Advanced polymer materials for mass production of BioMEMS devices

IMAPS workshop
November 25, 2015
From car tyres to...

It all started in 1957

We are a $4 billion leading supplier of advanced polymer materials with close to 6000 employees.
...materials for everyday use

Life Sciences

JSR technology is also at work in the medical field. Various particles developed by JSR based on polymer technology are used in biotechnology research, in-vitro diagnostics, and research reagents, among other applications.

Fine Chemicals

Semiconductors such as CPUs and memory lie at the heart of PCs and other equipment. JSR provides materials essential for semiconductor manufacturing including photorefractors, CMP materials, and interconnect materials.

Petrochemicals

JSR offers a portfolio of products including general-purpose synthetic rubber with excellent abrasion resistance and resistance to aging, and high-performance, fuel-efficient tire materials with characteristic molecular structure, workability, and excellent dynamic properties.

Energy

Storage devices are required to make effective use of wind, solar and other renewable power sources. The JSR Group has developed and marketed a lithium ion capacitor capable of rapid high-capacity charging and discharging. This new energy storage device is expected to find widespread use in a broad range of fields.
JSR business sectors

Core Business

Petro-Chemicals

Fine Chemicals

Strategic Business

Energy

Life Sciences
Combining our polymer expertise

- Exchange of material knowledge for new applications
- Extended expertise to design and to develop materials for emerging technologies
- Good network to evaluate and test our materials
- High volume manufacturing facilities
- Quality performance is a top priority

New material solutions for wafer-scale packaging
# JSR advanced packaging materials

## Thick resist for plating [THB series]
- Nega type photo resist
- Good sensitivity and resolution
- Good plating performance

**Micro-bump [THB-S392N]**
- Thickness: 25um
- 20um Via Hole

## Photo sensitive insulator [WPR series]
- Nega / Posi type lithography available
- Low residual stress (less bowing than PI)
- Lower elastic modulus
- Lower curing temp (lower than PI)

### Positive type [WPR-S395P]@200°C
- Film thickness: 10um
- Pattern size: 25um

## Temporary bonding material [TA series]
- Room temperature de-bonding type
- Higher adhesion force for horizontal direction, and lower for vertical direction
- Easily cleaning
- Available for 12 inch wafers

CSAM: No void

**Under development**

## Photo-sensitive adhesive [PA series]
- Nega type lithography
- Strong adhesion
- Great bonding properties

**Proposed applications**
- Chip to chip
- Wafer to chip
- Wafer to wafer

MEDICAL APPLICATIONS
JSR advanced packaging materials

**Photo sensitive insulator [WPR series]**
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**MEDICAL APPLICATIONS**

**Photo-sensitive adhesive [PA series]**
- Nega type lithography
- Strong adhesion
- Great bonding properties

**Driver applications**
- Wafer-scale chip embedding
- Wafer-scale microfluidics

JSR Confidential
Material requirements

Biocompatibility = key requirement for medical packaging applications

- Morphology observation
- Fluorescent viability staining

**Results:**
- PA and WPR series were observed to be non-cytotoxic (> 90% cell viability)
- HS resulted in 50% decrease in cell viability → new grades formulated

Viability staining using fibroblast cells

No cytotoxic effects on cells

Cytotoxic effect on cells

Focus materials

ISO10993
Material requirements

Biocompatibility = key requirement for medical packaging applications

Optimization of HS material resulted in improved cytotoxicity results

- WPR, PA and HS series were proven to be non-cytotoxic
- Applied process conditions and material composition determines in great extent the biocompatibility of the materials for medical applications
**JSR chip embedding materials**

**Material Requirements**

<table>
<thead>
<tr>
<th>Chip Embedding Material</th>
<th>WPR-series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Adhesive</td>
<td>PA-series</td>
</tr>
<tr>
<td>Release Layer Material</td>
<td>HS-series</td>
</tr>
</tbody>
</table>

**JSR Material Recommendations**

- PDMS
- PU
- PA
- PI
- WPR

**Silicone elastomer packaging approach**

**Wafer-level packaging of Si chips**

In Collaboration with Imec

JSR Confidential
JSR chip embedding materials

Process overview

i) HS material on substrate

ii) Base layer embedding material and patterning

iii) Application of adhesive and patterning

iv) Thin chip placement

v) Coating of subsequent embedding layer and patterning

Wafer-scale embedding (v)

Chip release (vi)
JSR microfluidics materials

Sensors

- Bridge the gap between prototyping and mass fabrication
- Merging sensors with microfluidics
- Easy integration of active components (mixers, pumps, sensors, actuators) & biological components (surface chemistry, biomolecules)
- Wafer-scale bonding-packaging

Microfluidics

Wafer-scale fabrication of lab-on-chip devices
Channel patterning & bonding

A typical polymer fluidics process flow for silicon biochips

SiO2  Sensor  Bondpad

Silicon wafer
Channel patterning & bonding

A typical polymer fluidics process flow for silicon biochips

Wafer-scale polymer channel  
(FT: 3 µm – 100 µm)

Bonding of microfluidic channel

Glass cover (pre-punched)

Wafer-scale Bio-functionalization

JSR

SiO2  Sensor  Bondpad

Silicon wafer
Channel patterning & bonding

Process flow

- Photopatternable, negative tone adhesive with **low cure temperature**
- **Biocompatible, transparent** material
- **Fine microfluidic structures** can be generated using **CMOS compatible** processing
- Direct & strong bonding in **mild conditions**
- Fulfil the demand for increased microfluidic complexity at **low cost**
- Easy and fast **prototyping** (e.g. Maskless UV Laser Direct Imaging) BUT can easily be upscaled to **wafer-scale production**
Patterning properties

- Constant improvement of the material to achieve the desired specs
- Thickness: 10-100 µm
- Resolution: > 10 µm
Bonding properties

- 1-step bonding / no surface pre-treatment necessary
- Straight profile & no channel deformation
- No delamination
- Can potentially bond to different substrates (e.g. PDMS, PET, COC, PMMA...)

**Designed Line**
(Bonded at 200°C and 1 Mpa)
(Line width 60um)

**X-SEM image of the PA bonded channel**
(Bonded at 200°C and 1 Mpa)

**Bonded capillary µ-fludic device**
(Bonded at 200°C and 1 Mpa)

*Microscopic top view through glass*

*Strong Glass-Si bond for microfluidic packaging > 2bar*

*Capillary flow was demonstrated after bonding*
Bonding properties

Low temperature bonding materials

Compatibility with surface chemistry and biomolecules

- Bonding strength at 100°C sufficient for most microfluidic applications
- New material to bond at room temperature under development
Many applications...

Wafer-scale production of μ-fluidic devices

Cell sorter chips

Biosensors

Capillary microfluidics
Cell sorter

Wafer-level fabricated and bonded cell-sorter devices

- Direct on-chip microfluidic patterning using PA
- Pressure driven device in which high pressures are induced
Capillary Microfluidics

Wafer-level fabricated capillary flow devices

- Perfectly bonded capillary flow devices with high yield
- Capillary flow through devices is demonstrated
- More complex structures such as pumping/mixing units, trigger valves and multiple channel devices have been successfully introduced
- Very promising alternative for Si capillary microfluidics
New material developments

Low temperature bonding material

- Biocompatible / non cytotoxic
- Excellent patterning & bonding properties
- Limited autofluorescence (no fluorescent backbone)
- Low temperature bonding material

UV bonding & Patterning = Dual X-link or DXL material
New material developments

Solution for bio-applications

- Resolution similar to PA
- Good bonding performance to glass at room temperature
- Biomolecules can be coupled to sensor prior to bonding

10 um dense pillars and lines

PA

DXL

Bond by heat

Bond by exposure
Conclusion

Using the strong expertise in semiconductor JSR is developing a wide variety of materials to support specific medical applications

Chip embedding – Bonding – Surface modification

Bridge the gap between prototyping and mass-fabrication & Facilitate full integration

With chemistry, we can.
Interested in learning more about our company?
www.jsrmicro.be
ruben.vanroosbroeck@jsrmicro.be
Appendix

PA film properties after final cure

<table>
<thead>
<tr>
<th>Item</th>
<th>Result</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass Transition Temperature (Tg)</td>
<td>135°C</td>
<td>TMA method Film Thickness : 20um</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>93ppm (α1) 156ppm (α2)</td>
<td>TMA method Film Thickness : 20um</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>72MPa</td>
<td>Tension Test 5 mm/min</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>2.3GPa</td>
<td></td>
</tr>
<tr>
<td>Elongation</td>
<td>5.0%</td>
<td>Film Thickness : 20um</td>
</tr>
<tr>
<td>Thermal decomposition temp.</td>
<td>250°C (1% loss)</td>
<td>TGA method 10C/min in N₂</td>
</tr>
</tbody>
</table>
## Stability Study

### Patterning stability

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Incubation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>IPA</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>DNDSO</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>Toluene</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>1M HCl</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>NaOH (pH 9.3)</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>Glycine (pH 2.2)</td>
<td>1h @ RT ✔️</td>
</tr>
<tr>
<td>Temperature</td>
<td>30 min @ 200°C ✔️</td>
</tr>
</tbody>
</table>

* ✔️ = less than 5% film thickness change

### Bonding stability

![Graph showing relative bonding strength for different conditions](image)

- **Contro**
  - 20 um
- **Toluene**
  - 20 um

- **No Film thickness loss**
  - **Stable bond after 5d storage**

- Long term storage tests are scheduled
Material Biocompatibility

Cytotoxicity evaluation

- Non-cytotoxic according to ISO-10993 standards
- Cell viability evaluation of primary mouse fibroblast cells using Calcein AM
- Good cell adhesion and cell growth onto PA layer
Appendix

PA film properties

Hardness

Elastic Modulus

Film thickness: 8μm (hardness) / 24μm (elastic modulus), SB: 110C-3min, Exp: 1000mJ(/-line), PEB: 110C-5min, Dev: 60sec 2.38% TMAH puddle, Rinse: 60sec, Cure: 180CX2h(N2)