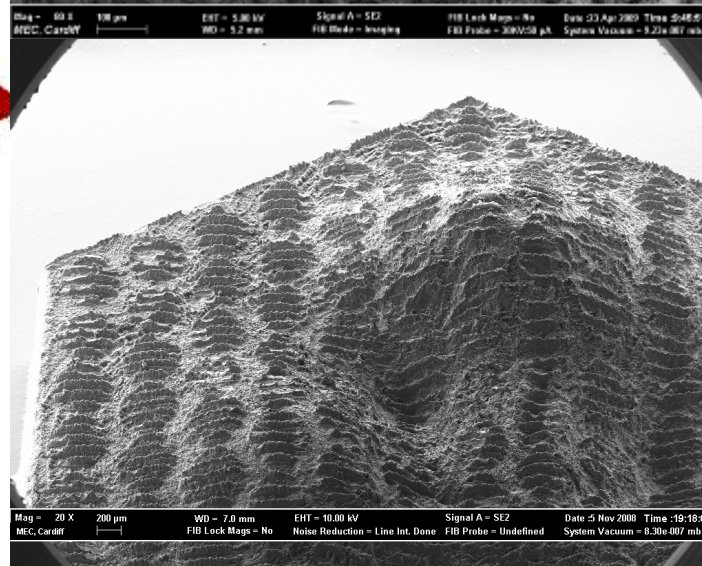
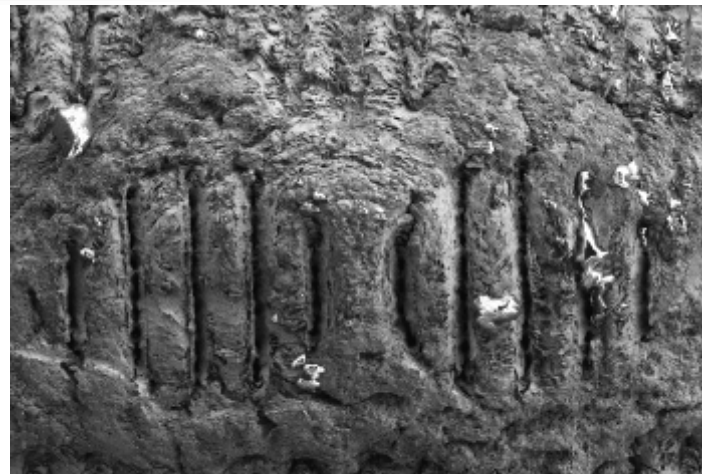
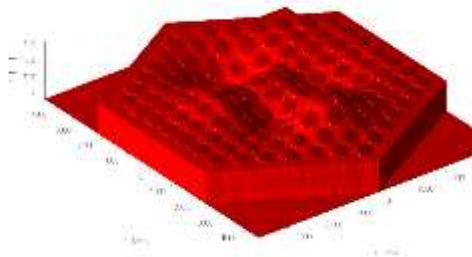


ms Laser

ps Laser

Mold(AISI316):

Model:



Replica (PP):

Scholz, S., Petkov, P., Brousseau, E., Griffiths, C., Hirshy, H. and Dimov, S. *Process chain for replicating bio inspired micro structured surfaces*. 4M/ICOMM 2009 - The Global Conference on Micro Manufacture. Karlsruhe, Germany, September 2009.

★ Laser ablation system, DML 40 SI

- pulse duration 10 μ s
- repetition rate 30 kHz
- scanning speed 280 mm/s
- power 70 % (5.2W)
- fluence of 1.8 J/cm²

★ Processing time

- Planar: 20 min
- 3D: 1,5h

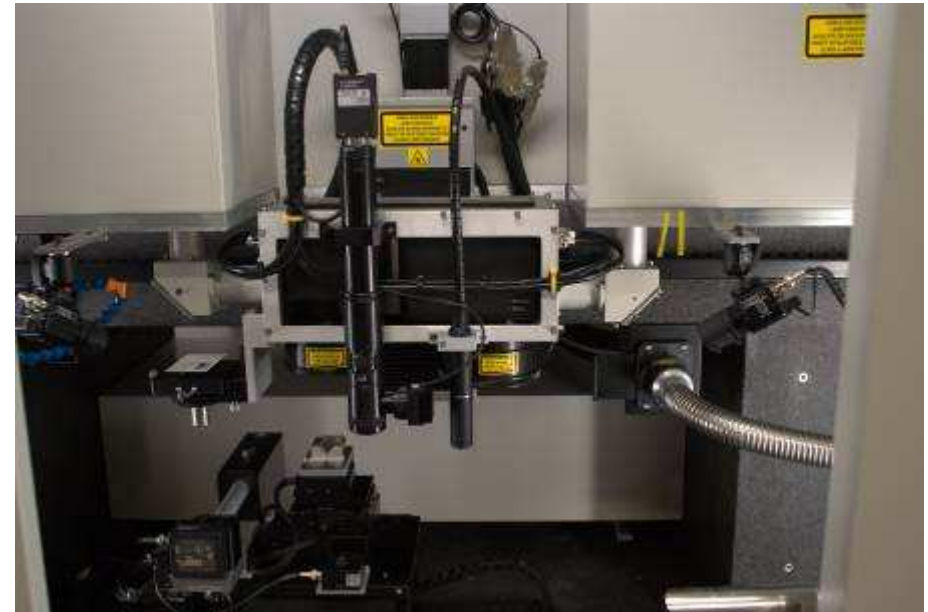


✪ Laser ablation system, Oxford laser, 2 beam lines

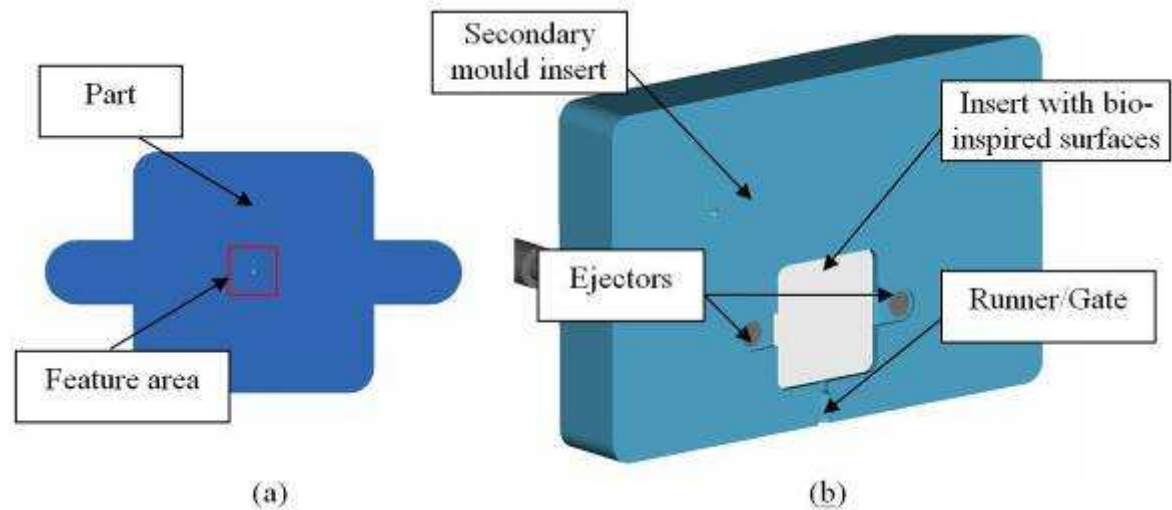
- Wavelength 355 nm
- Pulse duration 8 ps
- Repetition rate 50 kHz
- Scanning speed 10 mm/s
- Power 40 mW
- Fluence of 0.31 J/cm²

✪ Processing time

- Planar: 630 min
- 3D: 15000 min

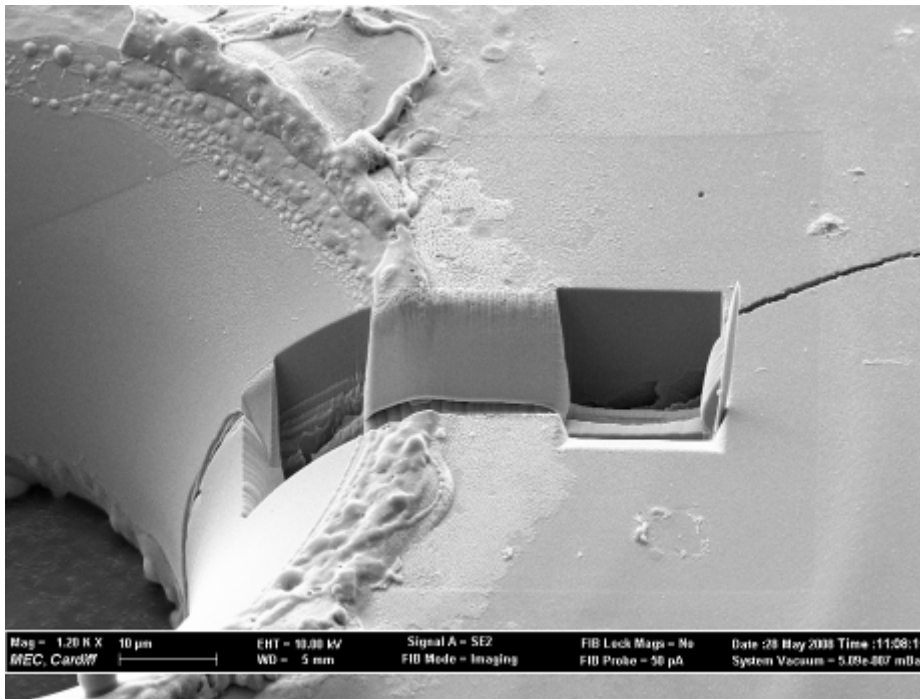


Replication by injection molding



- ✧ Battenfeld Microsystem 50
- ✧ Material: SABIC 56M10 (PP)
- ✧ Process parameter:
 - ➔ Barrel temperature 220 °C
 - ➔ Mold temperature 40 °C
 - ➔ Injection speed 200 mm/s
 - ➔ Cooling time 4 s
 - ➔ Holding pressure time 6s

Micromachining response of amorphous and crystalline Ni-based alloys



SEM image of the FIB milled trench in an amorphous Ni₇₈B₁₄Si₈ that starts at the hole side wall and continues through its surrounding area

Conclusions:

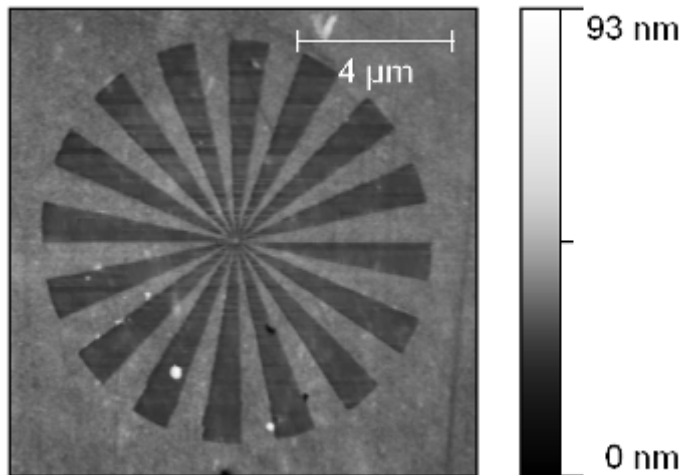
- ✧ Laser processing both with short and long pulses is a promising technique for micromachining amorphous Ni-based alloys because does not lead to material crystallisation.
- ✧ There was no signs of crack formation in amorphous Ni-based alloys and thus a higher surface integrity can be achieved after after µs laser machining.
- ✧ The µs and ps laser machining of micro-scale features and micro-structures in metallic glasses is possible while preserving the attractive mechanical properties of metallic glasses.

Quintana I., Dobrev T., Aranzabe A., Lalev G., Dimov S. (2008) Investigation of amorphous and crystalline Ni alloys response to machining with micro-second and pico-second lasers, *Applied Surface Science*, 255(13-14), 2009, 6641-6646

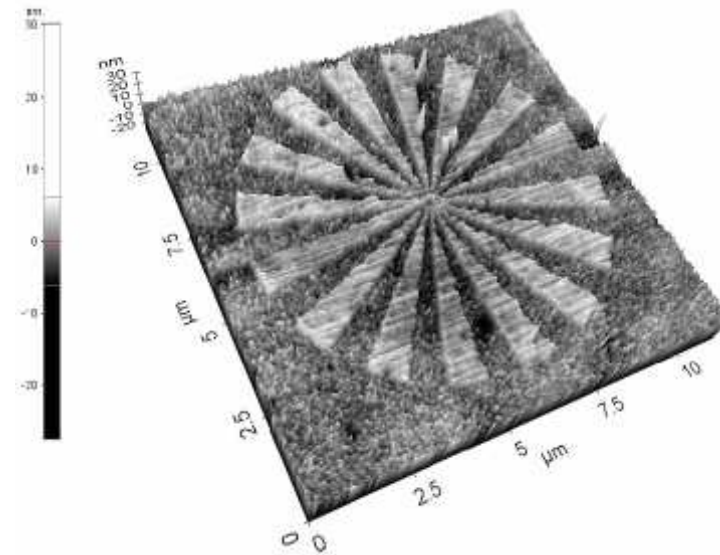
AFM-scratching for master making

■ Feasibility study for rapid master making

AFM scratching of Au/Pd layer on Si substrate



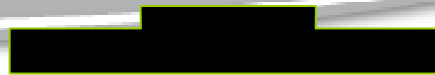
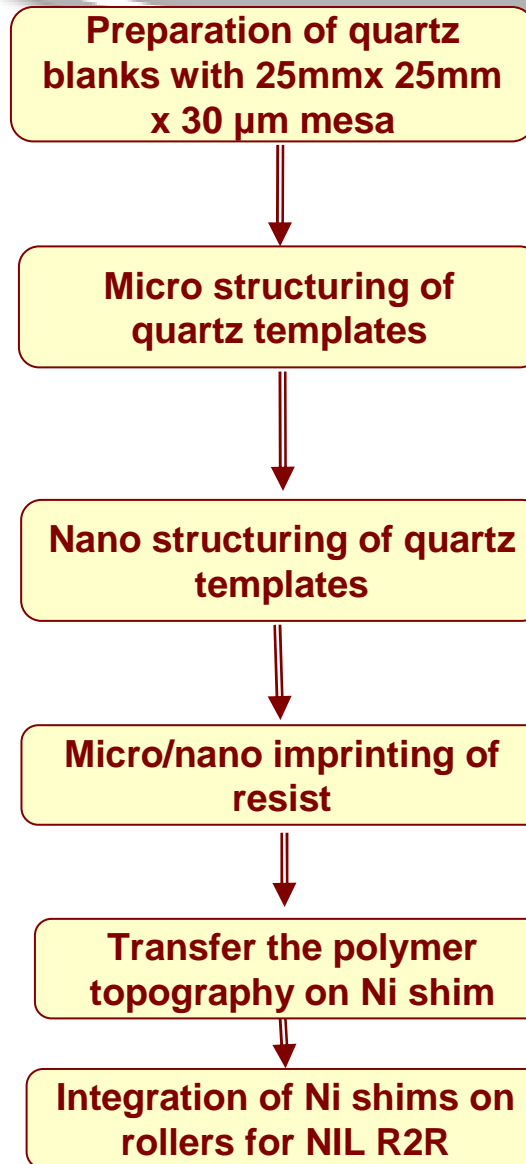
Micro injection moulding (PP replica)



■ Main result

- Validation of AFM scratching as a master making route for small batch manufacture of nano structured polymer components.

Hybrid Processing Chain for Organic Electronics

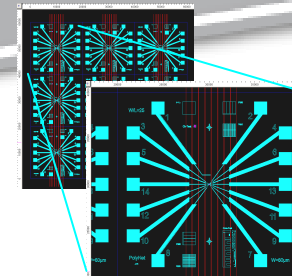


Photolithography

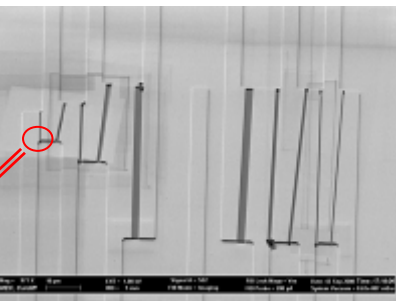
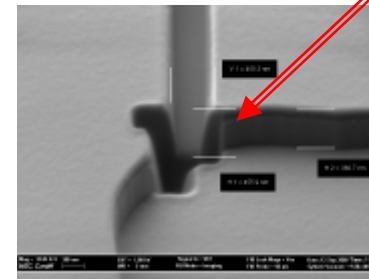
FIB

UV NIL

Ni eletroforming

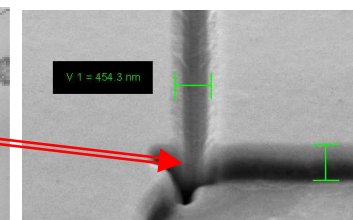
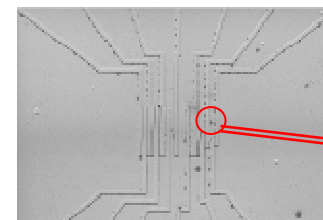


Pre-structured quartz template



Adding 300-400nm functional features

Producing an array of 25x25 mm functional fields



V. Velkova, G. Lalev, H. Hirshy, S. Scholz, J. Hiitola-Keinänen, H. Gold, A. Haase, J. Hast, B. Stadlober, S. Dimov (2010)
Design and validation of a novel master-making process chain for organic and large area electronics on flexible substrates,
Microelectronic Engineering

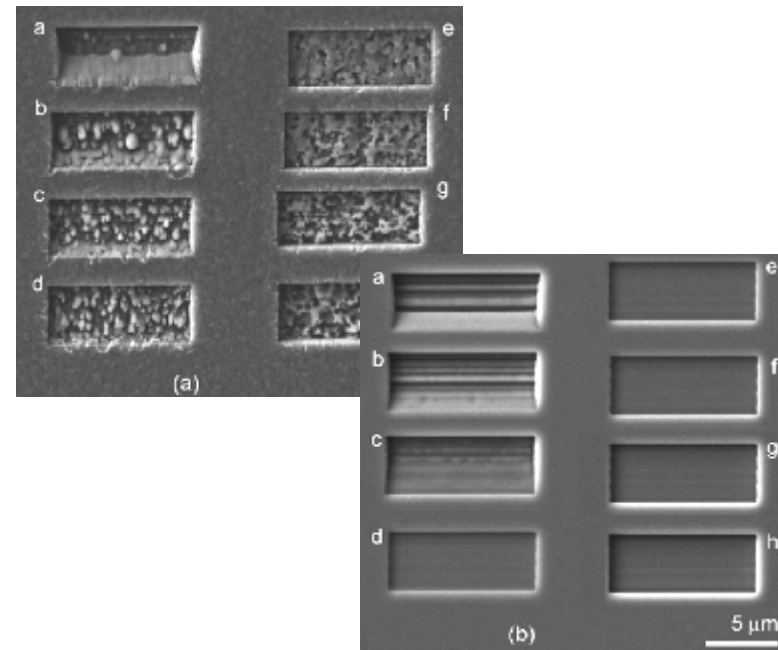
Maturity assessment of processes and process pairs



The proposed work comprises the following tasks:

- (i) Characterisation of the morphology of the coatings
FIB/SEM(STEM) installation
- (ii) Micro/nano structuring of the Ti(TiC-N) coatings with FIB
- (iii) Micro/nano-structuring of the Ti(TiC-N) coatings with Laser
- (iv) Characterisation of the surface integrity of the resulting patterns using AFM or/and SEM.

Polycrystalline (a) and amorphous (b)
Ni₇₈B₁₄Si₈ - 90 s exposure time & scan loops
of 1, 2, 3, 4, 10; 20, 40 and 56, respectively.



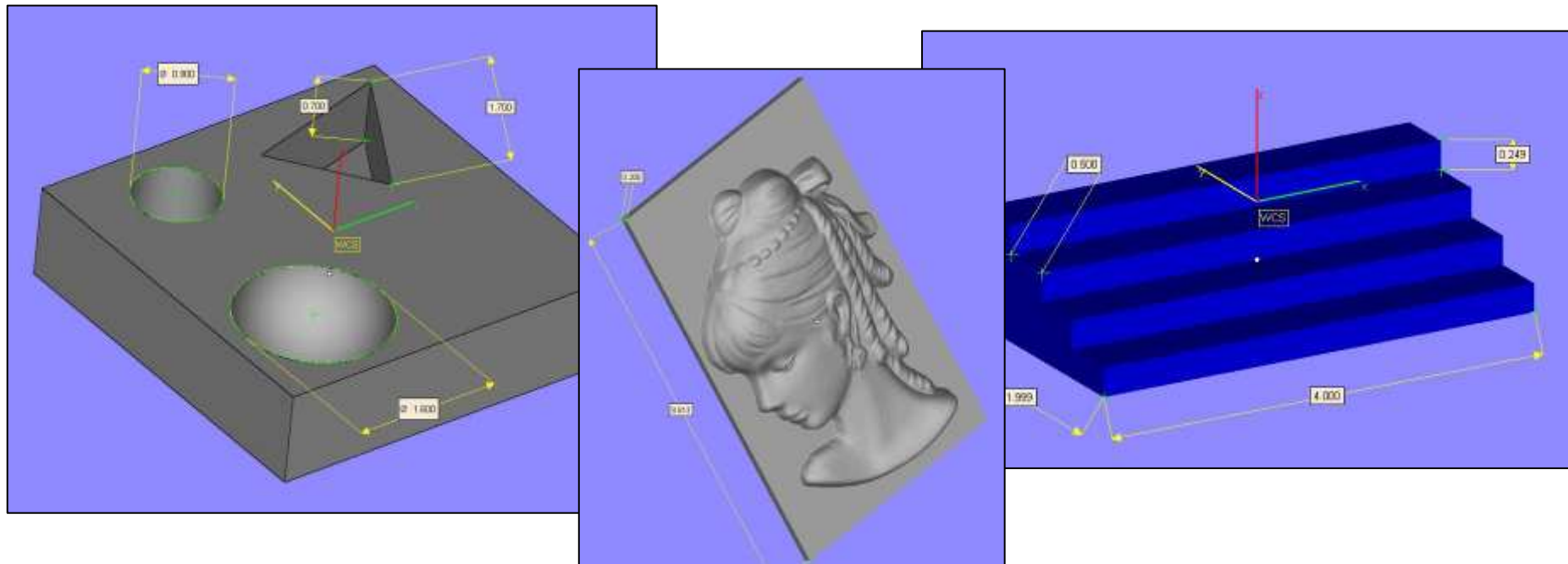
W Li, R Minev, S Dimov and G Lalev (2007)
Patterning of amorphous and polycrystalline Ni₇₈B₁₄Si₈
with a focused-ion-beam, *Applied Surface Science*,
Vol. 253 (12), 5404-5410

Maturity assessment of processes and process pairs

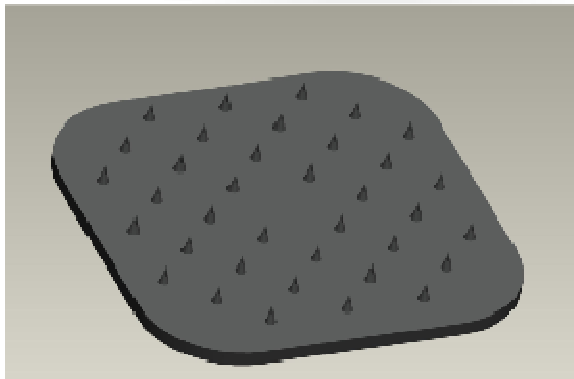


Comparative study on laser material processing utilizing DPSS and fibre lasers (second and third generation) for tool making and prototyping

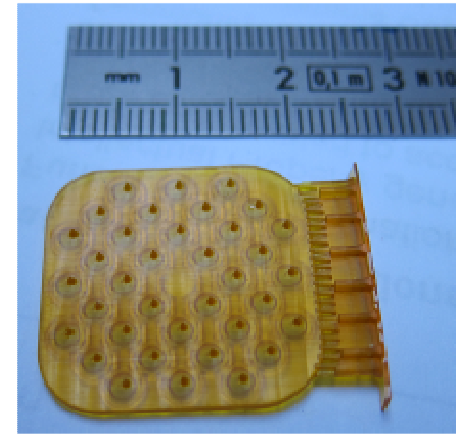
- agreeing the design of test part & selecting a material
- test structures:
 - (i) DMG machine utilizing IPG fibre laser source
 - (ii) MEC 3G fiber laser source
 - (iii) MEC DPSS laser source
- characterization: surface roughness, heat affected zones, planarity and uniformity, dimensional accuracy and true form representation



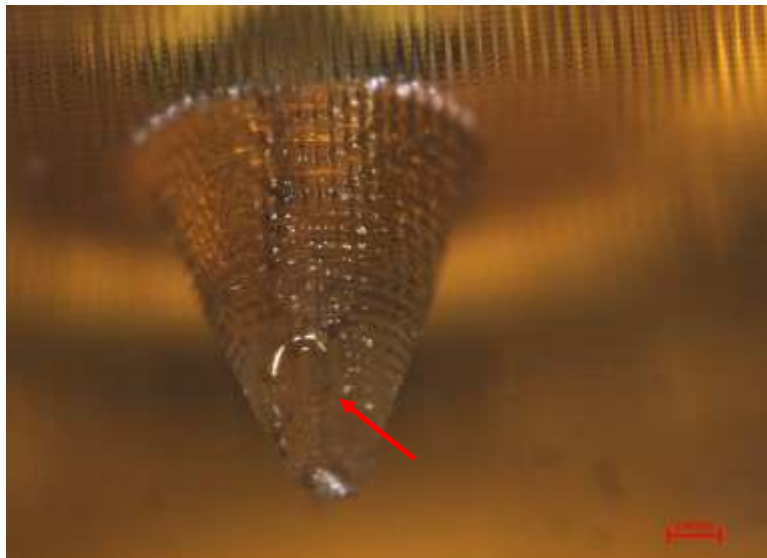
Feasibility Study: Array of hollow Micro needles



Model



Micro SLA



Pico Second Laser Hole: 50 μm

Technology Datasheets



Thin film deposition

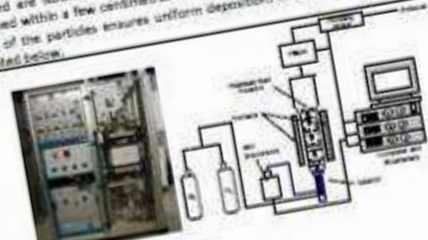
CVD

CEA-LITEN

Contact: Sébastien Dorel sebastien.dorel@cea.fr Phone: +33 438 783020
Fax: +33 438 783020

Material class: Silicon X Polymer X Metal X Ceramic X Glass X Organic X Other X

Short technology description: Fluidized Bed Deposition (FBD-MOCVD). Compared with wet chemistry methods Chemical Vapour Deposition (CVD) allow avoids various time-consuming oxidation and reduction steps, which might influence the purity of the material obtained. Combined CVD process with fluidisation allows deposit particles on porous powders. The principle of this method is that a bed of solid particles over a gas distribution plate is made to behave like a liquid by passing gas through it at a flow rate above critical value (value of a gas velocity when forces lifting particles become equal to the downward gravitational forces causing the particles to become suspended within the fluid). During fluidisation metal-organic precursor is injected into the bed in form of small drops dispersed in inert gas. The metal-organic precursor diluted in organic solvent (organic solvents are used because they have low temperature of evaporation) is introduced in an evaporator. The drops are instantaneously evaporated and transported to the deposition zone in a flux of gas. The high degree of contact between gases, powders and reactor walls ensure that conditions in the gas-solid bed are isothermal. In consequence, gaseous precursors are frequently wholly consumed within a few centimetres of the fluidized bed reactor entrance. The vigorous mixing of the particles ensures uniform deposition. A schematic graph of apparatus is presented below.

Typical structures and designs: 


Limitations/constraints: • Deposition on powders (from 50µm to 2mm diameter)
• Flat support

Special features: • Deposition on powders (from 50µm to 2mm diameter)
• Flat support

Material examples: • PE and PP particles

Micro nano patterning

Petko Petkov petkov@tekniker.es Phone: +34 (91) 20 67 40
Fax: +34 (91) 20 67 40

Material class: Silicon X Polymer X Metal X Ceramic X Glass X Organic X Other X

Short technology description: Microsecond laser: 1064nm wavelength, 10µs pulse, 50kHz pulse frequency, 20µm Machining limited to metals and ceramics Full 3D structures limited only by 2.5 aspect ratio and minimum 50µm Pico-second laser: 355nm and 532nm wavelength, 12ps pulse duration, up to 100kHz Machining virtually any material 3D structures with a minimum feature size down to 2µm

Typical structures and designs: 




Limitations/constraints: • Undercuts
• Face roughness for µs laser 1µm
• Face roughness for ps laser 5µm
• Vertical walls possible, but do less than 5deg possible

Replication

REPLICATION LAB -- Microreplication


TEKNIKER, Spain

Contact: Iñaki Etxebarria ietxebarria@tekniker.es Phone: +34 (943) 20 67 40
Fax: +34 (943) 20 67 40

Material class: Silicon X Polymer X Metal X Ceramic X Glass X Organic X Other X

Short technology description: Production of short series of microcomponents made out of polymers and metal by Hot embossing system Jenoptik HX303 Substrate: 4" and 6" waffer; Mask: 4" Maximum force 200 kN Maximum temperature 220°C Automatic demolding Microinjection molding (Battenfeld Microsystem) For small components in the milligram range Extremely short cycle around 1.5s

Typical structures and designs: 

Limitations/constraints: • Aspect ratio of 4
• Total volume of material injected 1.2 cm³ (part + runner)
• Maximum embossed area: 4" waffer

Material examples: • Hot embossing of bulk and thin film polymers: PMMA, PC, DGE, PLA, PCL, Polycarbonate and commercial NC thermoplastic polymers
• Microinjection: polymers (PSU, PPS, PEEK) and metal powders (stainless steel and alumina)

Acknowledgements



EUMINAFab partners: KNMF, CU-MEC, CEA-liten, CRF, KTH, TEKNIKER, PHILIPS, FhG, IMS-NANO, NPL

- ✪ *European Commission* for supporting EUMINAFab
- ✪ EMRS for the kind invitation

Thank you for your kind attention!

www.euminafab.eu

