Liquid Crystal Polymer (LCP) for MEMS Applications

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LCP Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>LCP (Vectra A-950)</th>
<th>Kapton (HN100)</th>
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</thead>
<tbody>
<tr>
<td>Melting Temperature</td>
<td>280 °C</td>
<td>&gt;400 °C</td>
</tr>
<tr>
<td>Glass Transition Temp</td>
<td>145 °C</td>
<td>360-410 °C</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Loss Factor, tanδ</td>
<td>~0.004</td>
<td>~0.002</td>
</tr>
<tr>
<td>Moisture Absorption</td>
<td>&lt;0.02%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>0-30 ppm/°C</td>
<td>20 ppm/°C</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>27 ksi</td>
<td>34 ksi</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>1500 ksi</td>
<td>370 ksi</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.4</td>
<td>1.42</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>&gt;20,000</td>
<td>-</td>
</tr>
</tbody>
</table>

- Low substrate cost ($20/sq ft, 50%-80% lower than Kapton)
- Low melting point enables low temperature processing
- Low permeability to moisture and gases
- Excellent electric isolation to high frequencies
- Dielectric strength 550 V/mil
- Mechanical flexibility

Comparison of physical, mechanical, thermal, and electrical properties of LCP and Kapton
Micro Machining Technology

• Traditional LCP machining: excimer laser drilling
  – feature size > 25 µm
• Injection molding
  – limited by mold making process
• MEMS applications: micro machining
  – photolithography and metallization
    • standard IC fabrication process
  – oxygen plasma etching
    • etching rate 0.22~0.27 µm/min
  – thermal lamination
    • LCP can be bonded on glass, Cu, Au, silicon, or another LCP
    • lamination temperature 260~270 ºC
    • bonding time < 2 min
Surface Topology

LCP: 
- **Rq=258nm and 459nm**
- **Rt~4 μm**

Kapton: 
- **Rq=197nm and 243nm**
- **Rt~3 μm**

Si Wafer: 
- **Rq=20nm**
- **Rt~200nm**

Free Surface
Vertical scanning optical interferometric surface topology data for LCP (Vectra A-950) and Kapton (HN100) Films

Roller Surface
Bonding Strength (Blister Test)

- Bonding at 260-270°C, moderate pressure
- LCP-glass bonding withstood 28 psi (193 kPa) pressure difference
- Bonding energy > 46 J/m²
Microfluidic Channel Fabrication I

Fluid channel in glass

- Deposition and patterning Au/Cr mask on glass

- Wet etch glass channel with 49% HF (70 µm)

- Removal of mask in metal etchants

- Thermal bonding LCP to glass
Microfluidic Channel Fabrication II

Fluid channel in LCP

- Deposition and patterning Al on LCP
- Dry etching fluid channels by oxygen plasma (350W @ 500mT)
- Removal of Al mask and thermal bonding LCP to glass
SEM micrograph shows the cross-section of channel in an LCP film bonded to glass substrate.

LCP-LCP bonding can form flexible 3D multi-layer fluid circuits.

Cross-sectional view of the LCP channel
Microfluid CE Experiment Setup

- Glass channel (70 μm deep) sealed with bonded LCP film
- Via holes drilled in LCP by mechanical punching
- Plastic inlet and outlet pipes bonded to LCP film with epoxy
- Platinum wires inserted as electrodes
- Voltage applied across electrodes

Schematic illustration of a capillary electrophoresis experiment setup
CE Operation

- Fluid circuit: channel with double T section
- Buffer solution: TBE 10X
- Fluorescent marker: polystyrene beads Fluosphere® (Molecular Probe)

Flow channel under epi-fluorescence microscope
CE Operation

Glass-LCP microchip under Argon laser excitation

Experiment shows the speed of fluorescent beads varies from 36~60 µm/s at 50 V/cm
Flow Sensor Fabrication

- Deposition and patterning NiCr strain gauges on LCP (Vectra A-950)

- Deposition and patterning of Au/Cr wiring

- Physical cutting of LCP to form sensor beam and bonding to glass carrier
Flow Sensor Operation

- Testing in wind tunnel
- Flow (v) directed normal to flat area of sensor beam

![Diagram showing flow sensor operation and resistance change graph.](image)

- Resistance change (PPM) vs. Flow Rate, v (m/s)
- Sensor Beam
- Strain Gauge

3000 µm
Tactile Sensor Fabrication

- Double-sided alignment, deposition and patterning of NiCr Strain gauges and Al mask on 2mil (50µm) thick LCP

- Dry etching (O2 plasma) of 35µm deep, 500µm square backside cavity, remove Al

- Deposition and patterning of Au interconnects

- Spin and pattern 20µm tall polyimide tactile bumps
Tactile Sensor Operation

- Converts normal applied load into change in resistance
- Array can image tactile contact
- Similar fabrication techniques can provide shear data
Tactile Sensor Experimental Setup

- Micromanipulator and linearly variable differential transformer (LVDT) displacement gauge are used to deflect (d) membrane
- Multimeter reads direct change in resistance
- Linear response over designed 20µm range, with 0.86 Ω/µm sensitivity
LCP for MEMS packaging

- Copper-LCP laminates for flexible circuit boards
- LCP thermal bonding for environmental encapsulation
- LCP substrates for robust devices

15mm
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Questions

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