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Micro-processing of polymer parts for life sciences applications

Choudhury, N.; de Grandpré, C.; Mir, H.; Bardetti, A.; Thibault, F.; DiRaddo, R.

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NRC-CNRC

*Industrial Materials
Institute*

CompMed
Symposium on Computer Simulation in Medicine
May 16-18, 2007

Micro-Processing of Polymer Parts for Life Sciences Applications

N. Choudhury, C. de Grandpré, H. Mir, A. Bardetti, F. Thibault, R. DiRaddo

May 17th, 2007



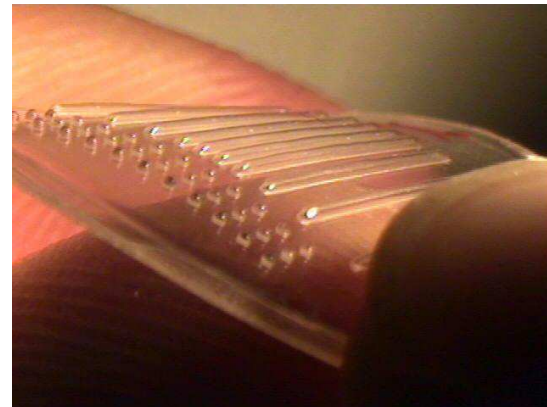
National Research
Council Canada

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de recherches Canada

Canada

Micro-Fabrication

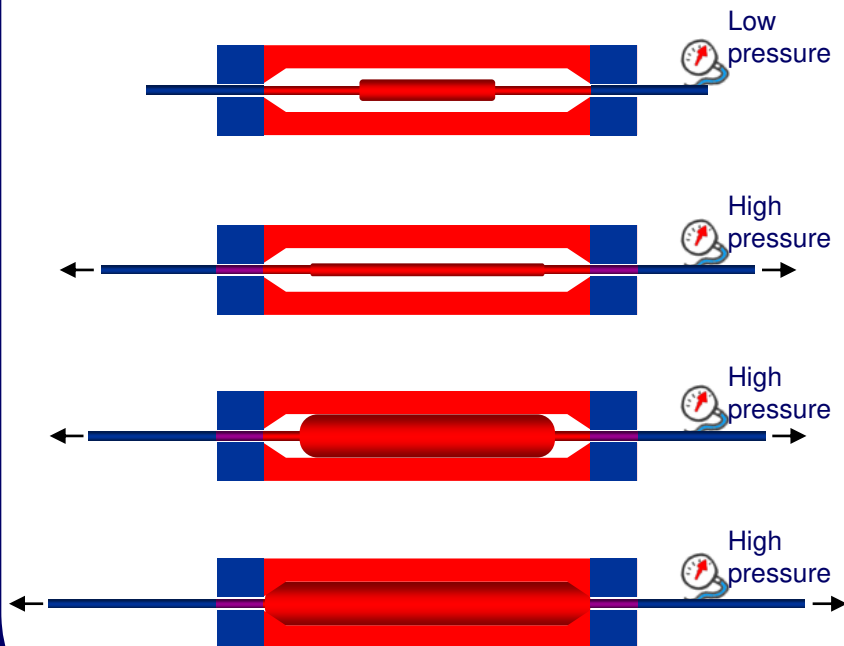
- Micro-scale (range from μm to mm)
- Miniaturization technologies found in many areas
 - Optics, electronics, medicine, bio-technology, communications, and avionics
 - Wide range of engineering materials, three-dimensional features, and high relative accuracies
- New processes and manufacturing equipment being developed



Process Descriptions

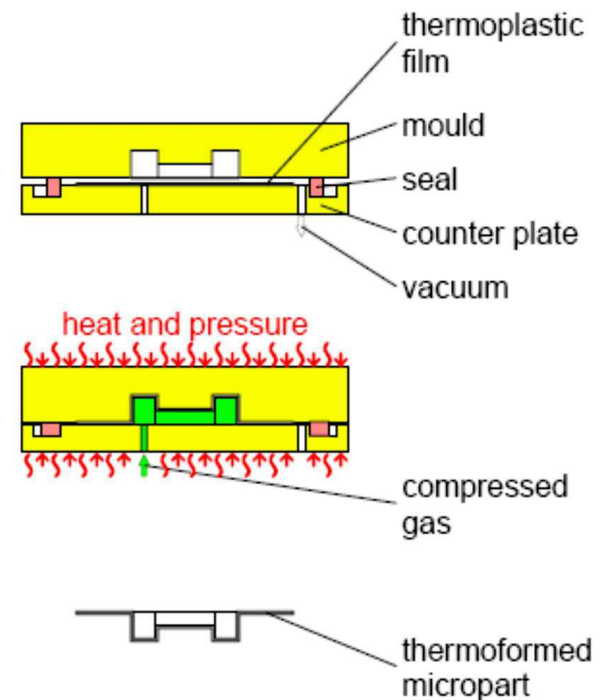
Blow moulding

Used to form hollow parts



Thermoforming

Used to form thin walled parts with high surface area

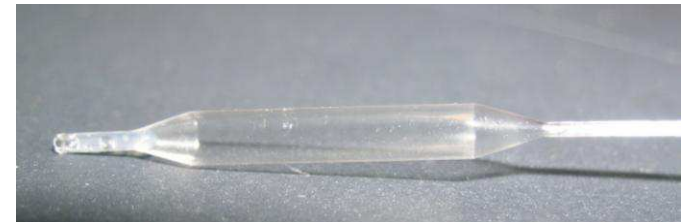


Micro-Blow Moulding

Medical Balloon Products

Driven by increase in minimally invasive procedures and localized drug delivery

- Interventional cardiology
- Minimally invasive spinal therapy (kyphoplasty)
- Neurology
- Interventional gastro-enterology (stone extractors)



Micro-Blow Moulding

IMI Infrastructure

Tube Fabrication

Extruder



Tube Preparation

Computerized Double-End Stretcher



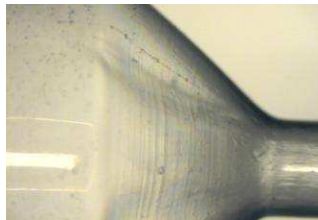
Blow Moulding

Computerized Hot-Mould Forming
Machine



Tubing/Balloon Validation Tests

Hydraulic Pressure-Tester, Micro-Structure Inspections



Catheter Assembly

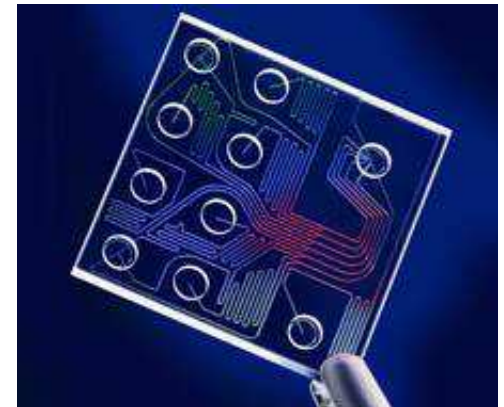
Tube Welding Machine, Multi-Flute Balloon Folder



Micro-Thermoforming

Life Sciences Products

- Pioneered by Forschungszentrum Karlsruhe Research Center
 - Two step process to heat seal rigid backing onto formed part
- Lab on a chip/micro fluidics
 - Capillary electrophoresis
 - *In-vitro* cell culture
- Thin films 25 μm (0.001")
 - Polystyrene, Polypropylene, Polycarbonate
 - Transparent, thermally stable

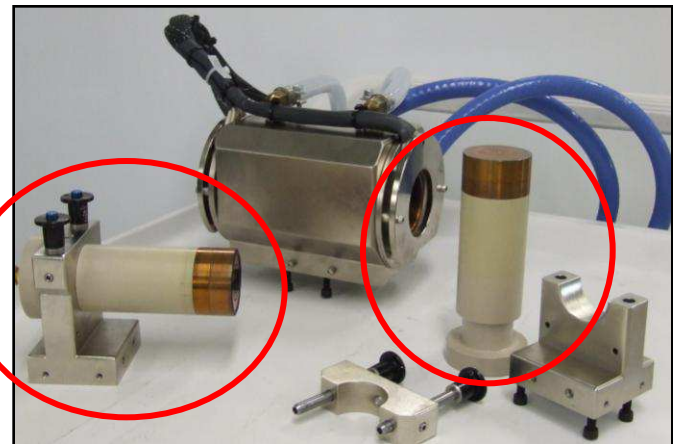


Micro-Thermoforming

Infrastructure Modifications

- Rapid heating and cooling
- Pressurizing system up to 1000 PSI with vacuum
- Quick mould opening and closing
- Mould can be machined at an affordable price

Computerized Hot-Mould Forming Machine

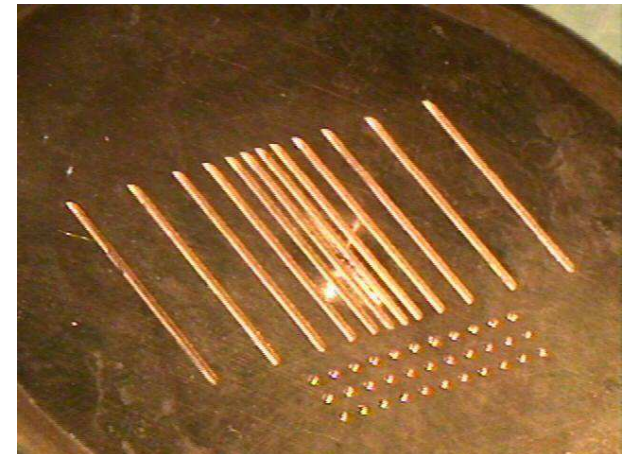


Micro-Thermoforming

Mould Modifications

Blow moulding machine mould modifications

- Beryllium copper mould
- Pits machined with sub miniature end-mills
 - 375 μm wide and 375 μm deep
- Series of lines burned by EDM machining
 - 375 μm wide
- Surface finish of Ra 0.2 μm is necessary



Micro-Scale Parts at IMI

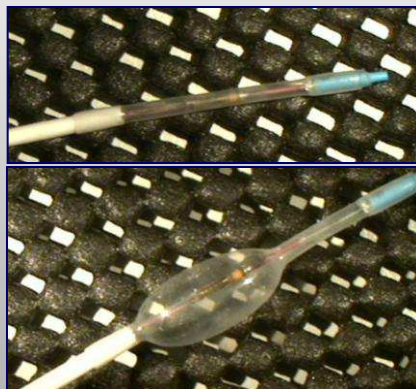
Medical Balloons



- Minimally Invasive Interventions
- Drug Delivery



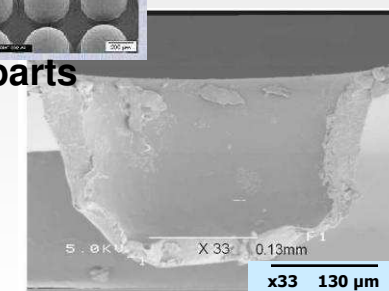
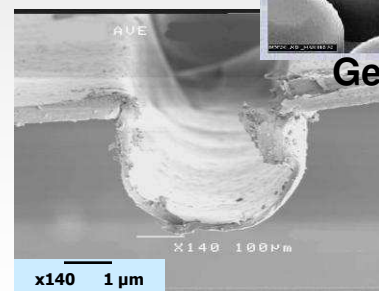
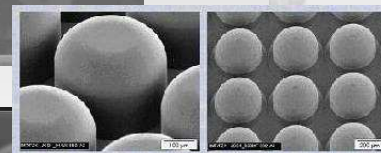
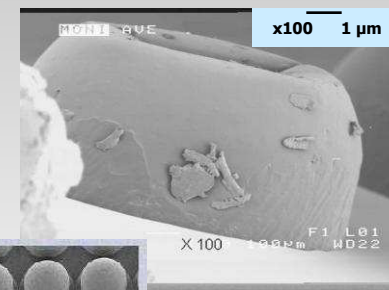
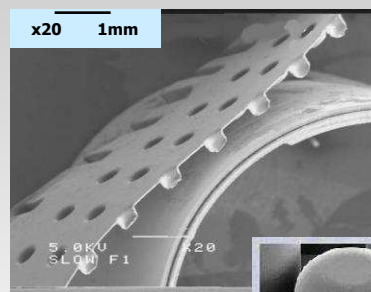
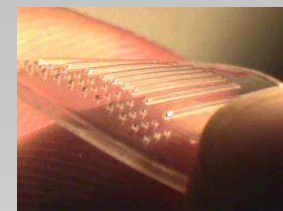
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NRC-IBD

Life Science Products

- “Lab-on-a-Chip”
- Cell Culture



German parts

Process Simulation

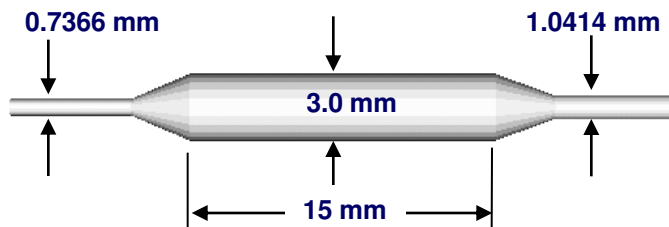
Blow moulding

Blowsim 8.4 with PEBAX model
(Elasto-Plastic) -- with slip

Tubing:

Material : PEBAX
Diameter = 0.9144 mm
Thickness = 0.176 mm

Mould Dimensions:



Thermoforming

Blowsim 8.4 with KBKZ model
(Viscoelastic)

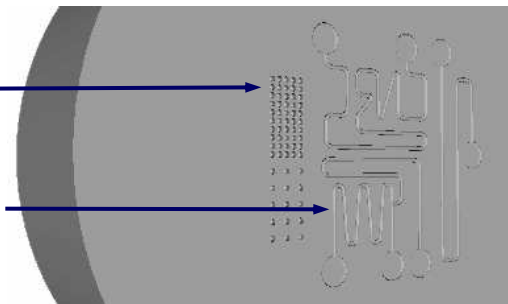
Sheet:

Material : PS
Thickness = 0.025 mm

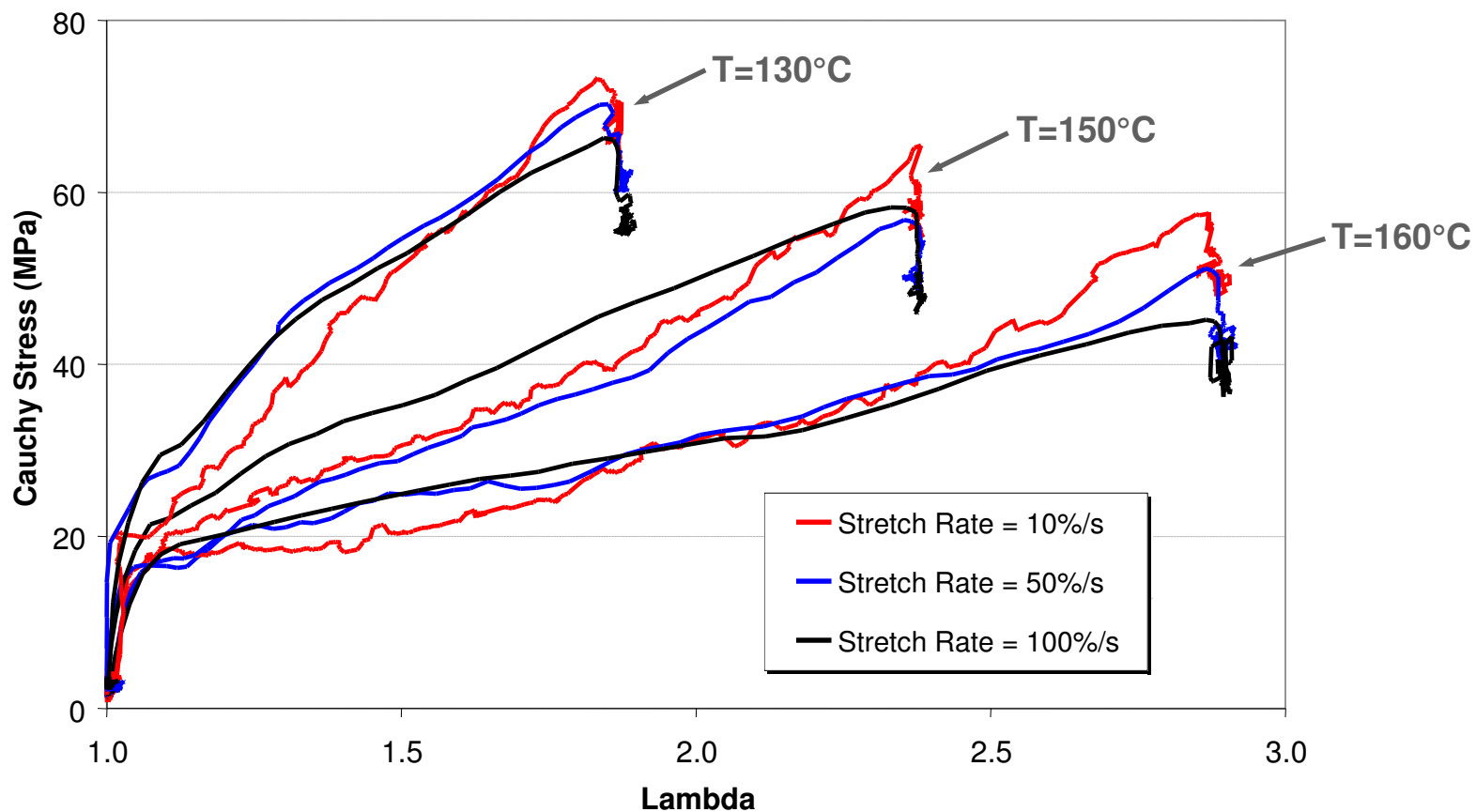
Mould Dimensions:

Pits
0.38 mm wide
0.38 mm deep

Channels
0.30 mm wide
0.11 mm deep



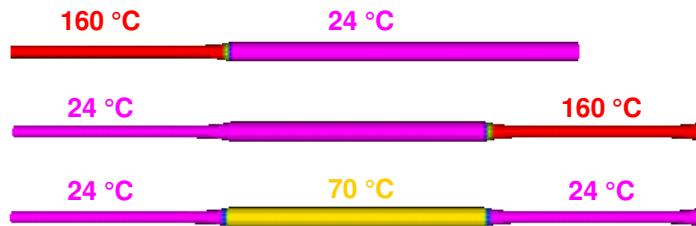
PEBAX Material Model



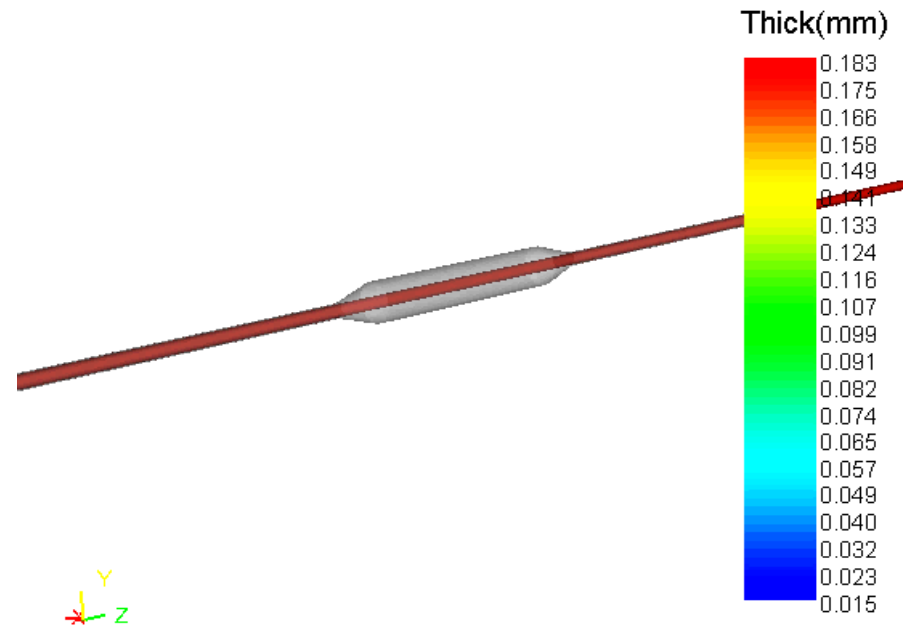
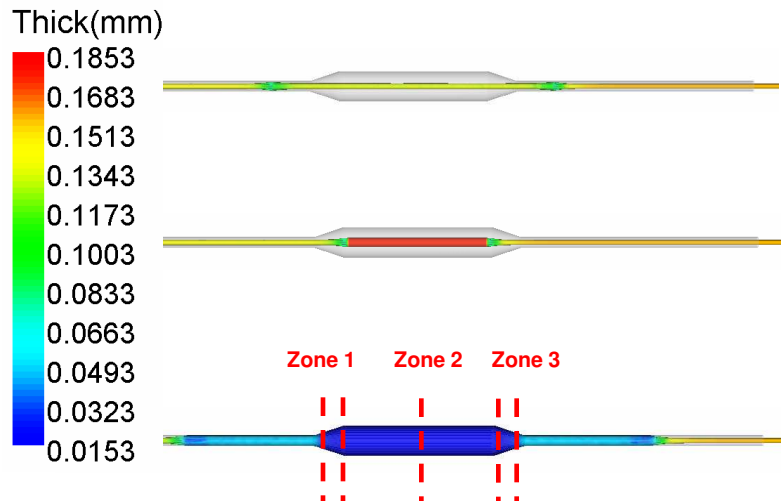
Micro-Blow Moulding

Simulation and Validation

Parison Preparation



Stretch Blow Moulding



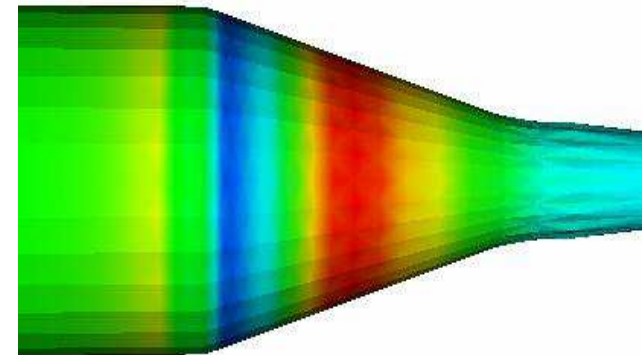
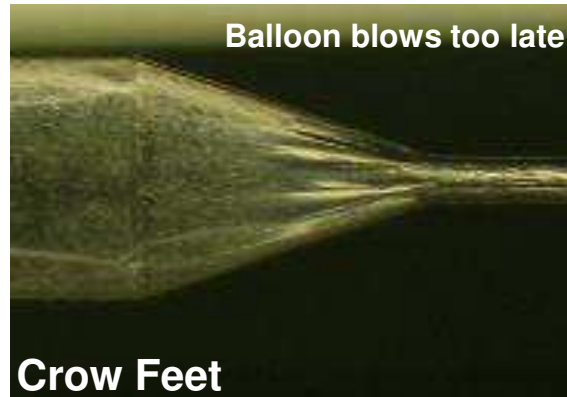
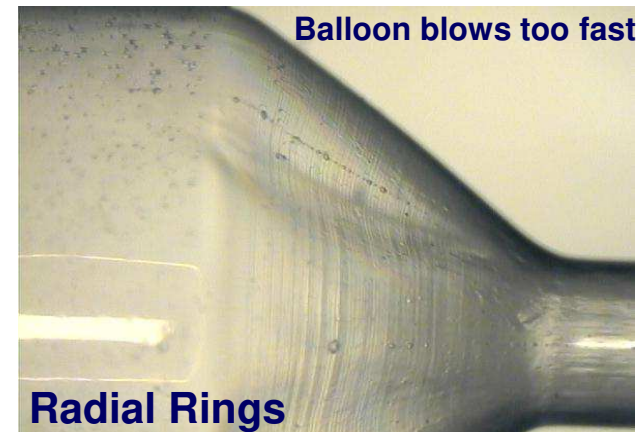
Thickness Comparison

Thickness (mm)	Zone 1	Zone 2	Zone 3
Experimental	0.0175	0.0180	0.0175
Simulation	0.0197	0.0170	0.0197

Micro-Blow Moulding

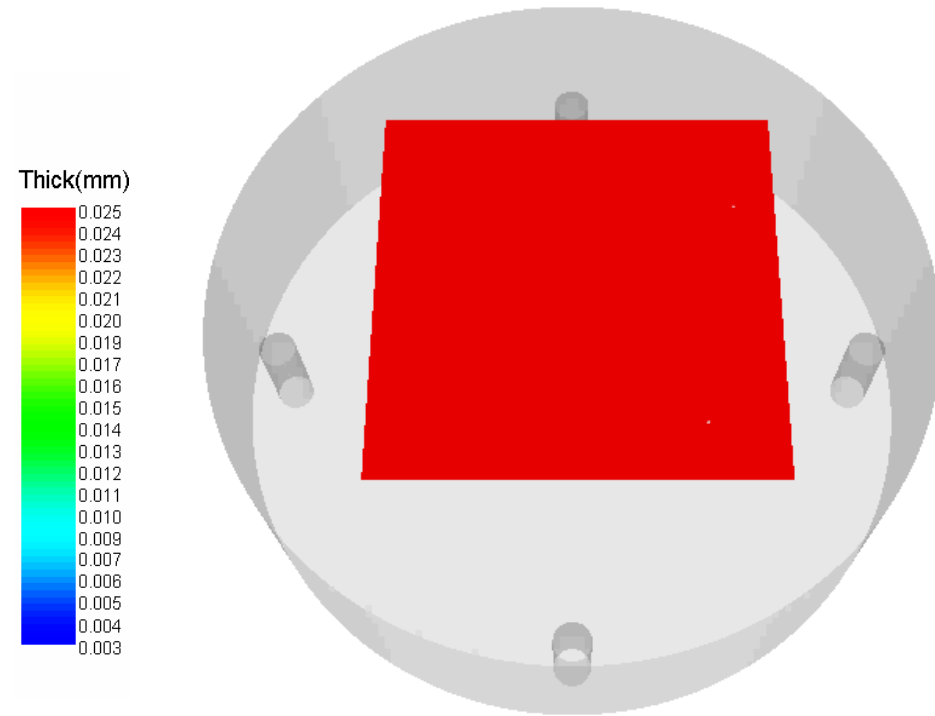
Processing Challenges

- Multi input-output process
- Complex material behaviour
- Miniature products, difficult to see



Simulation

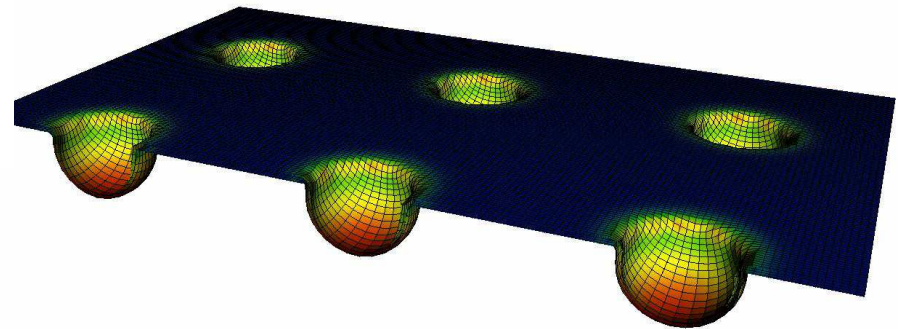
Thermoforming



2.5D Simulation



3D Simulation



Conclusions

- Micro-fabrication at IMI
 - Micro-blow moulding: optimized process for balloons
 - Micro-thermoforming: investigative work promising
- Numerical simulations useful tool
 - biaxial stretch behavior of PEBAX in micro-blow moulding
 - wall thickness distribution of formed parts
 - presence of defects (useful for industrial optimization)



Thank you



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