

# Fabrication techniques for Metal MEMS like as Metal Micro Pump

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UCI CALIT2 building auditorium

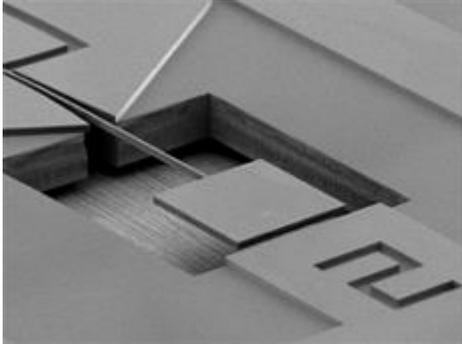
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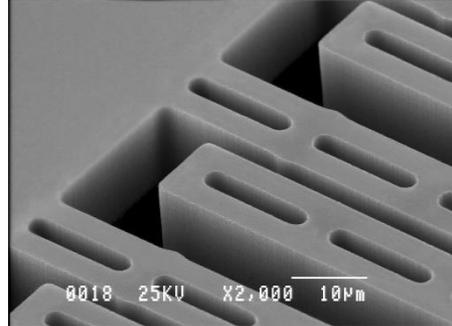
## 3. Conclusions

## Silicon process has been adopted in general MEMS (Micro Electro Mechanical Systems)



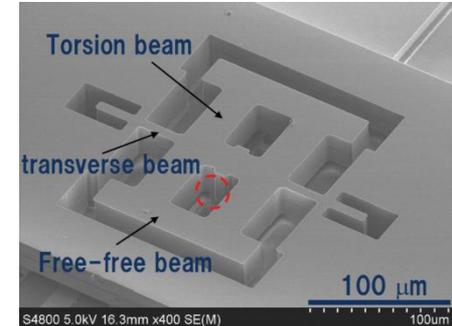
<http://www.fujielectric.co.jp/about/technology/mems.html>

a) Ultra-high-sensitivity gyro-sensor



[http://www.denso.co.jp/ja/events/tokyomotorshow/2007/pressinformation/F\\_MEMS/](http://www.denso.co.jp/ja/events/tokyomotorshow/2007/pressinformation/F_MEMS/)

b) Accelerometer



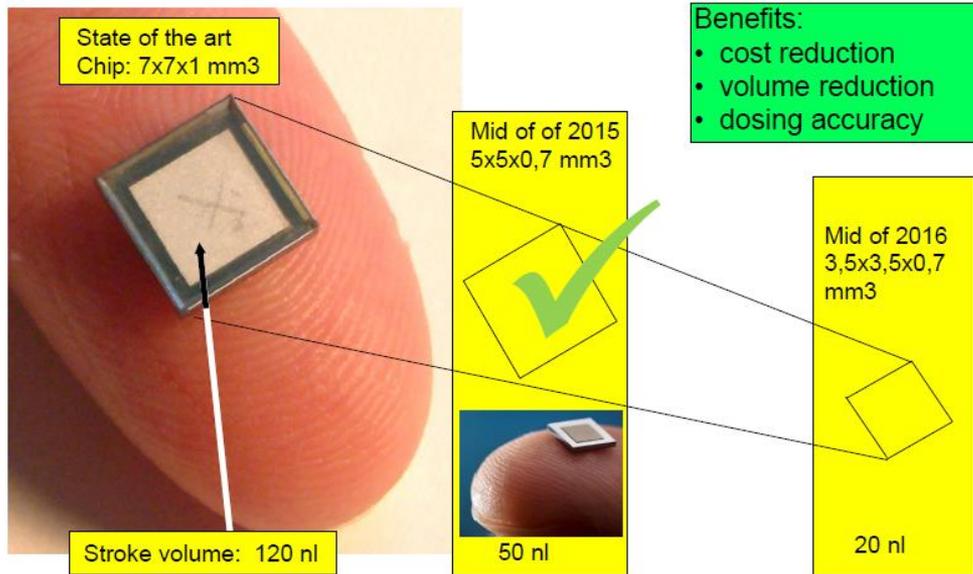
<http://www.ritsumeiseeds.jp/80mhzmems>

c) 80MHz resonator

**Fig. 1** General MEMS parts

Silicon micro-pump has been developed.

## Fraunhofer EMFT: micropump roadmap



If using a silicon



Flow volume limited only nano-liter



Metal micro-pump has been expected.

M. Richter, Semicon MedTech, 7.10.2015:  
Cost efficient miniaturised silicon micropumps for medical applications



Fig. 2 Silicon micro-pump

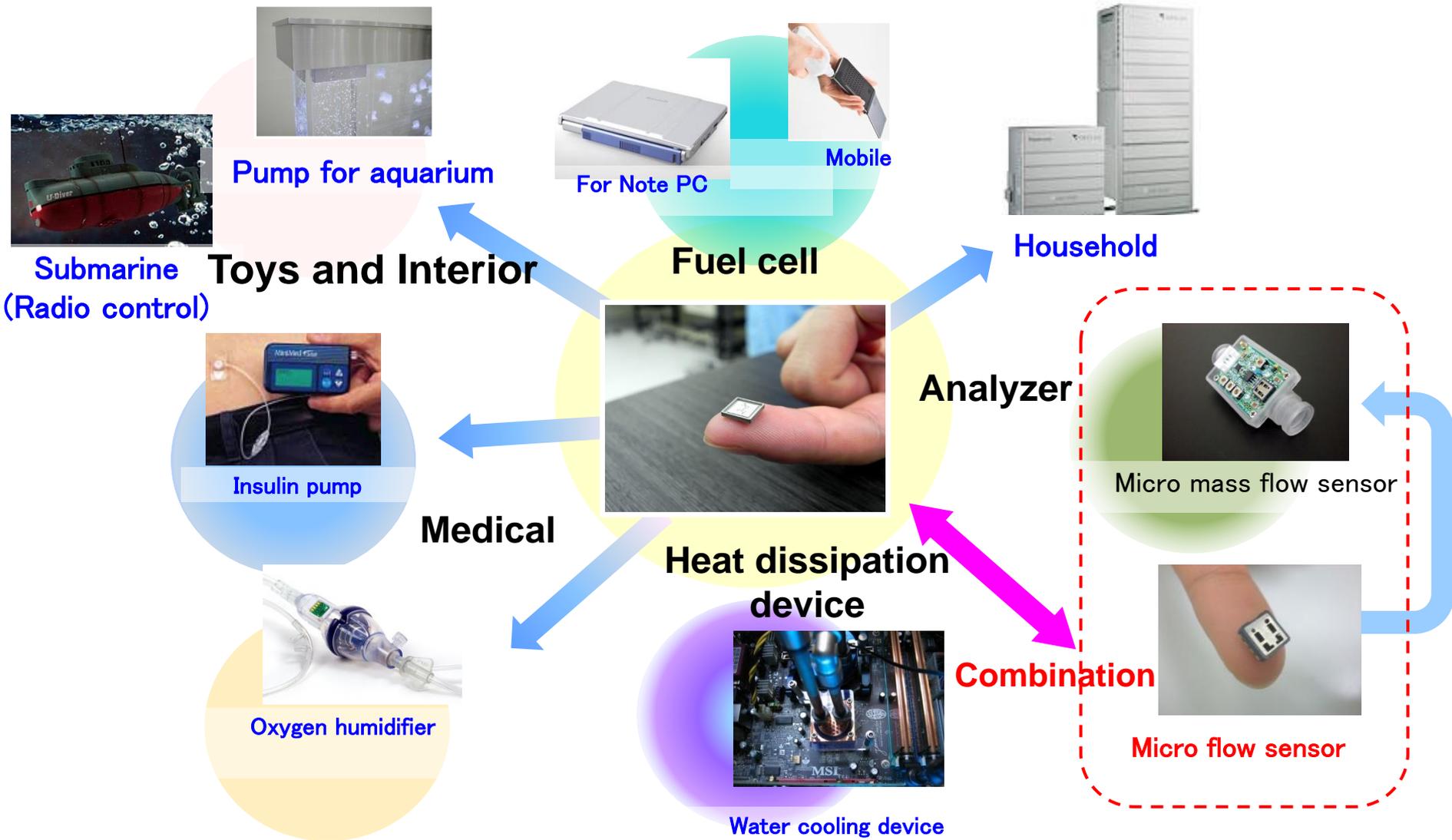
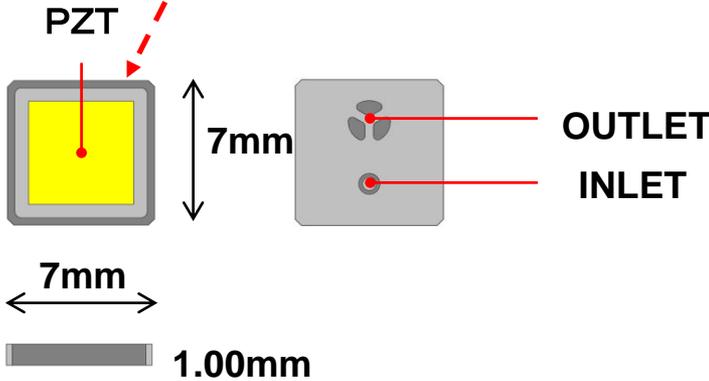
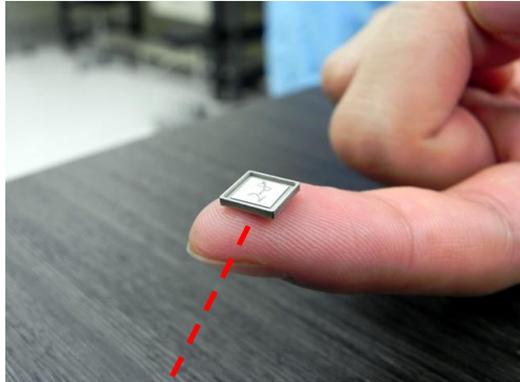


Fig. 3 Application area of metal micro pump

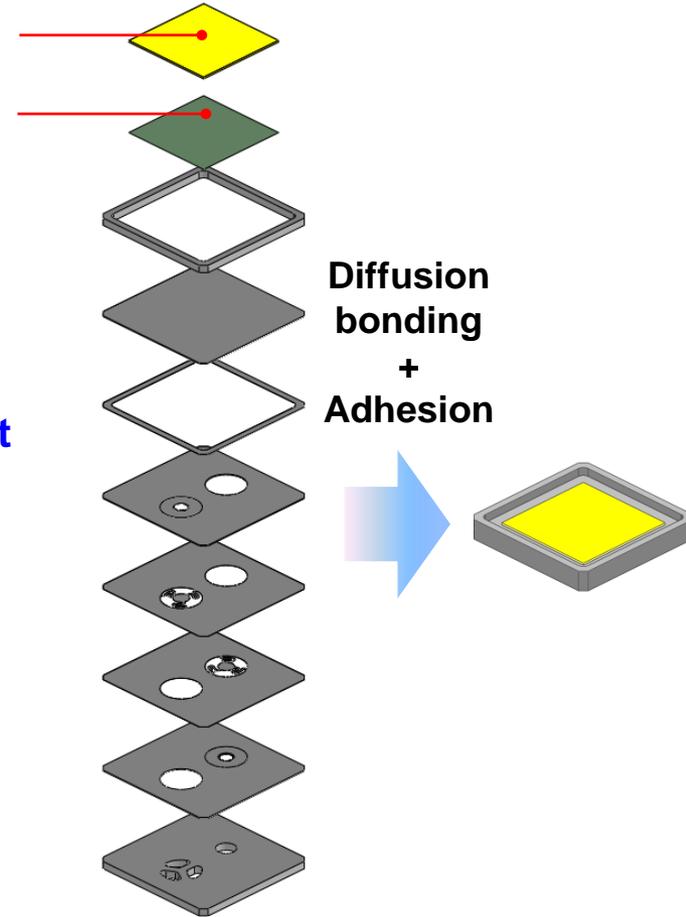
# 1. Introduction

We make a metal micro-pump



PZT  
Adhesion layer

Stainless sheet  
(8 pcs)  
Thickness  
0.01mm  
0.02mm  
0.05mm  
0.40mm

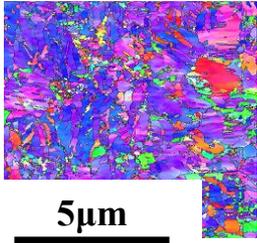


<http://www.kikuchiseisakusho.co.jp/mechatro2/MicroFluidDevice.html>

Fig. 4 Metal micro-pump

# 1. Introduction

## Using novel 3 processes for fabrication of metal micro-pump

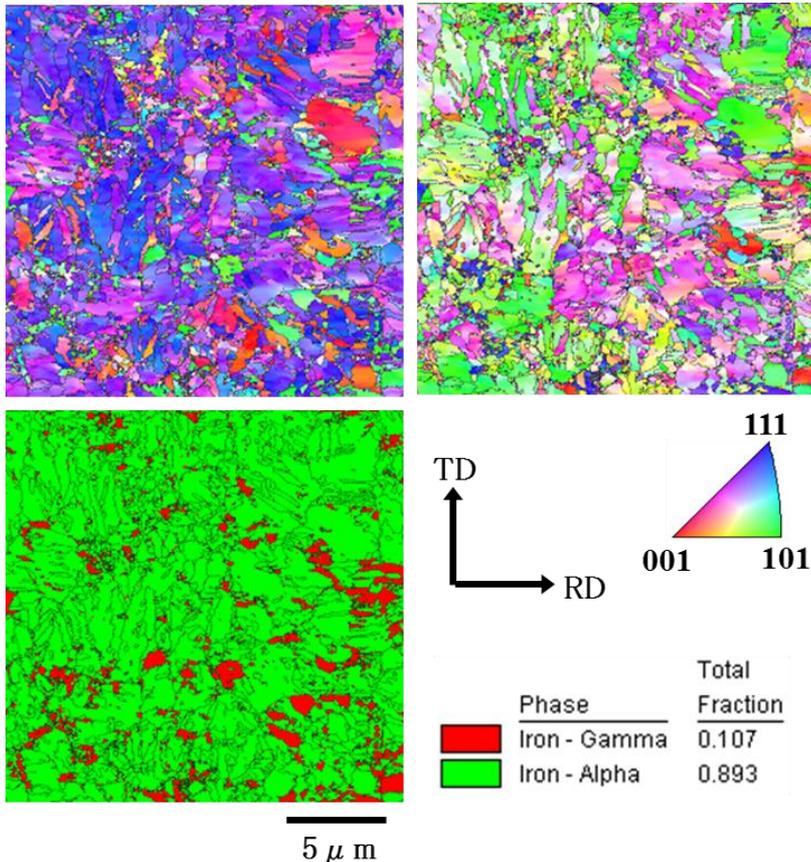
	【1】	【2】	【3】
	Material	Sheet forming	Diffusion bonding
Novel processes	<p>Fine-grained stainless steel</p> 	<p>Nano-metric accuracy punching process</p> 	<p>Low-temperature diffusion bonding</p> <p>Low-temperature 1073K→973K</p> <p>Short-bonding time 10hour → 30min</p>
Effectiveness	<ul style="list-style-type: none"> <li>▪ Low- temperature diffusion bonding</li> </ul>	<ul style="list-style-type: none"> <li>▪ High-accuracy</li> <li>▪ High-productivity</li> </ul>	<ul style="list-style-type: none"> <li>▪ High-productivity</li> <li>▪ bonded together without leakage</li> </ul>

**Fig. 5** Compare of current and novel processes

[1]

## Fine-grained stainless steel

Thickness: 0.010mm



Coarse general grainsize : **10 μm**



Fine-grained size : **1 μm**



Effectiveness

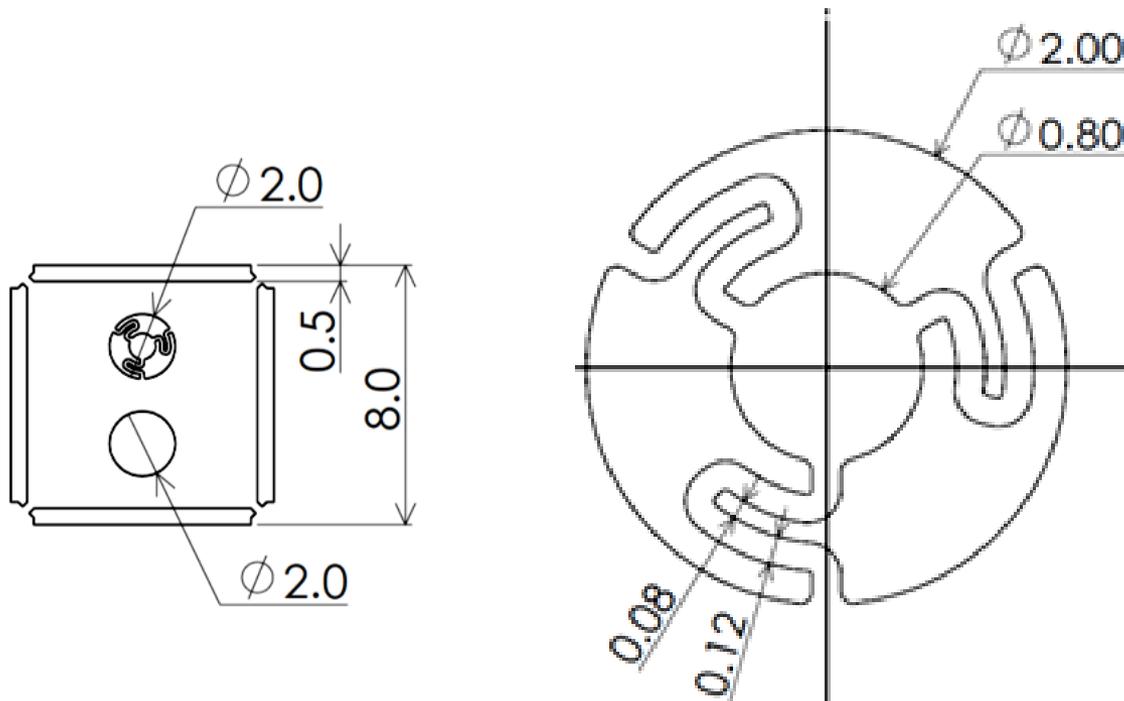
▪ Decrease diffusion bonding temperature

▪ Higher yield stress

Average grainsize : **1 μm**

## [2] Nano-metric accuracy punching process

How to punch with 0.01mm thickness sheet ?

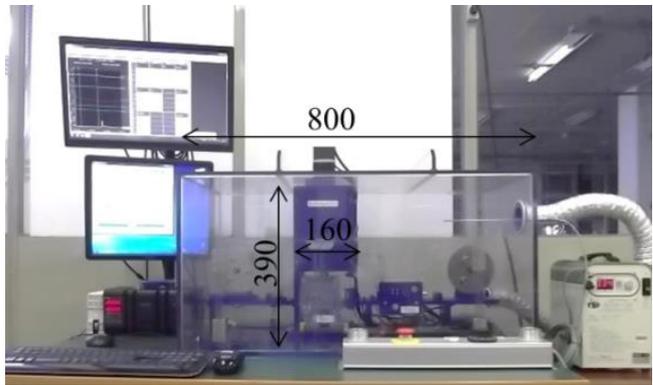


a) Parts over all

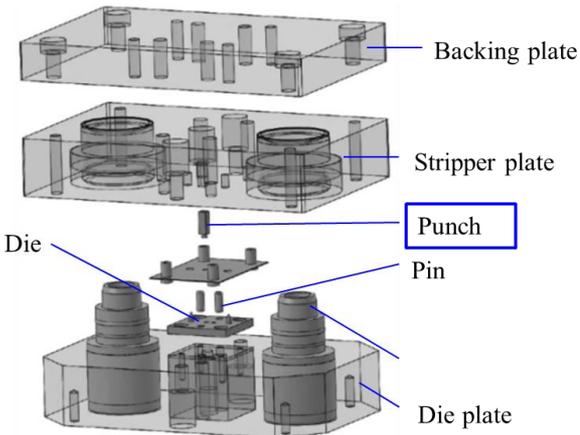
b) Valve shape

Fig. 6 Micro piercing shape

## [2] Nano-metric accuracy punching process



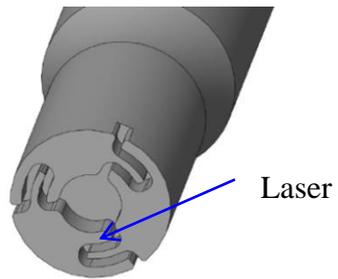
a) 10kN small servo press system



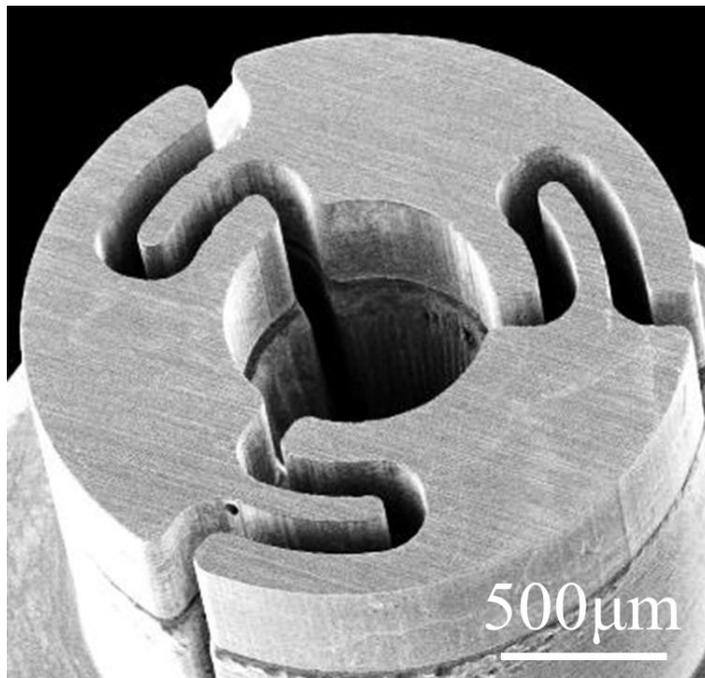
b) Nano-metric accuracy die



c) Pico second laser



d) Punch shape

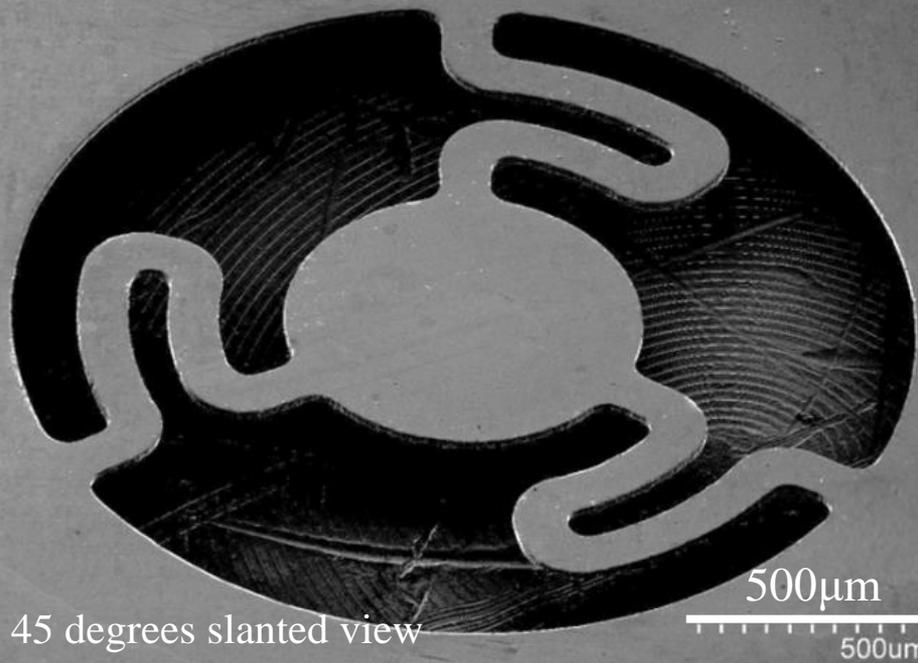


e) Laser machining and shaving punch

### [2] Nano-metric accuracy punching process

After punching of 0.01mm thickness stainless foil

Burr can't see in the image



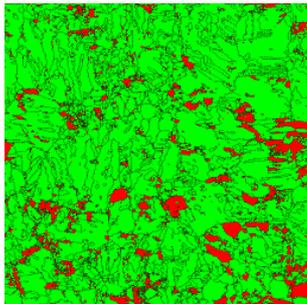
a) Shear droop side

b) Fractured surface side

**Fig. 7** SEM image of pierced valve sheet (thickness 0.01mm)

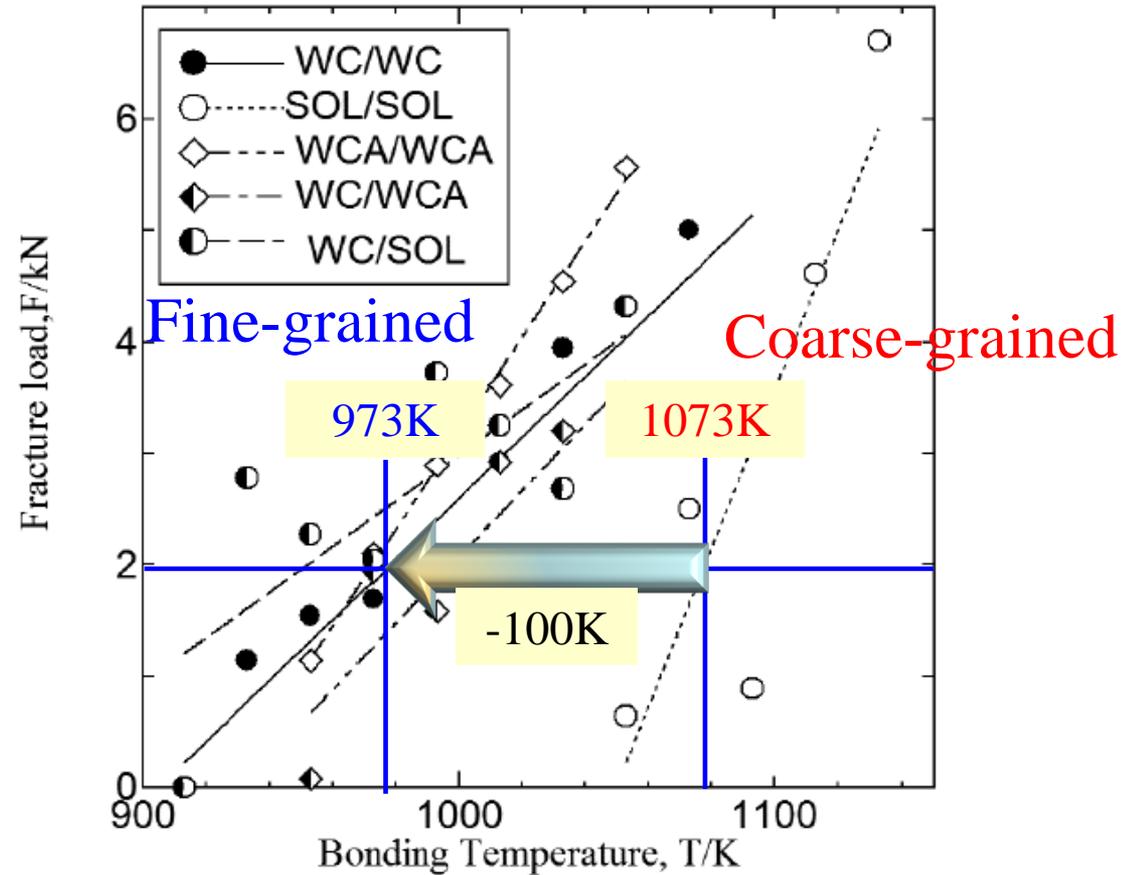
**Nano-metric punching process has been developed completely.**

## [3] Low-temperature diffusion bonding



■ : Strain induced martensitic phase  
■ : Austenitic phase

**Fig. 8** EBSD phase map of full-martensitic stainless steel



Masahito. Katoh et al., Tetsu-to-hagane, 2016; 102: 34-

**Fig. 9** Correlation between fracture load and bonding temperature

Fine-grained material decrease diffusion bonding temperature

【3】

### Low-temperature diffusion bonding

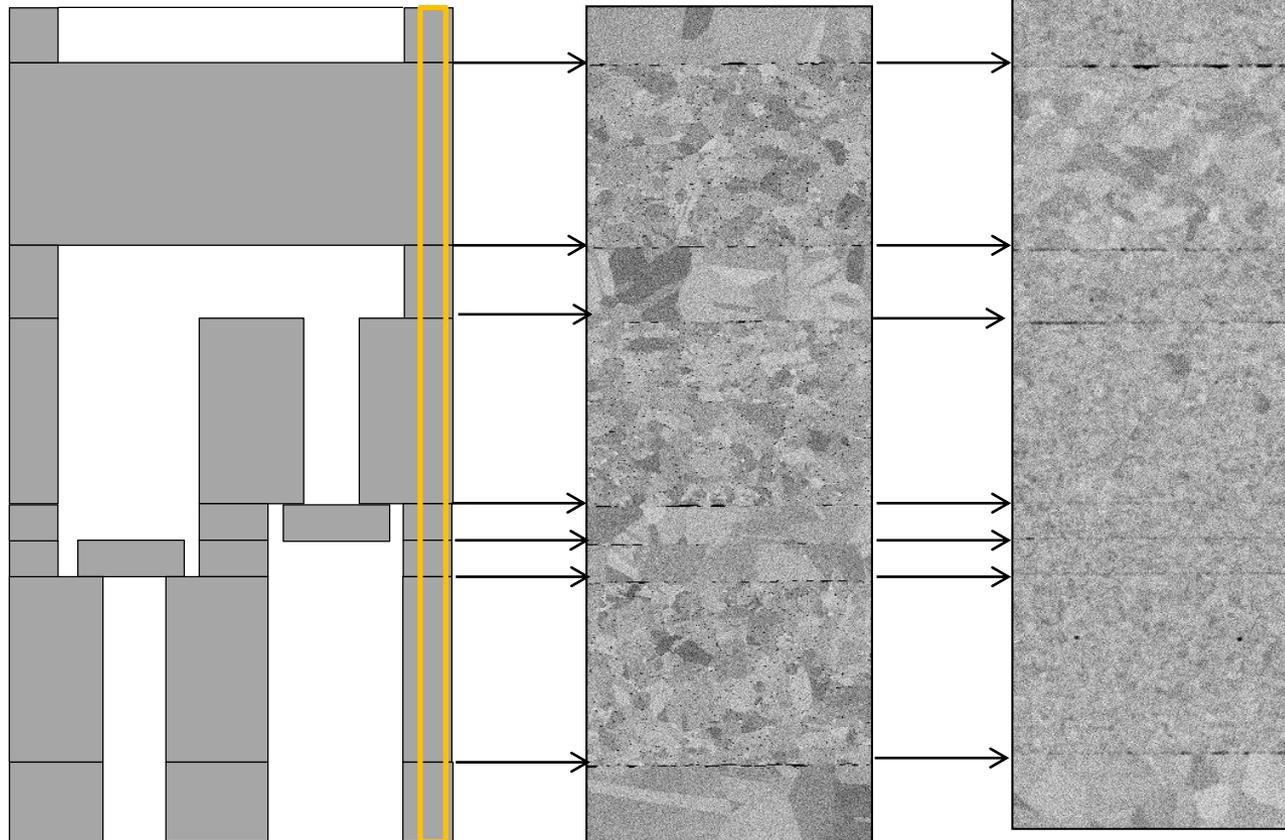
Construction of pump

Current product

**1273K, 10h**

Developed

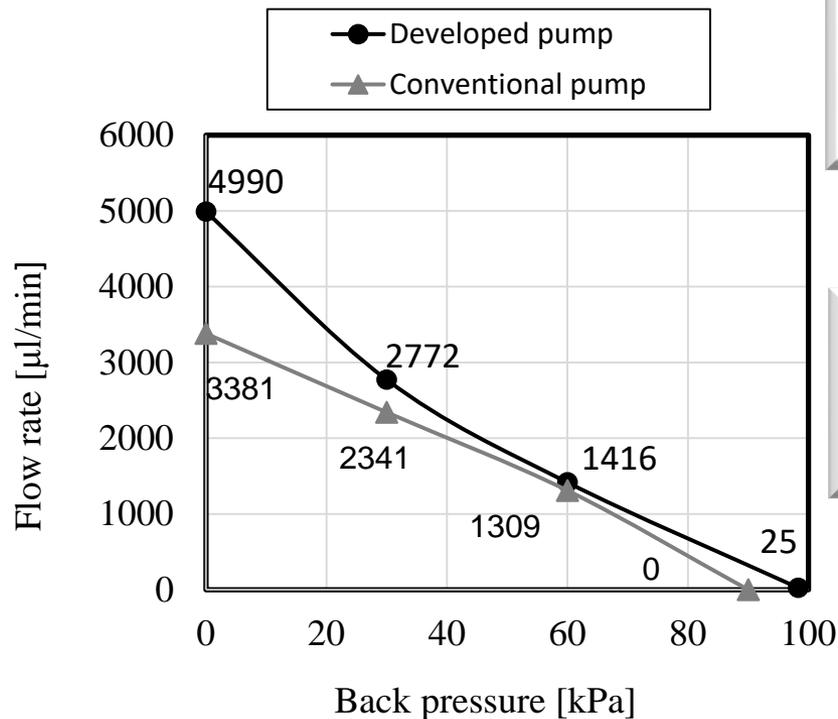
**973K, 30min**



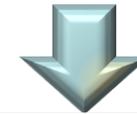
**Fig. 10** Cross section of pump

Low temperature and short time diffusion bonding has been completed successfully.

### Pump performance

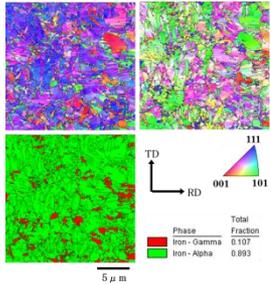


Developed technologies improve flow volume of pump.



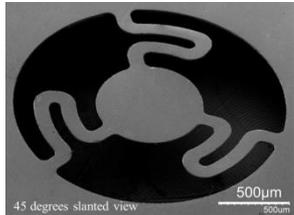
Leakage between valve and valve sheet are improved.

**Fig. 11** Results of flow rate and back pressure test



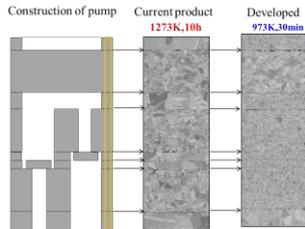
【1】

Fine-grained stainless steel



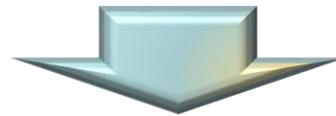
【2】

Nano-metric accuracy punching process



【3】

Low-temperature diffusion bonding



Metal MEMS manufacturing succeeded by combining 3 new techniques.