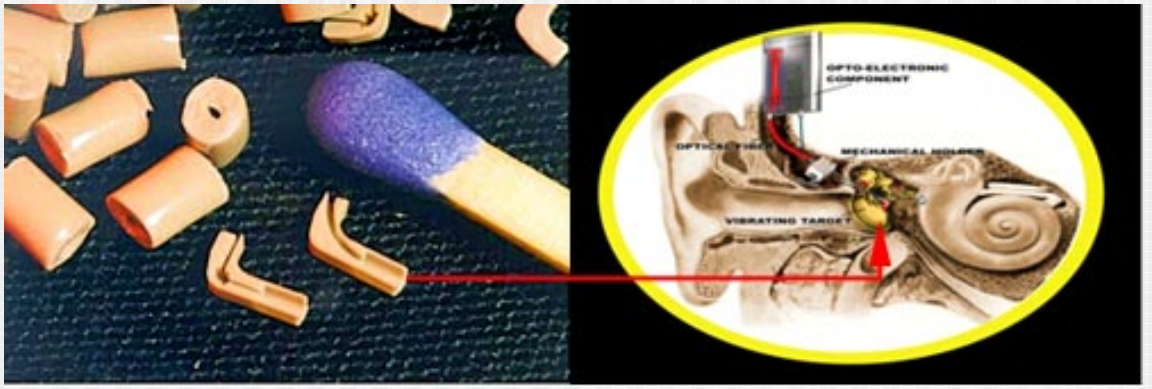
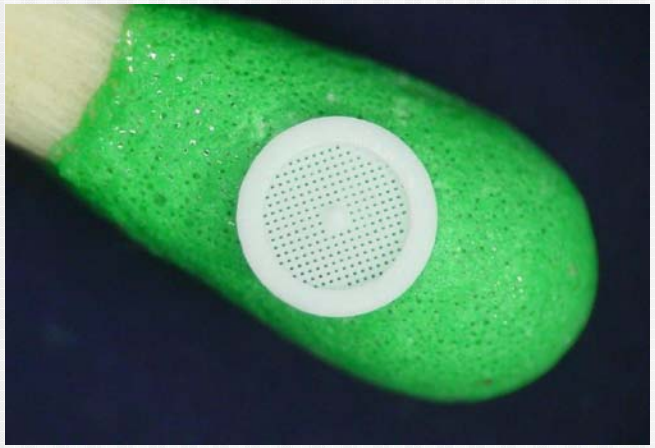
MICRO INJECTION MOLDING





Vishu Shah

Consultek

Topics

- What is "MICROMOLDING"
- Markets and applications for Micromolding
- Machines for Micromolding
- Materials for Micromolding
- Processing
- Tooling for Micromolding
- Part Extraction challenges
- Part Inspection
- What next?

What is Micromolding?

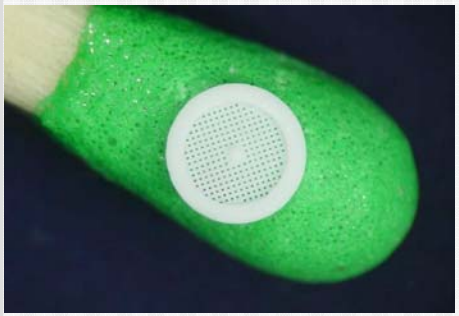
Micromolding is defined as a very unique Injection Molding process requiring specialized molding machine capable of delivering high injection speed , high injection pressure, precise shot control, uniform melt temperature and ultra fine resolution using servo-electric drives and sophisticated controls.

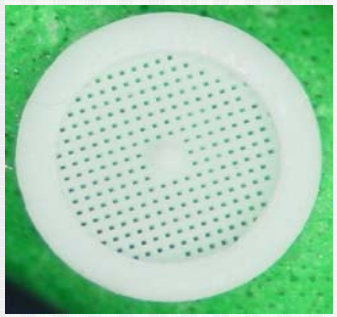
MICROMOLDING

MICROMOLDING IS A VERY SPECIALIZED, PRECISION INJECTION MOLDING TECHNIQUE GEARED SPECIFICALLY TO MOLD MICRO MINIATURE COMPONENTS

MICROMOLDING

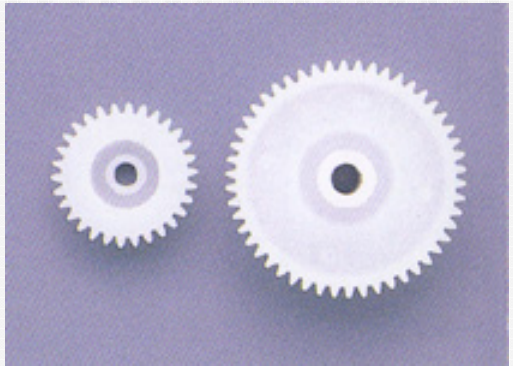
- Part weight… 0.1 to 0.001 gram
- Part size….0.100 in. diameter
- Specialized machines
- Intricate tooling
- Specialized part extraction
- Micromolding Technical expertise
- Microscope to see part geometry





MINIATURE MOLDING

- Part weight…0.1 to 1.0 gram
- Part size…0.250 in. diameter
- Conventional machines
- Standard tooling
- Part ejection
- Conventional molding expertise
- No special tools required



Size Comparisons……

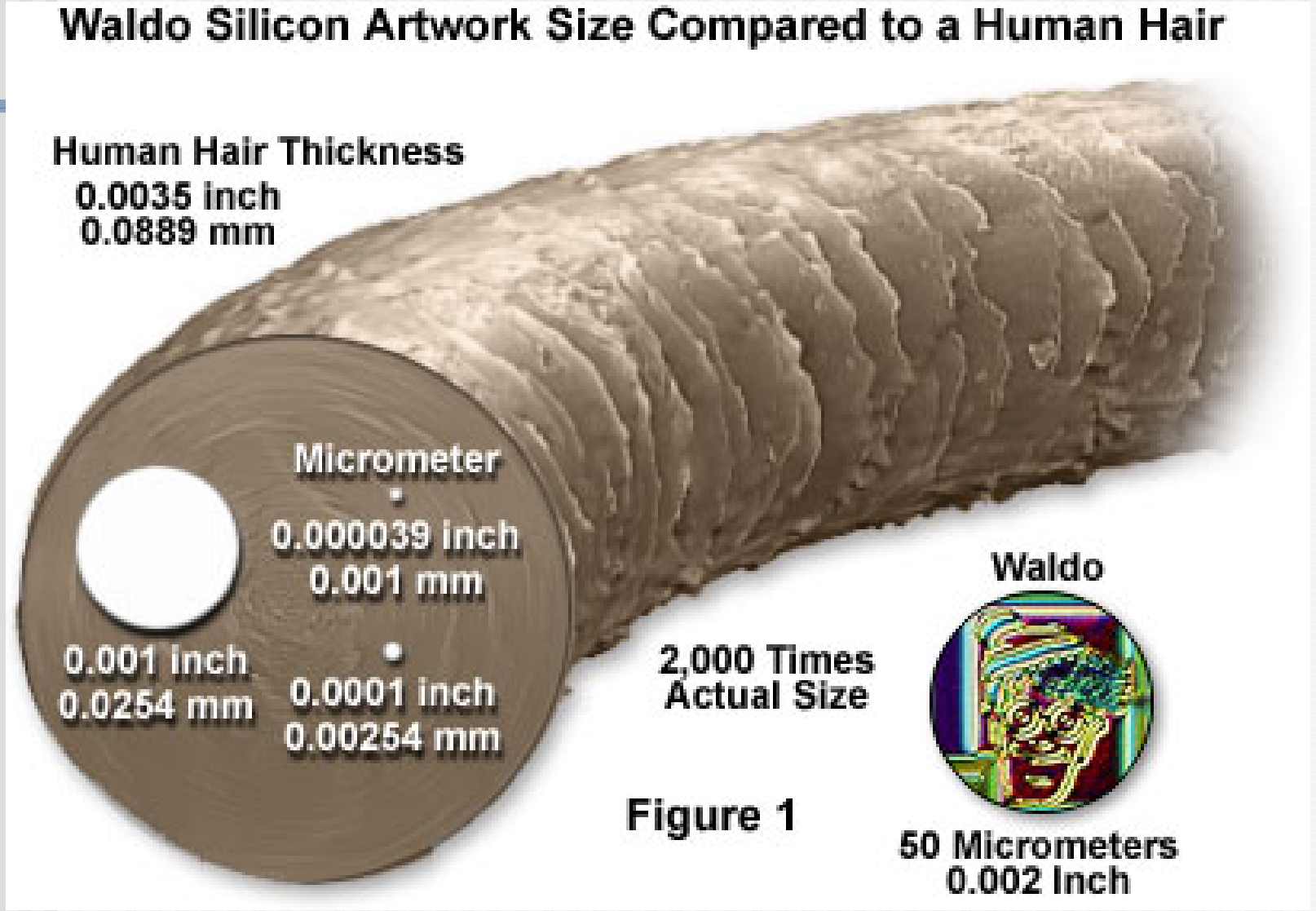


Figure 1

Source: web: Molecular Expressions (http://microscopy.fsu.edu)

How small is small?

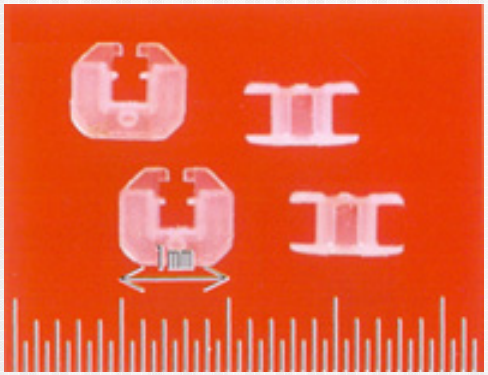
1 Nanometer = 0.001 micron

1 micron = 0.00004 in.

25 micron = 0.001 in.

50 micron = 0.002 in. Size of a human hair

1 mm = 0.040 in.



Bobbin

Material: Acetal

Wt: .0003 g

Or .3 mg

Size:

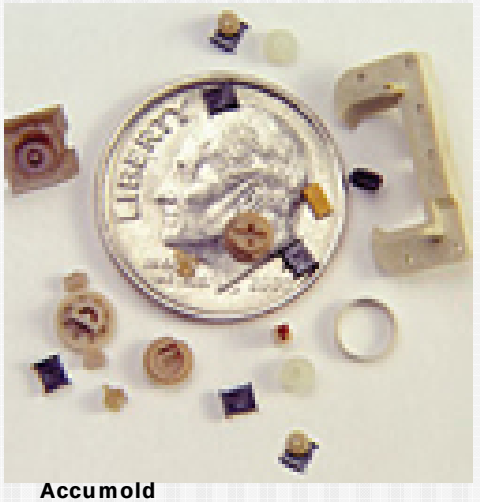
.044 x .025 x .038 in.

WHAT DEFINES A "MICRO" PART?

Less than 1/8 " overall dimension

For example, here are just some dimensions of microparts:

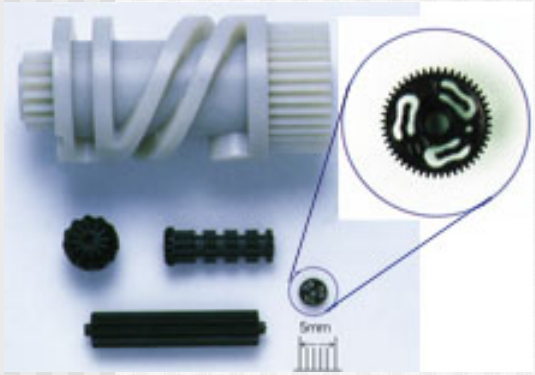
- Total part length of .060" (1.5mm)
- Gates down to 0.002" (0.05mm)
- Core pins of 0.0045" (0.11mm)
- Wall thickness down to .0015" (0.04mm)
- Cavity and Core TIR less than .0001" (.003mm)
- Overall part volume of 0.00013 grams
- **520 parts per plastic pellet!**



Accumold

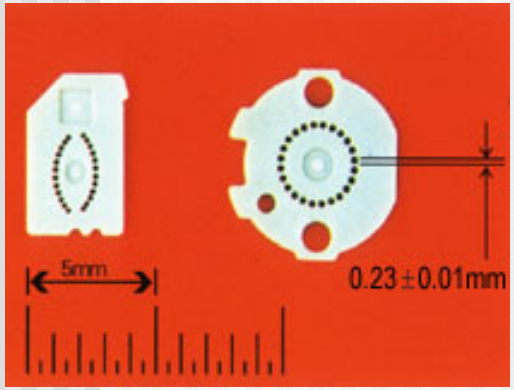
Examples of Micromolded parts.....

Watch out for ants!

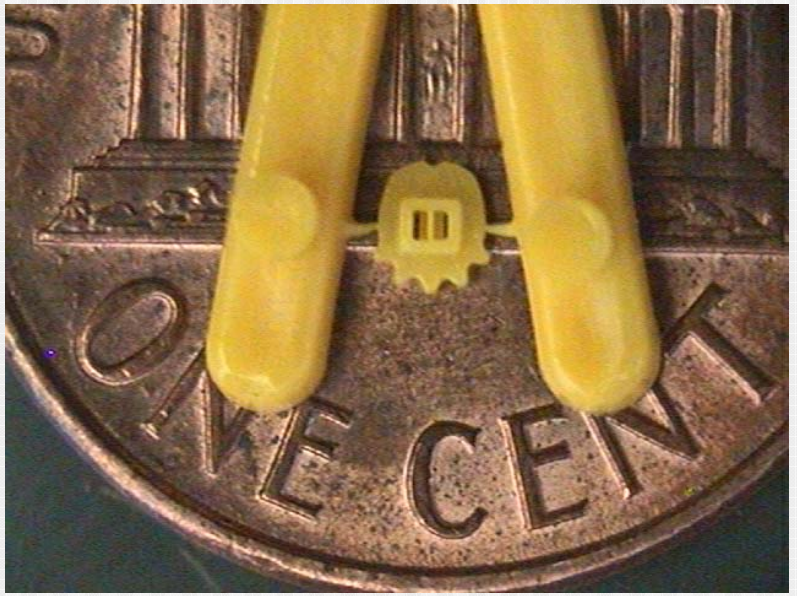


5mm Gear:

Uses: Electronics
Material: POM
Feature: Gear Module 0.08, Tolerances of 5 microns.



Miniature Holes:
Uses: Dot matrix printer head
Material: PBT
Feature: Hole Diameters 0.23 +/- 0.01mm



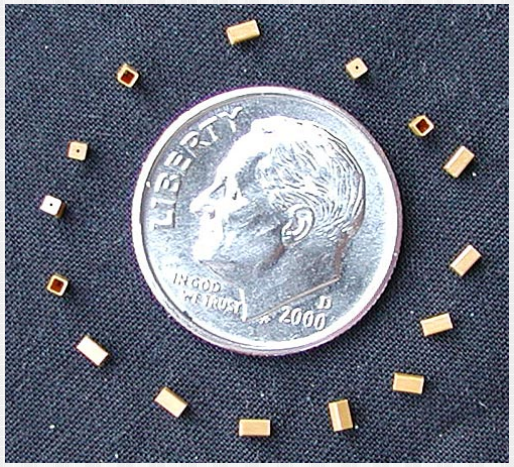
Markets and applications for micromolding

Telecom-Fiber Optics

Micro Connectors

Ceramic Ferrule Holder

Fiber Optic Housings



Capacitor Housing

Material: LCP

Diameter of the hole: .007”

Wall section: .004”

Markets and applications for micromolding

Automotive

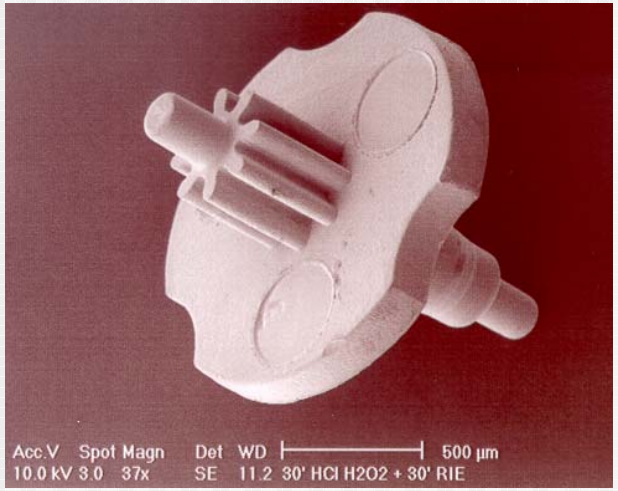
Axle for Cockpit Instruments

Markets and applications for micromolding

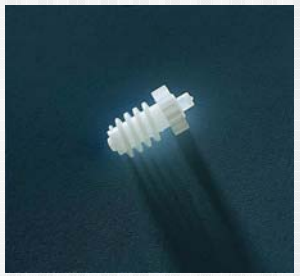
Microdrive Systems and Control

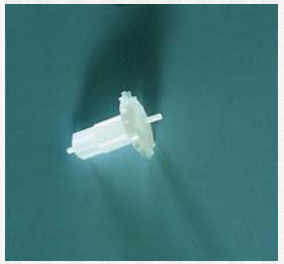
Potentiometer Gear

Material: PPA



Part weight: 0.0008 g Acetal
Stepper Motor axle for Watches



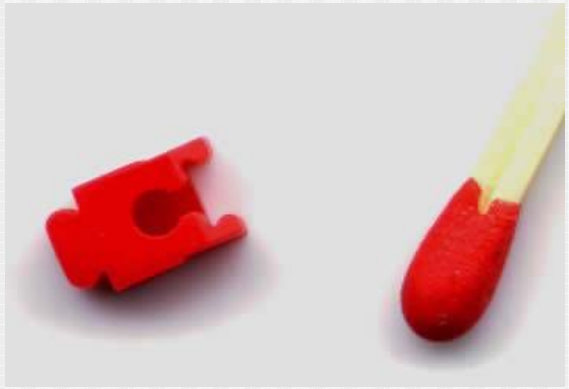


Gears

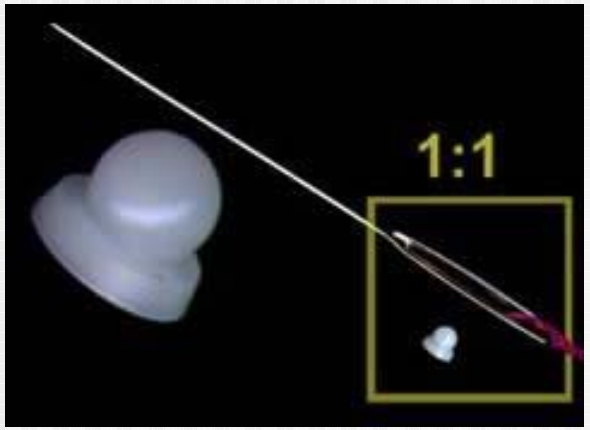
Markets and applications for micromolding

Medical and Surgical

Blade Holder

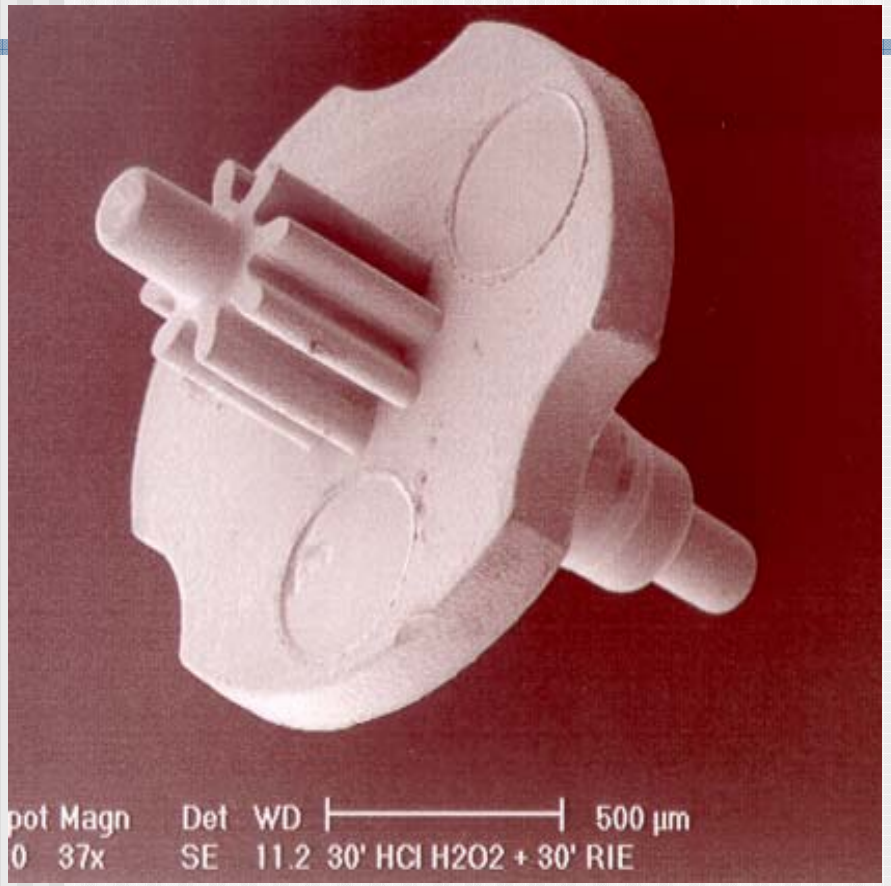


Dental Prosthetic



Dental Prosthetic

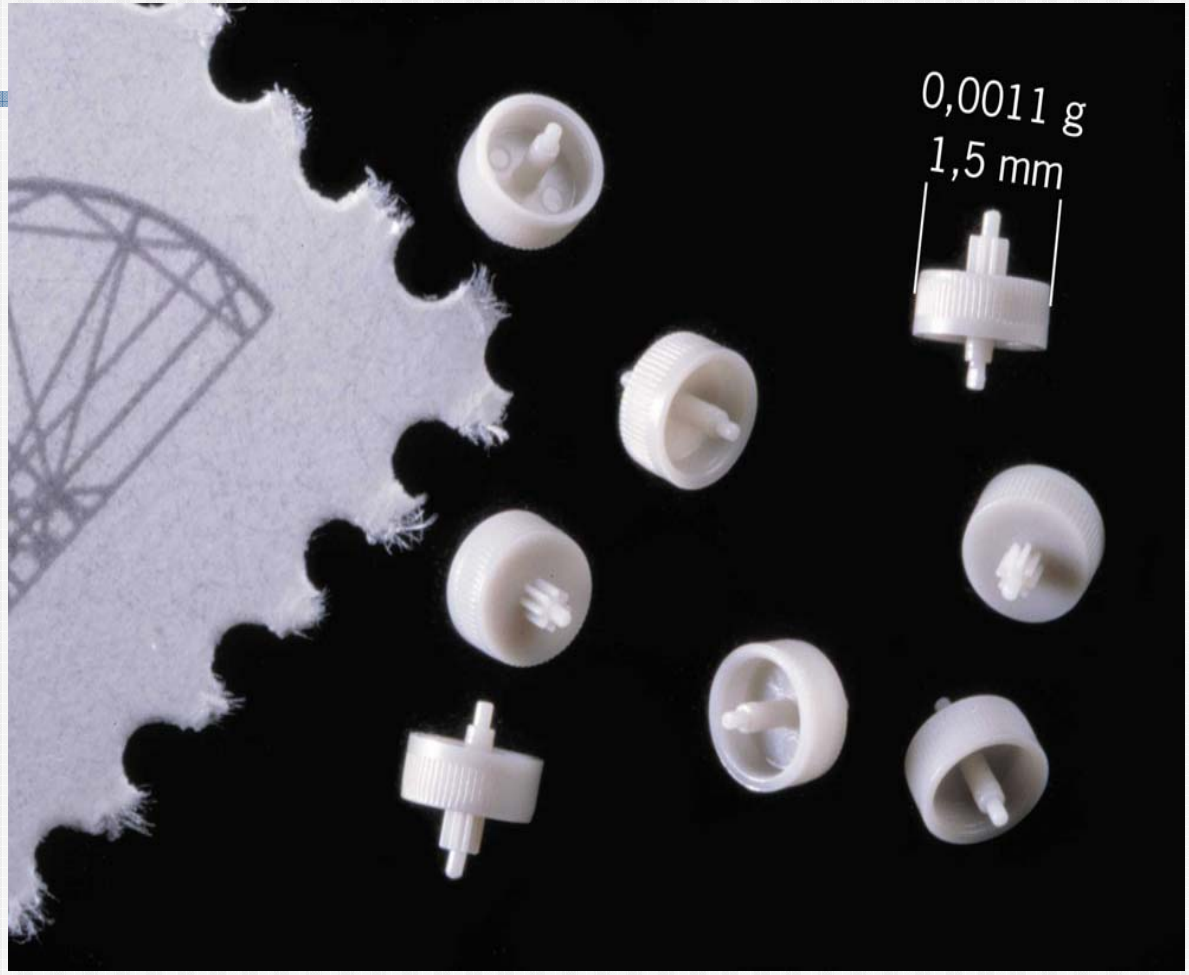
Micro gear



Part weight 0,0008 g, Material POM, for watch industry

Quelle/Source:Battenfeld

Micro gear



Part weight 0,0011 g, Material POM, for watch industry

Quelle/Source:Battenfeld

Weight: 0.00033 grams

Largest diameter: 0.584 mm

Smallest Diameter: .183 mm

Overall length: 1.463 mm

Gear teeth: 8

Width of gear tooth: 0.066mm

Overall length of the gear tooth: 0.508 mm

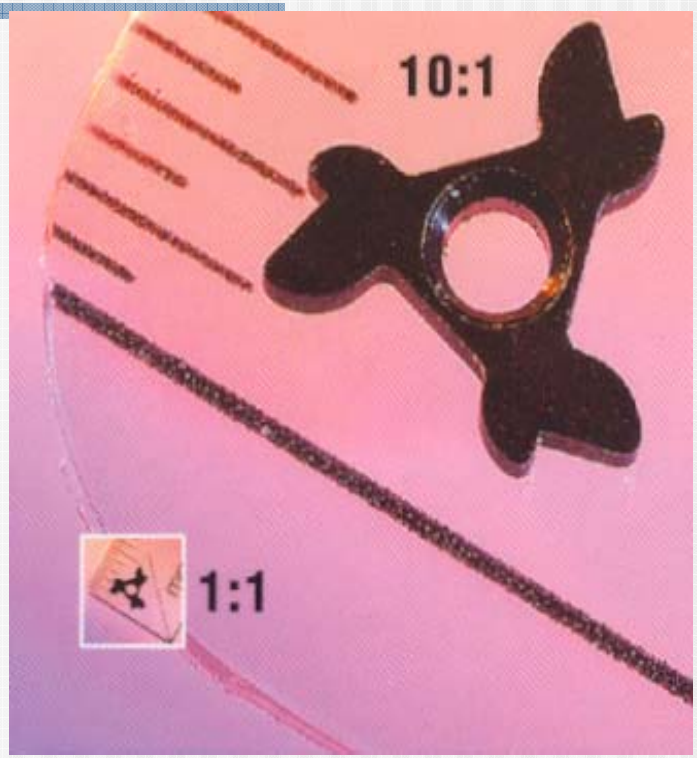
Molded by:

MICROMOLD, Inc.

Riverside, CA

Machine: 15 ton BOY

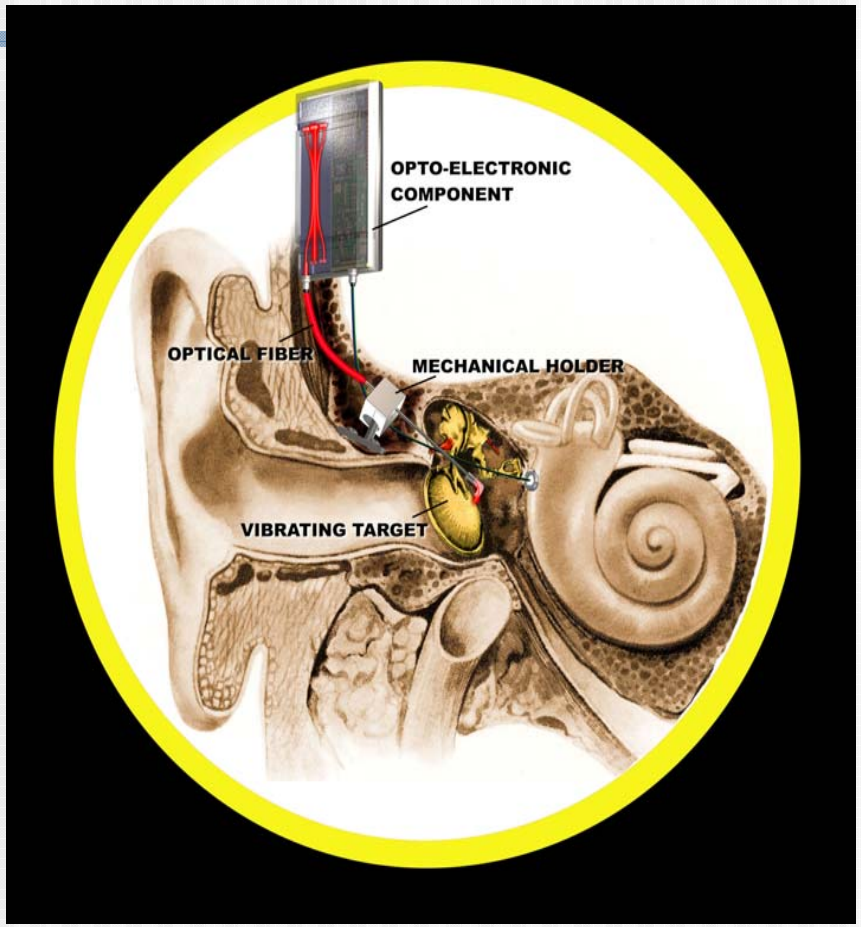
Catch wheel



Part weight 0,0067 g, material POM, for micro mechanic

Quelle/Source:Battenfeld

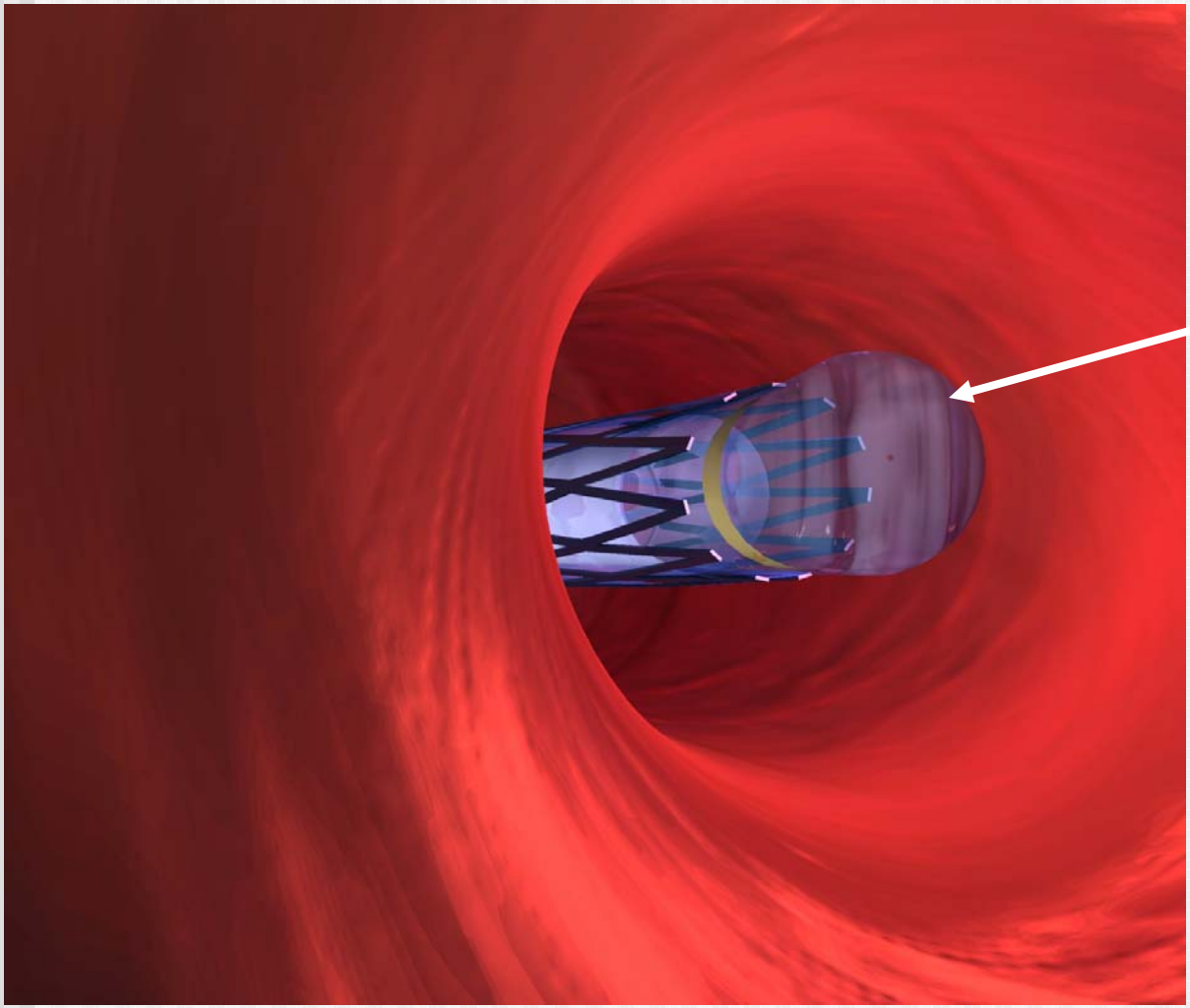
Sensor housing



Part weight 0,0022 g, material POM, for hearing aid

Quelle/Source:Battenfeld

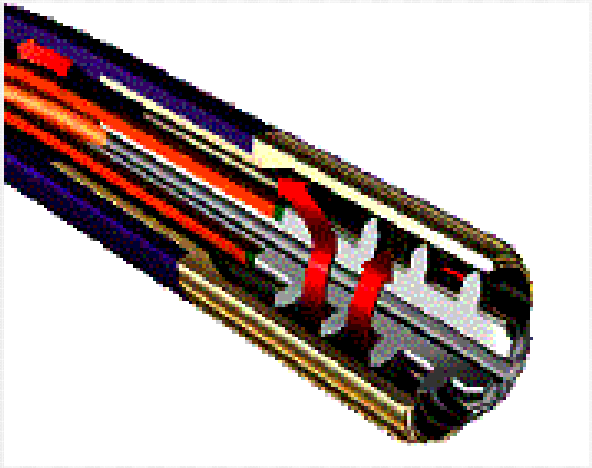
Catheter components



600 micron diameter catheter tip

Source: www.medicalmurray.com

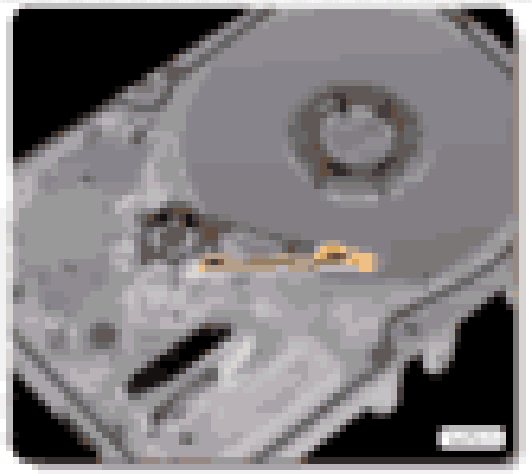
Clot Removal Catheter



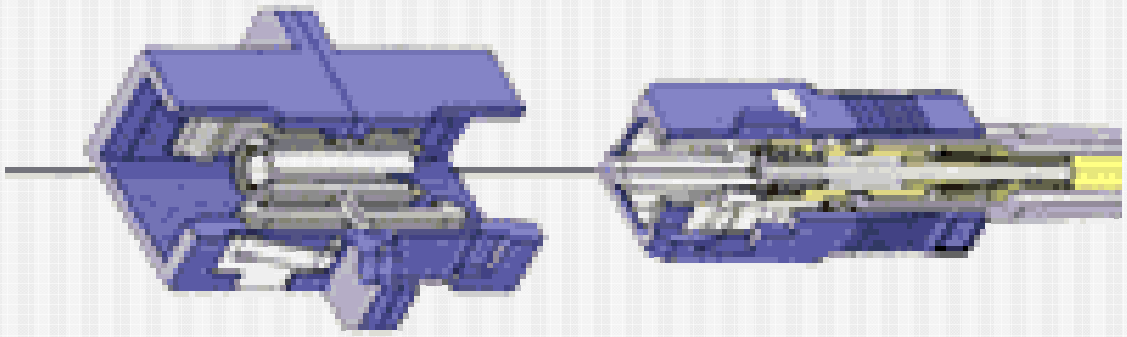
1.8 mm diameter rotary cutter and vacuum system for removing clots requires bearings, guides, etc.

Source: www.medicalmurray.com

Communications



5 mm thick hard disk drive



Fiber optic cable connectors

Devices require sensors, bobbins, switches, lenses, gaskets, rollers, etc.

Source: www.medicalmurray.com

Markets

Main industries:

• Automotive	micro switches, connectors
• Computer	connectors, printer ink heads
• Telecomunication	Fiber optics connectors
• Electronic	micro parts
• Medical	hearing aid, implants
• Sensors	airbag sensor
• Micromechanics	micro engine, rotators
• Optics	lenses, displays
• Watch industry	cog-wheel, micro gears
• GF-transmission	connectors
• Institutes, Univers.	Material and technology trials

Quelle/Source:Battenfeld

Injection Molding Machines for Micromolding

Typical concerns…….

- **Material Plasticizing (Plastification)**
- **Material feeding**
- **Consistent shot size using standard check ring (reproducibility)**
- **Material freezing due to extremely small mass**
- **Shot size generally too large for micro parts**
- **Material degradation from long residence time**
- **Melt homogenization**
- **Static electricity Issues**

SIZE OF THE PLASTICS PELLETS USED IN STANDARD MACHINES LIMITS THE SIZE OF THE PLASTIFICATION SCREW TO 14 MM DIAMETER MIMIMUM.
IN ORDER TO UNIFORMLY MELT THE PLASTIC, SCREW MUST RECEPROCATE CERTAIN DISTANCE

New Developments

Small screws……14 mm

High speed injection up to 760 mm/sec

Low injection volume, Shot size of 1.0 gram

Two stage machines….Screw/plunger type

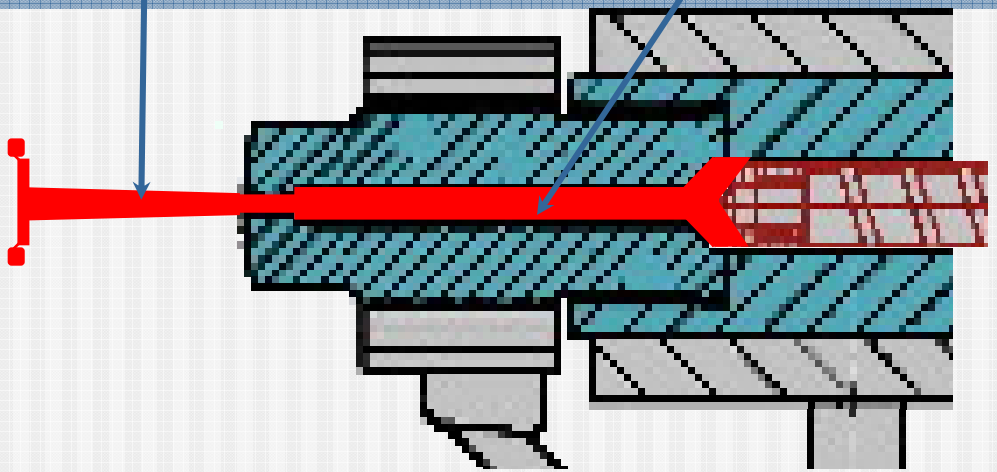
All electric machines for precision and accuracy

Operating principles of two stage screw / plunger type machine

Comparison

sprue 0,7 ccm

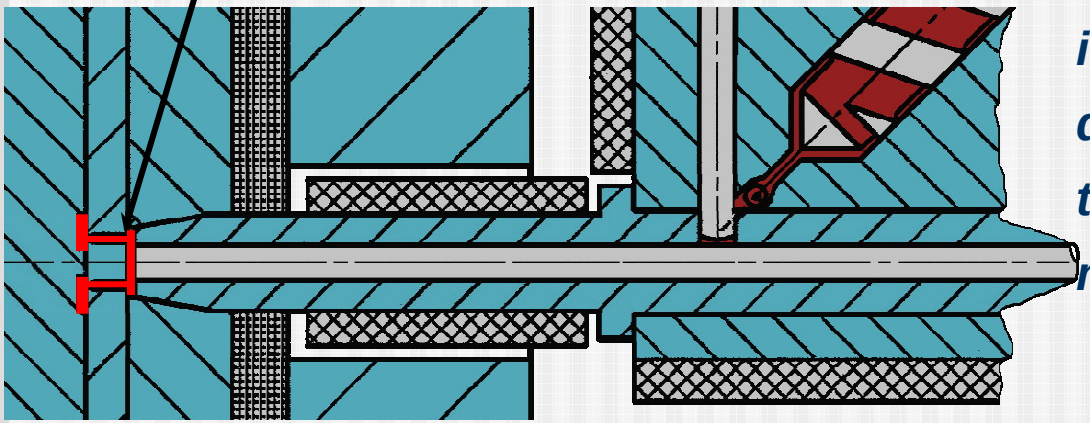
melt cushion 1,8 ccm



Standard injection 14mm screw

injection speed :	*250mm/s*
deceleration	
to zero velocity :	*30ms*
melt cushion :	*2,5ccm*

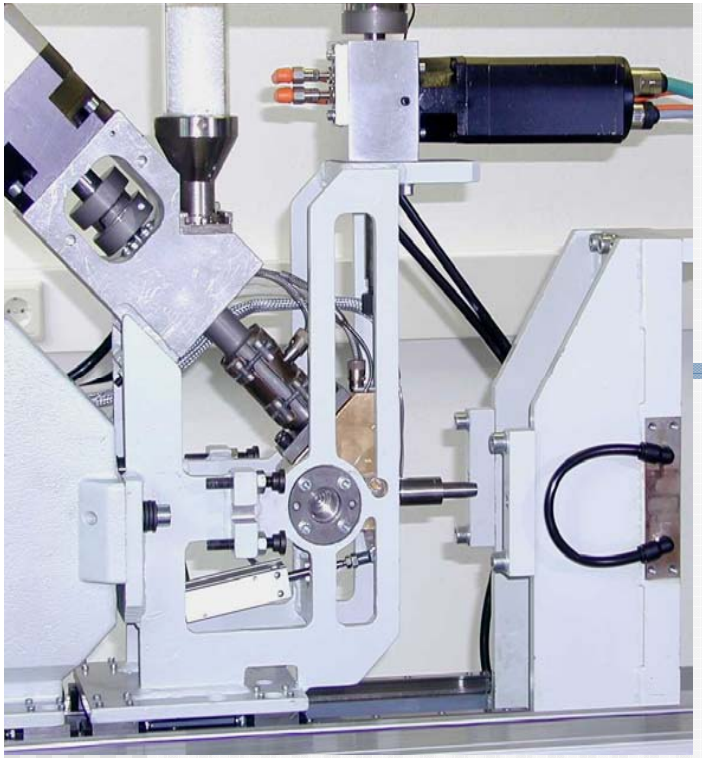
sprue + melt cushion 0,2 ccm

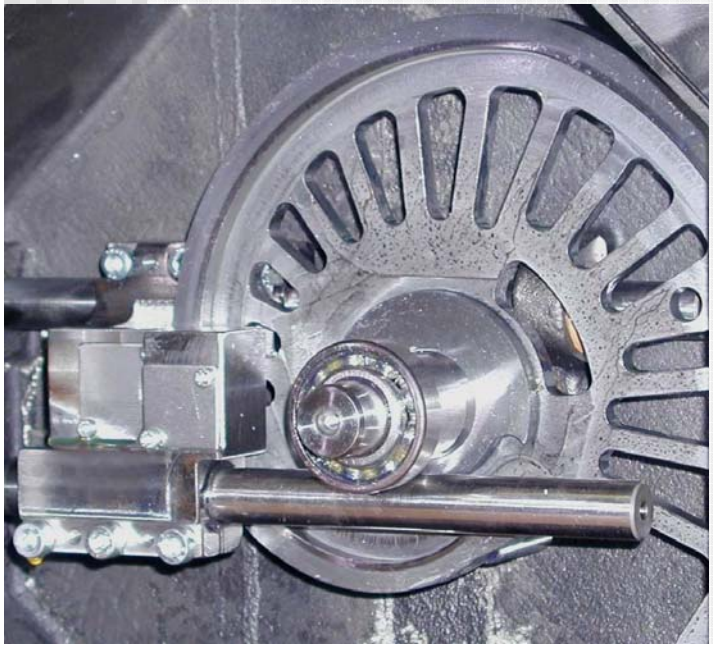


Microsystem 50

injection speed :	*760mm/s*
deceleration	
to zero velocity :	*2,5ms*
melt cushion :	*0,2ccm*

Quelle/Source:Battenfeld





Injection module

- **Benefits:**

- **shortest possible runners and gates**

- **minimum pressure lost**

- **injection of thermal and homogeneous material**

- **repeatable processing results**

Injection Molding machine designed specifically for Micromolding

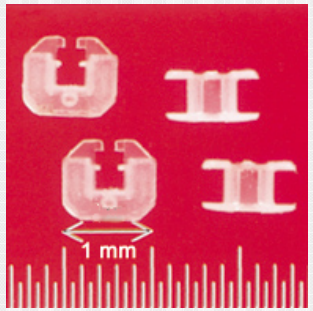
Clean room Module

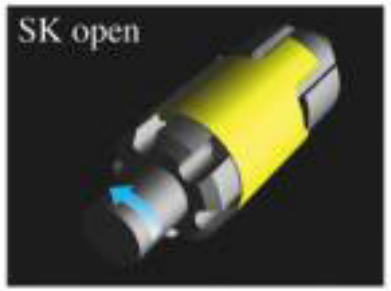
Optical inspection module

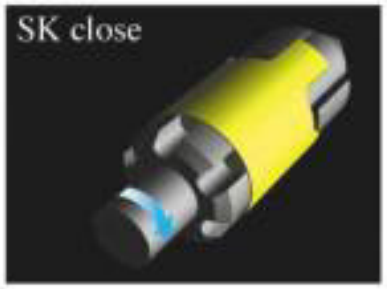
Ionization module

Part extraction (Handling) module

Packaging Module







During plasticizing, screw rotation allows the check ring and seal to align so the channel is open for melt flow.

On completion of recovery, the screw counter-rotates to block the flow channel, and the channel remains blocked during screw pull back and fill.

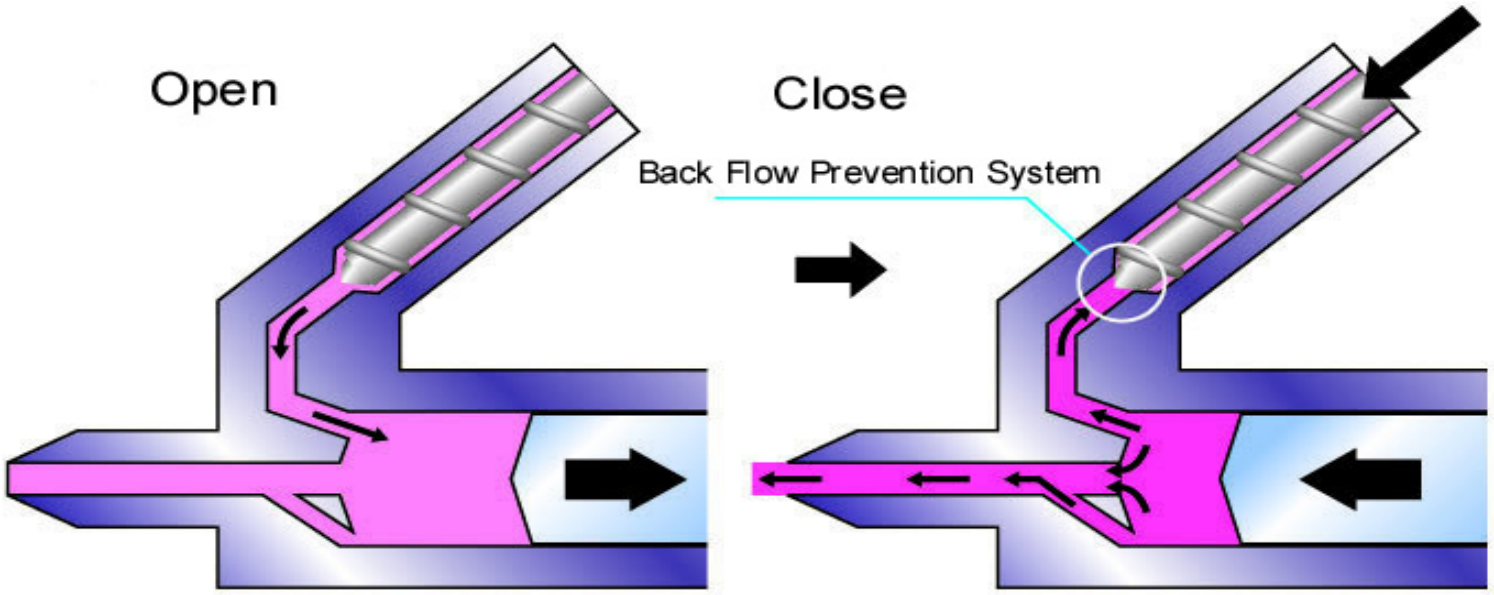
TOSHIBA MACHINE

TOSHIBA MACHINE

1. Super Precision All Electric Micro Molding Machine
    1. Energy savings up to 80%
    2. The Ultimate in repeatability
2. Tie bar-less Mold Clamping Structure
    1. Much larger mold space
    2. Equivalent to wide platen style
3. Direct Lock Ball Screw with Cross Head
    1. Accurate and stable clamping
    2. Equalized force on mold
4. Mechanical Ejector with servo control
5. Injectvisor V21 controller

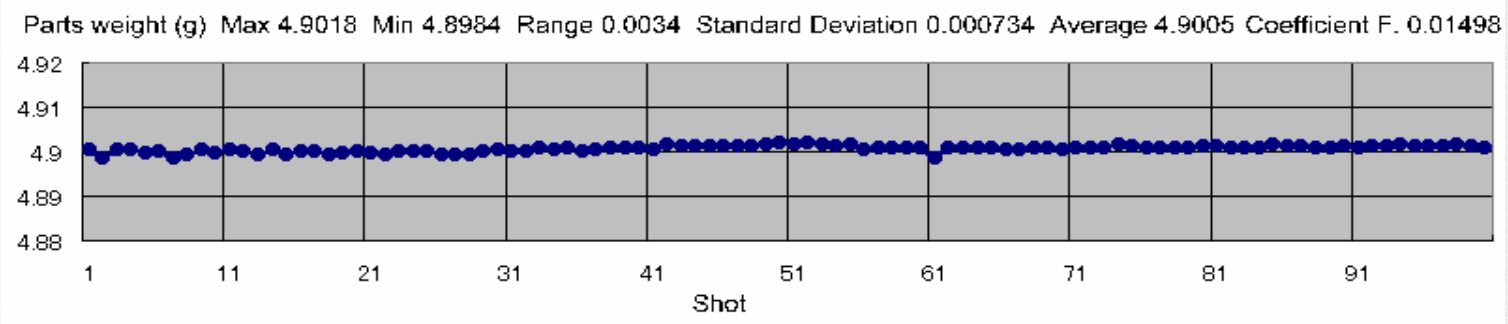
No Back Flow

Sodick V-line



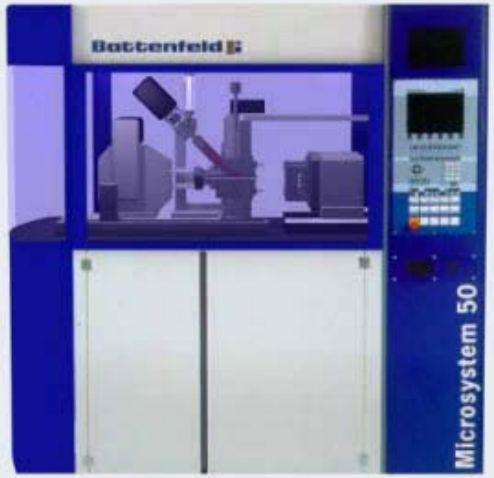
The direct shut-off screw mechanism is adopted by eliminating a check valve. After plasticizing and sending the melted plastic into the injection chamber, the screw tip is then pushed forward in order to prevent any backflow.

Stability of parts weight



Microsystem

www.ukmig.com



Ben Whiteside 2003

Microsystem Movie

Unique Patented Technology

Sesame NanoMolding Machine

- .01 to 80 mm^3 parts
- Silicone rubber or thermoplastic
- Insert molding

Source: www.medicalmurray.com

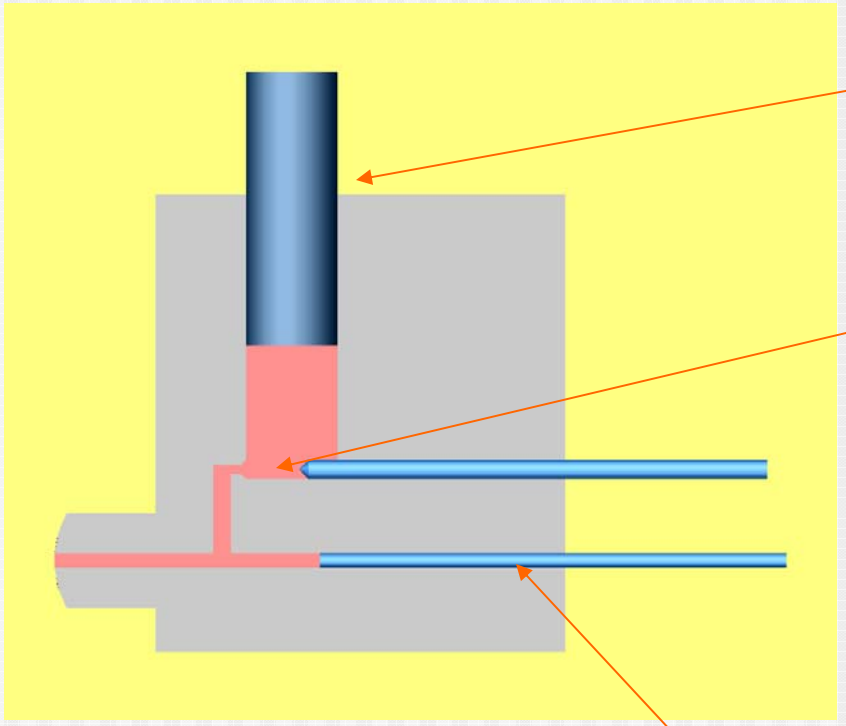
Molding Machine Comparison

	Screw	Plunger	Screw/plunger	Sesame
	Nissei	Butler	Battenfeld	Murray
Screw/plunger, mm	12	10	14/5	1
Shot size, mm3	6000	4000	1100	49
Max pressure, ksi	33.1	18	36	50
Accuracy, mm3	1.5	200	0.11	0.012
Melted volume, mm3	21540	10000	21500	1570

Accuracy calculated on controlling to 0.01 mm position accuracy

Source: www.medicalmurray.com

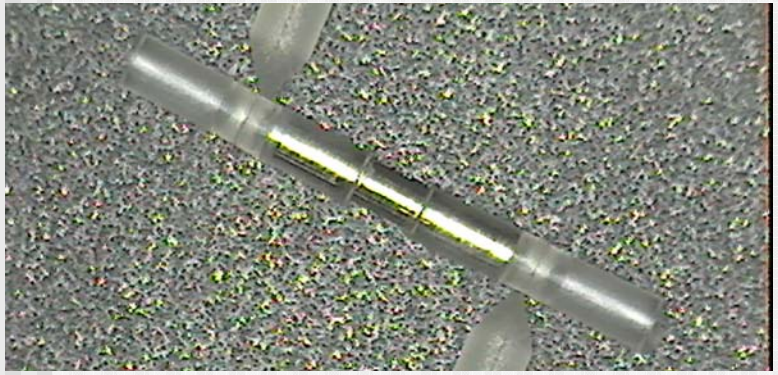
Injection System Design



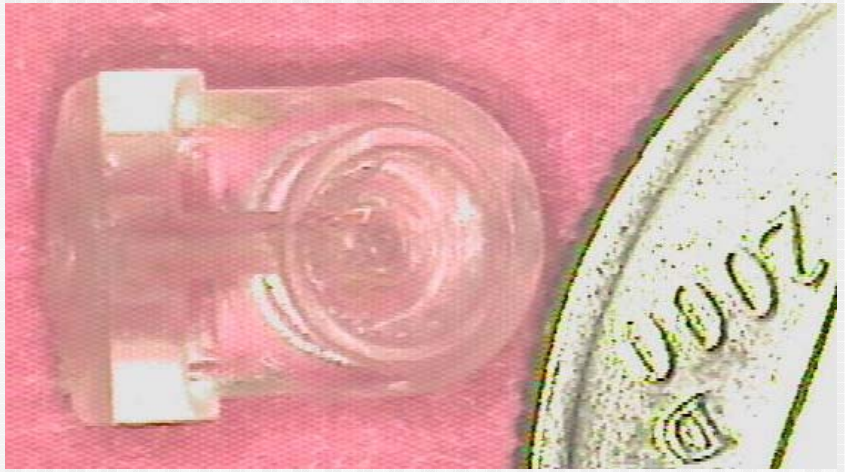
Source: www.medicalmurray.com

NanoMolding Examples

- Bioabsorbable implants



- Silicone Rubber – polycarbonate molding



Source: www.medicalmurray.com

Micro Surgical Component

- Tube
  - ID = 90 micron
  - OD = 280 micron
  - Length = 1.8 mm
  - Volume = 0.1 mm^3
  - Weight = .0001 g
  - Material - TPE

Source: www.medicalmurray.com

Materials for Micromolding

- LCP (Liquid Crystal polymers)
- Acetal
- Polyester
- Polycarbonate
- PEEK
- Glass and Mineral filled compounds adds to the rigidity and stability
- Hygroscopic materials like Nylons are not suitable for micromolding since they change size making it difficult to hold close tolerances

Material Challenges

- Process does not correlate well with published rheological data
- Published Molding Guides not very useful
- Mold flow simulation data not available
- Molders forced to develop their own techniques
- Material does follow physical property data

Processing Micro parts

Challenges	Possible Solutions
Plasticizing	Small Diameter Screw (14 mm) 14:1 L/D
Uniform Melt Temperature	Short residence time
Freezing off and filling thin walls	Fast Injection Speed, High melt temperature and High Injection pressure
Shot Size and Accuracy	All Electric Machines, Fiber Optic Measurement System, Two Stage
Overheating	Small Barrel and Short Residence Time Evacuate barrel every shot
Ejection and Part Extraction	0.2 mm ejector pins & Suction Cups
Insulating Nozzle from Mold	Heated Nozzle

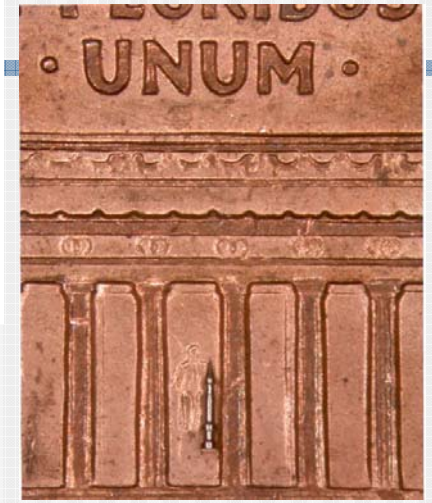
Tooling for Micromolding

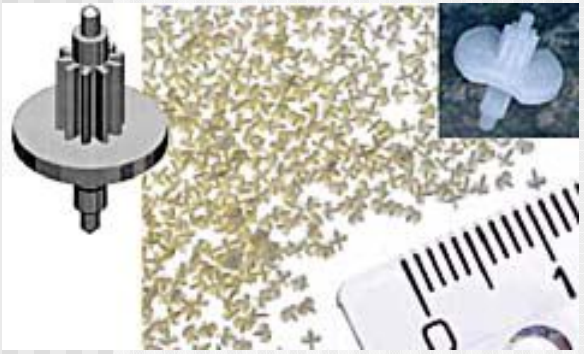
Challenges in micro mold construction

- Physical limitation to how small one can cut or burn something, established by the geometric characteristics of the feature being formed
- Shear strength of the steel can not resist the pressures exerted by cutting head or in case of EDM surface finish is eroded beyond acceptable level
- Mechanical, thermal and chemical properties of the material being formed are affected

Tooling Techniques

Mechanical Machining
EDM
Laser
Lithographic Systems





Plastic gear for watches

- Ø magnet shaft 0.350 mm
- Ø pivot 0.180 mm,
- Tolerance ±1µm

High precision finishing

High precision simultaneous electrode µEDM grinding

No material alteration:
Hardened Steel & Carbide...

•EDMing highest precision cylindrical holes down to 0.020 mm diameter or complex geometry holes.

•Erosion on X and Y axes to erode special slots or grind smallest electrodes down to 10 µm.

SARIX EDM Technology

Aerosol spray nozzle

High quality finishing on precise micro holes

High precision finishing
High quality surface
No burning effect

No material alteration: Hardened Steel & Carbide

Micro EDMing machining technology with solid and tube electrode from 45 Microns to 3.0 mm.

Micro holes, high Precision Micro holes and shape holes down to 20 Microns
High surface finishing capability down to Ra 0.1 and Ra 0.05 with the **Micro Fine Pulse Shape Generator MFPS**.

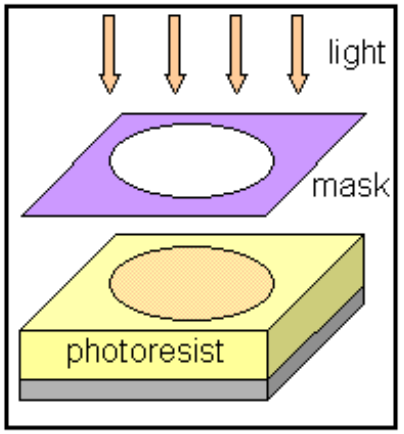
Gating solutions

What is LIGA or UV LIGA?

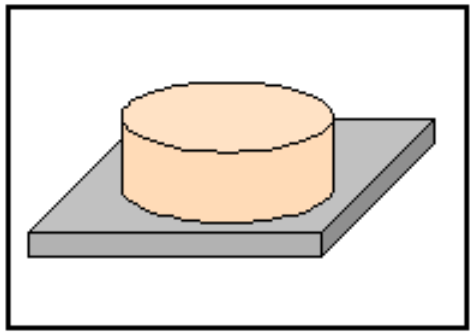
If raw material can not be "cut" any smaller, then how can it be formed into these products which have features of only a few microns in size?
Answer: It is "grown", molecule by molecule with the shape of the feature "grown" in place! The process are known as LIGA. It is an acronym for the German words for lithography, electroforming, and injection molding.

Lithographic tooling is based on the same concept as is used by the semi-conductor industry for making electronic chips. By focusing the energy and accuracy of light, patterns can be "written" into silicon or polymer materials, so that 3-dimensional products can later be produced which replicate those patterns. This is simplistic explanation for a highly complex, multiple step operation which is shown in the following concept diagrams:

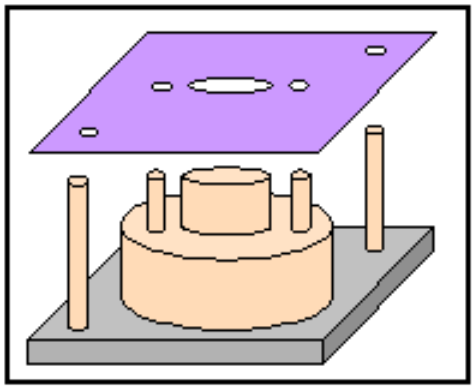
One of the most useful benefits of the lithographic tolling is the mirrored *surface finish.* Walls of lithographic tools are very smooth giving smooth finish on plastics parts, very important in applications such as micro gears, light pipe, connectors etc.



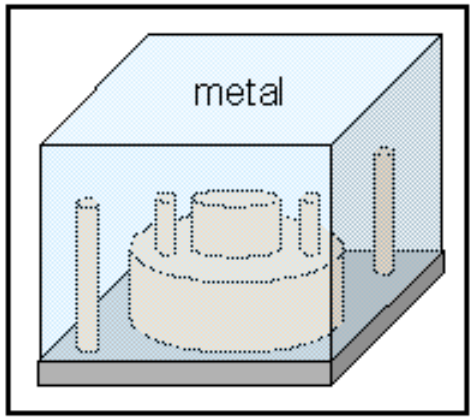
1. Exposure



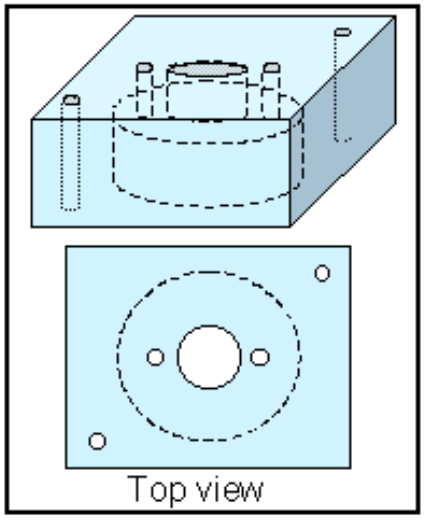
2. Development



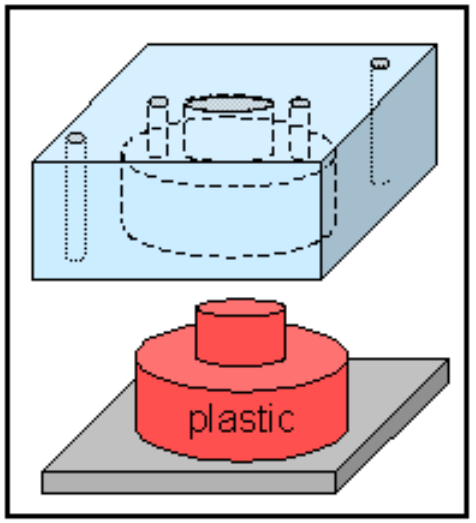
3. Iteration : multilevel master



4. Electroforming



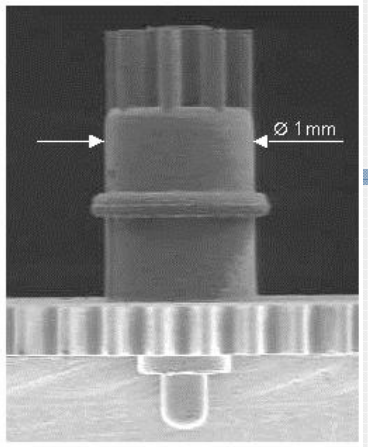
5. Molding Tool

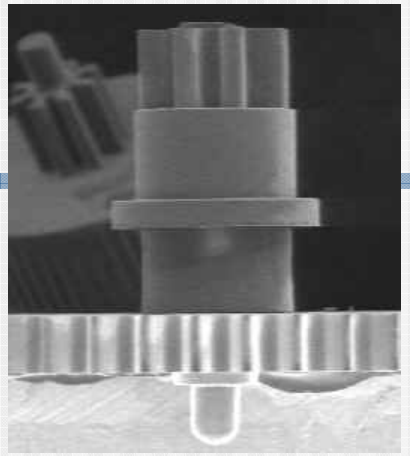


6. Molding

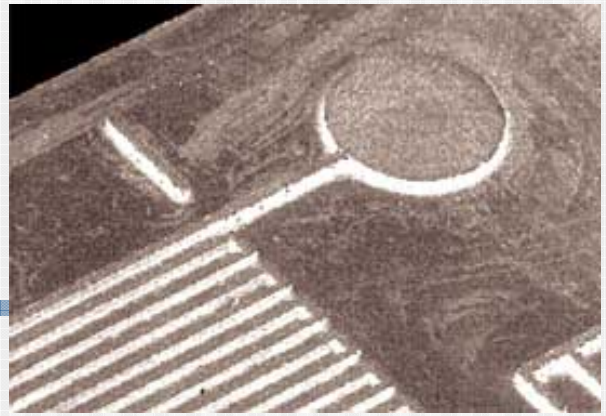
LIGA advantages

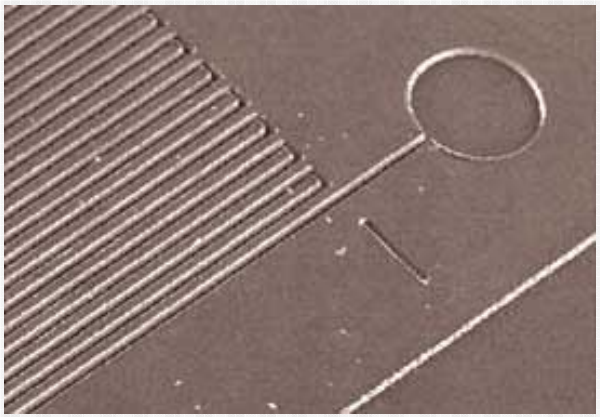
Sharper edges



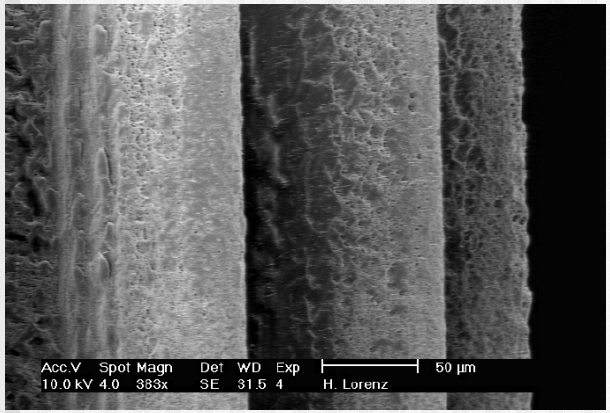


Injected in EDM cavity Injected in Mimotec cavity

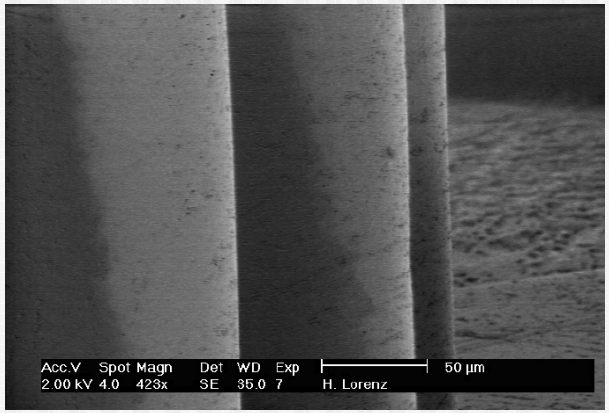




Reduction in Roughness

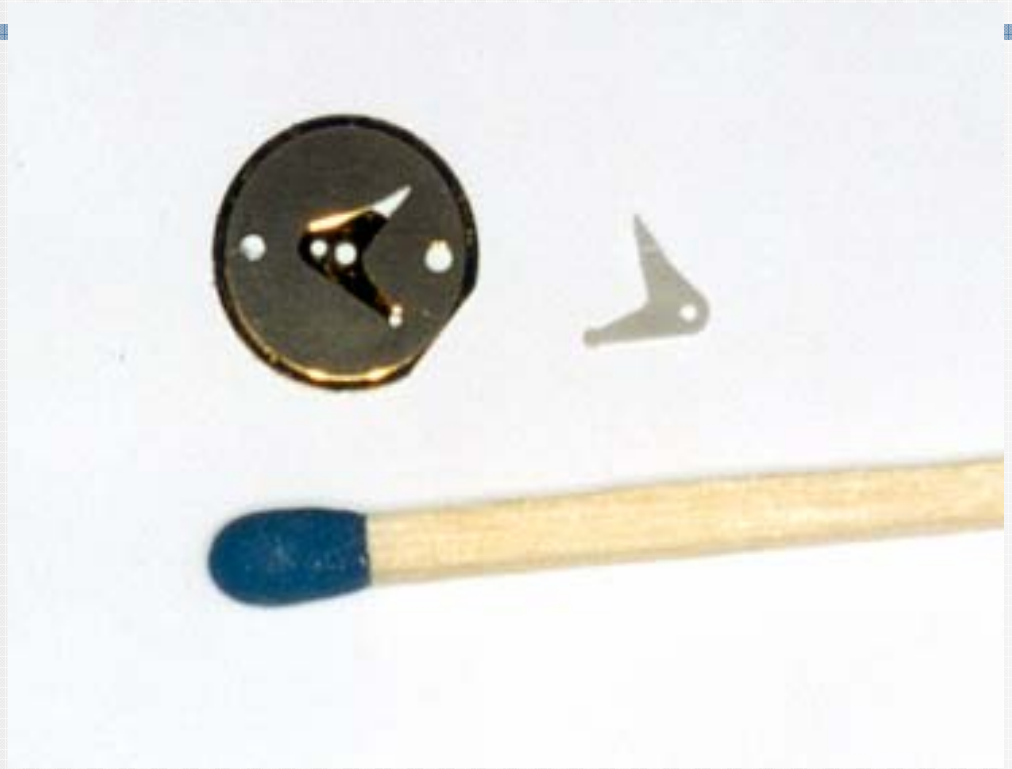


Injected in EDM Micromold 423 X



Injected in Mimotec Micromold 382 X

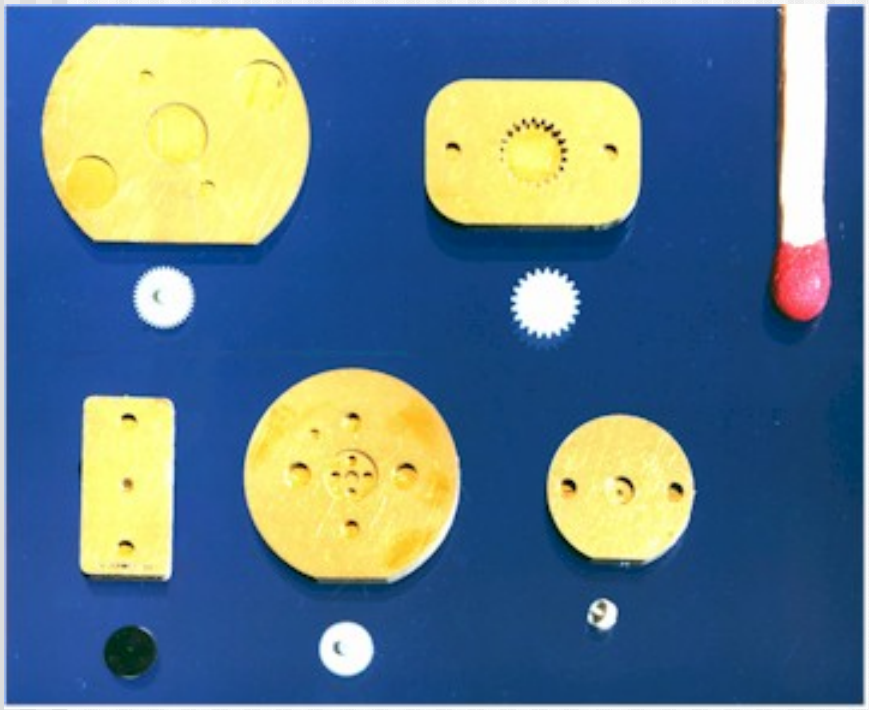
Micro cavity

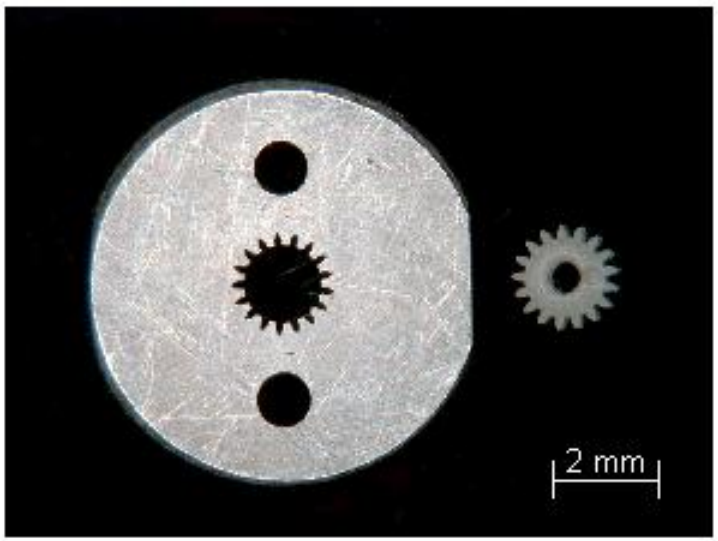


Cavity insert made with UV-irradiation, i.e. photolithography

Quelle/Source:Battenfeld

Tooling: LIGA technique



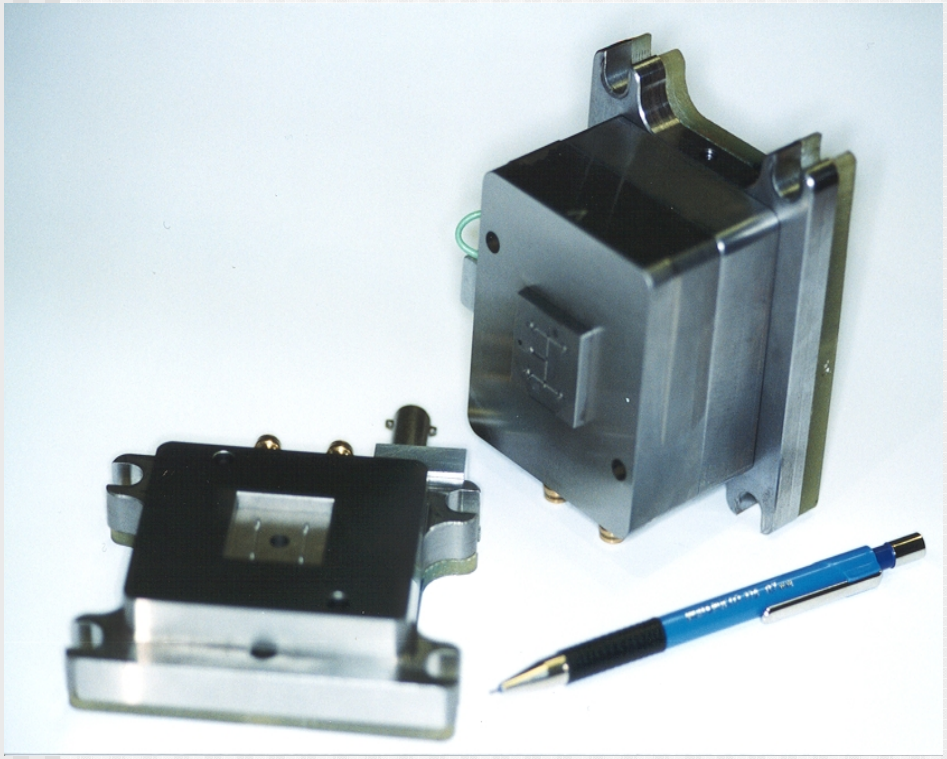


Limitations: Only vertical side walls possible

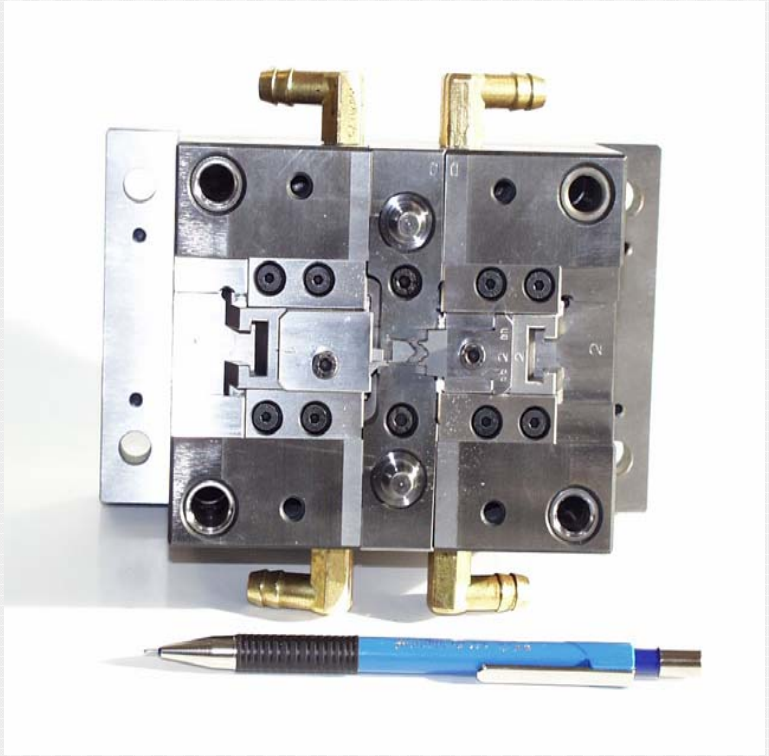
Structures up to 1.5mm high only

No draft allowed

Moulds for MICROSYSTEM 50



4-cav. mould, Rastrad,

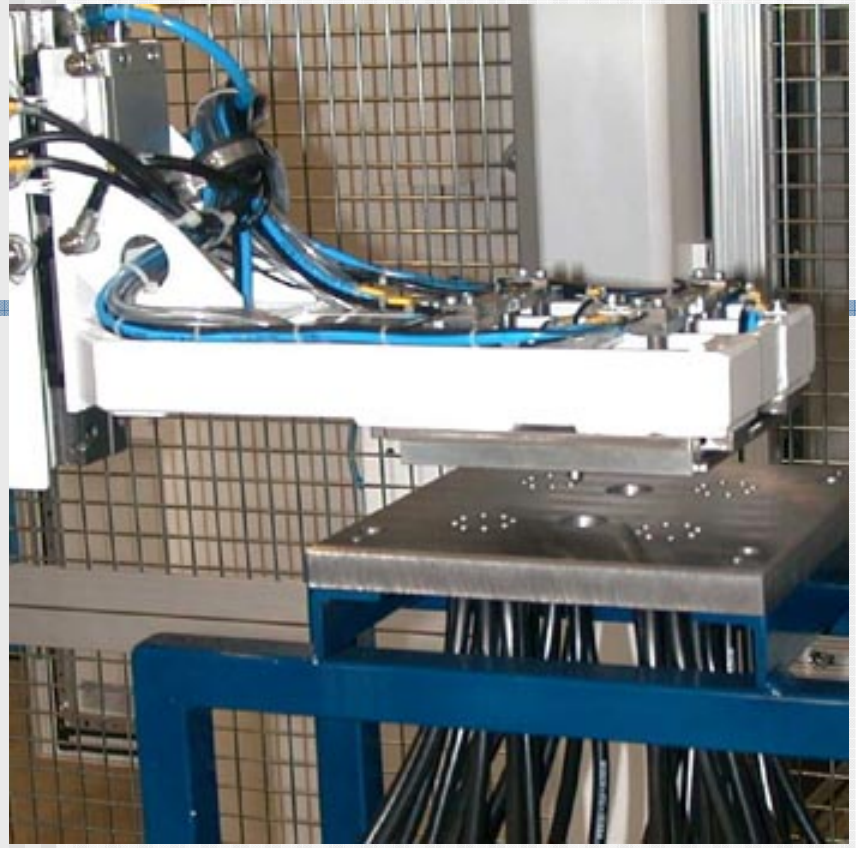


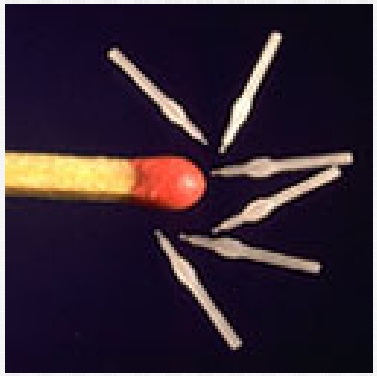
1-cavity mould,

Quelle/Source:Battenfeld

Part Extraction Material handling and packaging

- parts too light to fall out of the mold
- Static electricity issue
- Special robotics and vacuum extraction into small tubes
- “ Reel to Reel” methods such as one used in semi conductor industry
- Assembler unwilling to pick parts one at a time out of a plastic bag
- Bowl fed or vibratory automated assembly systems tend to jam up



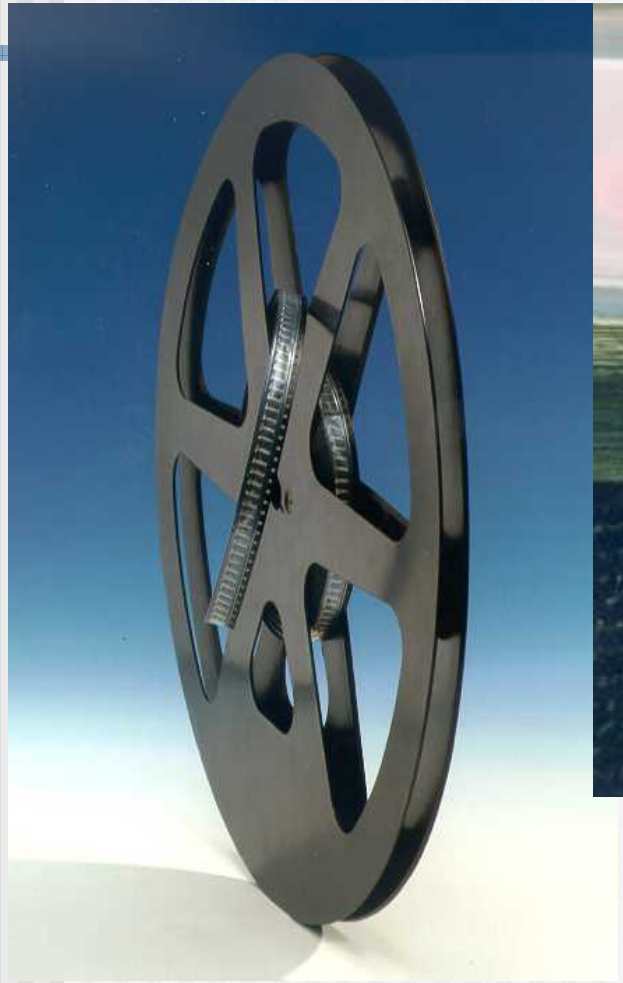


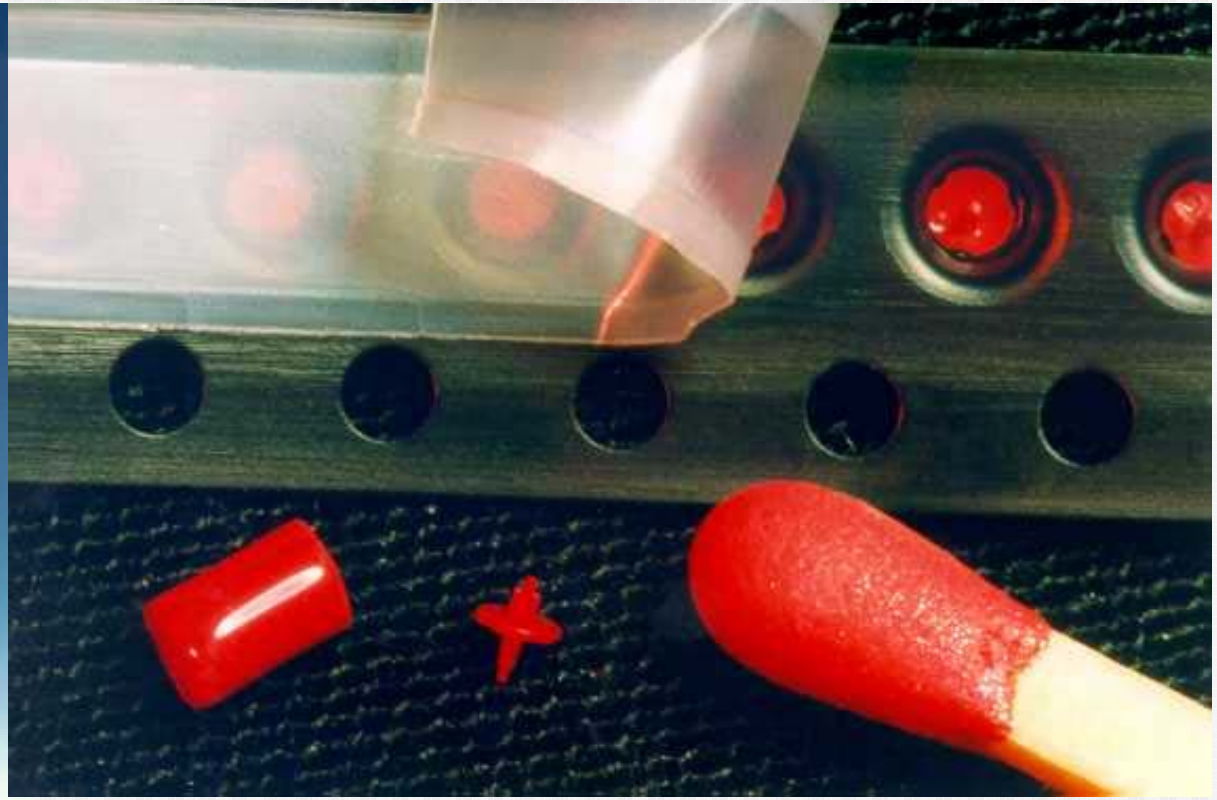
The Hekuma handling system for Stamm's tiny ballpoint pen nozzles sorts the parts by cavity. The tubes below the receiving plate carry the parts by vacuum pressure to individual containers that can be checked while the system is running.

E Media

www.emedia.com

Blister for micro parts





Blister pack and micro gear with granule

Quelle/Source:Battenfeld

Part inspection

Video measuring system

OGP SMARTSCOPE

Resolution: 0.00025 mm (0.00001”) Standard

0.00001 mm (0.000004”) optional

SEEBREZ 6 x 6

Resolution: 0.0005 mm (0.00002”) STD

0.00001 mm (0.00001”) OPT

Quality control solutions Inc.

Automated Inspection

MicroTest 21
Automatic concentricity and roundness
inspection system for ferrules and sleeves

Short information

- 100% quality security
- Mechanical check
- ±0.15 microns accuracy, repeatability
- Automatic quality selection (4 groups)
- Average cycle time 10 seconds

Future of Micromolding

What comes first?…….. Chicken or the Egg???

How big is the market for Micromolded parts?

Nano Technology…..Are we there yet?

(1 nanometer = one millionth of a mm or .001 micron)

Human hair is 50 Micron thick

- **New territory for both molder and mold maker**
- **Lots of trial and error**
- **Propitiatory technology and expertise developed**
- **Prepare to spend R & D money and time**

Micromolding machine manufacturers

- Battenfeld — Microsystem 50
- Nissei — AU3E
- Sodick — TR5 S3
- Sumitomo — SE18 S
- Ferromatik Milacron — Babyplast
- Arburg
- Boy

Micromolding Toolmakers

Miniature Tool & Die, Inc. www.miniaturetool.com

MIMOTEC SA www.mimotec.ch

Molders specializing in Micromolding

ALC Precision (American Laubsher Corp.) NY	www.alcprecision.com
Accumold, IA	www.accu-mold.com
Micromold, Inc. CA	www.micromoldinc.com
Makuta technics, IN	www.makuta.com
Precimold Inc. Canada	www.precimold.com
Rolla AG, Switzerland	www.rolla.ch
American precision Products, AL	www.injection-moldings.com
Sovrin Plastics, UK	www.sovrin.co.uk
Stack Plastics, CA	www.stackplastics.com
Micro Precision Products, CA	www.microprecisionproducts.com
Stamm, Switzerland	www.stamm.ch
Rapidwerks	www.rapidwerks.com

Special Thanks to…..

Battenfeld America

ALCprecision

Micromold Inc.

Sumitomo

Accumold

Sodick

Miniature Tool & Die

Makuta Technics

Quality Control Solutions

G-S Plastic Optics

Rapidwerks

Toshiba Machines

CAL POLY POMONA

COLLEGE OF THE EXTENDED UNIVERSITY

Plastics Engineering Technology Certificate

This four-course certificate program provides practical instruction applicable to materials, processing, product design and tooling. The program is targeted to technical and non-technical audiences desiring to acquire basic knowledge, expand their horizon, enhance their career or simply take as a refresher course. The main emphasis is on practical aspects of Plastics Engineering Technology without being extremely technical so that the knowledge achieved can be applied in day-to-day applications.

	2005
PLASTICS: THEORY AND PRACTICE	Winter
PLASTICS PRODUCT DESIGN FOR INJECTION MOLDING	Spring
TOOLING FOR INJECTION MOLDING	Summer
SCIENTIFIC INJECTION MOLDING	Fall

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