

“PUTTING THE LID ON MICROFLUIDICS...”

**A Review of Cover Layer Bonding and
Sealing Techniques for Thermoplastic
Microfluidic Lab-on-Chip Devices**

microfluidics.technicolor.com



MICROFLUIDIC LAB-ON-A-CHIP DEVICE BONDING TECHNIQUES

1. THERMOPLASTIC POLYMER BONDING TECHNIQUES

- ⊖ FUSION (Adhesive-free) BONDING
 - ⊖ Laser welding / Thermal fusion bonding / Solvent bonding / Ultrasonic bonding
- ⊖ ADHESIVE BONDING
 - ⊖ PSA film lamination / UV-Curable resin adhesive bonding
- ⊖ BONDING QUALITY TESTING METHODS
 - ⊖ Bond strength testing / Leak testing / Metrology

2. MICROFLUIDIC BONDING CASE STUDIES

- ⊖ 2-CHAMBER FLOWCELL WITH MEMBRANE
- ⊖ 3-LAYER HYBRID DROPLET GENERATOR / LENS ARRAY
- ⊖ MULTI-DEPTH MULTI-FEATURED CELL SORTER
- ⊖ MULTICHANNEL MICROFLUIDICS ASSEMBLY

BONDING TOOLBOX : FUSION BONDING TECHNIQUES

LASER WELDING

Fast, high precision, scalable, automatable

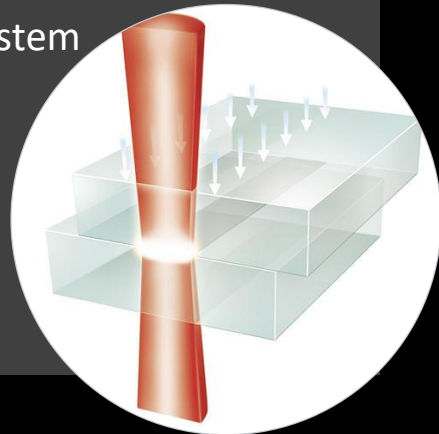
- ⊕ Contour or full-surface (mask) welding
- ⊕ *Clear-to-Dark* & new *Clear-to-Clear* welding
- ⊕ Vision systems for alignment

Pros

- (+) Custom welding path (CAD file adoption)
- (+) Cycle time (100mm/s travel speed)
- (+) Clear-to-clear welding
- (+) High precision alignment using vision system
- (+) Automation friendly

Cons

- (-) Warpage
- (-) Weld "swelling"
- (-) Custom fixturing/clamping



ULTRASONIC WELDING

Contour welding through ultrasonic friction/heat

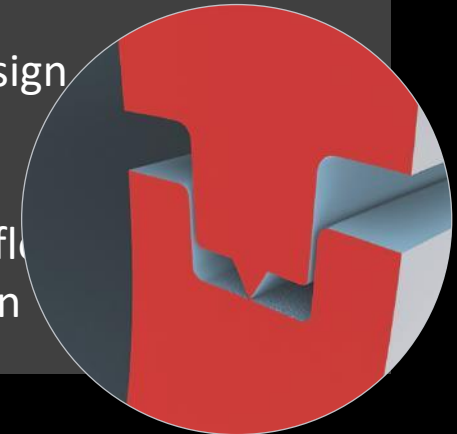
- ⊕ Suitable for lower precision and perimeter welding applications

Pros

- (+) Cycle time
- (+) Macro scale cartridge assembly

Cons

- (-) Energy director required in part design
- (-) Low precision
- (-) Coarse bonding
- (-) Difficult to control the plastic melt flow
- (-) Custom fixture/horn for each design



BONDING TOOLBOX : FUSION BONDING TECHNIQUES

THERMAL FUSION BONDING

Full surface clear bonding

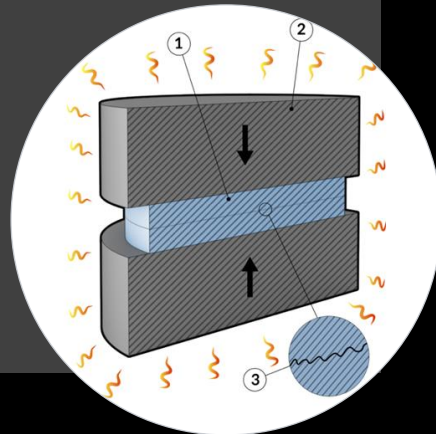
- ➡ Application of heat, pressure near glass transition temperature to fuse 2 surfaces together
- ➡ Typically same material for both surfaces

Pros

- (+) Clean full surface bonding
- (+) Surface activation to improve bonding strength and reduced deformation
- (+) Preserve optical clarity in the channel

Cons

- (-) Cycle time
- (-) Deformation
- (-) Process compatibility – heat
- (-) Not automation friendly



SOLVENT BONDING

Full surface bonding

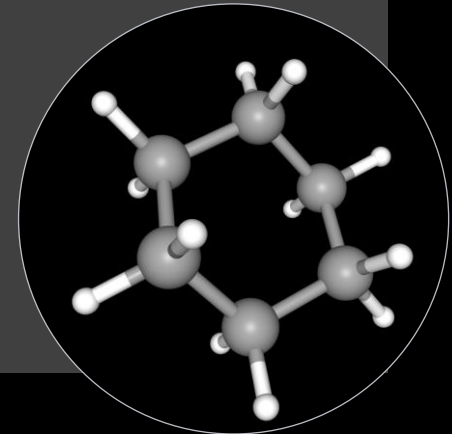
- ➡ Strong, clear bonds
- ➡ Chemical sensitivities
- ➡ Environmental and safety considerations (solvent)

Pros

- (+) Clean full surface bonding
- (+) Strong bonds

Cons

- (-) Slow, difficult to control
- (-) Process compatibility – chemical
- (-) Environmental and safety concerns



BONDING TOOLBOX: ADHESIVE BONDING TECHNIQUES

PSA FILM BONDING – LAMINATION

Wide variety of flexible, compliant adhesive films

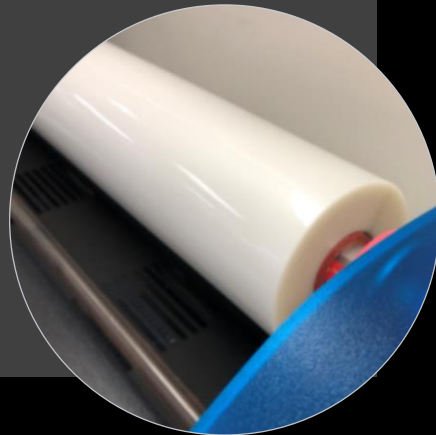
- ⊖ Strong adhesion and conformance to surface features and dissimilar materials
- ⊖ Wide variety of PSA adhesive film materials and properties
- ⊖ Requires converting / precision alignment

Pros

- (+) Engineered PSA adhesive properties (low autofluorescence, no outgassing, hydrophilic/hydrophobic, good adhesion)
- (+) Controlled PSA thickness
- (+) Flexible film and deformable adhesive

Cons

- (-) Converting
- (-) Precision alignment
- (-) Non-homogeneous channel properties
- (-) Channel depth dependent



UV CURABLE RESIN BONDING

Fast, scalable, automatable adhesive technique

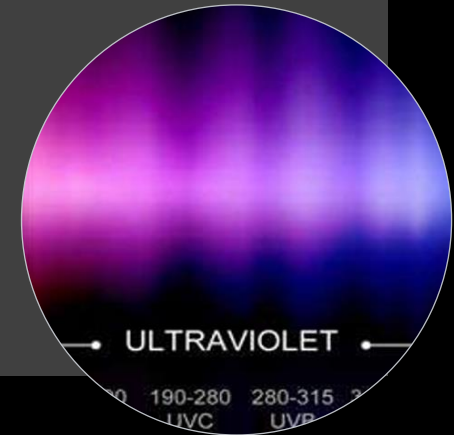
- ⊖ Excellent adhesion/cure properties
- ⊖ Challenge / controllability to avoid channel clogging

Pros

- (+) Controlled thickness
- (+) Adhesion strength

Cons

- (-) Losing homogeneous channel properties (different material for one side of the channel)
- (-) Channel depth dependent



LAB-ON-A-CHIP BONDING CASE STUDIES

CHALLENGES...



SOLUTIONS...



RESULTS...

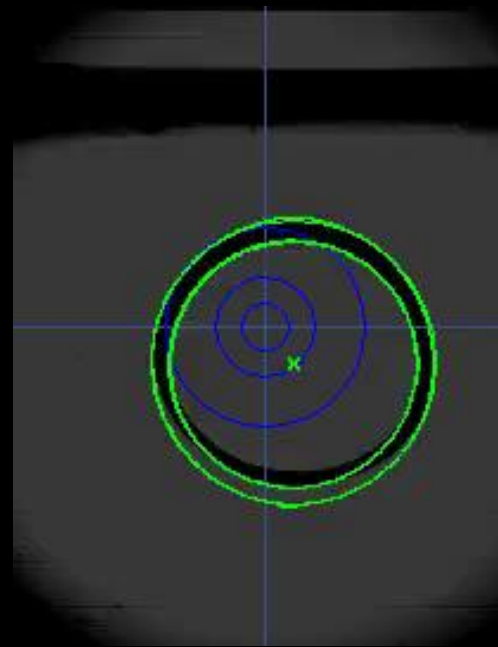
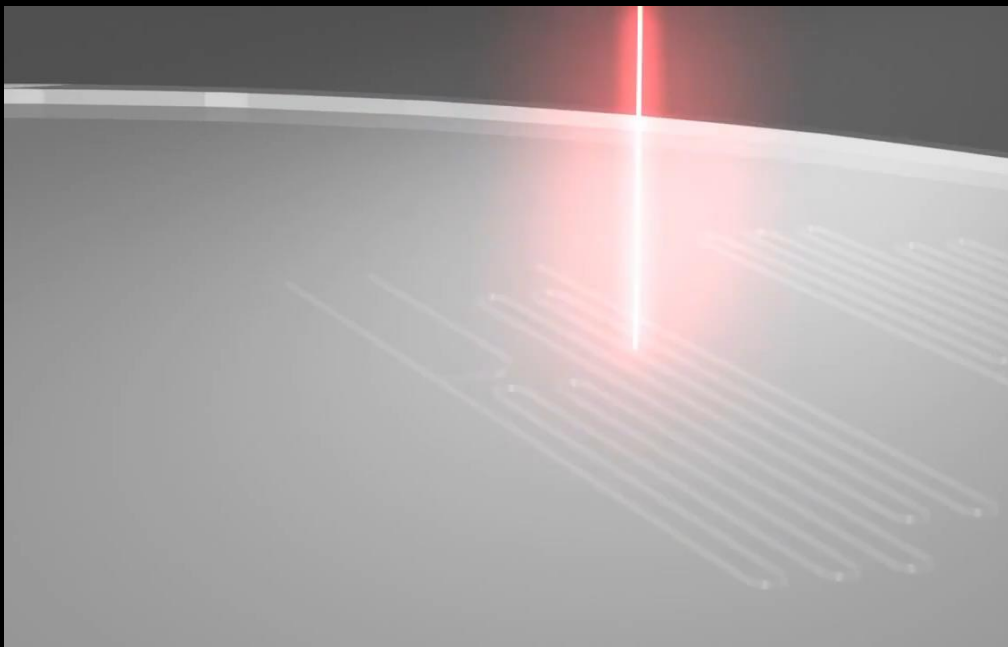
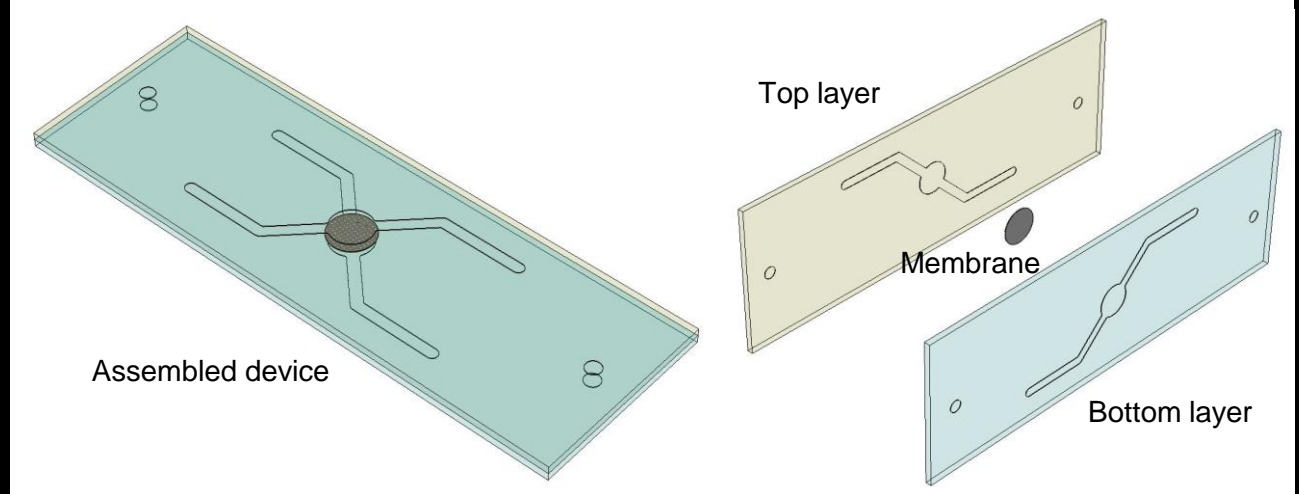


PROJECT #1: 2-CHAMBER FLOWCELL WITH MEMBRANE

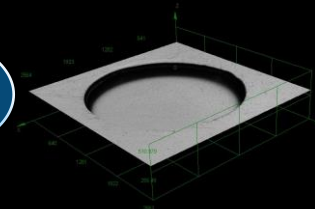
THE CHALLENGE

- ⊕ Dissimilar Materials
- ⊕ Precise 3-layer Alignment
- ⊕ Hermetic sealing
- ⊕ Chemical / mechanical sensitivity of membrane

DEVICE CONCEPT: 3-layer assembly with membrane in the middle



10 μ m
positional
accuracy



THE SOLUTION

Laser Welding

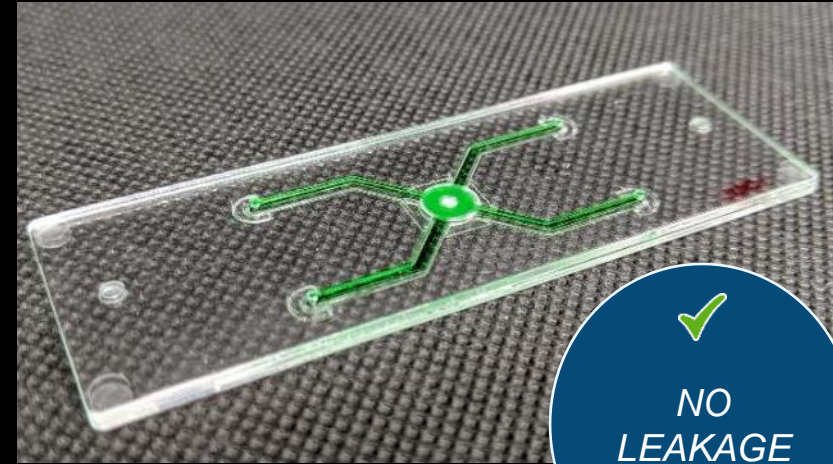
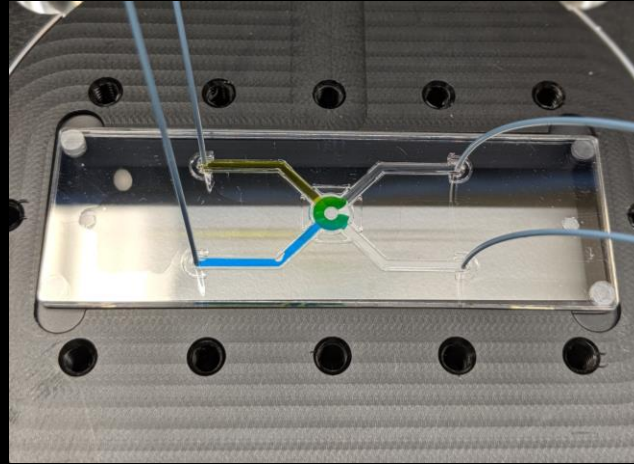
- ⊕ Suitable for welding dissimilar materials ✓
- ⊕ Precise alignment ✓
- ⊕ Avoids chemical and heat sensitivity ✓

PROJECT #1: 2-CHAMBER FLOWCELL WITH MEMBRANE

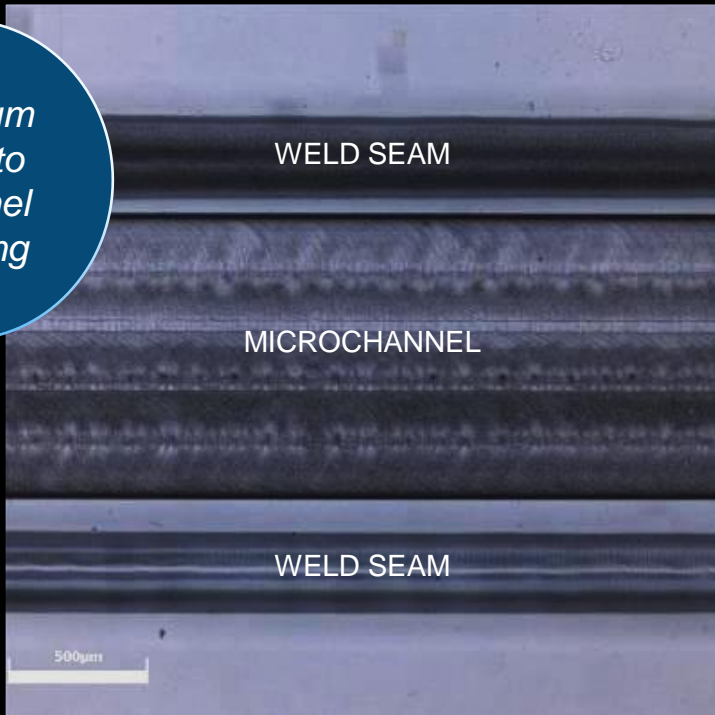
RESULTS

Process Optimization

- ⌚ Laser power / Speed / Focus Clamping
- ⌚ 2-micron (λ) clear-to-clear laser welding
- ⌚ Precise alignment with vision system – fiducial recognition



✓
<100 μm
Weld to
Channel
Spacing

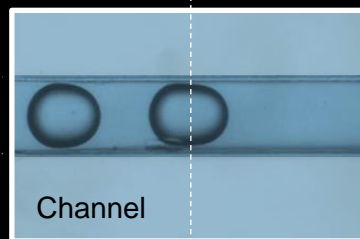
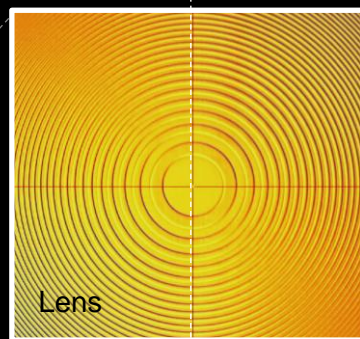
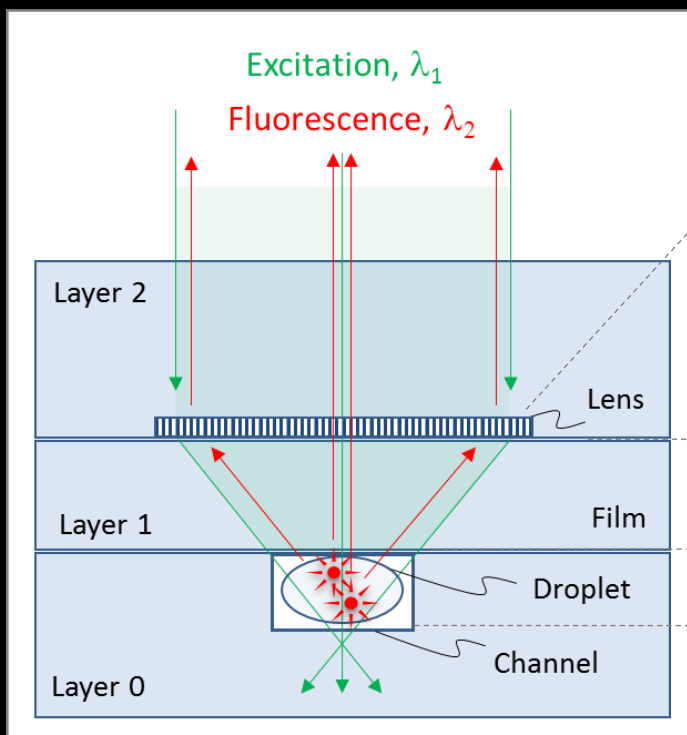
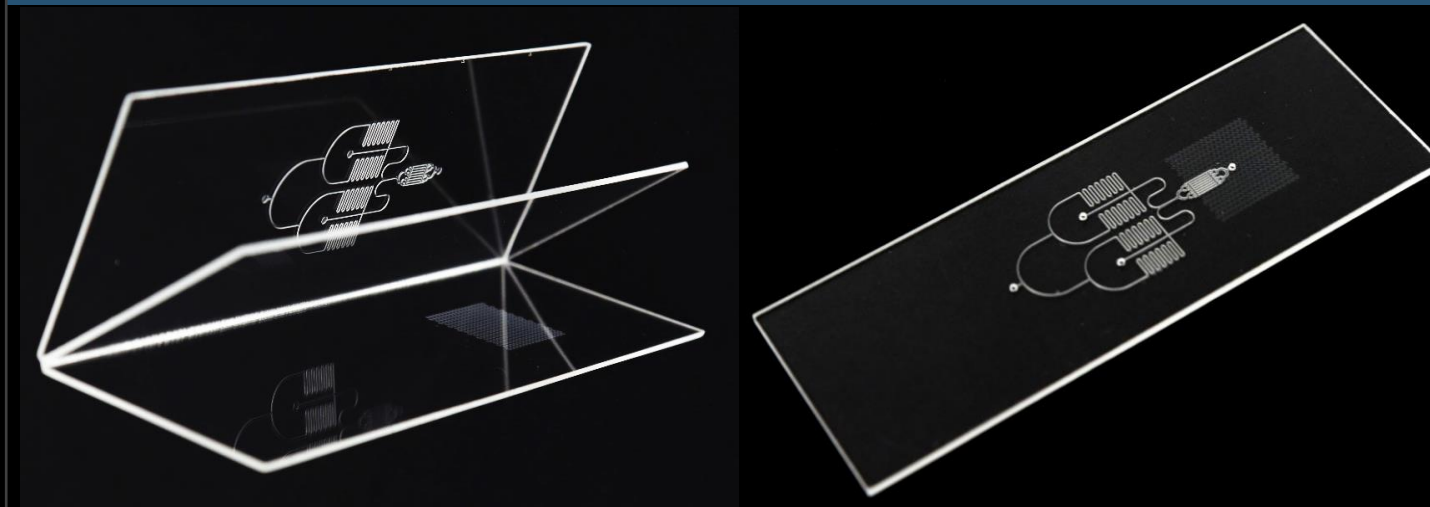


PROJECT #2: 3-LAYER HYBRID DROPLET GENERATOR / LENS ARRAY

THE CHALLENGE

- ⌚ 0.5 μm deep diffractive lens array – *NO DEFORMATION*
- ⌚ 3-layer Alignment and Bonding – lens to channel alignment
- ⌚ Hermetic sealing for droplet generator
- ⌚ Optical clarity for lens array

DEVICE CONCEPT: 3-layer assembly with nano- and micro-features



THE SOLUTION

Thermal Fusion Bonding

- ⌚ Optical clarity preserved ✓
- ⌚ Hermetic sealing from full-surface bonding ✓
- ⌚ Preserves lens array feature integrity ✓

PROJECT #2: 3-LAYER HYBRID DROPLET GENERATOR / LENS ARRAY

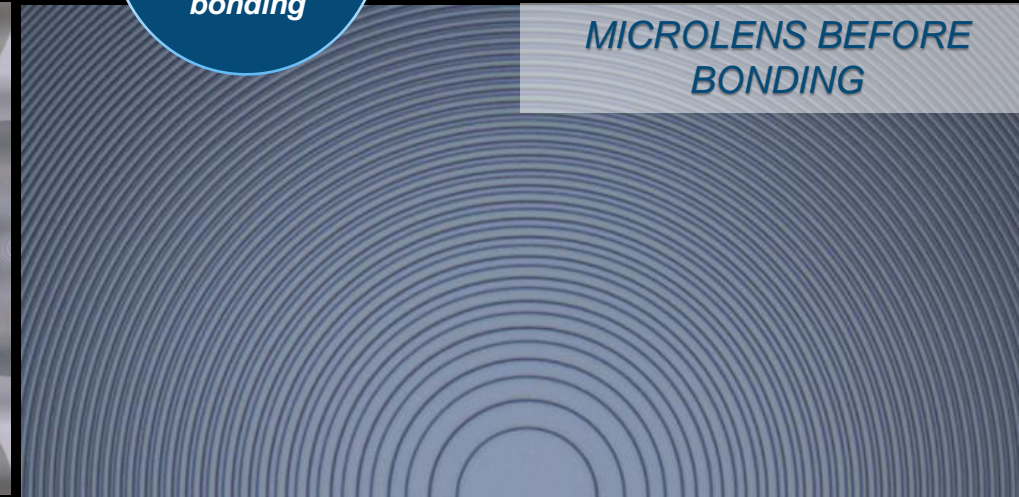
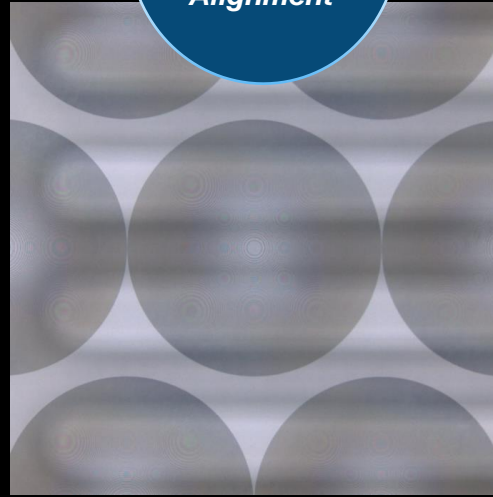
RESULTS

Process Optimization

- ⌚ Microlens array features preserved producing required optical efficiency and clarity
- ⌚ Temperature / Time / Pressure to ensure 3-layer bond strength
- ⌚ Custom fixturing for alignment

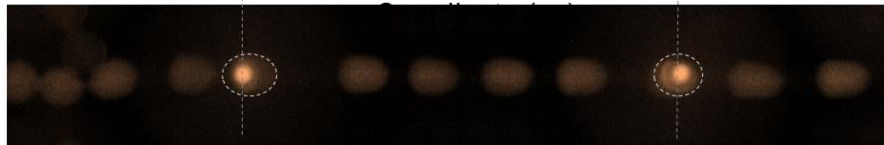
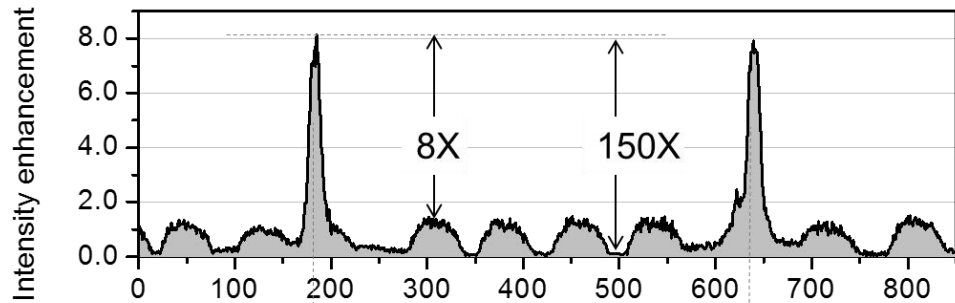
✓
Precise
lens /
channel
Alignment

✓
Lens
features
preserved
after
bonding



MICROLENS BEFORE BONDING

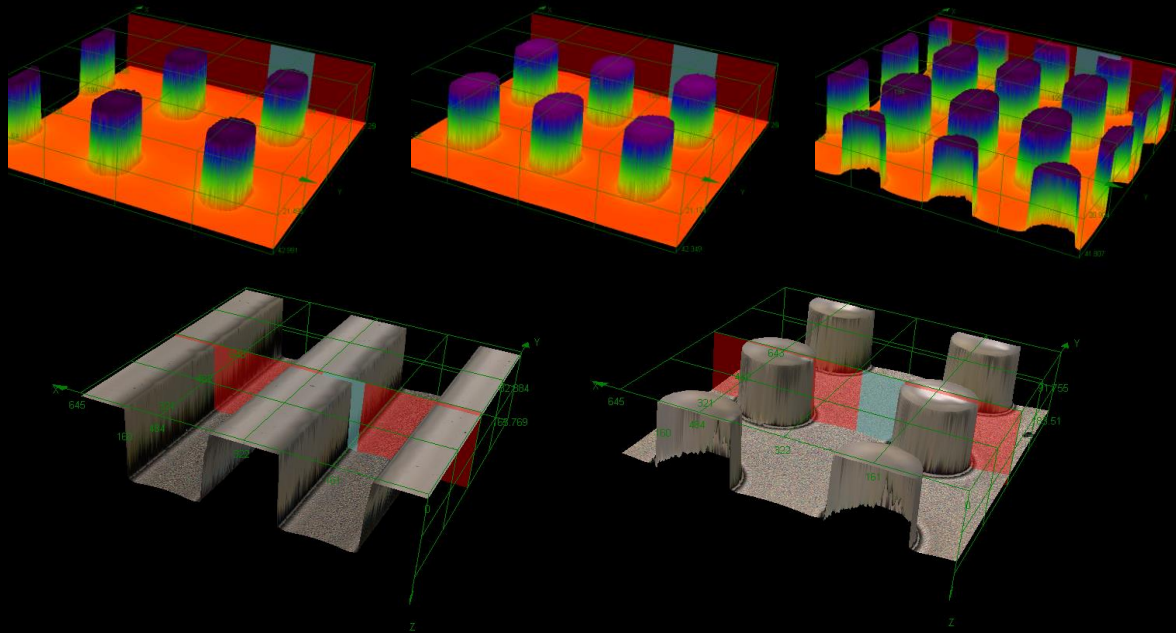
MICROLENS AFTER BONDING



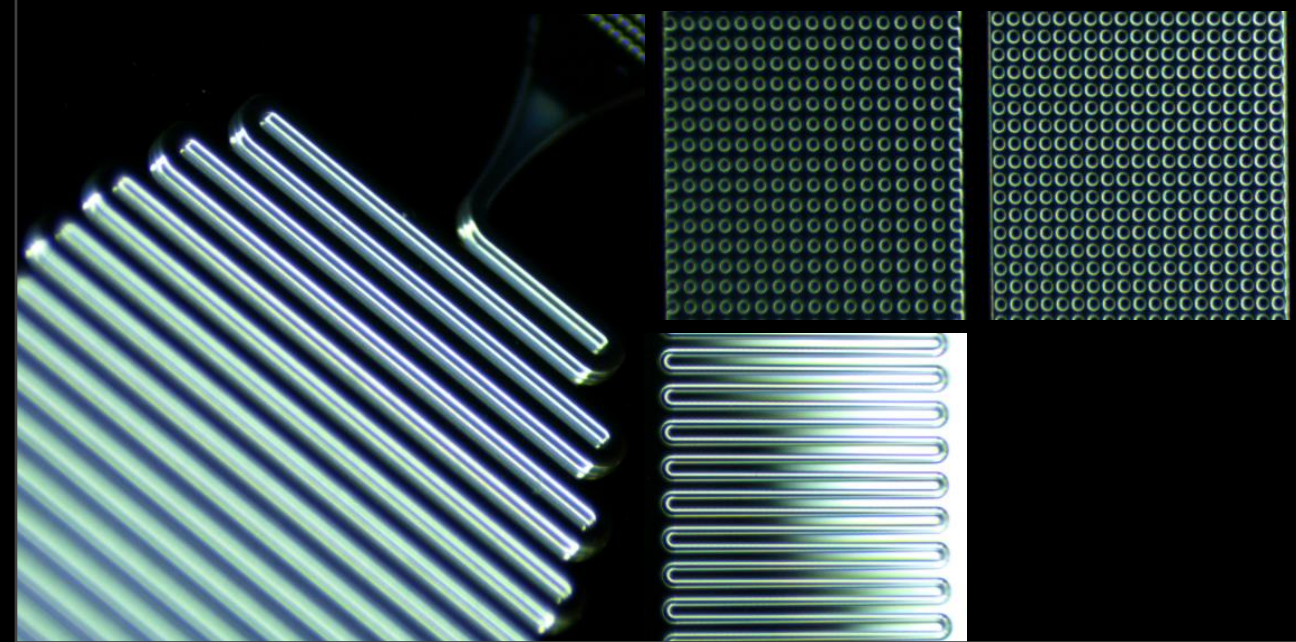
PROJECT #3: MULTI-DEPTH MULTI-FEATURED CELL SORTER

THE CHALLENGE

- ⊕ Hermetic sealing of multiple features and topographies
- ⊕ Hydrophilic coating required
- ⊕ Channel height and aspect ratio preservation post-bonding



DEVICE CONCEPT: flowcell with various pillar and channel arrays



THE SOLUTION

PSA Film Lamination

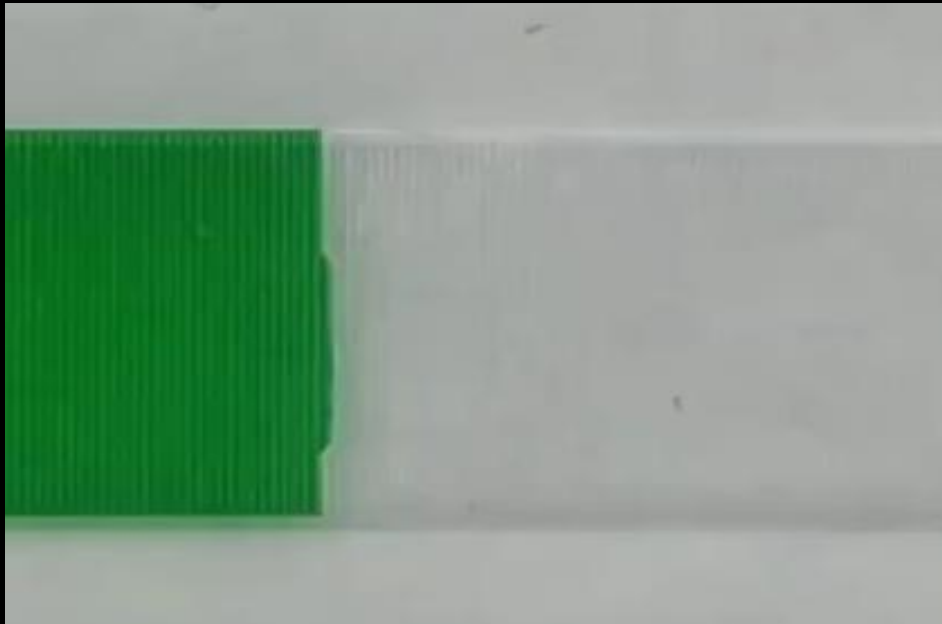
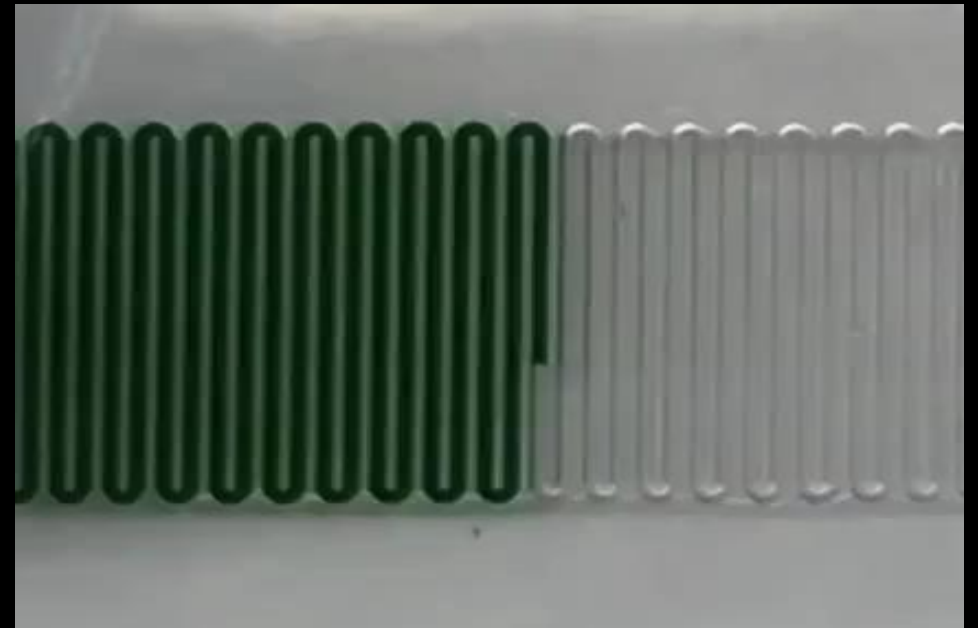
- ⊕ Compliant, full surface bonding of fine features ✓
- ⊕ Hydrophilic coating compatibility ✓
- ⊕ Preserves channel finish / quality ✓

PROJECT #3: MULTI-DEPTH MULTI-FEATURED CELL SORTER

RESULTS

Process Optimization

- ⌚ Temperature / Pressure / Time
- ⌚ Uniform channel depth providing desired steady/uniform flow front profile
- ⌚ Controlled adhesive thickness

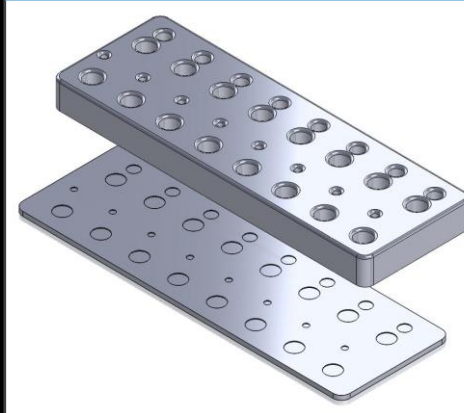


PROJECT #4: MULTICHANNEL MICROFLUIDICS ASSEMBLY

THE CHALLENGE

- ⌚ Requires homogeneous material due to chemical sensitivity
- ⌚ Hermetic sealing
- ⌚ Precise alignment of channel network to manifold
- ⌚ Preserve channel surface quality for optical analysis

DEVICE CONCEPT: single material channel network bonded to well manifold



Channel details removed



Custom
fixturing

CLAMPING UNIT

400 4433-2

CUSTOM FIXTURE PLATE

THE SOLUTION

Laser Welding

- ⌚ Fusion bonding – homogeneous bond ✓
- ⌚ Precision contour welding ✓
- ⌚ Preserves channel finish / quality ✓
- ⌚ Custom fixturing for precise alignment ✓

PROJECT #4: MULTICHANNEL MICROFLUIDICS ASSEMBLY

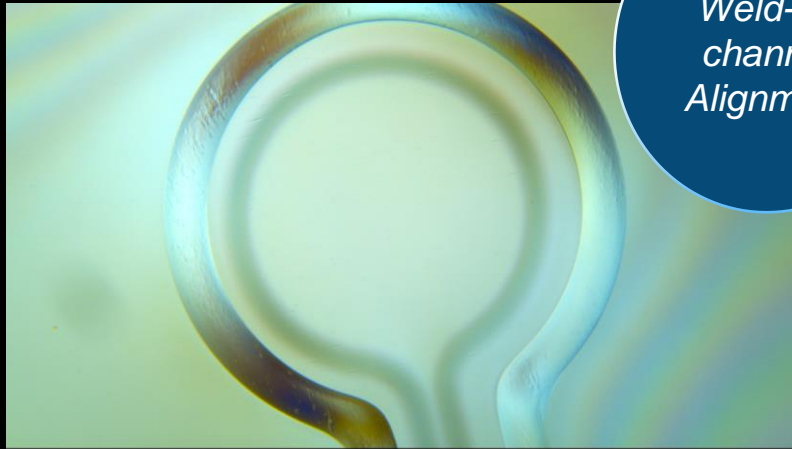
RESULTS

Process Optimization

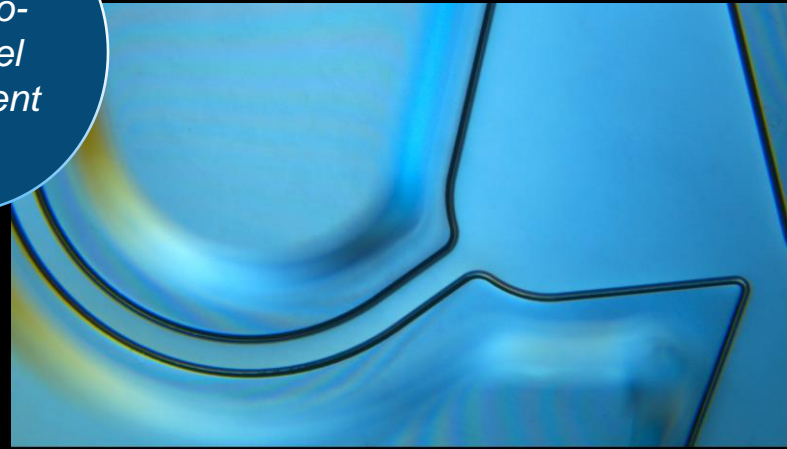
- Custom fixturing – precise alignment
- Laser power / Speed / Focus Clamping
- 2-micron *clear-to-clear* laser welding



✓
Layer-to-layer
Alignment



✓
Weld-to-channel
Alignment



200 μm
Weld

120 μm
Channel

DST1: 204.57 μm

150 μm
Channel -
Weld
Spacing

CHECKLIST – BONDING TECHNOLOGY

- Types
- Thickness
- Color

Materials

- Deformation
- Flatness
- Warpage
- Adhesive squeeze in

Physical tolerances

- Channel sealing
- 3D macro structures

Assembly

- Optical
 - Imaging
 - Fluorescence signal
- Electrical
 - Lens
 - Texture

Detection methods

- Channel surface
- Welding/bonding surface

Surface roughness

- Temperature
- Pressure
- Assembly with O-ring

Operating conditions

- Thermal conductivity
- Glass Transition Temp (T_g)

Thermal performance

- Layer to layer
- Microchannel to welding pattern

Alignment

- Pre – reagent loading, coating, surface treatment
- Post – physical alteration (dimple on film), heat-treat (annealing)

Process-compatibility

- Chemically inert
- Medical grade
- No outgassing
- No leaching

Bio-compatibility

THANK YOU !

technicolor



Precision BioDevices

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