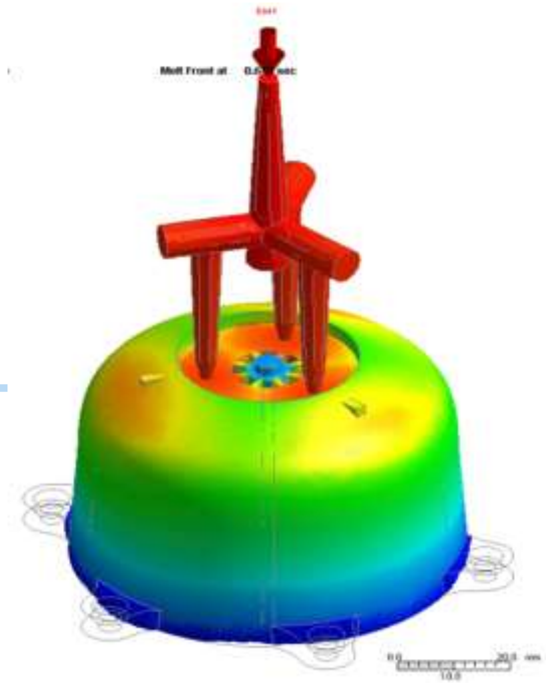
Moldex3D Application in Microcellular Injection Molding Development

SimpaTec Sarl



Fabien BUCHY
24.04.2013

SimpaTec

- founded 1/2004
- Reseller Moldex3D
  - since 2004 in Germany
  - since 2005 in BeNeLux
  - since 2006 in France, Swiss et Austria
  - Office at Guebwiller, Grenoble, Aachen, Stuttgart, Bangkok.

- Since 10/2007 Beaumont Technologies Inc. reseller

SimpaTec - Focus

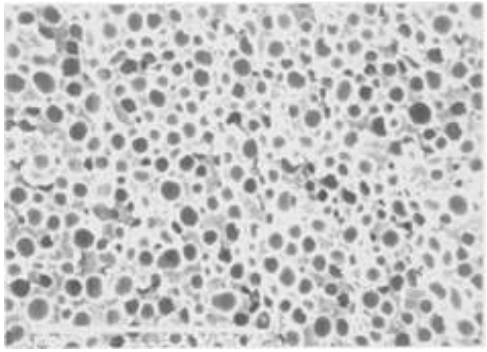
1. **Services**
   - Plastic injection simulation services;
   - Moldex3D distribution
   - Moldex3D support and training
   - BIMS seminar with Dr Vito LEO

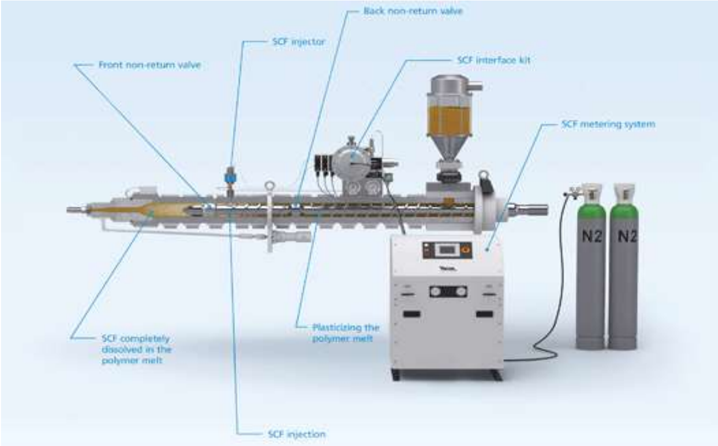
2. **Commitment**
   - Research
   - Software development
   - Workshop, seminar
   - Partnership…

Microcellular Foam Injection Molding

- The Microcellular Foam Injection Molding is based on the control of supercritical fluid (PBA) during the injection molding cycle to create millions of micron-sized voids in thermoplastics.

- MuCell® is most well known commercial microcellular foaming injection process registered and marketed by Trexel, Inc.

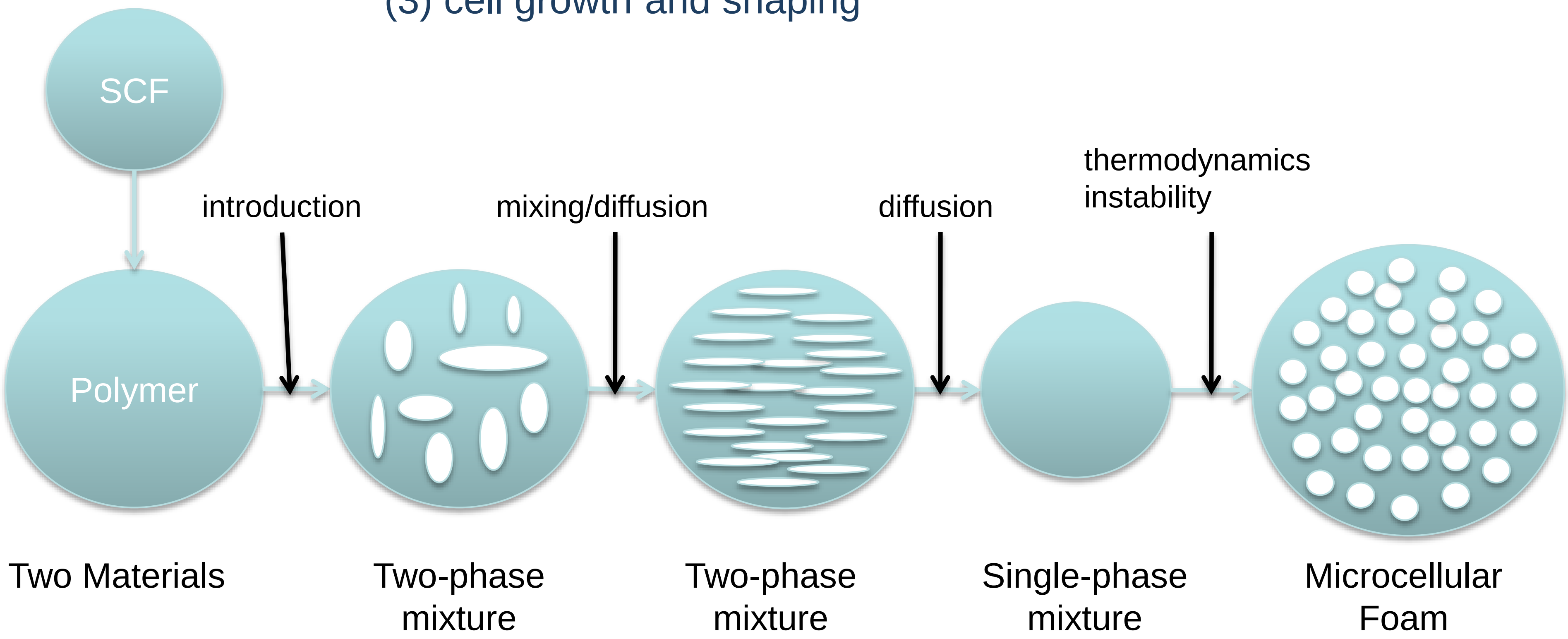




MuCell is a registered trademark of Trexel, Inc.

Microcellular Foaming Process

Three major steps: (1) formation of a uniform polymer-gas solution;
(2) cell nucleation;
(3) cell growth and shaping

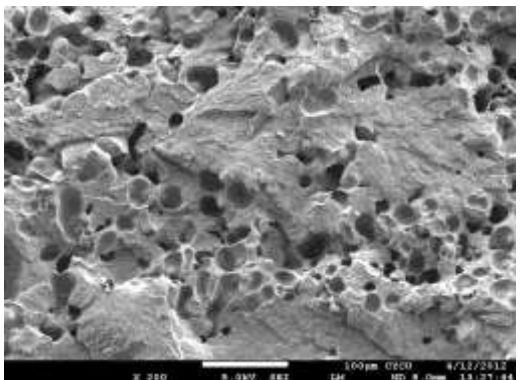


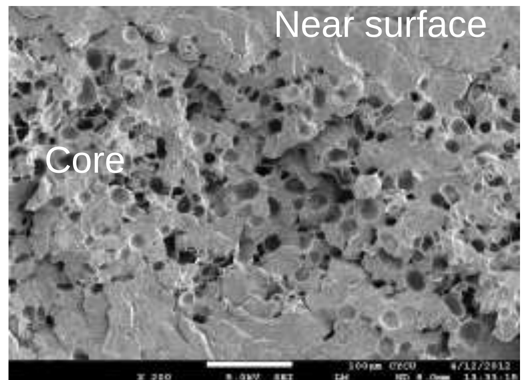
Reproduced from US patent No.5,158,986

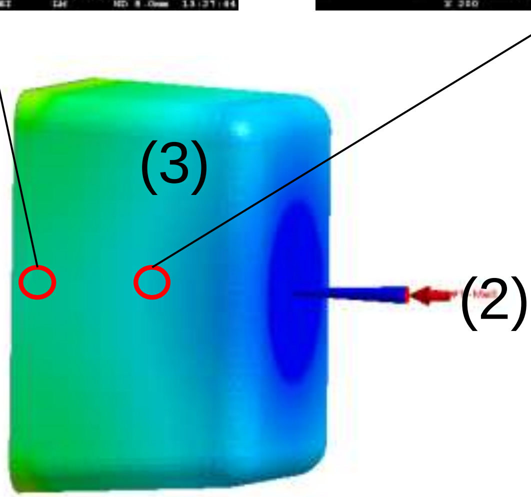
Principle

Three major steps:

(1) formation of a uniform polymer-gas solution;
(2) cell nucleation;
(3) cell growth and shaping



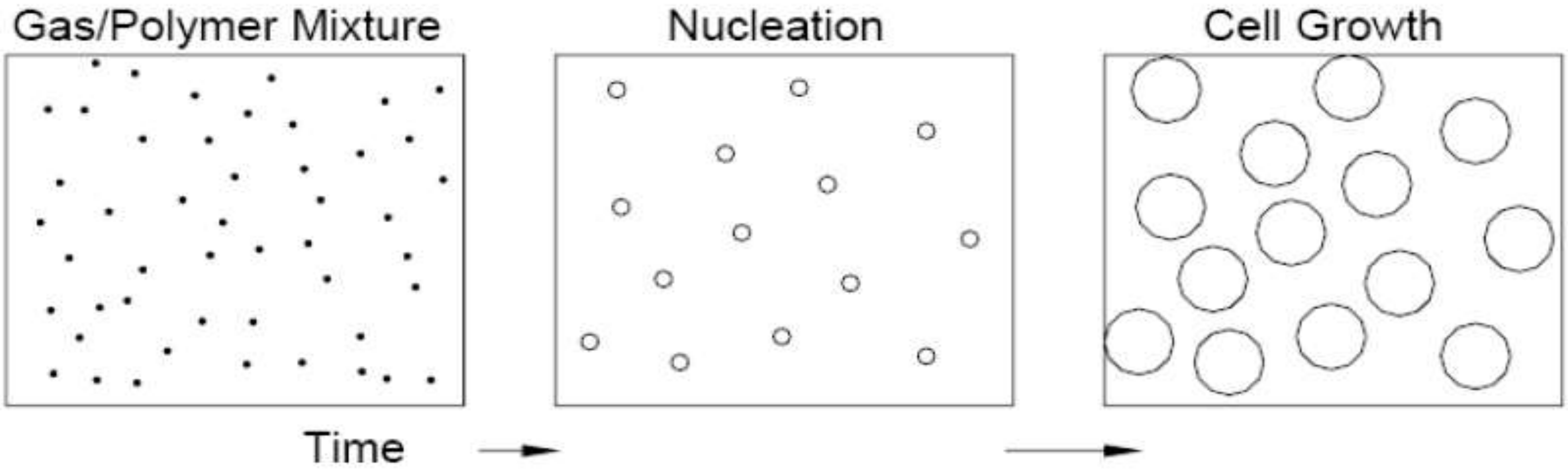




Foaming Fundamentals

- Cell Nucleation
  - Formation of cell site driven by the pressure drop
  - Related to the "cell number density"

- Cell Growth
  - Cell growth on cell site driven by the gas diffusion
  - Related to the "cell size"



Motivation and Objectives

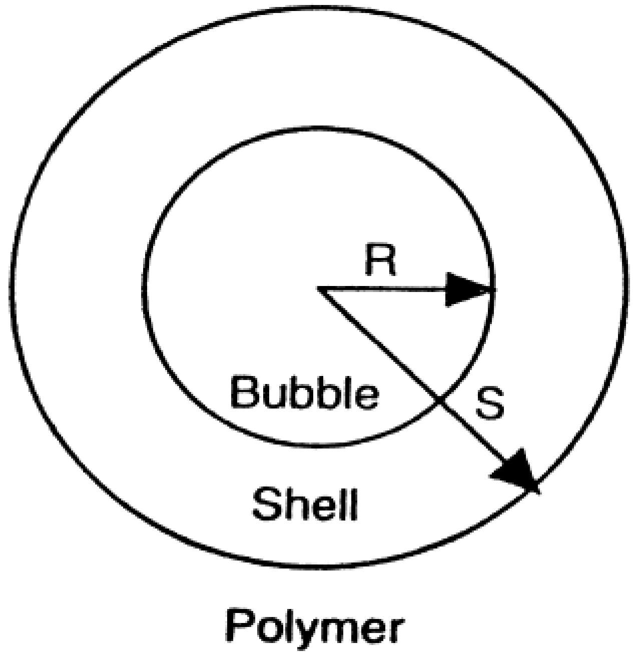
True 3D approach to provide more accurate micro-structure fluid flow information.

Predict cell number density and cell size by considering the cell nucleation and cell growth simultaneously.

Consider the interaction between cell development and melt flow during molding.

Consider the effect of cell structure to the part warpage.

Fundamental Theory and CAE Method

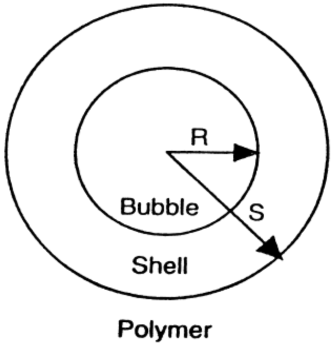


Theory of Cell Growth and Bubble Pressure

Radius over time

$$\frac{dR}{dt} = \frac{R}{4\eta}\left(P_D - P_C - \frac{2\gamma}{R}\right) \quad (2)$$

where R is the bubble radius, η the viscosity, P_D the bubble pressure, P_C the ambient pressure, and γ the surface tension.



Bubble pressure and cell concentration

Han and Yoo (1981) stated that

$$\frac{d}{dt}(P_D R^3) = \frac{6D(\Re_g T)(c_\infty - c_R)R}{-1 + \left\{1 + \frac{2/R^3}{\Re_g T}\left(\frac{P_D R^3 - P_{D0} R_0^3}{c_\infty - c_R}\right)\right\}^{1/2}}$$

where the assumed concentration profile:

$$\frac{c_\infty - c}{c_\infty - c_R} = \left(1 - \frac{r - R}{\delta}\right)^2$$

and δ is the concentration boundary thickness.

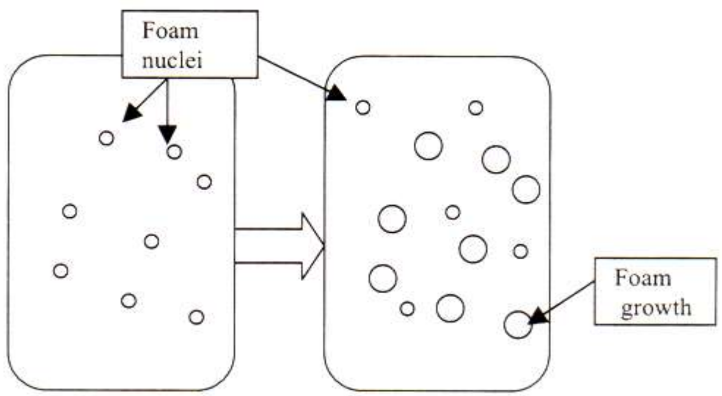
Theory of Cell Nucleation

Nucleation model

$$J(t) = f_0 \left(\frac{2\gamma}{\pi M_w / N_A} \right)^{1/2} \exp\left(- \frac{16\pi\gamma^3 F}{3 k_B T (\bar{c}(t)/k_H - P_C(t))^2} \right) N_A \bar{c}(t)$$

- *f0 and F are fitting parameters of bubble nucleation rate equation*
- *nucleation commences when the bubble nucleation rate* $J(t) > J_{threshold}$

$$\bar{c}(t) V_{L0} = c_0 V_{L0} - \int_0^t \frac{4\pi}{3} R^3(t-t',t') \frac{P_D(t-t',t')}{\Re_g T} J(t') V_{L0}\, dt'$$



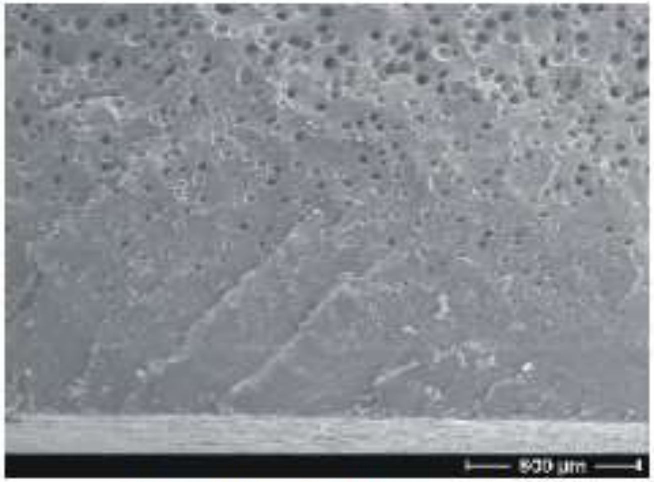
Output of Molex3D MuCell® Simulation

Cell radius distribution (typically 5-100 microns)

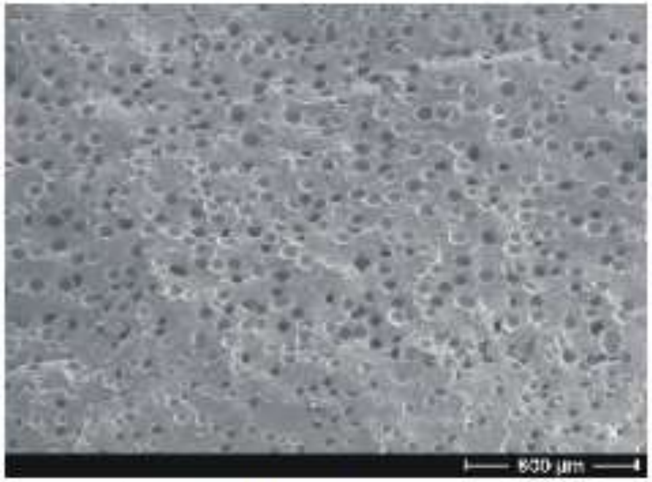
- Skin (as small as better)
- Core

Cell number density distribution (typically,10^7 -10^9 [cells/cm^3]

- Skin (as less as better)
- Core



Microstructure Near Surface

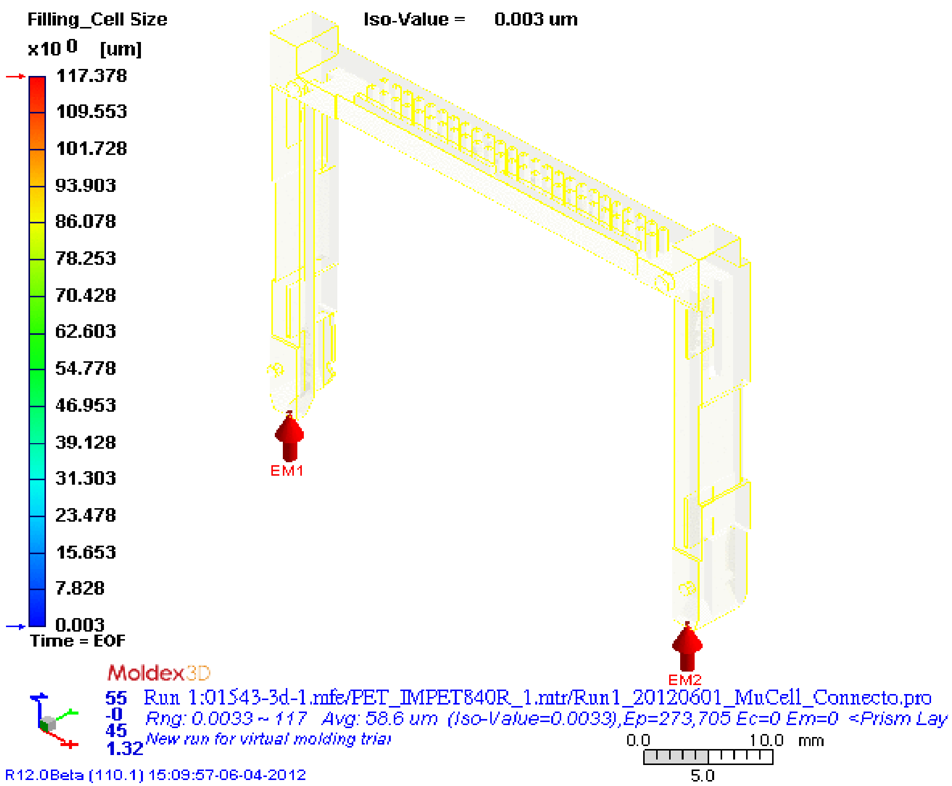


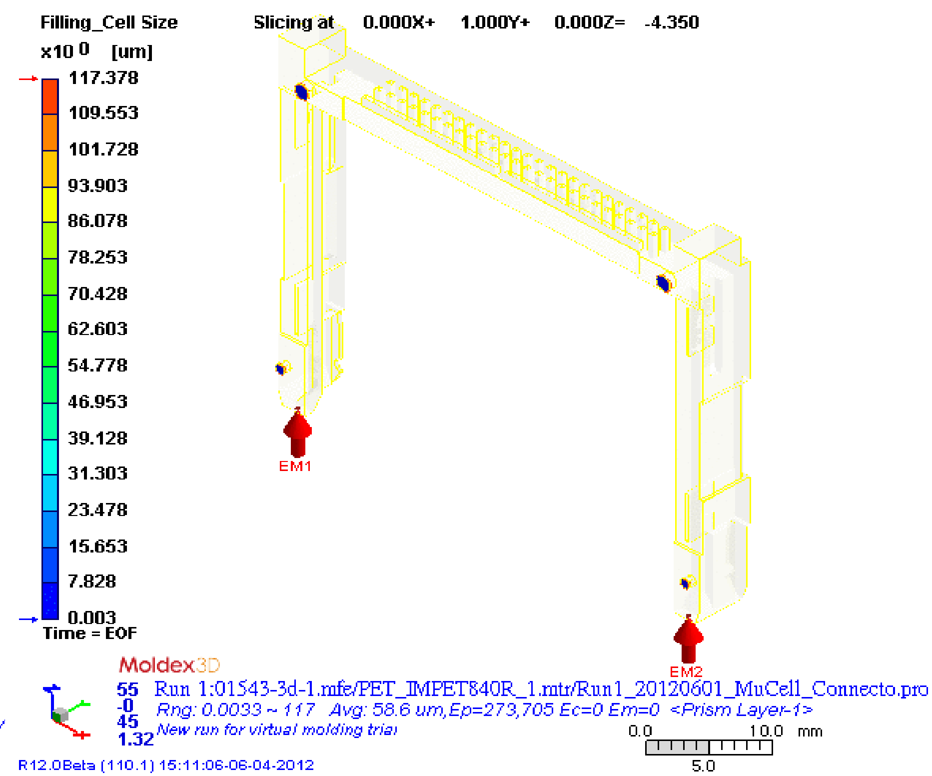
Microstructure Near Core

http://www.forestprod.org/composites09pilla.pdf /

Output of Moldex3D MuCell® Simulation

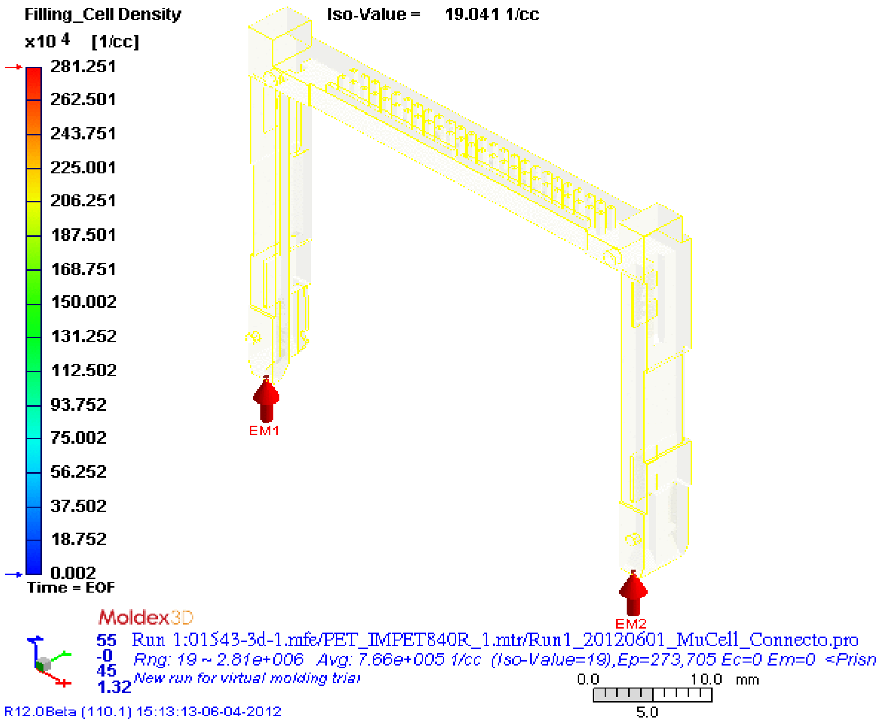
- Foaming quality: Micro cell sizes

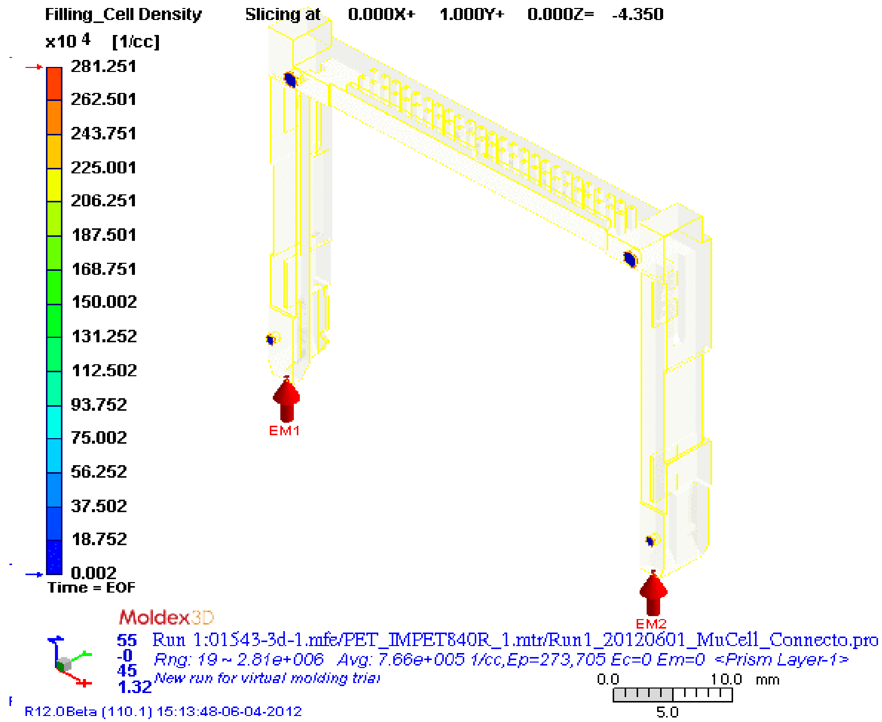




Output of Moldex3D MuCell® Simulation

- Foaming quality: Micro cell density distribution



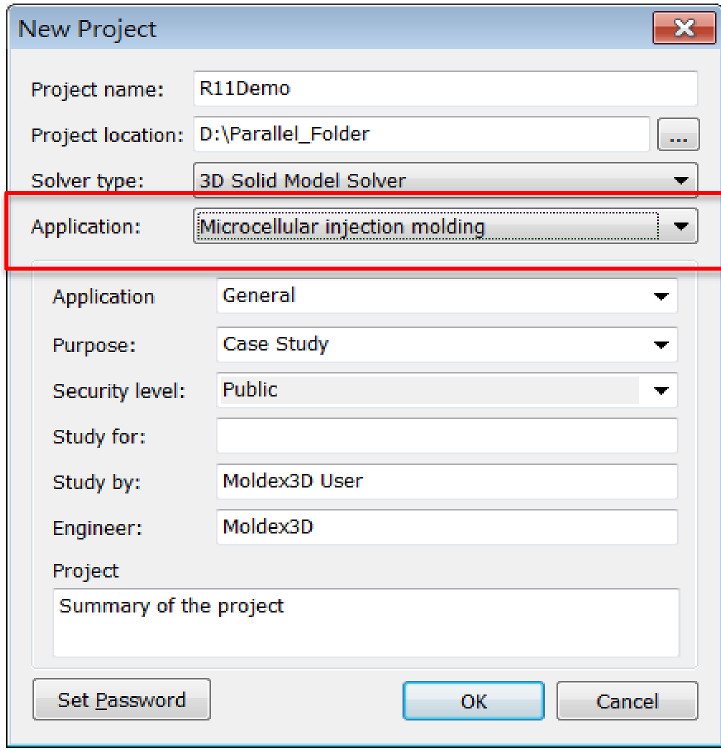


Moldex3D MuCell®:

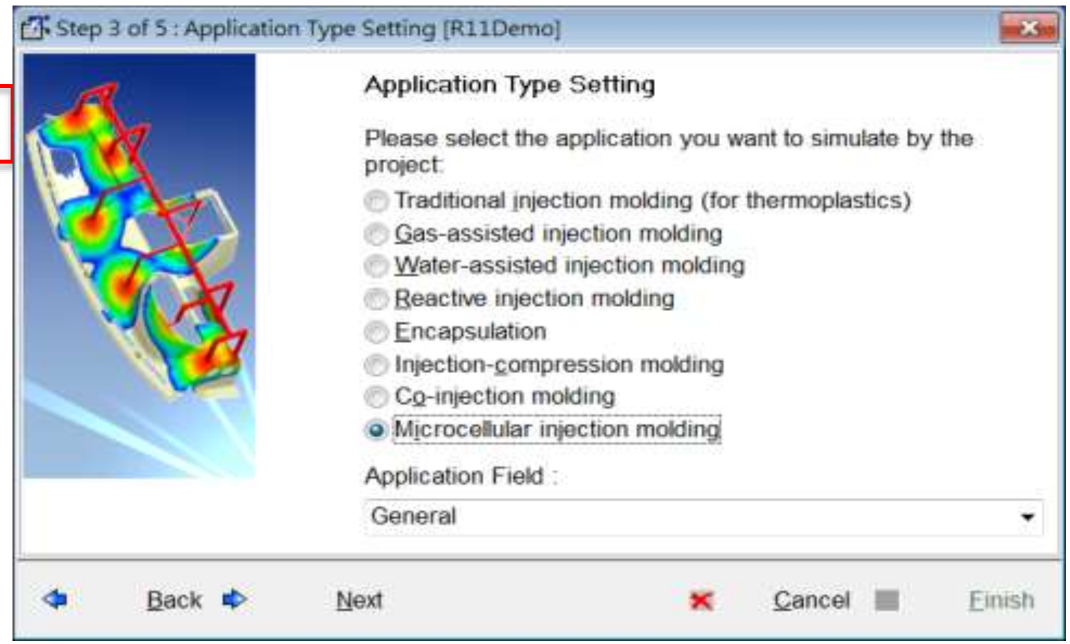
Step by Step Tutorial

Create a New Project

Choose type as “Microcellular injection molding” when creating a new project



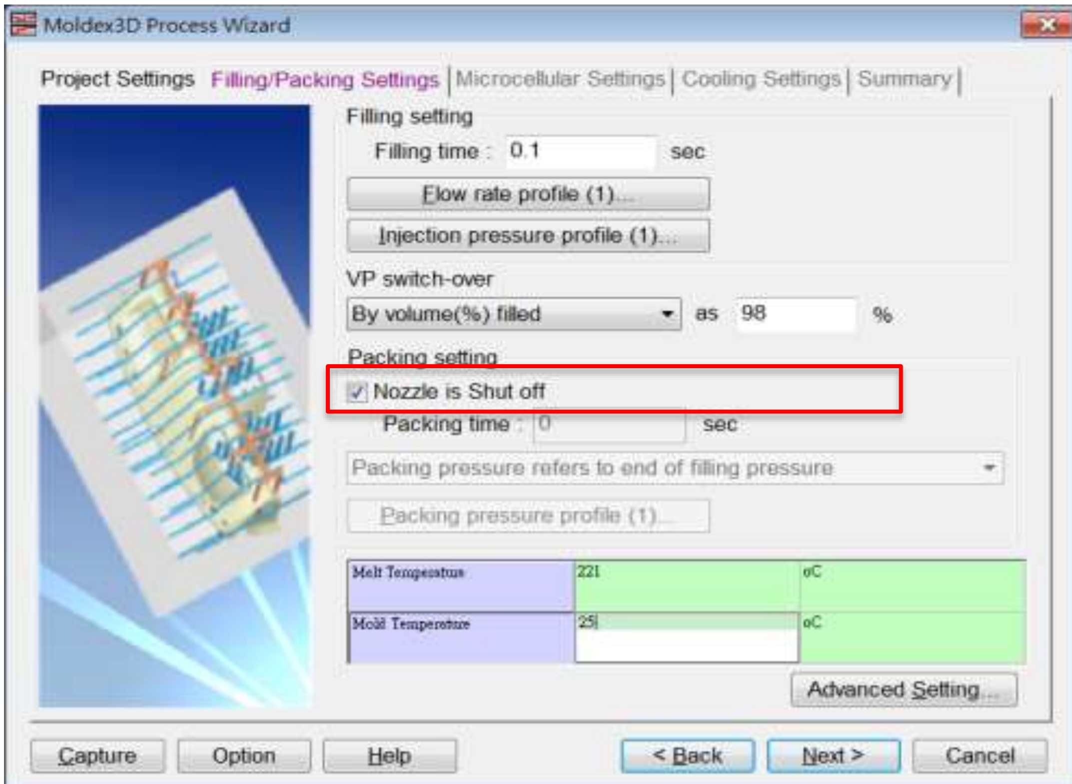
Simple Mode



Classic Mode

Process Settings (1)

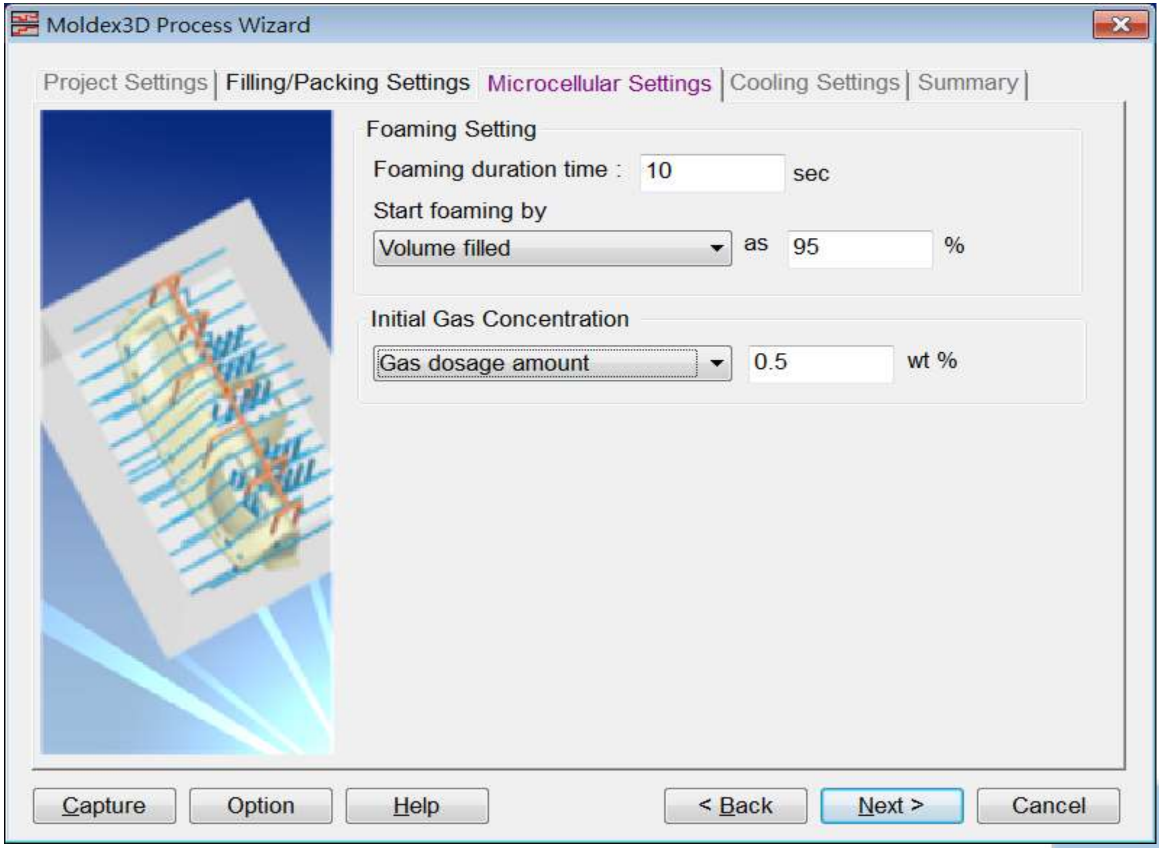
In filling/packing setting, users can shut off nozzle by checking the box “Nozzle is shut off”. This action can skip packing process and avoid reverse flow of melt during foaming.



Process Settings (2)

Microcellular settings

- three settings shown below: Foaming duration time, Start foaming setting, and Initial Gas concentration.



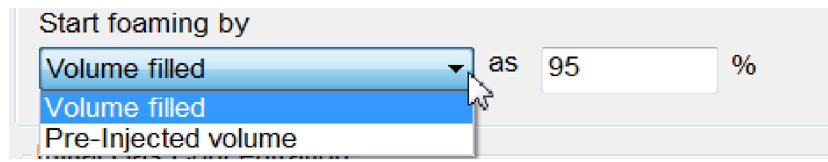
Process Settings (3)

Foaming duration time

– specify the holding time (sec) after filling to simulate the foaming process, which includes cell growth and solidification.

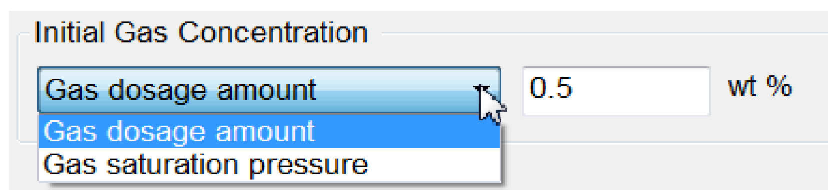
Start foaming by (Control shot size)

– If “Nozzle is shut off” is selected, nozzle is shut off at this starting time. Users can define the starting time in terms of *Volume filled* (%) or *Pre-injected volume* (cm^3) as below.



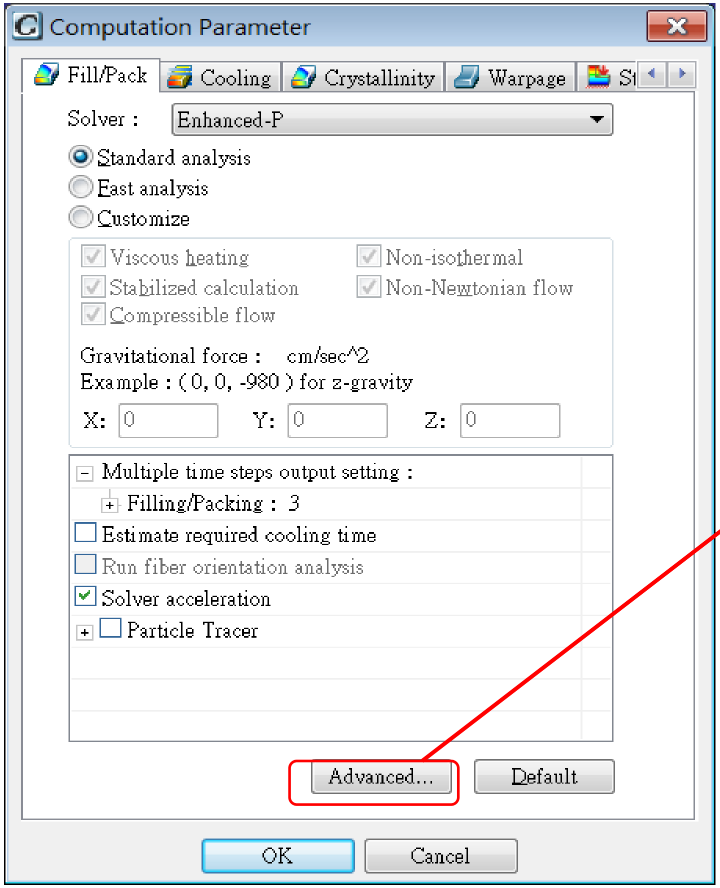
Initial Gas Concentration

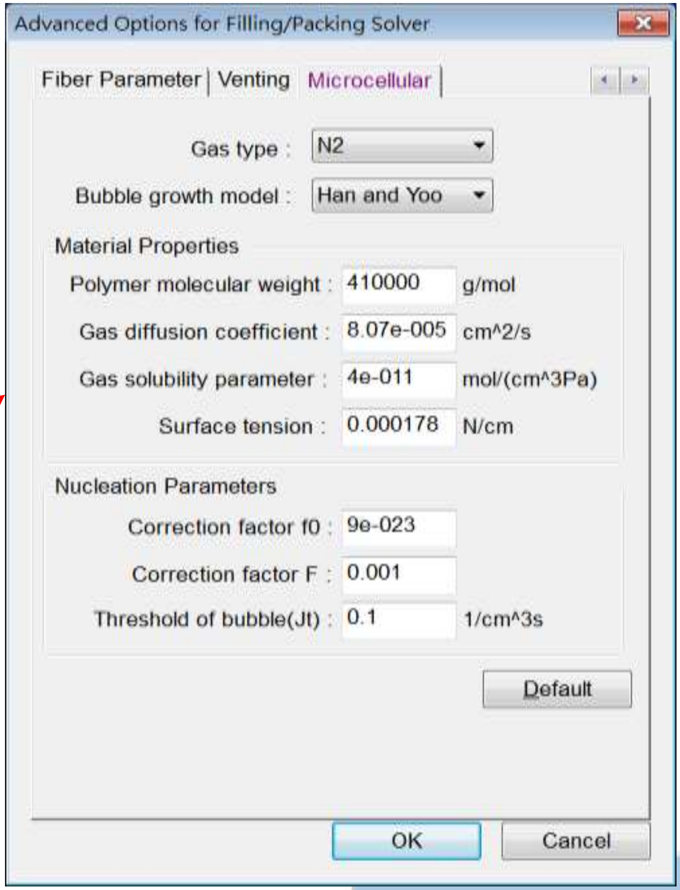
– define the initial gas concentration in terms of *Gas dosage amount* (wt %) or *Gas saturation pressure* (MPa) as below.



Computation Parameters (1)

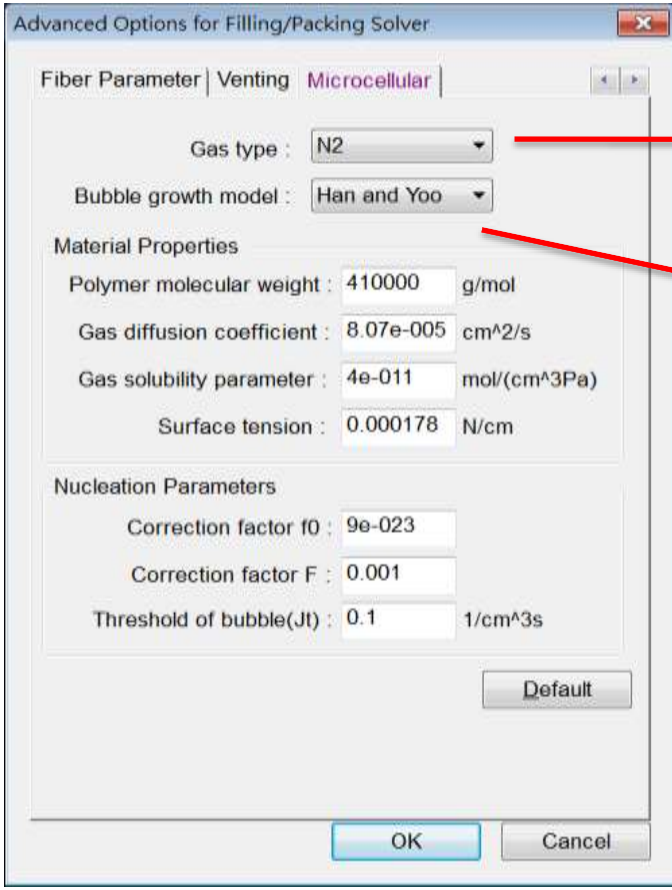
Click the “Advanced Options for filling/packing solver” button in Fill/Pack tab to input the parameters

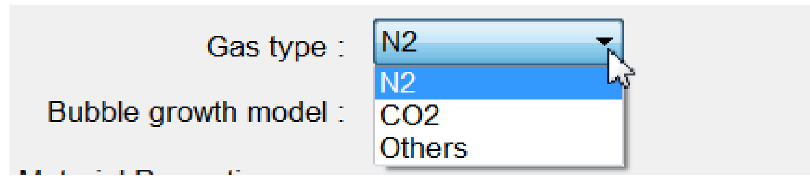


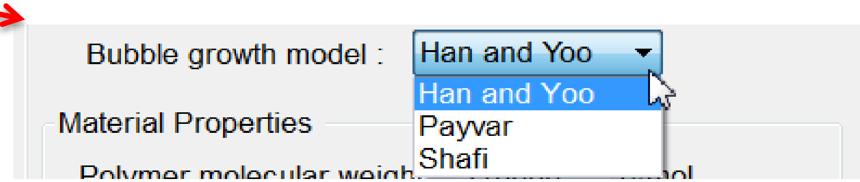


Computation Parameters (2)

Four settings: Gas type, Bubble growth model, Material properties and Nucleation parameters.





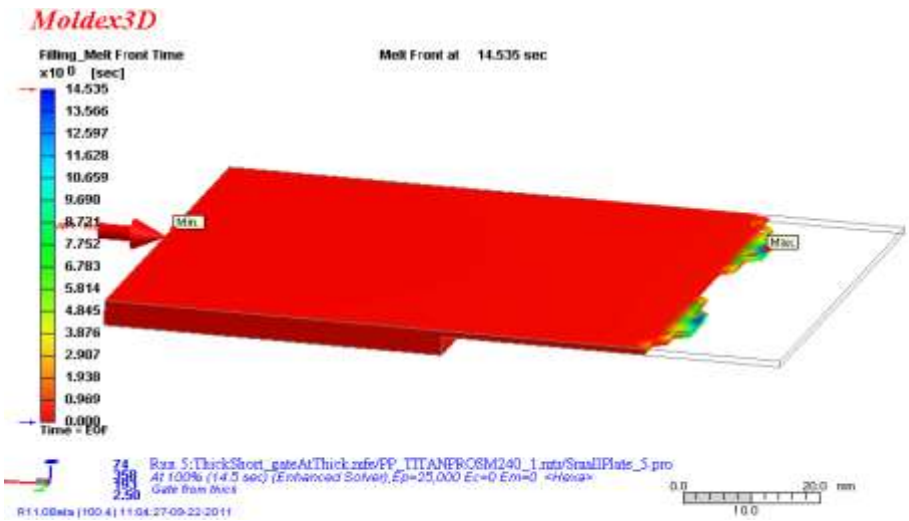


Note:

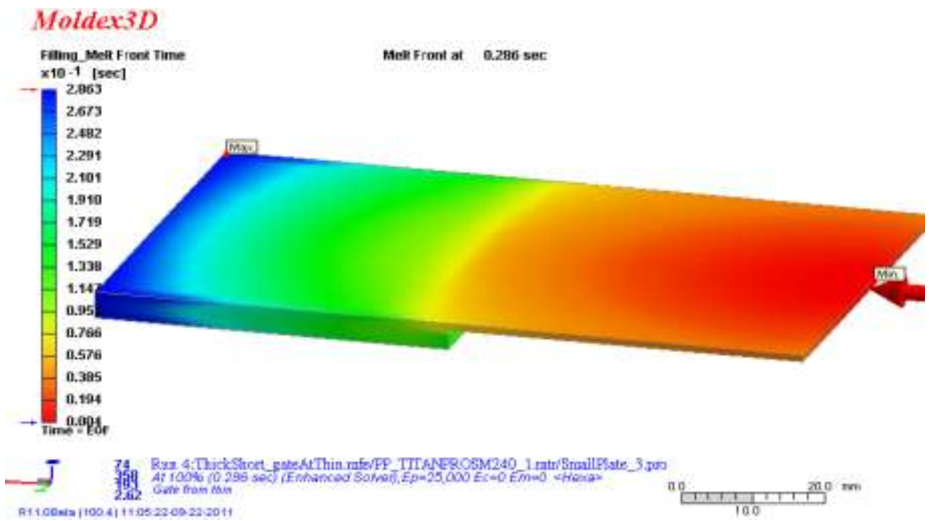
Parameters of N_2/PP (Gas/polymer) are set as N_2's default value and CO_2/PP as CO_2's default value. If a different Gas or polymer is chosen, user may modify the material properties and nucleation parameters to get an accurate result.

Gating Location Effect

Melt front animation

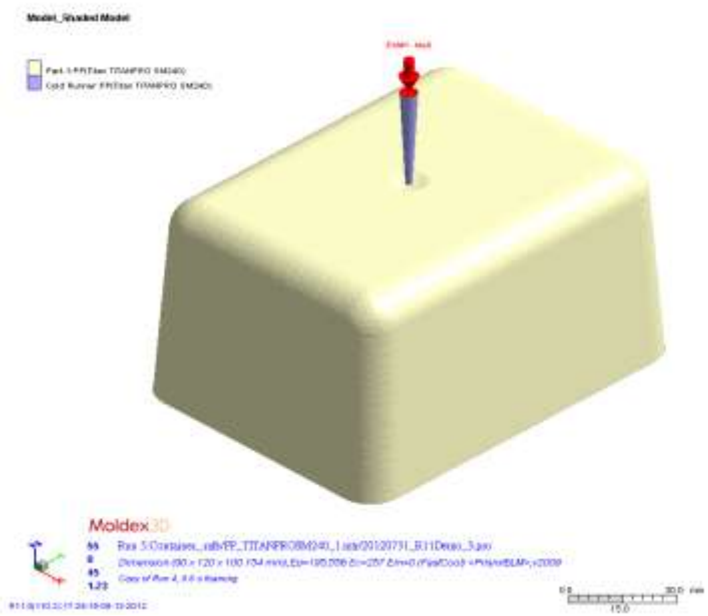


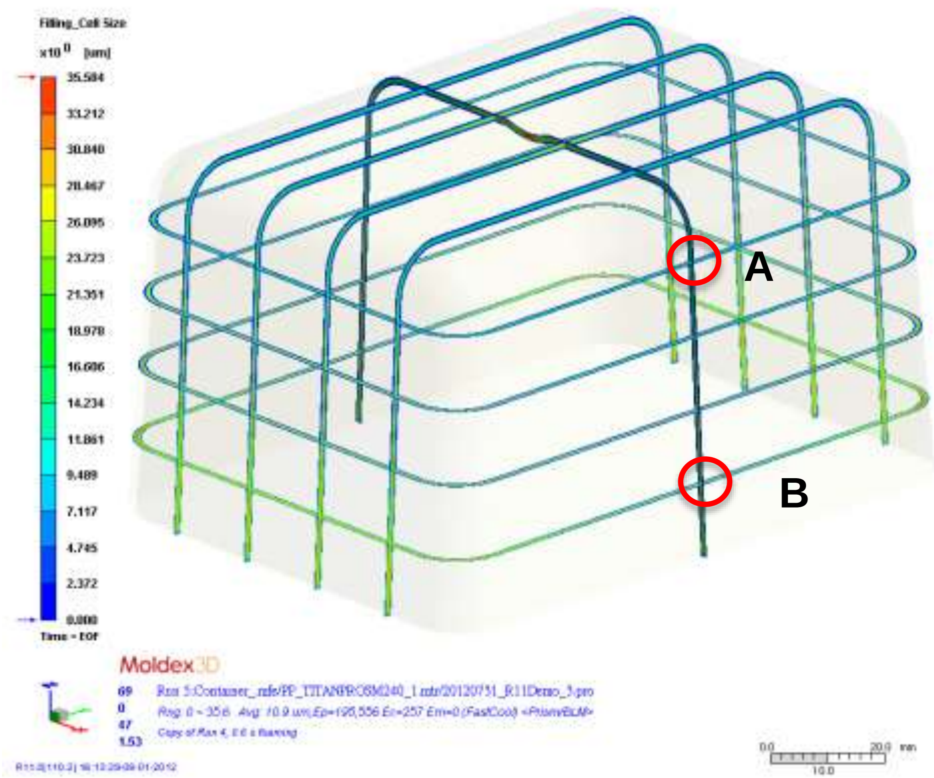
Gating from thick area



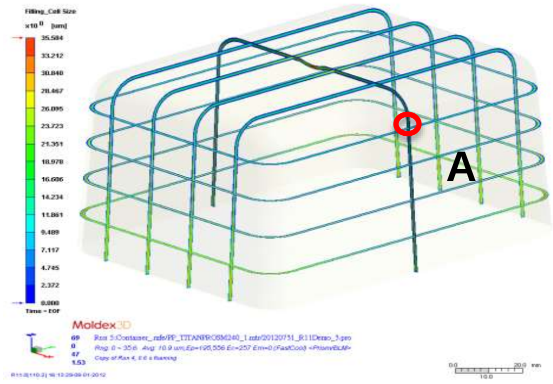
Gating from thin area

Case Study

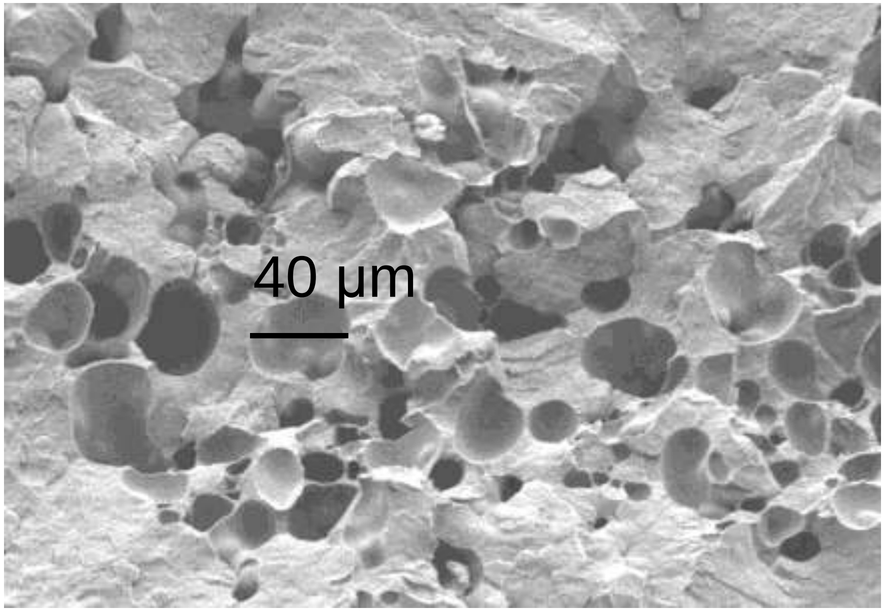

Model_Shaded Model
Moldex3D

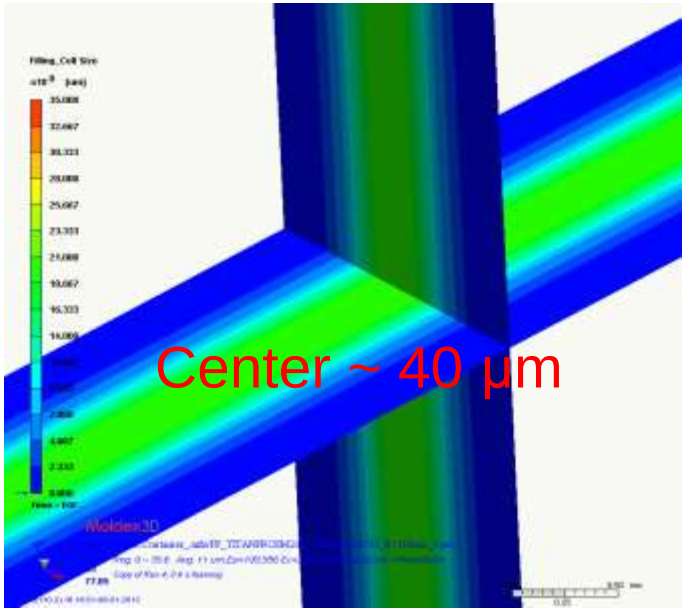

Filling_Cell Size
[um]
35.584
33.212
30.840
28.467
26.095
23.723
21.351
18.978
16.606
14.234
11.861
9.489
7.117
4.745
2.372
0.000
Time = EOF
A
B
Moldex3D

Comparisons of Simulation and Experiment of Position A

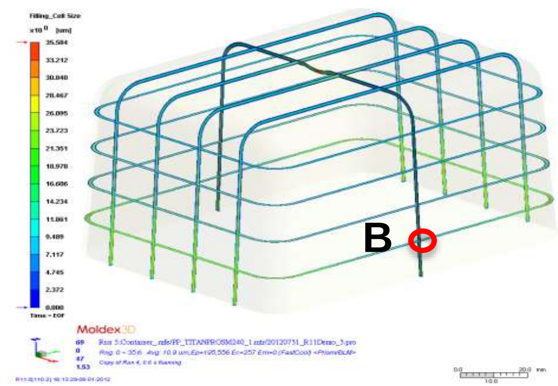


0.2 wt% N_2 SCF dissolved in PP

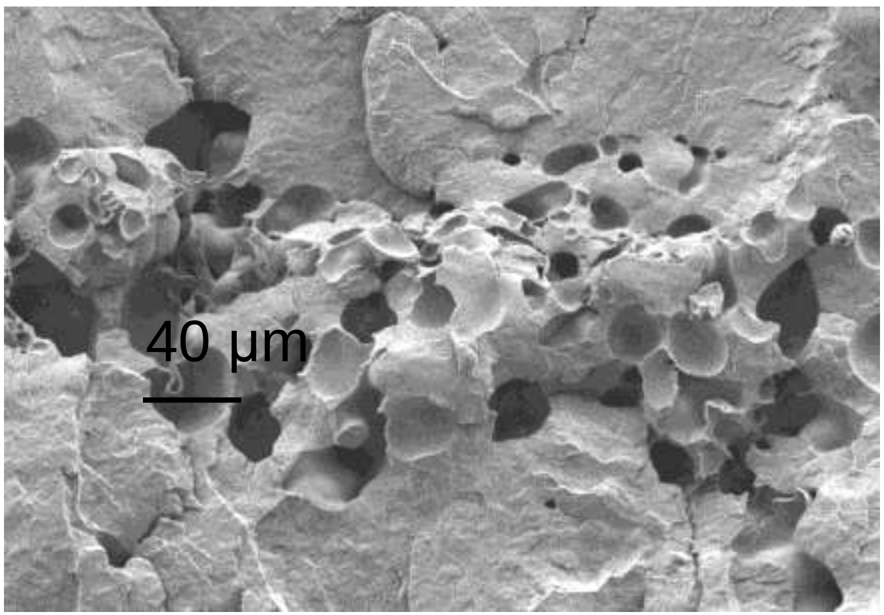


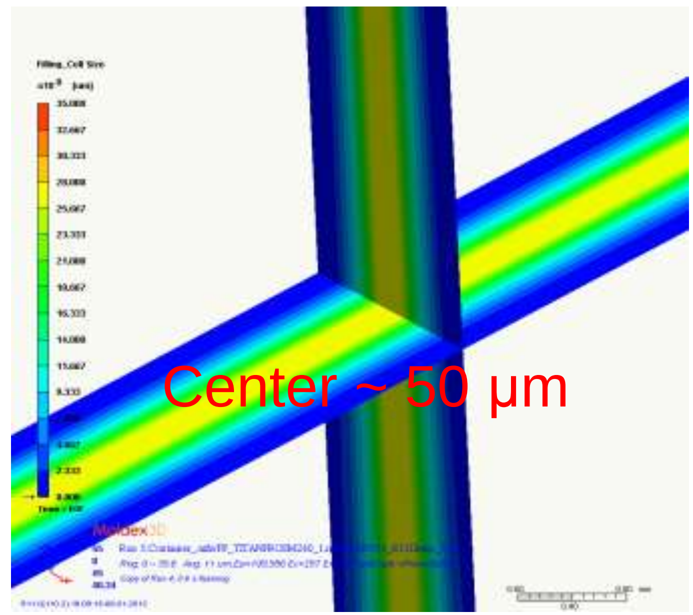


Comparisons of Simulation and Experiment of Position B



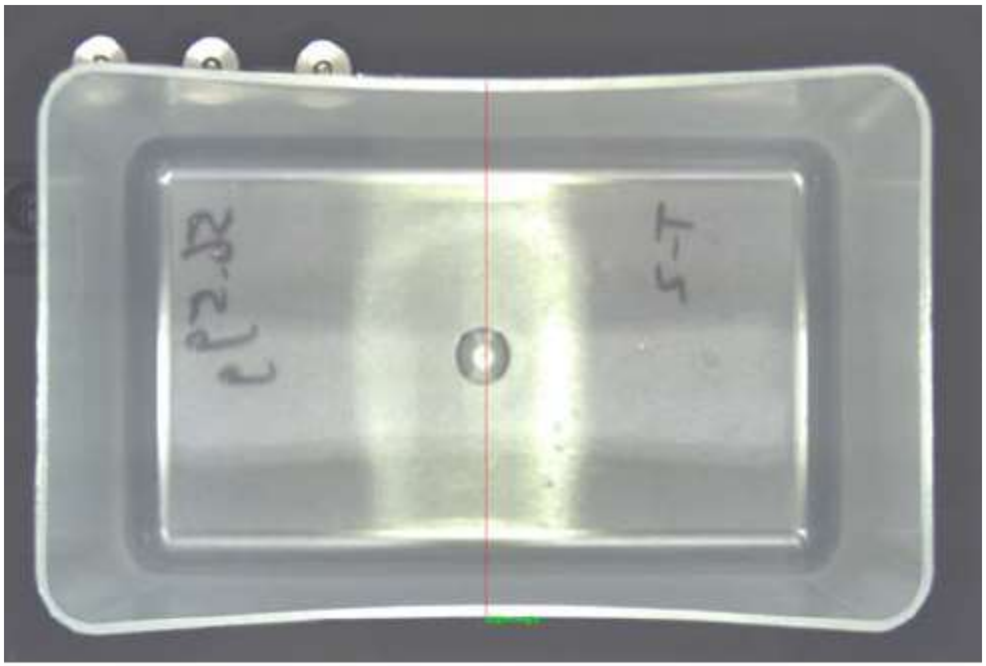
0.2 wt% N_2 SCF dissolved in PP





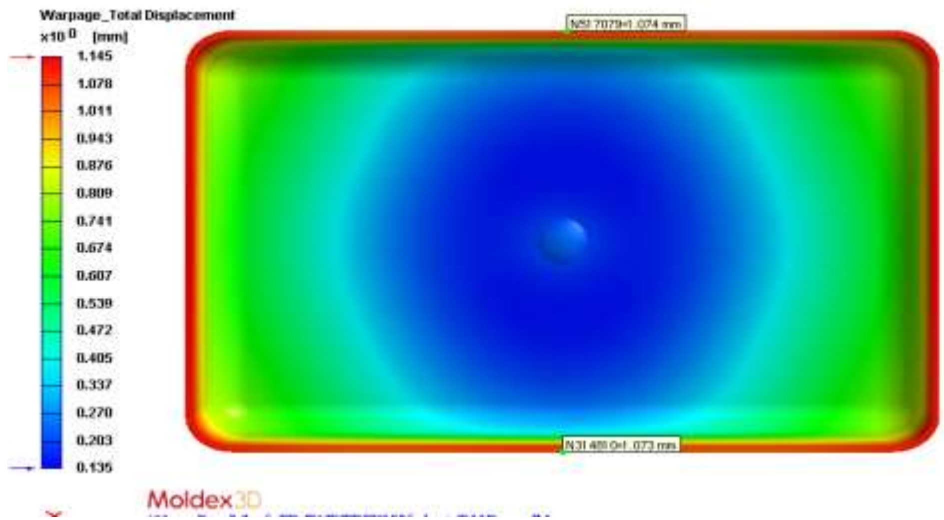
Solid Shot Warpage

Production – solid shot



傳統 第 2 模 (84.04mm)

Moldex3D – Solid shot

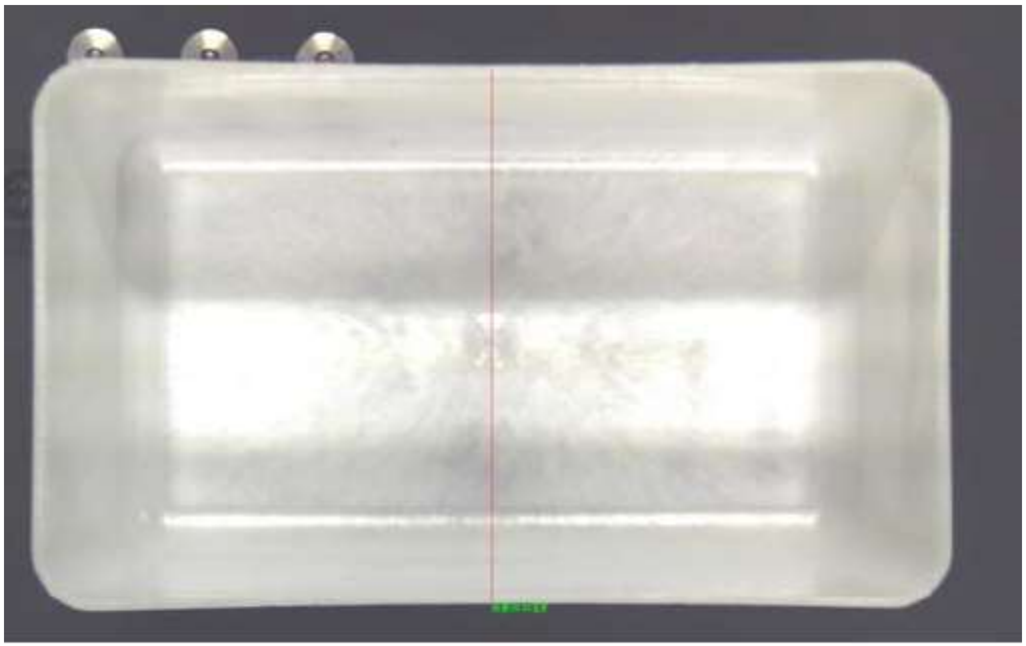


Solid Shot - mm

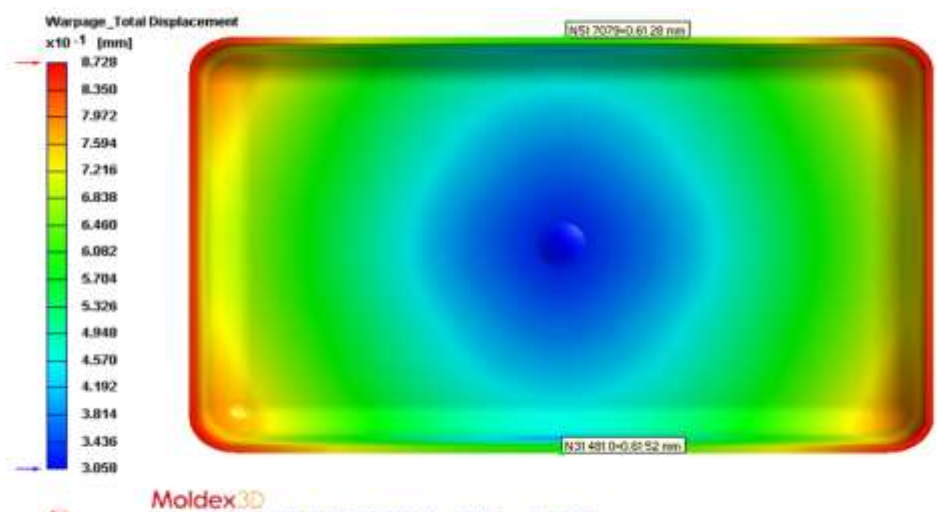
Mucell Warpage - 0.5 wt%

Production - Mucell

Moldex3D - Mucell



(濃度 0.5%) 發泡 第 20 模 (88.02mm)



0.5wt% - mm

DIGIMAT 5.0 – Moldex3D Mucell

Workflow for Mucell part
structural
performance
evaluation

Measurements

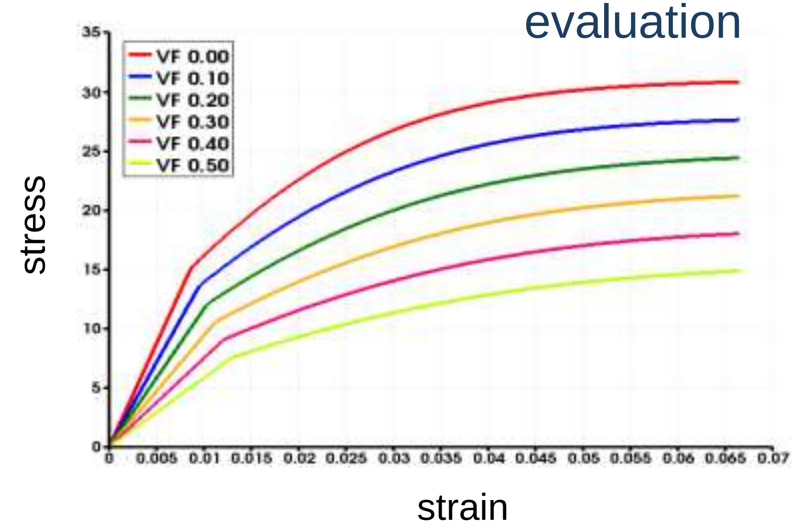
σ/ε curves

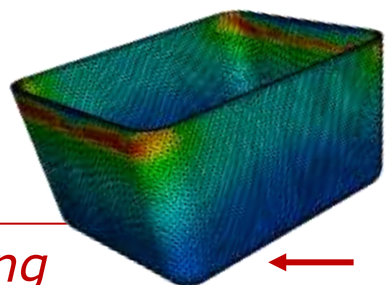
Material Model

Volume fraction

FEA

Structural analysis





Mapping

→ Structural mesh

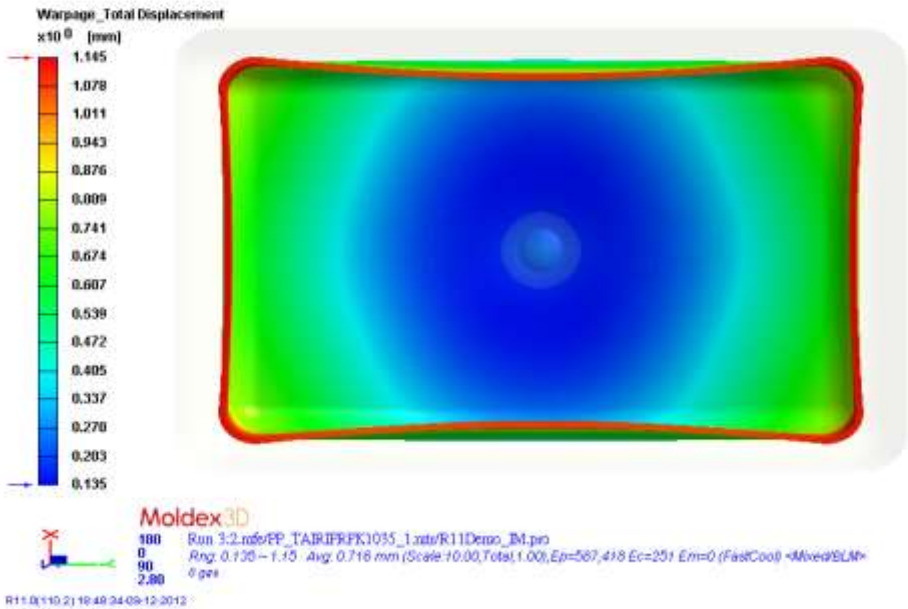
Moldex3D / Mucell

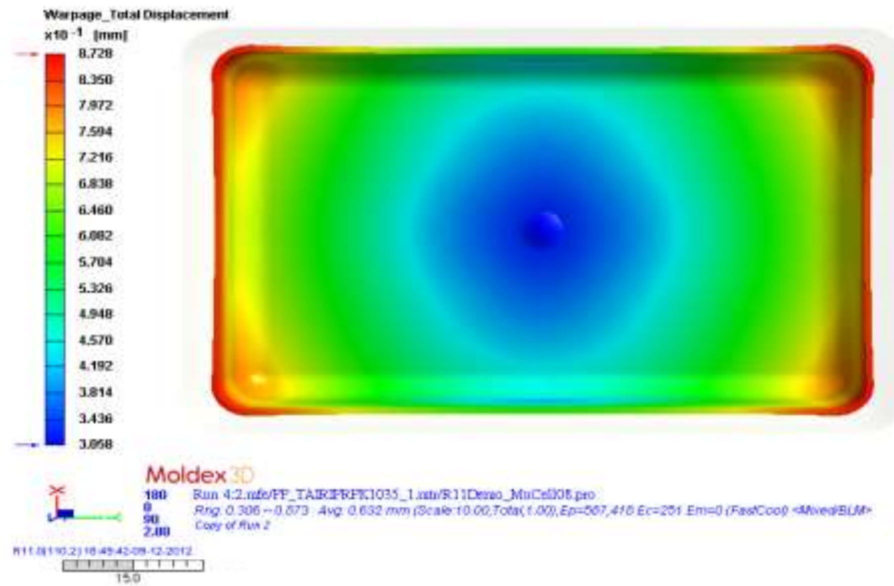
Data on processing mesh

Comparison (X10)

Solid

MuCell

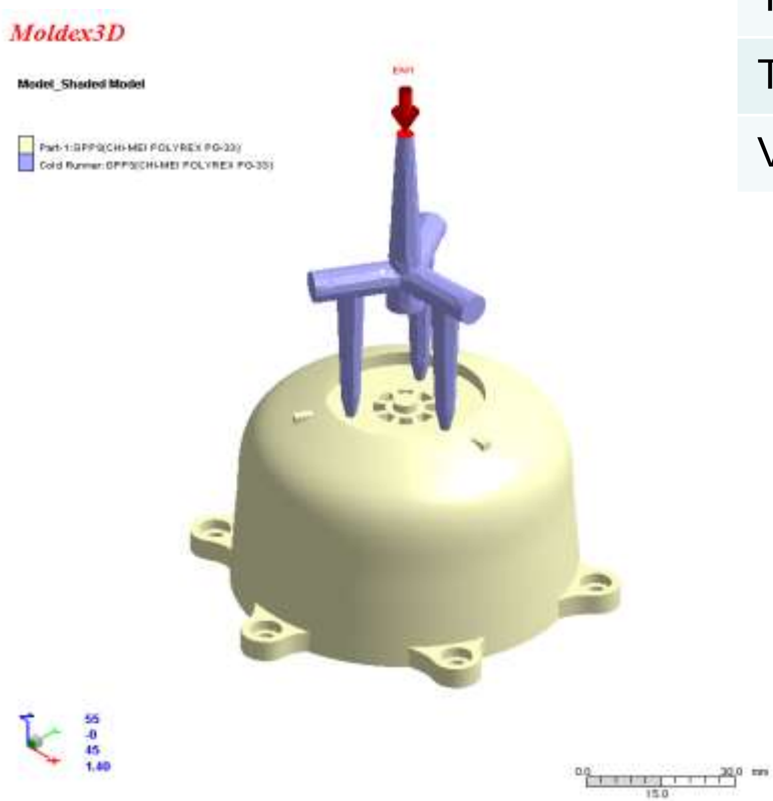


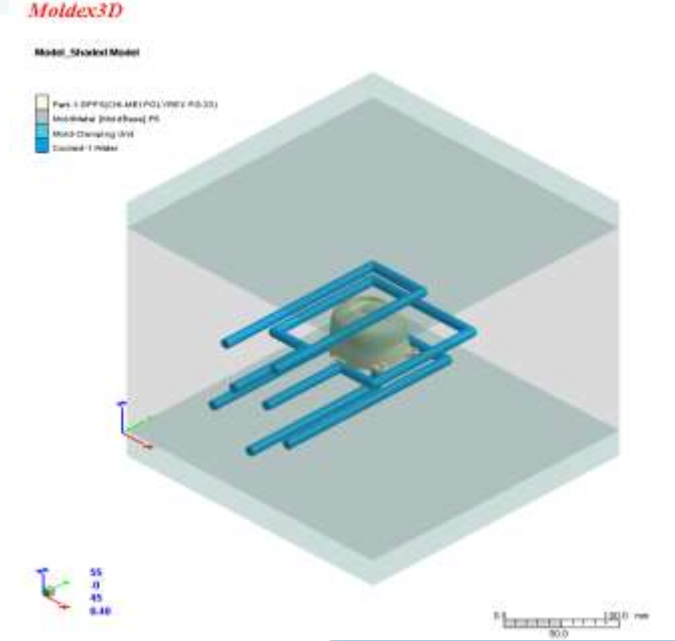


Application example: Warpage improvement

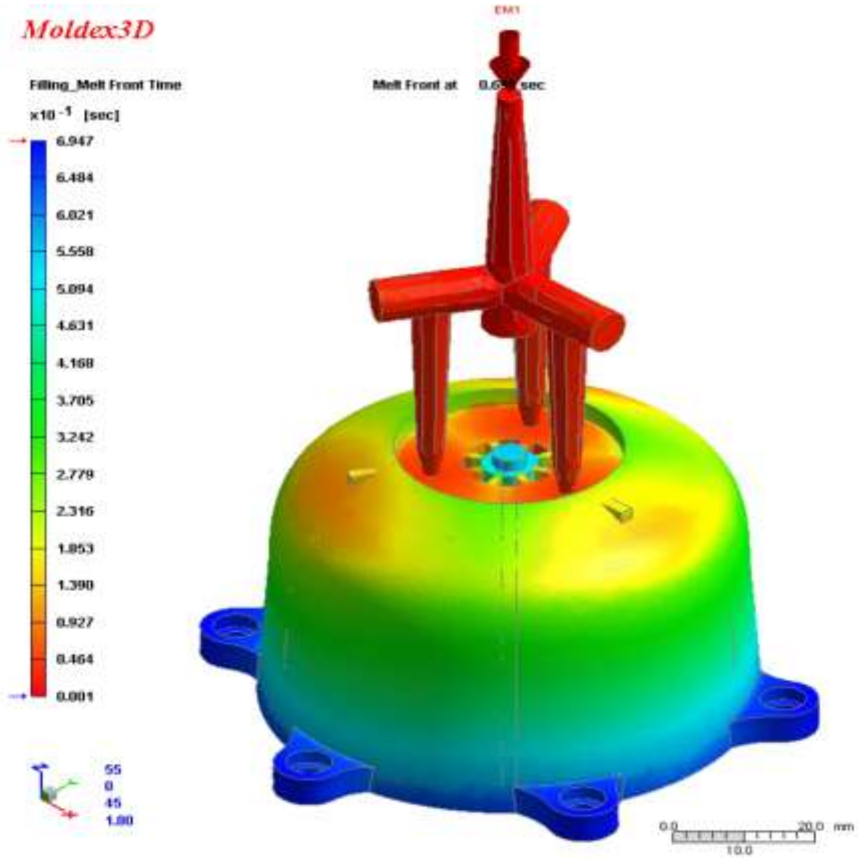
N2/PS
(Gas:0.5wt%))

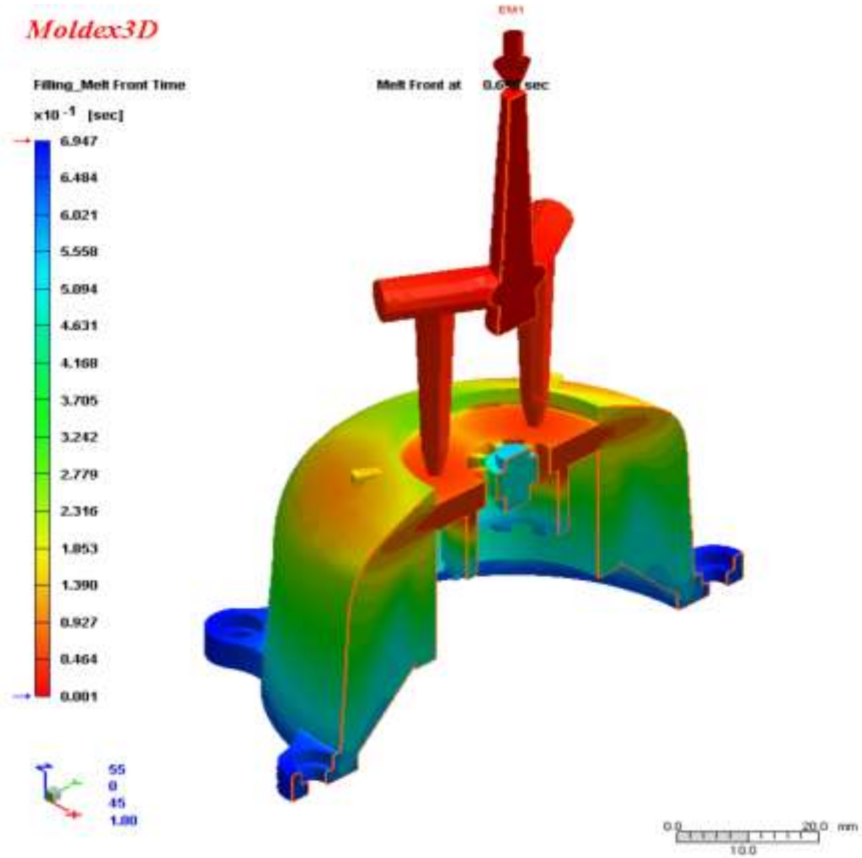
	Microcellular Injection Molding
Filling time	0.70 sec
T_{melt}	190 ℃
T_{mold}	60 ℃
Volume filled	90%





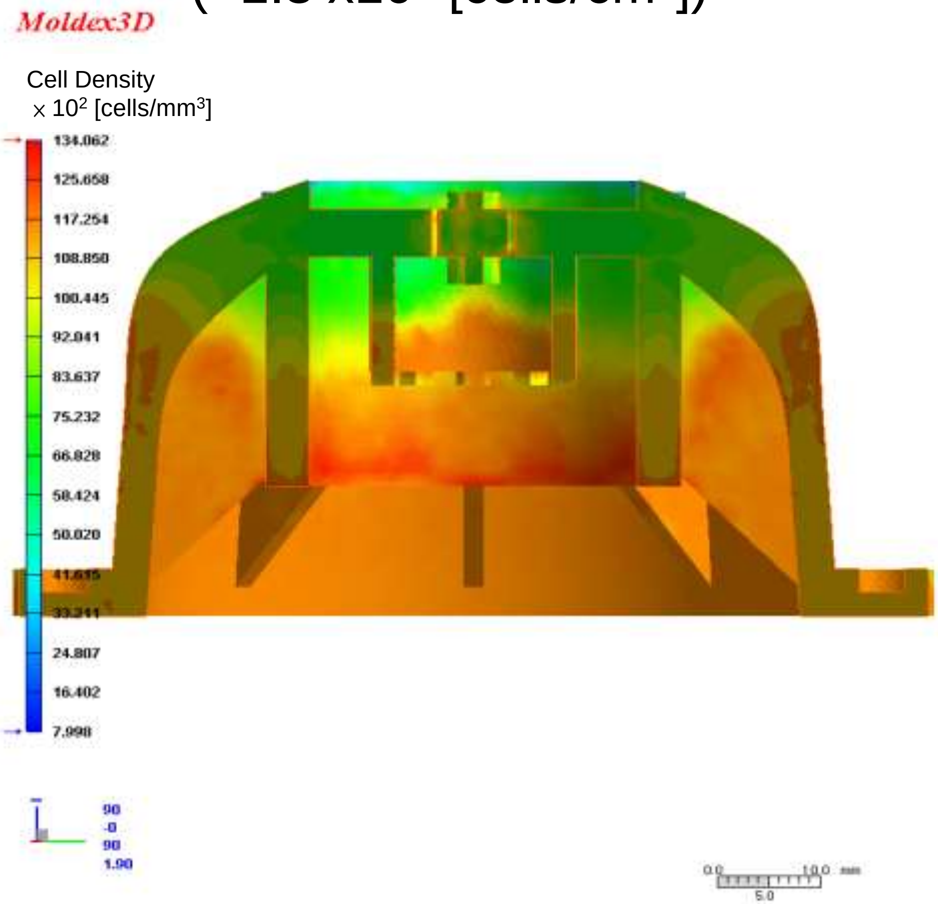
Melt Front Animation of Microcellular Molded Part



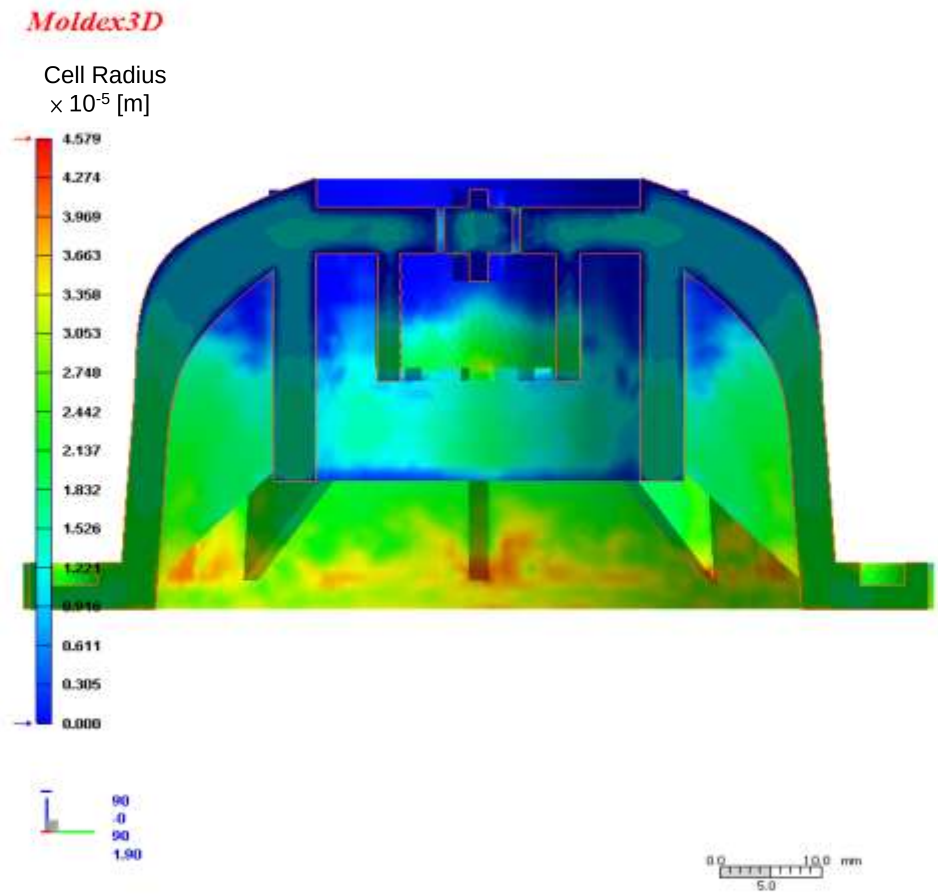


Foam Properties of Microcellular Molded Part

Cell Density of Microcellular (~1.3 x10^7 [cells/cm^3])

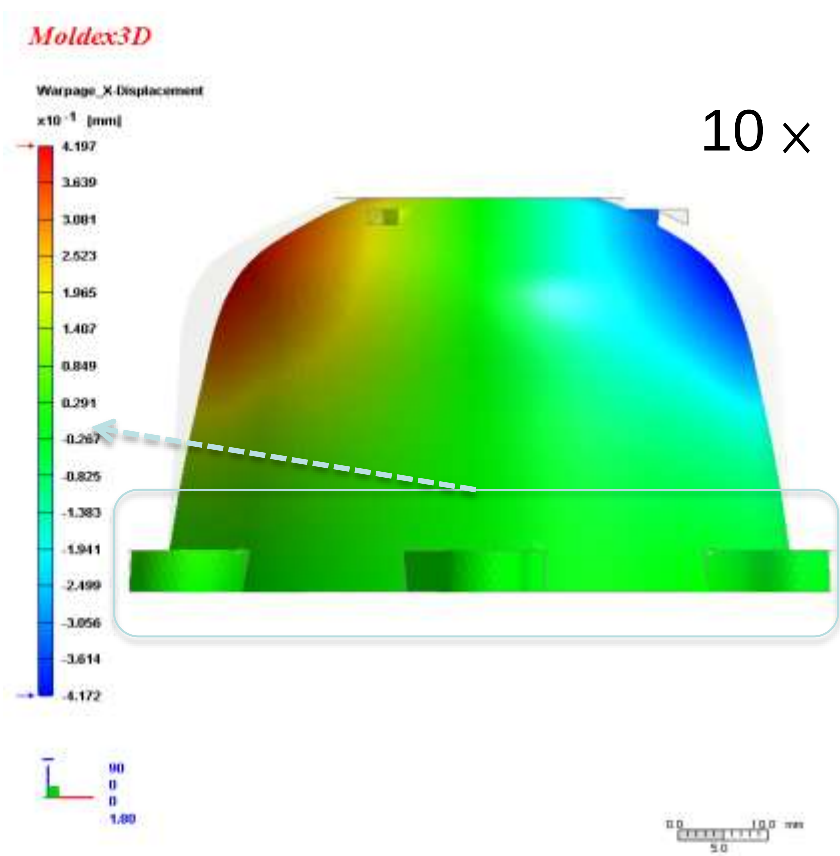


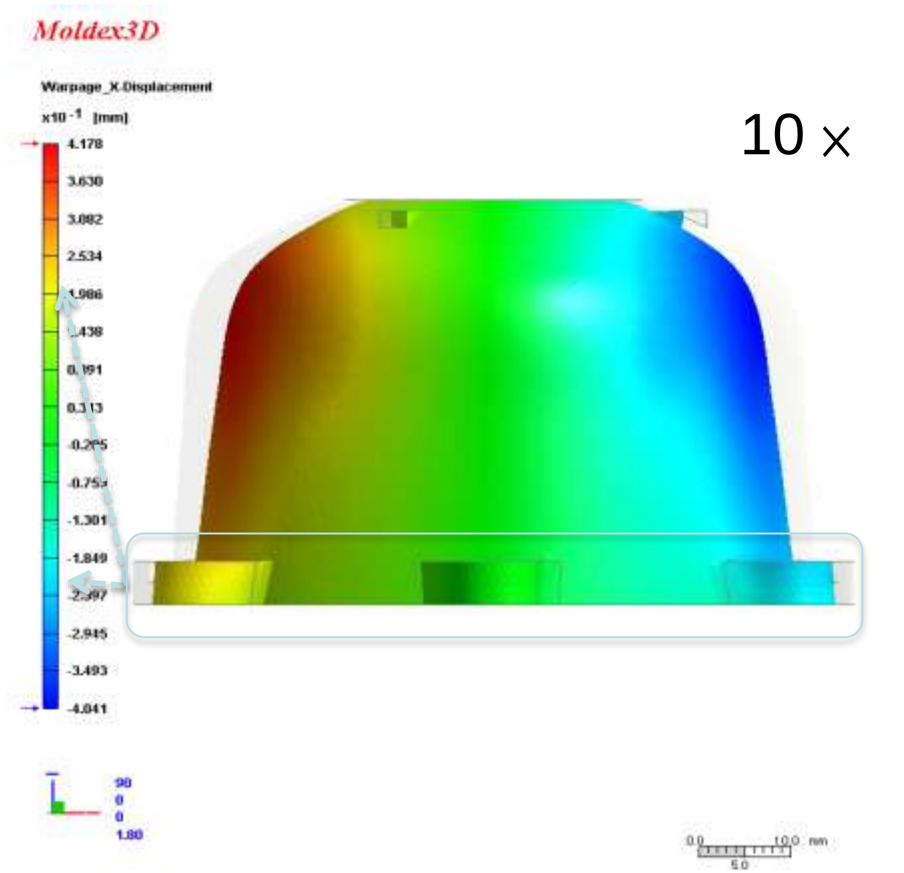
Size Distribution (<45 μm)



Dimensional Stability - X Displacement

Microcellular Injection Molding	Conventional Injection Molding
<0.1 mm	-0.2 ~ 0.2 mm





Conclusion

This study presents the 3D simulation capability of predicting dynamic behavior for microcellular injection molding process.

Good quantitative agreement between simulation and experimental results are found.

In the industrial application, simulation results meet the criteria of prediction capability for application on microcellular injection molding product.

R12 Support eDesign

R13 Support MuCell + “Injection Expansion” (Core-Back)

Acknowledge

Trexel Inc. for providing great information

- Special thanks for Steve Braig (President) and Levi Kishbaugh (V.P. Engineering)
- Many thanks to Patrick Tong, GM of Trexel Hong Kong Limited

Prof. Lih-Sheng (Tom) Turng, at University of Wisconsin - Madison (UW)

- For providing the experimental result and a lots of assistance in microcellular injection molding study.

Interested? Talk to us:

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