

# Micro-Injection Molding of Ultra-Thin Parts With Microstructures on Both Sides

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# Outline

- Introduction
- Experiment Setup
- Operation Window
- Results and Discussion
- Conclusions

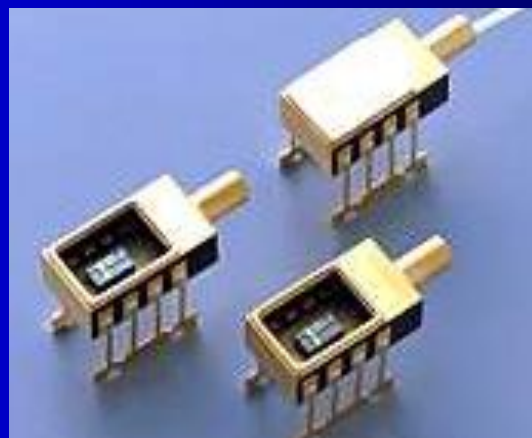
# The Definition of Micro-Injection Molding

1. micro-injection molded parts (micro- molding)
  - a parts with a mass of a few milligram, not necessarily having dimension on the  $\mu\text{m}$  scale
2. injection molded parts with micro-structured regions
  - characterized by the  $\mu\text{m}$  order such as the micro-hole and micro-slot
3. micro-precision parts
  - parts could have any dimensions, but has tolerances in the  $\mu\text{m}$  range

Kukla et al (1998)

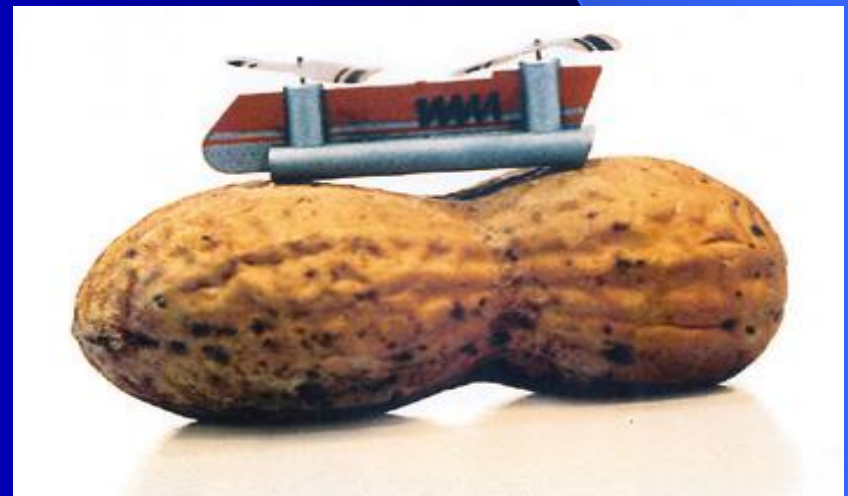
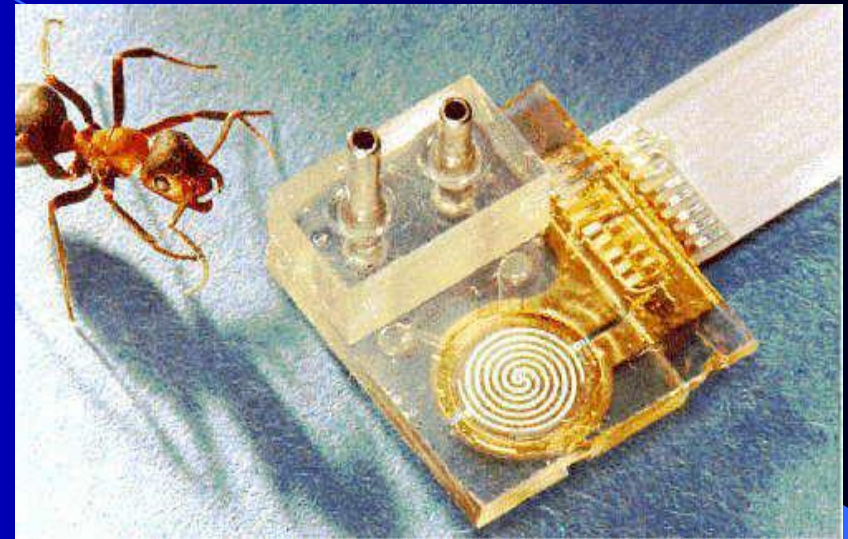
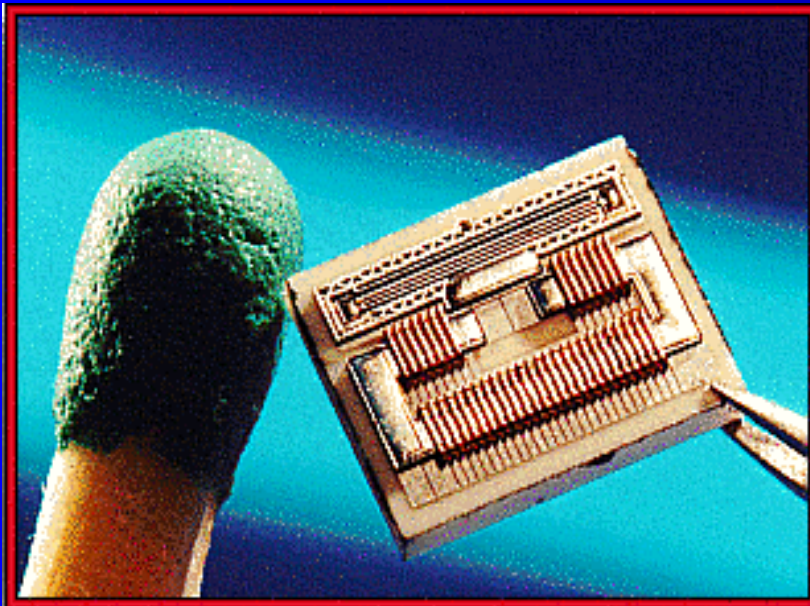
# The Application of Micro-Injection Molding (1/3)

## ➤ Precision Micro-parts



# The Application of Micro-Injection Molding (2/3)

- Micro-Electro-Mechanical System (MEMS)

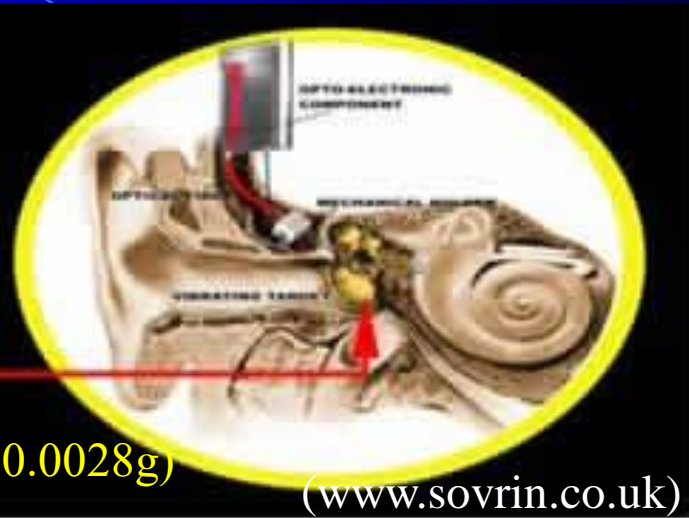


# The Application of Micro-Injection Molding (3/3)

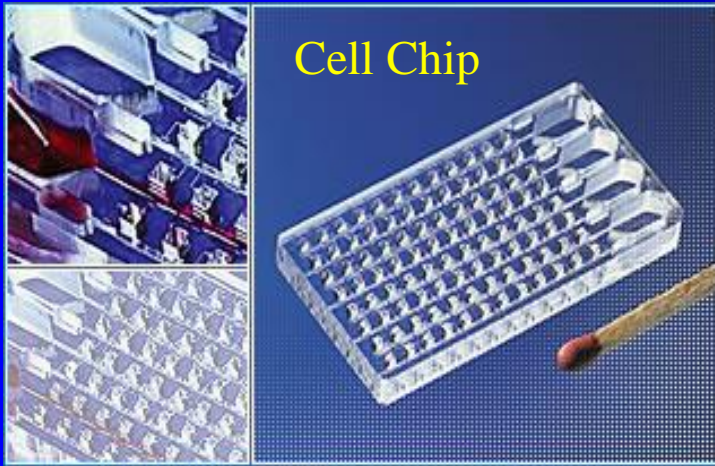
## ➤ Biotechnology



Component of audiphones ( $\psi 0.8\text{mm}$  0.0028g)

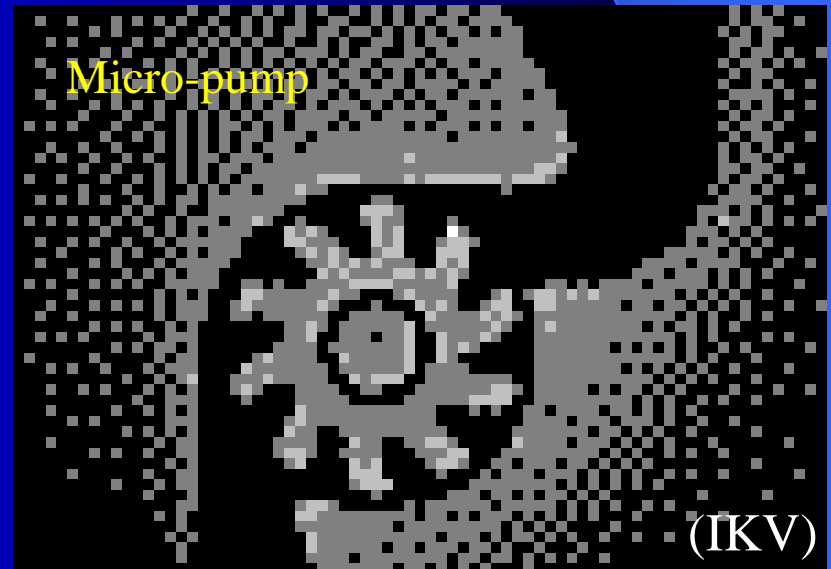


([www.sovrin.co.uk](http://www.sovrin.co.uk))



Cell Chip

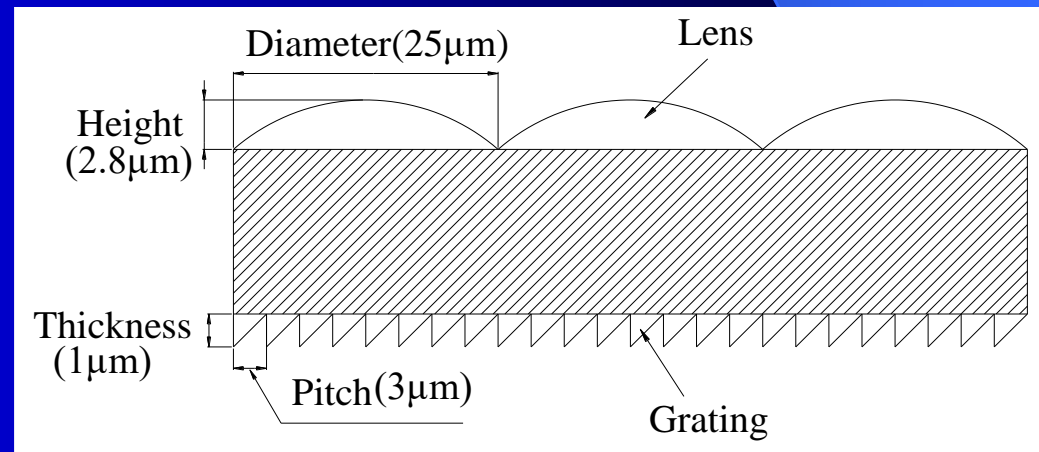
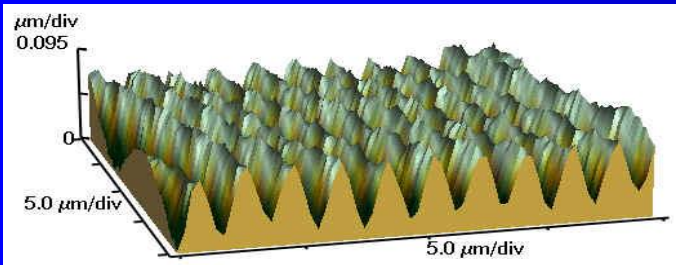
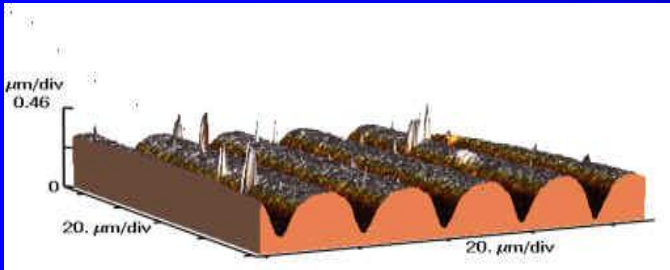
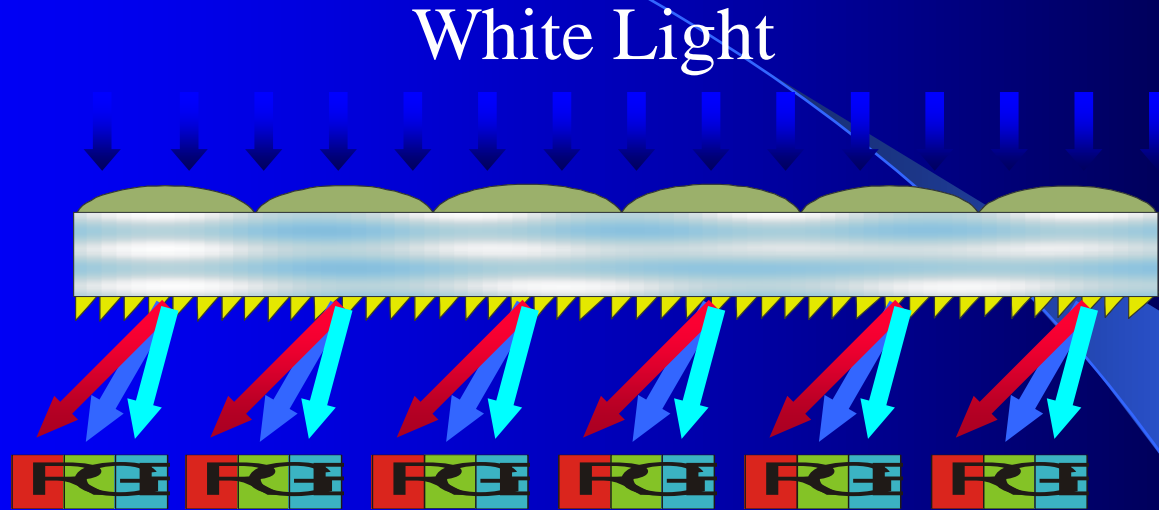
(LILLIPUT)



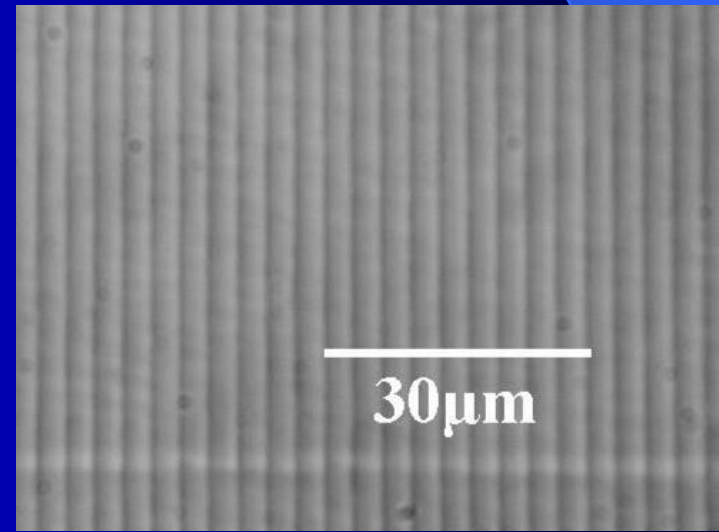
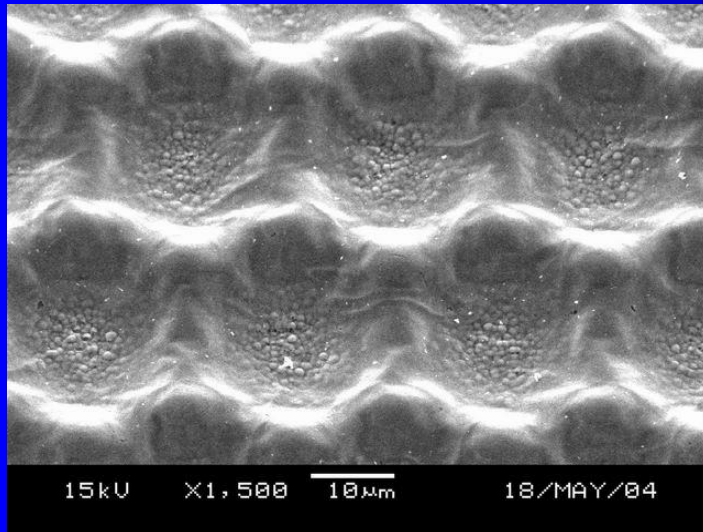
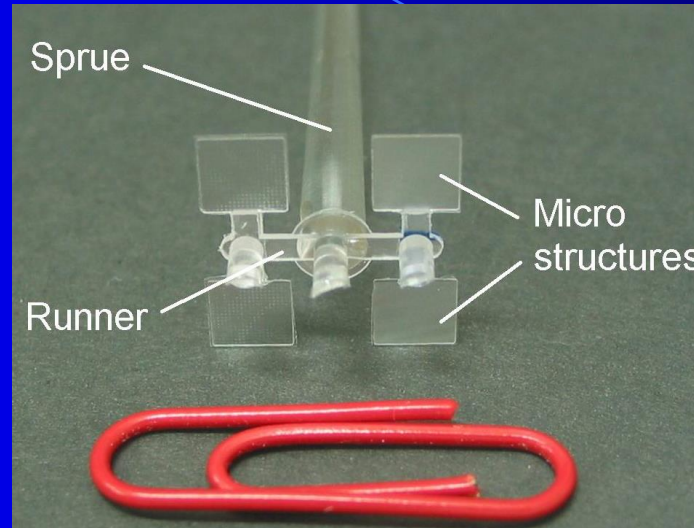
Micro-pump

(IKV)

# Light Enhance Color Divider for CMOS Image Sensor

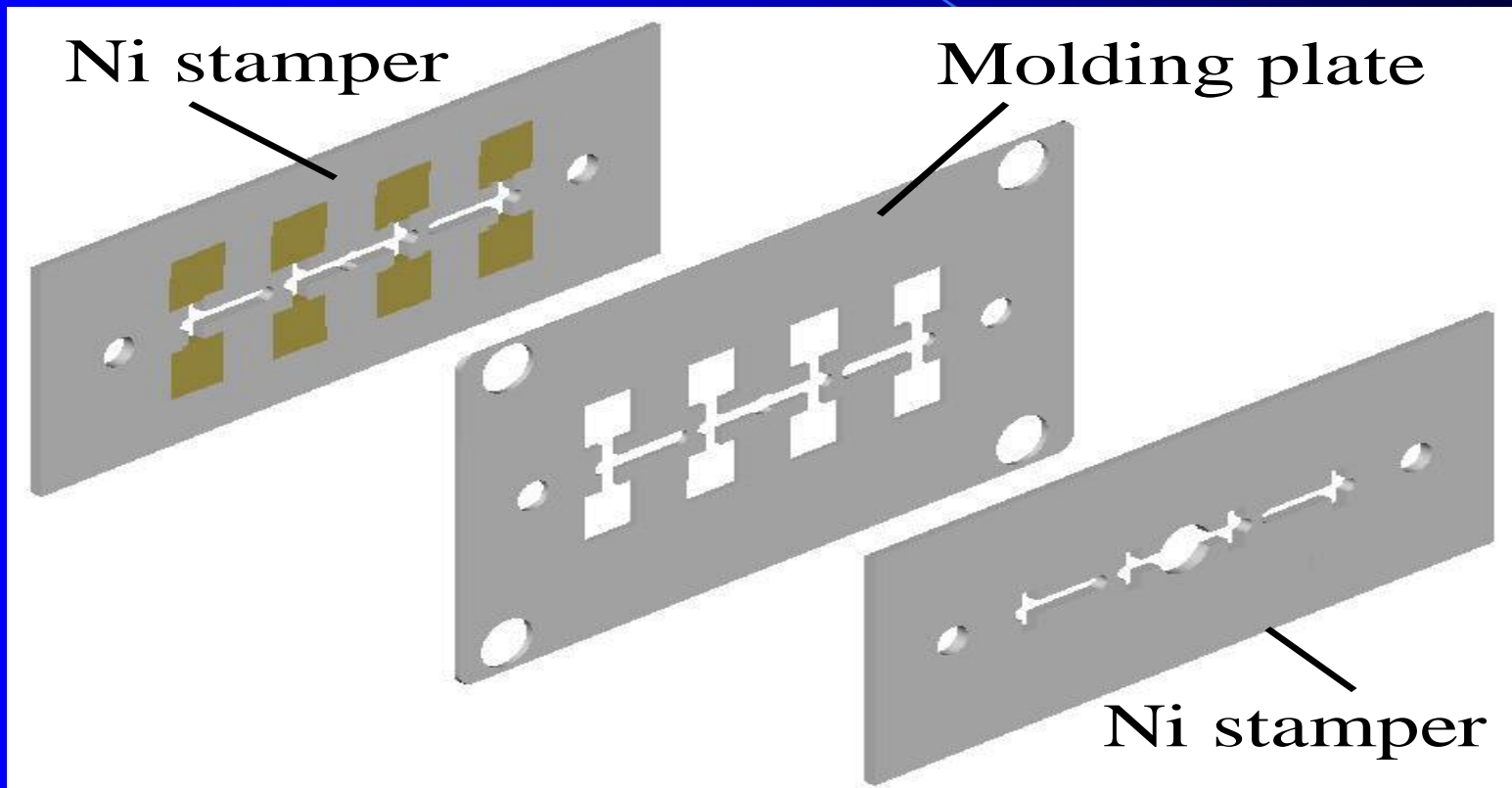


# The Molded Parts with Micro-Lens Array and Grating on Both Sides

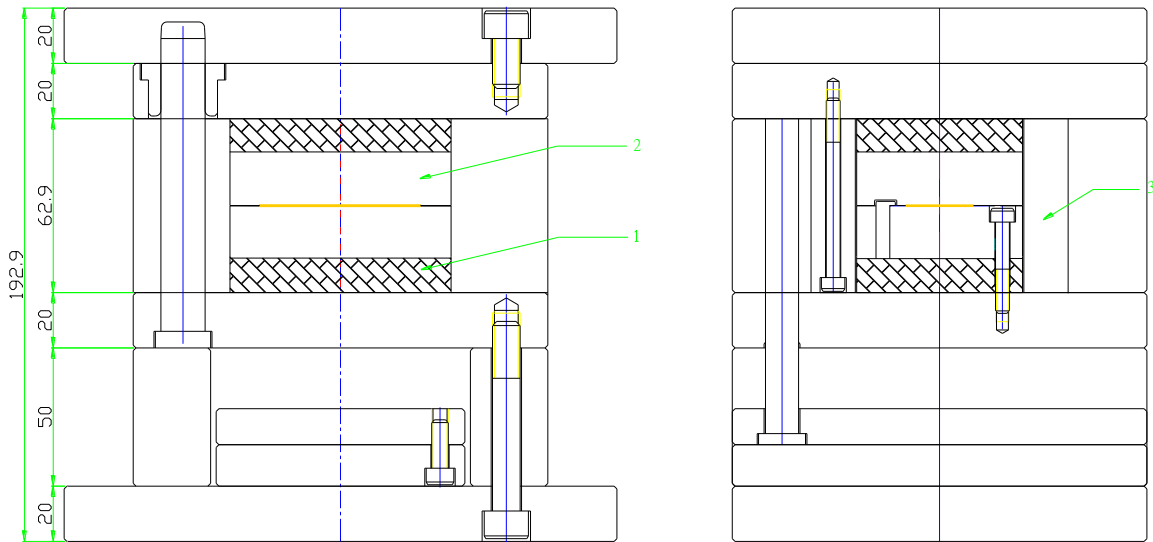
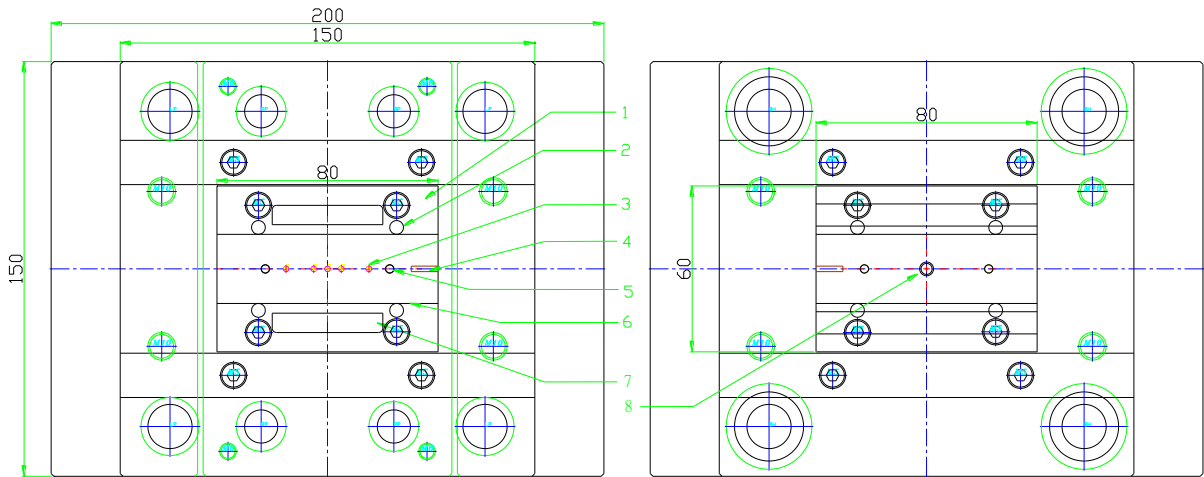




# Mold Design <sup>1/2</sup>



# Mold Design 2/2



# Injection Molding Machine

## ➤ FANUC $\alpha$ -15iA (15-ton)



### ❖ Specifications

Clamping Force : 15 tonf

Screw Diameter : 16 mm

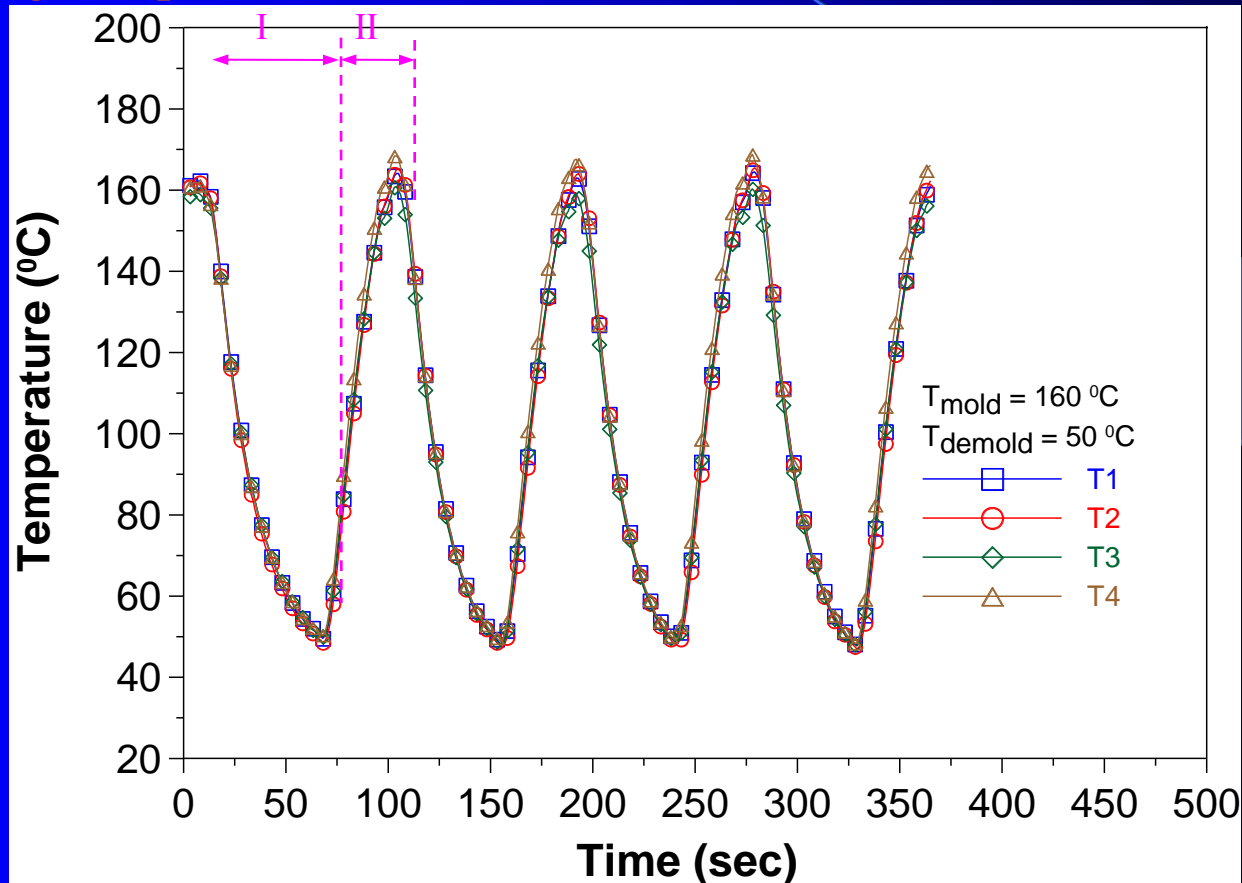
Max. Injection Speed : 200 mm/s

Max. Injection Pressure : 220 MPa

# The Heating and cooling Process

Molding Temp. = 160°C

Demolding Temp. = 40°C



I : Cooling 50sec

II : Heating 36sec

$t_{cycle} : 86\text{sec}$

# The Experiment Parameters of Moldability Study

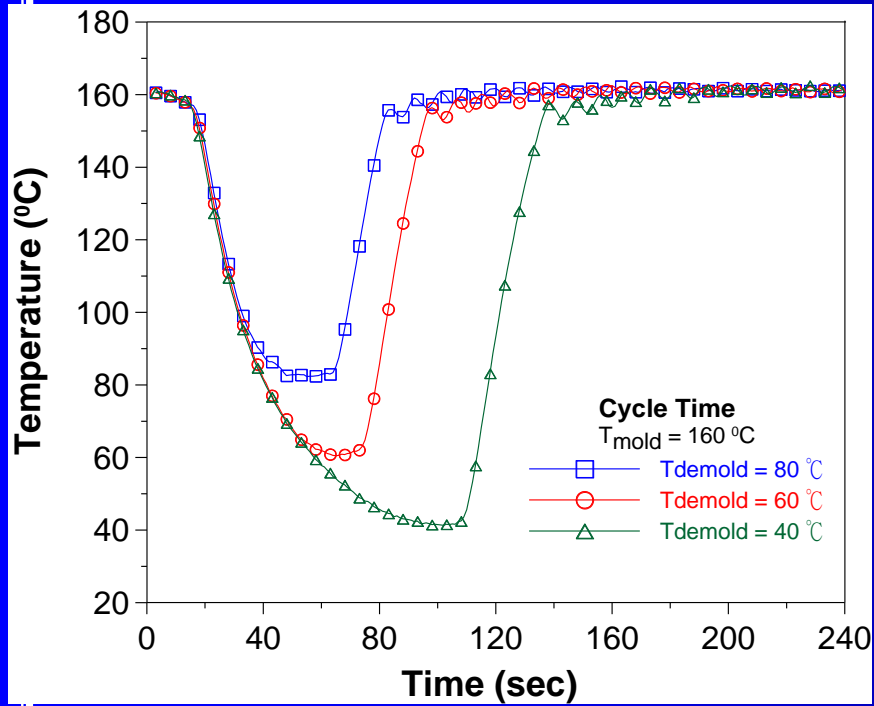
The parameters setup of moldability study of 3 different thicknesses

Material	PS		
Thickness	250 $\mu$ m	100 $\mu$ m	60 $\mu$ m
Mold Temperature	20 ~180 $^{\circ}$ C (div.20 $^{\circ}$ C)		
Injection Speed	10 ~140 mm/s (div.10 mm/s)		

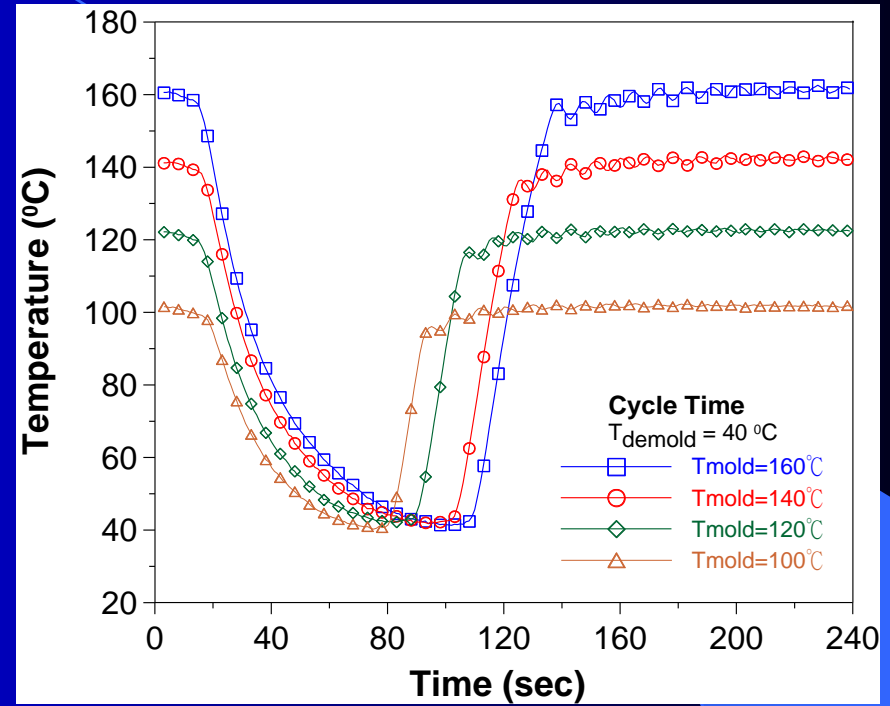
The parameters setup of moldability study of 3 different materials

Thickness	100 $\mu$ m		
Material	PS	PMMA	PC
Mold Temperature	40 $^{\circ}$ C~180 $^{\circ}$ C (div.20 $^{\circ}$ C)		
Injection Speed	40~200mm/s (div.10mm/s)		

# The Mold Heating and cooling Process 2/2

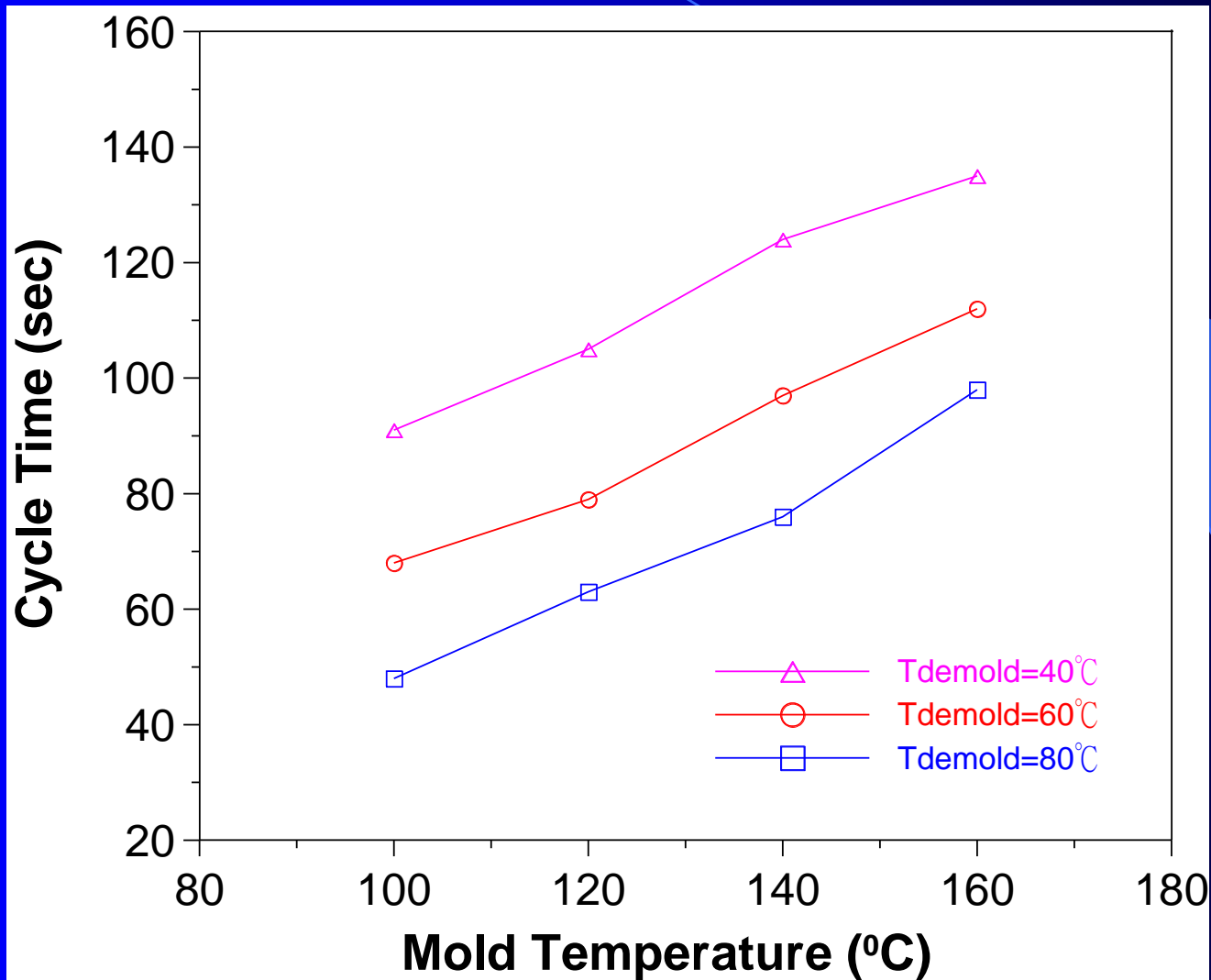


Molding Temp. =  $160^{\circ}\text{C}$   
Demolding Temp. =  $80, 60, \text{ and } 40^{\circ}\text{C}$

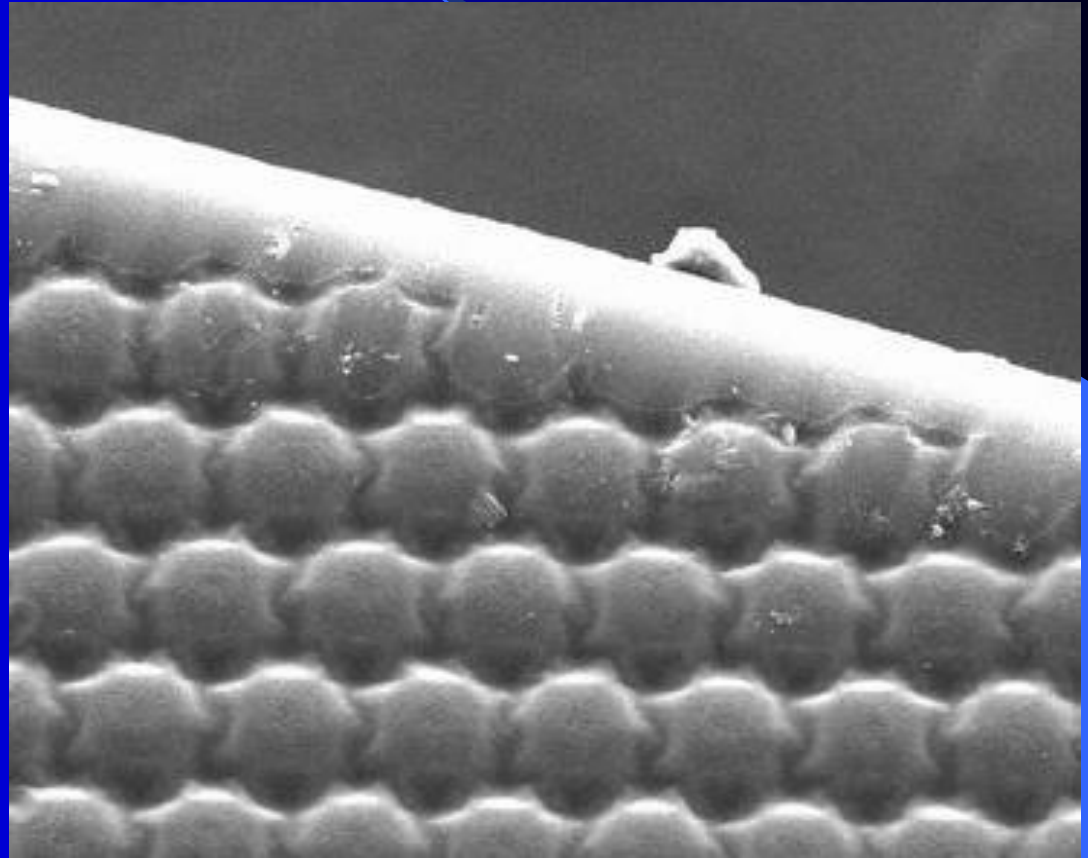
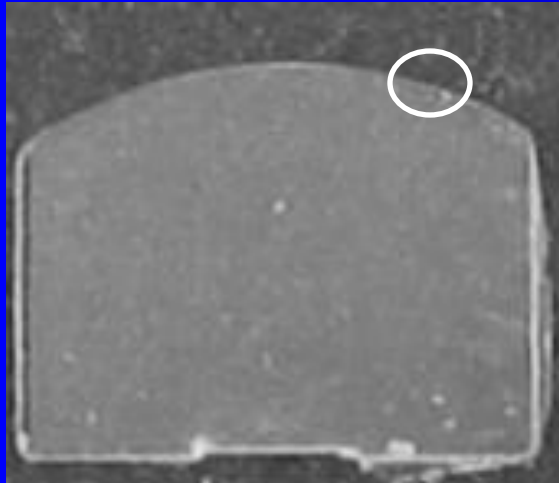


Molding Temp. =  $160, 140, 120, \text{ and } 100^{\circ}\text{C}$   
Demolding Temp. =  $50^{\circ}\text{C}$

# The Effects of the Various Molding and Demolding Temperature to the Cycle Time

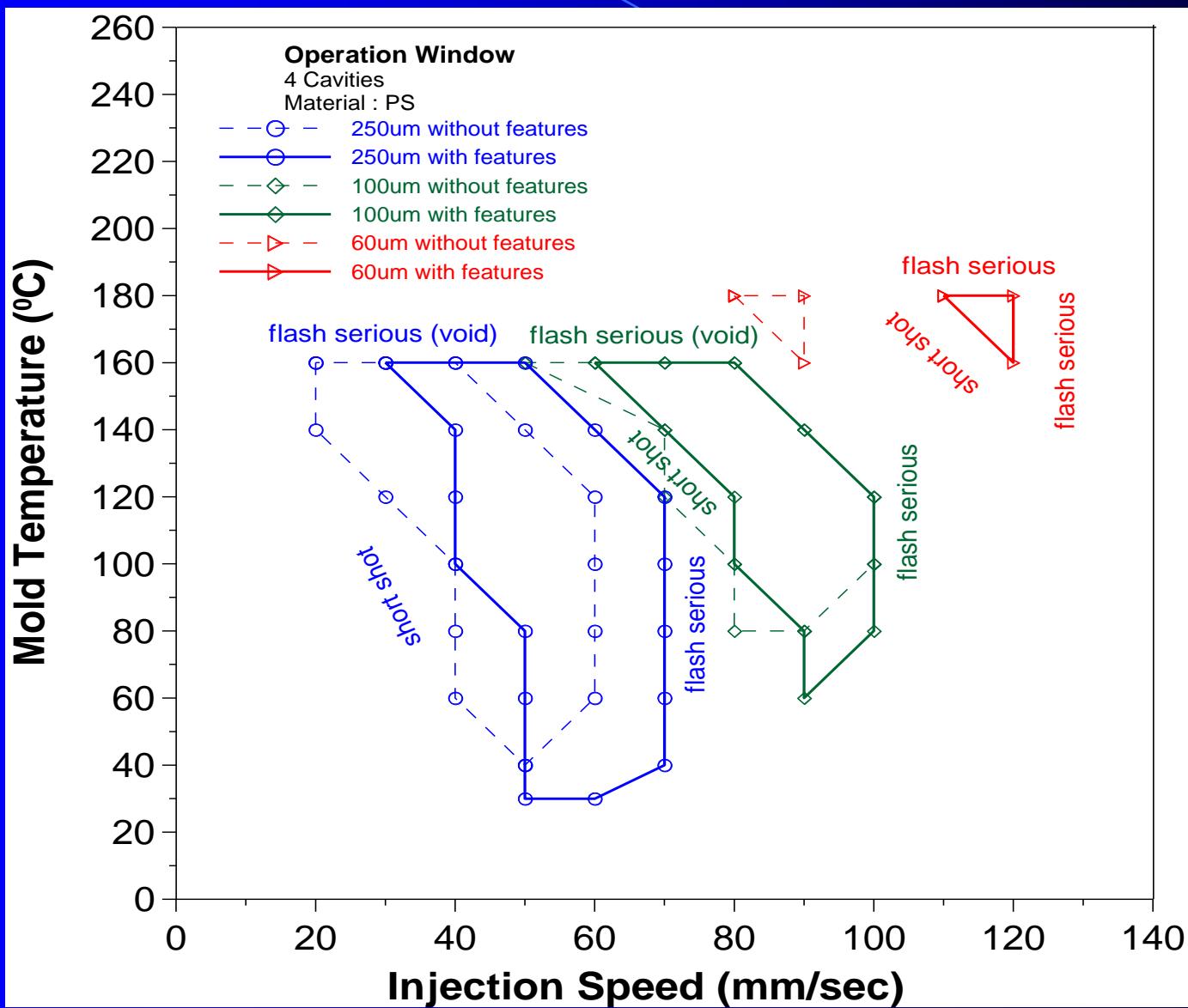


# The Replication Ability of Micro-Lens Array

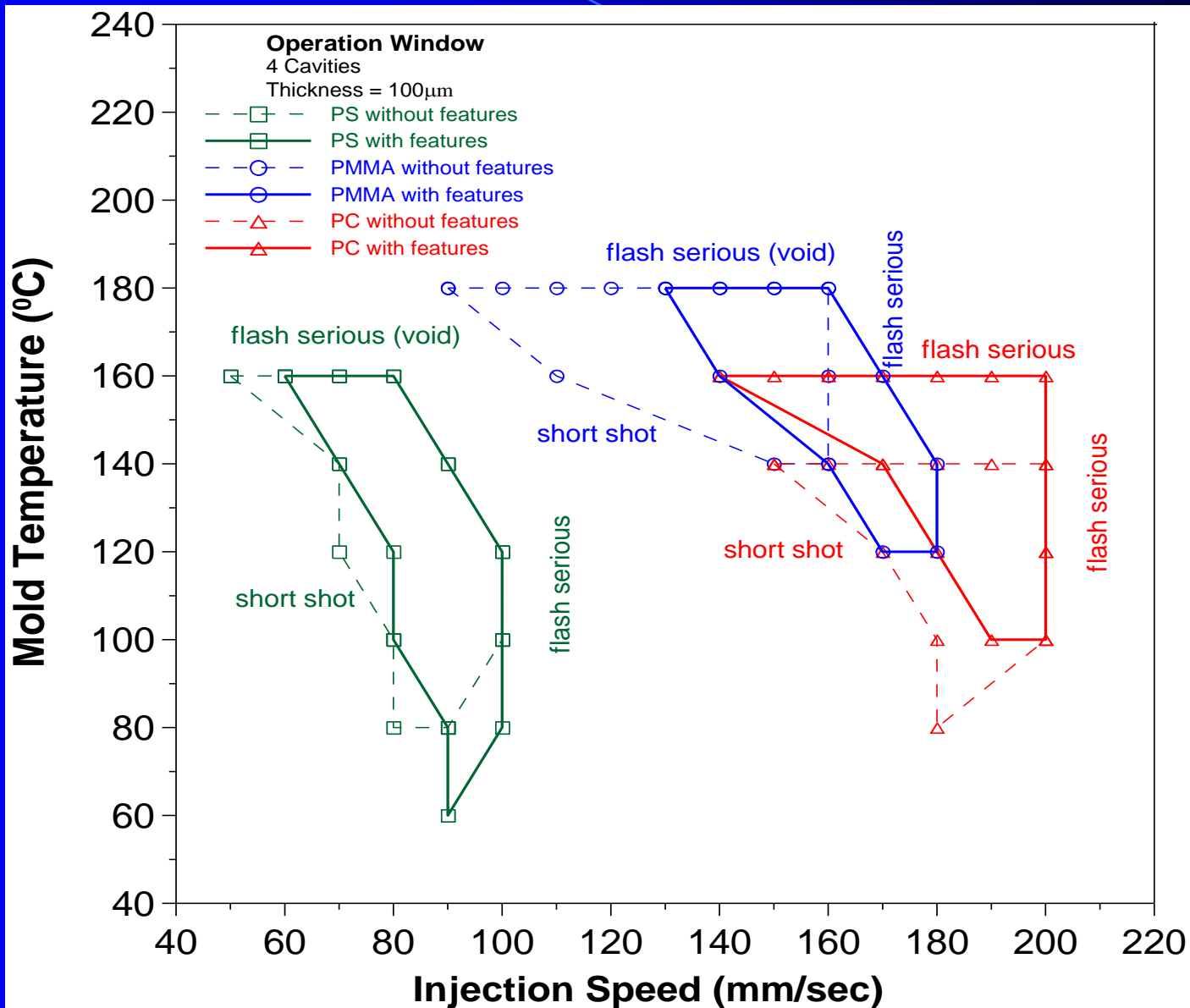




# The Operation Windows for Molding Parts with Different Thickness



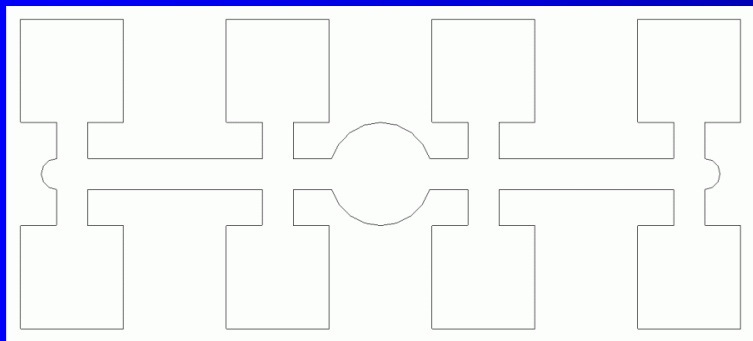
# The Operation Windows for Molding Parts with Different Materials and Surface Conditions



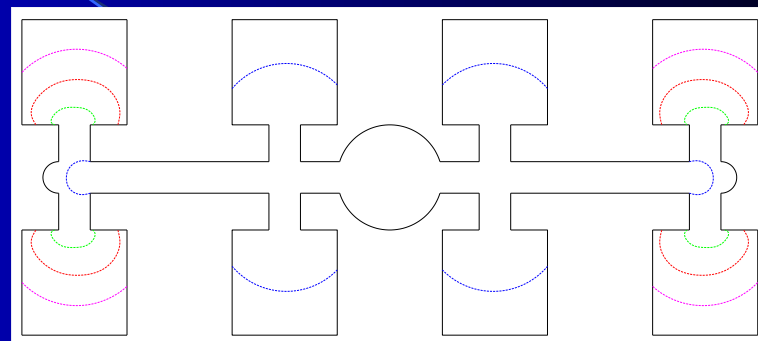
# The Shoot-Short Observation of Eight Cavities Molding (1/3)

➤ Cavities Depth=500 $\mu$

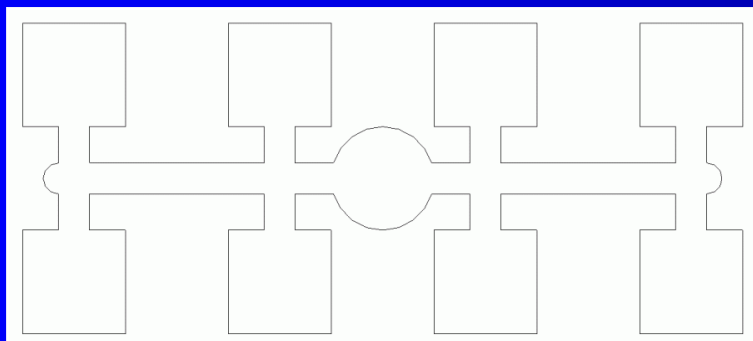
Mold Temp.



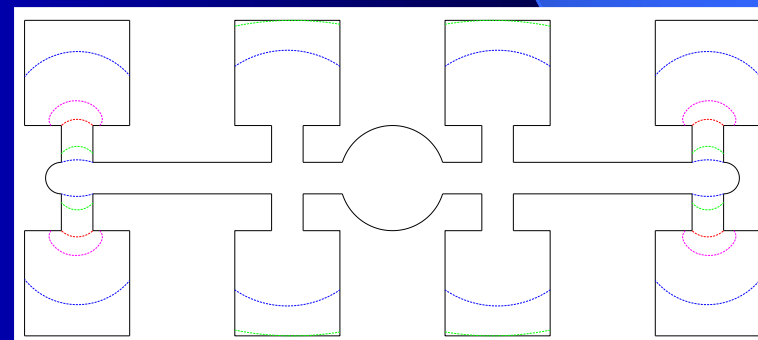
Speed=80mm/sec,  $T_{\text{mold}}=140^{\circ}\text{C}$



Speed=160mm/sec,  $T_{\text{mold}}=140^{\circ}\text{C}$



Speed=80mm/sec,  $T_{\text{mold}}=80^{\circ}\text{C}$



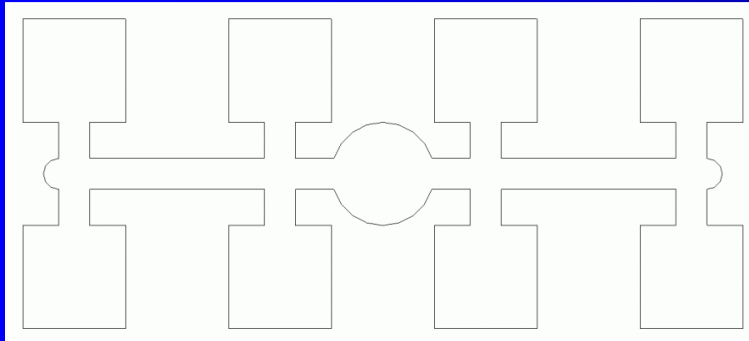
Speed=160mm/sec,  $T_{\text{mold}}=80^{\circ}\text{C}$

Injection Speed

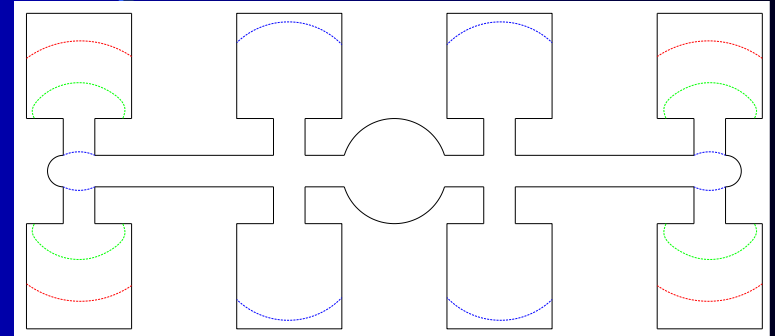
# The Shoot-Short Observation of Eight Cavities Molding (2/3)

➤ Cavities Depth=250 $\mu$

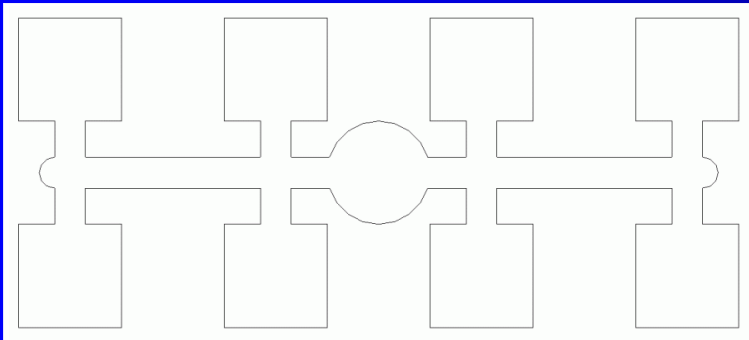
Mold Temp.



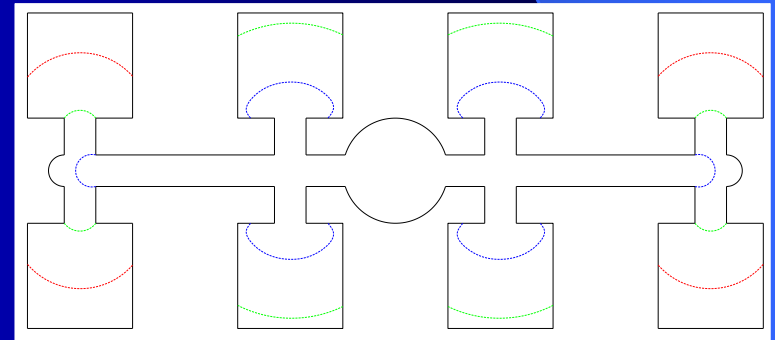
Speed=80mm/sec,  $T_{\text{mold}}=140^{\circ}\text{C}$



Speed=160mm/sec,  $T_{\text{mold}}=140^{\circ}\text{C}$



Speed=80mm/sec,  $T_{\text{mold}}=80^{\circ}\text{C}$



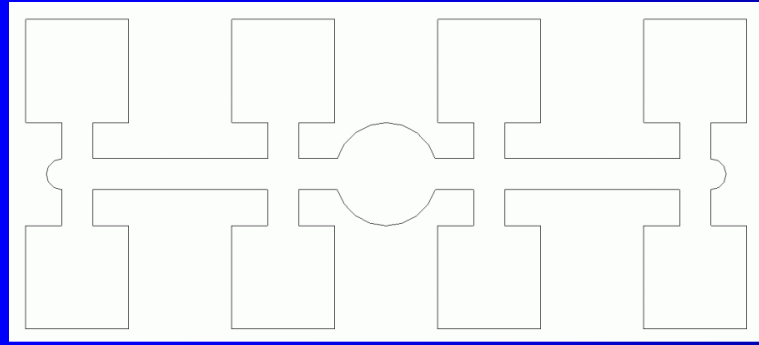
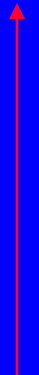
Speed=160mm/sec,  $T_{\text{mold}}=80^{\circ}\text{C}$

Injection Speed

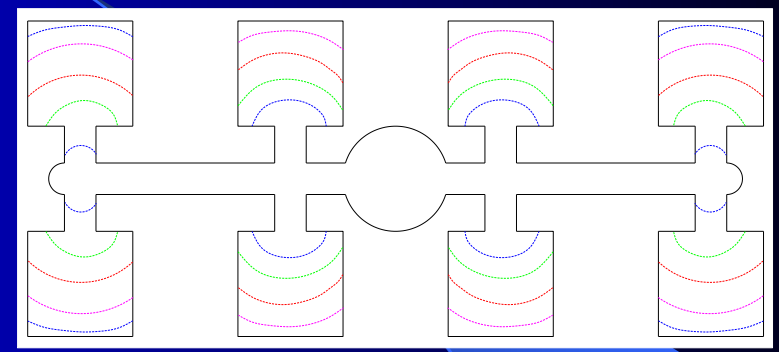
# The Shoot-Short Observation of Eight Cavities Molding (3/3)

➤ Cavities Depth=100 $\mu$

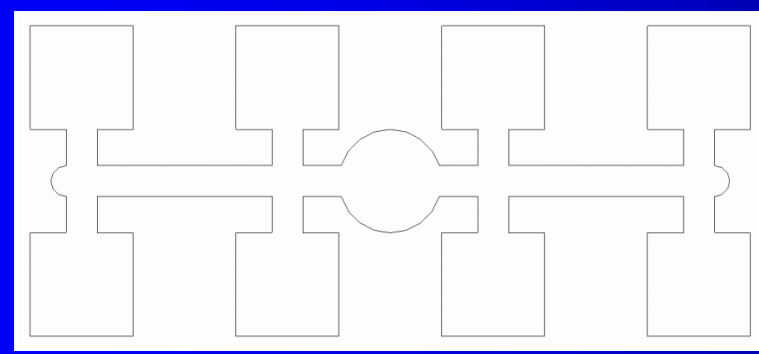
Mold Temp.



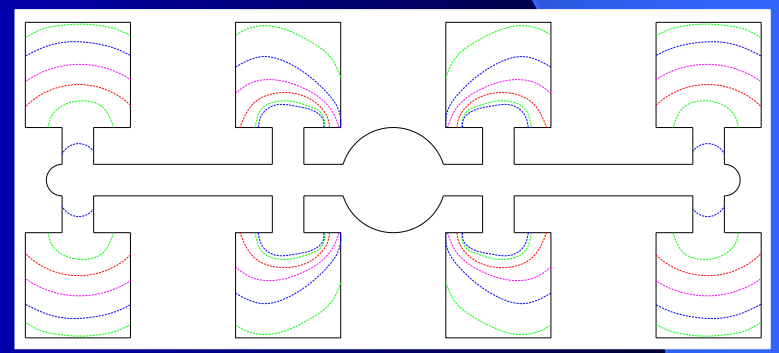
Speed=80mm/sec,  $T_{mold}=140^{\circ}C$



Speed=160mm/sec,  $T_{mold}=140^{\circ}C$



Speed=80mm/sec,  $T_{mold}=80^{\circ}C$



Speed=160mm/sec,  $T_{mold}=80^{\circ}C$

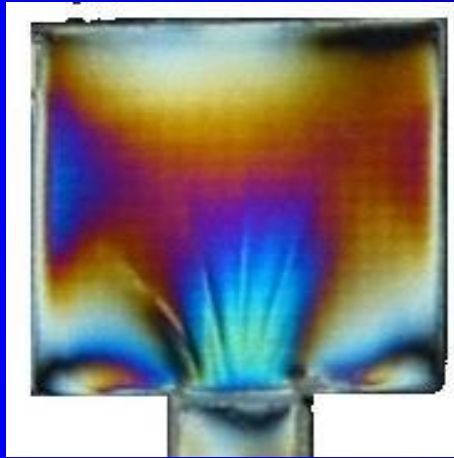
低射速



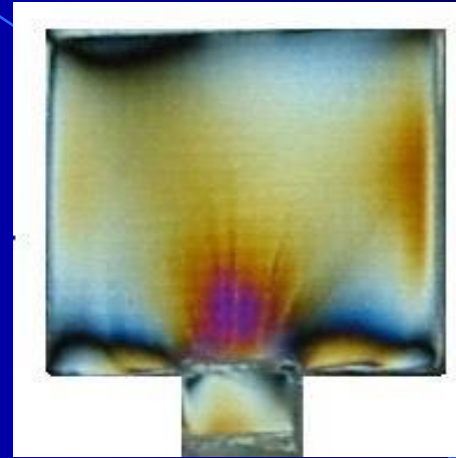
Injection Speed

# The Effects of Mold Temperature to the Parts Birefringence

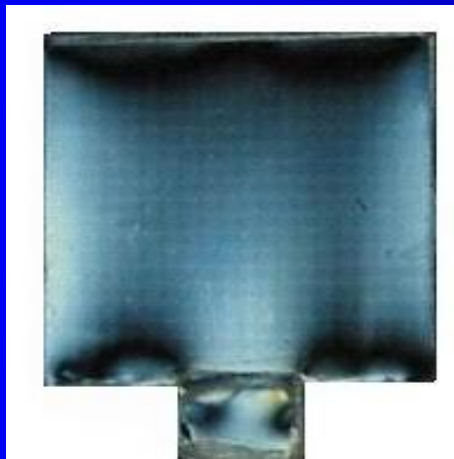
■ PS成品光彈圖 (Injection Speed=90mm/sec,  $T_{\text{melt}}=240^{\circ}\text{C}$ )



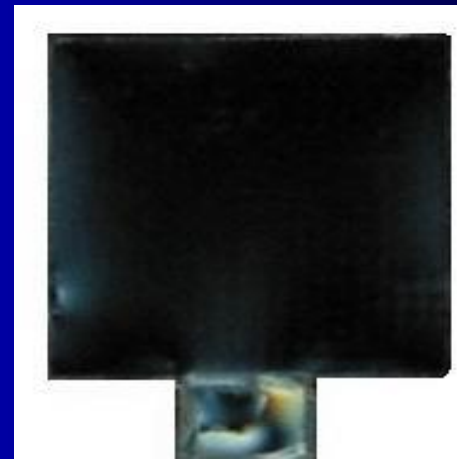
$T_{\text{mold}}=80^{\circ}\text{C}$



$T_{\text{mold}}=80^{\circ}\text{C}$



$T_{\text{mold}}=80^{\circ}\text{C}$



$T_{\text{mold}}=80^{\circ}\text{C}$

# Conclusions

1. The thin parts with micro-features on both sides can be molded using a 15-ton injection molding machine with molds implemented with rapid heating/cooling system.
2. The decrease in part thickness significantly reduces the area of operation window. Molding thin parts requires high injection speed and mold temperature.
3. The injection speed is the dominant processing parameter to successful molding of thin parts.
4. When the part thickness is below  $60\mu\text{m}$ , the microstructures on both surfaces induce significant flow resistance and demand of high injection speed for successful molding

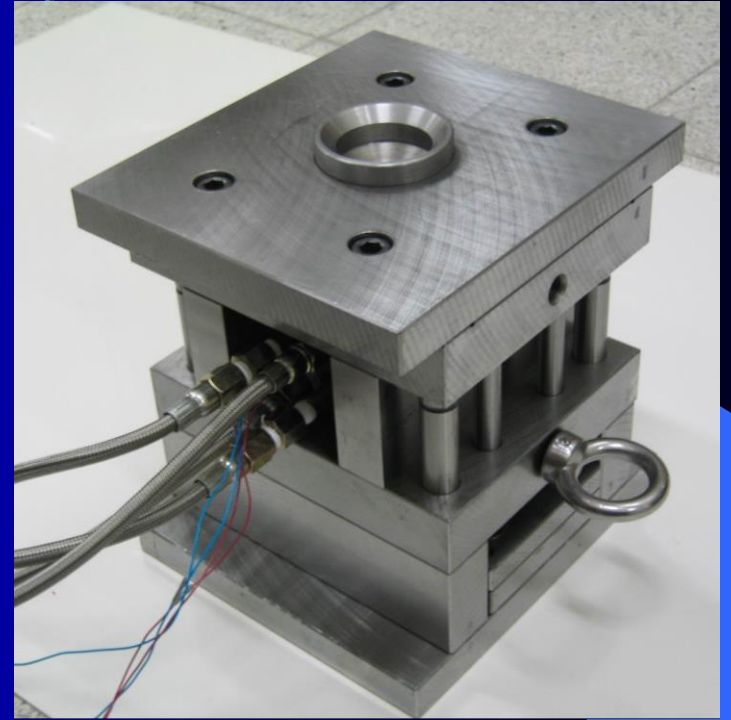
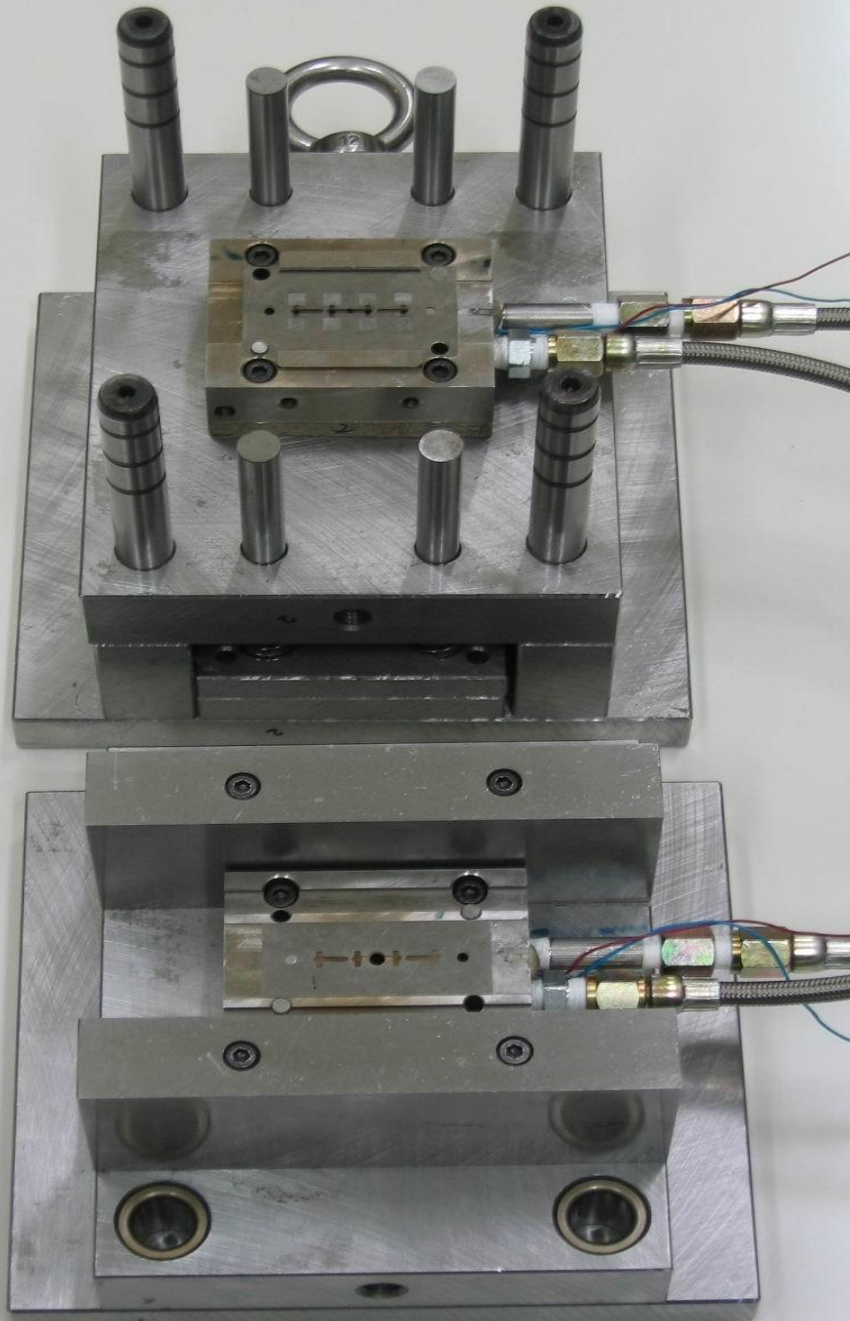
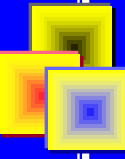
# Thank You !

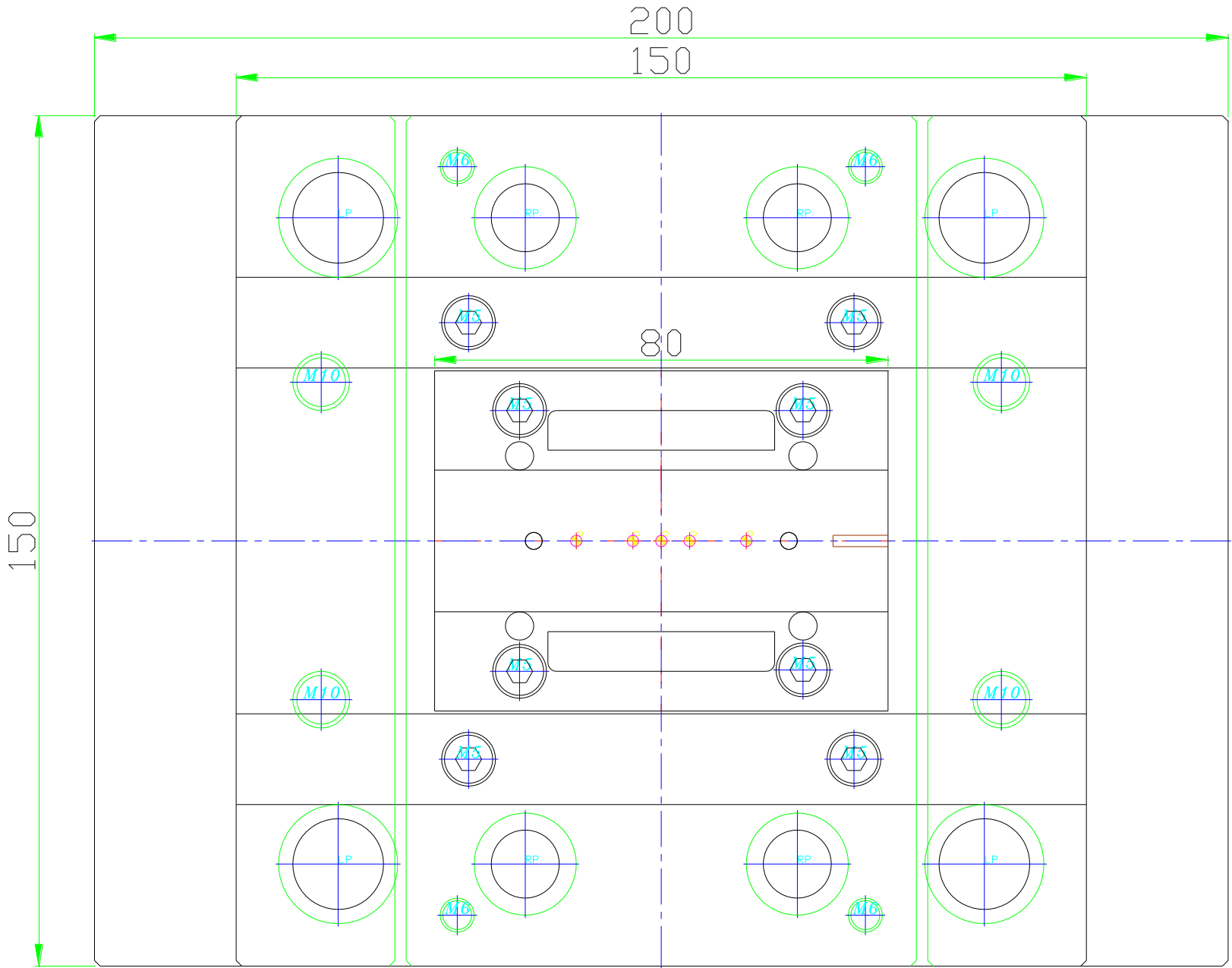
*S. C. Nian<sup>1</sup> and S. Y. Yang<sup>2</sup>*

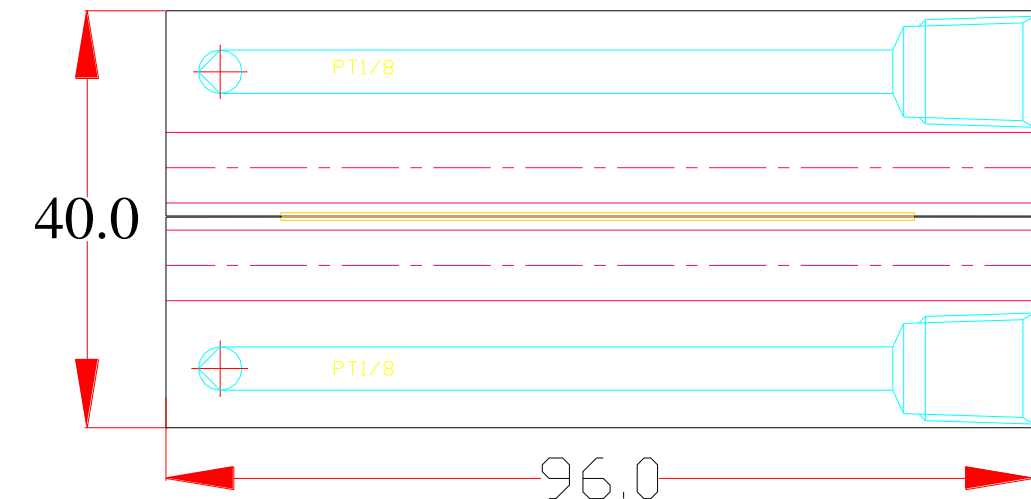
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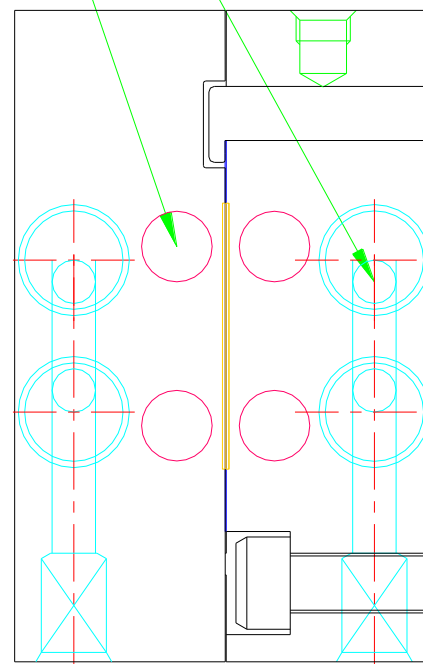
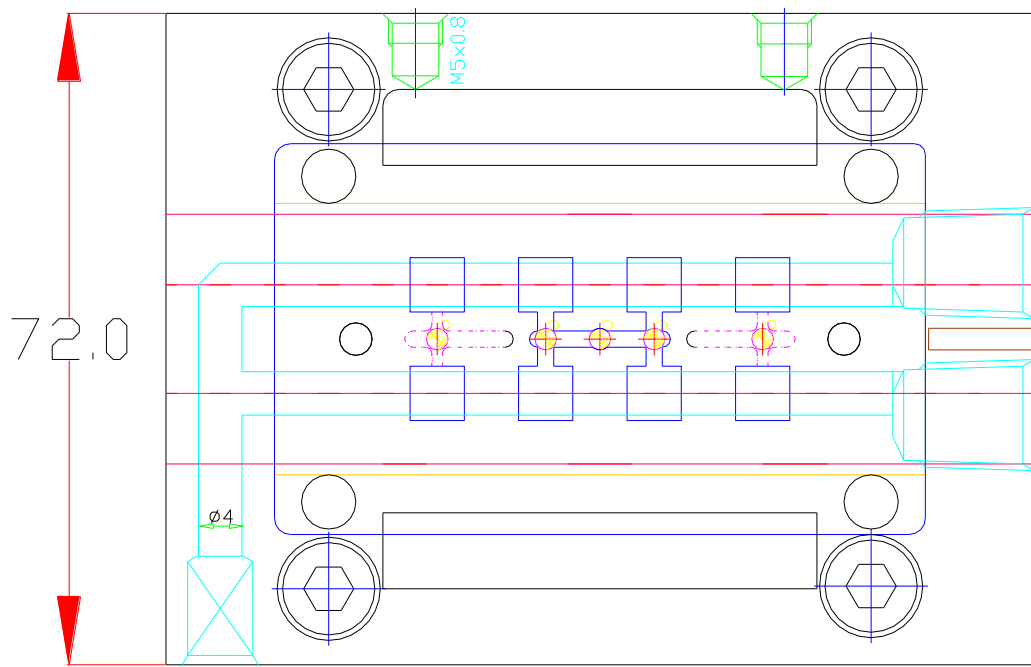






cooling channel  
(diameter 4mm)

electronic heater  
(diameter 6.5mm)



Insert



