FO-PLP Benefits for High Performance Applications in Automotive

nepes Corporation

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I. Automotive Industry Trend & SiP
Driving Applications

**Consumer**
- Application Processor/Base Band
- Micro Controller Unit
- Biometric Sensors
- Power Management IC
- RF Devices
- Display Driver IC
- MEMS Sensors

**Automotive**
- Radar (Transceiver, Receiver, VCO)
- Micro Controller Unit
- Sensors
- HBM Memory
- Discrete Power Devices
- Analog ICs

Packaging Technology Innovation !!!
Automotive Electronics Application Modules

**ADAS**
- ADAS Control Module
- Camera Modules
- Sensor Modules
- V2X Communications

**Aftermarket**
- Portable Navi Devices
- Audio Head Units
- Infotainment Head Units
- Video Recorders

**Body**
- Climate Control
- Remote Keyless Entry
- Lighting
- Electronic Control Units

**Chassis**
- Antilock Braking (ABS)
- Stability Control
- Tire Pressure Monitoring
- Steer/Brake-by-Wire

**EV/HEV**
- Electric Drive Controller
- Battery Management
- Inverter

**Infotainment**
- Audio Head Units
- Fixed Navi System
- Infotainment Head Units
- Rear Seat Entertainment

**Instrumentation**
- Instrument Cluster
- Head-Up Display

**Powertrain**
- Engine Control Module
- Transmission Control Module

**Safety**
- Airbag Control Module
- Airbag Crash Sensors
- Event Data Recorder

**ADAS** : Advanced Driver Assistance System
**EV/HEV** : Electric Vehicle & Hybrid
(source : IHS, Gartner)
Automotive Electronics Application Value Chain

![Diagram showing automotive electronics application value chain with values and CAGR rates for different categories.](image)

### 2016 vs 2021

<table>
<thead>
<tr>
<th>Category</th>
<th>2016</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>16.8B</td>
<td>53.5B</td>
</tr>
<tr>
<td>Entertainment</td>
<td>6.5B</td>
<td>14.5B</td>
</tr>
<tr>
<td>Mobility Management</td>
<td>4.8B</td>
<td>6.1B</td>
</tr>
<tr>
<td>Interlocking residence</td>
<td>0.1B</td>
<td>1.8B</td>
</tr>
</tbody>
</table>

### Growth Rates
- **Safety**: CAGR 33.6%
- **Entertainment**: CAGR 22.2%
- **Mobility Management**: CAGR 6.2%
- **Interlocking residence**: CAGR 105%
- **Autonomous vehicle**: CAGR 156%

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(Source: Gartner, IHS)

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*(Note: Conversion between 2016 and 2021 figures are implied; specific dollar amounts are not provided in the slide.)*
System in Package?

- **FUNCTIONAL SYSTEM** or **SUBSYSTEM**
  Assembled into a standard footprint package; LGA, BGA, QFN or FOWLP
- **TWO or MORE DISSIMILAR DIE**, typically combined with other components; passives, filters, MEMS, sensors, and/or antennas; *forms a FUNCTIONAL BLOCK*
SiP Driving Force

- MOBILE ELECTRONIC PRODUCT (SMARTPHONEs, TABLETMs … )
  (with ever-increasing functionality in the less SPACE and the demand for CONNECTIVITY everywhere) >>> MINIATURIZATION.

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**Reason for SiP adoption**

- **Miniaturization**
  - Form factor such as package height, footprint

- **Integration**
  - Different device types such as RF, analog, memory

- **Mixed process**
  - Die fabricated on different silicon technology nodes

- **Performance**
  - System performance (signal integrity, power consumption), Optimization

- **Sys. Flexibility**
  - Simplification of module level test and qualification
  - Higher production efficiency

- **Cost reduction**
  - Reduced system BOM and complexity, simplified product board and faster time to market

Source: Techsearch
II. *nepes* Packages for Automotive
nepes Technologies in Automotive

- **Key products – Cu pillar bump**
  - Stacked RDL(Cu/Ni/Au) for power device
  - FOWLP for sensor package in safety system

**Infotainment**
- Audio Drive IC
- QFP /CNA RDL

**Chassis**
- Brake system
- QFN PKG /CNA RDL, Cu pillar

**ADAS system**
- RADAR Sensor
- FO-WLP

**Safety**
- Airbag
- QFN PKG /CNA RDL

**Powertrain**
- Engine Motor IC
- QFP PKG /CNA RDL, Cu pillar
Fan Out WLP, Applications

- **77 GHz Radar**
- Excellent RF isolation, controlled impedance, low insertion loss, low attenuation, good thermal dissipation and automotive reliability

- Small (6x6mm, 1 metal layer), Short transmission lines
- Can expose back of die for heatsink
- Embedded Ground Plane for ground and shielding
- Can embed an antenna structure
# Fan Out WLP, Applications

## 77 GHz Radar

<table>
<thead>
<tr>
<th>Stress</th>
<th>AEC-1 Grade Requirement</th>
<th>Pass / Fail</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>uHAST</td>
<td>96 hrs</td>
<td>Pass (CSAM / Visual Inspection)</td>
<td>Passed extended readout 144 hrs</td>
</tr>
<tr>
<td>AATC -50°C to 150°C</td>
<td>1000 cycles</td>
<td>Pass (CSAM / Visual Inspection)</td>
<td>Passed extended readout 2000 cycles</td>
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<tr>
<td>AATC -65°C to 150°C</td>
<td>500 cycles</td>
<td>Pass (CSAM / Visual Inspection)</td>
<td>Passed extended readout 1000 cycles</td>
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<tr>
<td>HTS 150°C</td>
<td>1008 hrs</td>
<td>Pass (CSAM / Visual Inspection)</td>
<td></td>
</tr>
</tbody>
</table>

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CSAM & Optical Image after AATC 500 cycles

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Diagram: ECP Radar Board-Level Reliability

- AA (200 NSMD: 1099, 51% Fail, 2151)
- AB (200 SMD: 1371, 56% Fail, 2893)
- BC (270 NSMD: 785, 59% Fail, 2151)
- BD (270 SMD: 951, 69% Fail, 2151)

<table>
<thead>
<tr>
<th>Cell</th>
<th>1st Fail</th>
<th># Failed</th>
<th>% Failed</th>
<th># Cycles to % Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>1099</td>
<td>51%</td>
<td>2151</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>1371</td>
<td>56%</td>
<td>2893</td>
<td></td>
</tr>
<tr>
<td>BC</td>
<td>785</td>
<td>59%</td>
<td>2151</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>951</td>
<td>69%</td>
<td>2151</td>
<td></td>
</tr>
</tbody>
</table>
3D Fan Out WLP : Double side

- FOWLP (SiP) supporting PoP of commercial package (upper)
- Vertical Interconnection without TMV technology
- Thin Profile: 0.35T w/o Solder Ball
- RDL Line & Space: 10um/10um

<table>
<thead>
<tr>
<th>Test Mode</th>
<th>Test Condition</th>
<th>#</th>
<th>Sampling Plan</th>
<th>Result (Fail/Pass)</th>
<th>Result</th>
<th>REF. Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRECON*</td>
<td>Bake: 24hr @125(-0,+5)°C</td>
<td>90ea</td>
<td>Visual Inspection : All</td>
<td>0/90</td>
<td>Passed</td>
<td>JESD22-A113F:2008</td>
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<tr>
<td></td>
<td>Soak: 85±2°C, 60±3%RH, 168hr</td>
<td></td>
<td>CSAM : 11ea/Items</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reflow: &gt;260°C, 3cycles</td>
<td></td>
<td>Cross-section: 2ea/Items</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>T/C*</td>
<td>500cycles / -55(+10,-0) °C ↔ 125(+15,-0) °C</td>
<td>55ea</td>
<td></td>
<td>0/55</td>
<td>Passed</td>
<td>JESD22-A104D:2009</td>
</tr>
<tr>
<td>PCT</td>
<td>96hr / 121°C / 100%</td>
<td>77ea</td>
<td></td>
<td>0/77</td>
<td>Passed</td>
<td></td>
</tr>
<tr>
<td>UHAST*</td>
<td>96hr / 130°C±2°C, 85%±5%RH / 230kPa</td>
<td>55ea</td>
<td></td>
<td>0/55</td>
<td>Passed</td>
<td>JESD22-A118A:2011</td>
</tr>
<tr>
<td>HTS</td>
<td>1000hr / 150°C</td>
<td>77ea</td>
<td></td>
<td>0/77</td>
<td>Passed</td>
<td></td>
</tr>
</tbody>
</table>
Pressure Sensor

- Integration of MEMS and ASIC controller
- LGA pad on package bottom & Fan-Out PoP bottom package with wire bondable pad on top-side
- Smaller/Thinner Form-factor (2x2mm2, 0.2mm thin) with *Via-frame vertical interconnection*

< Exisiting Solutions >

- Side by side
- Die stacking

< 3D FOP Structure >

- Small/Thin
- Integration
- Low cost
3D System Package

- Applications
  - Digital signage, Human-machine interface
  - Home energy management systems
  - In-flight entertainment
  - Intelligent industrial control systems
  - IP phones, IPTV, Portable medical, Smart books
  - Point-of-sale devices, Smart watches
  - Home audio systems, Secure smart connected devices

PoP Module Package
- Package size: 17 x 14 x 1.7 mm³
- IC: AP, PMIC, Flash Memory
- Over 100 discrete components
Big data era drives optical interconnect replacing traditional metal interconnect even at short distance

**Concerns are:**
- Signal loss at wire bonding
- Complicate assembly – fiber alignment & assembly
- Form factor

**Optical Communication Module**

**Figure:**
- CFP 2
- CFP 4
- CX
- QSFP
Optical Communication Module

- Package level OSA based on Fan-out process

- Electrical Performance

- ≥ 6Gbps / channel (upto 8Gbps /channel)
- Raise & fall time = ~ 110ps
III. FO-PLP (Fan out-Panel Level Package) Technology
PLP (Panel Level Package)

- Innovative process & structure
- Advanced packaging platform with cost-effectiveness

FO-PLP (Panel Level Package) in large Panel @nepes

FO-WLP @300mm round
Panel Level Package: Solution

- Hybrid Process Technology between FOWLP & LCD
- Advanced packaging platform with cost competitiveness

**FO-WLP since 2009**
- Core technology know-how
  - Die drift or Warpage Control
- Wafer-level experience since 2001
  - 150mm, 200mm, 300mm
  - Process know-how (Bumping, RDL)
- Fan-Out Package R&D records
  - SiP, 4 metal layers, 2 sides RDLs

**FO-PLP**
- 600 x 600mm
- Since 2016
- “Collaboration & Synergy”

**LCD Panel since 2011**
- 650 x 750mm
- Touch Screen Panel
- 4th Gen. Process infrastructure
  - 650x750mm
- LCD process know-how
  - Panel Handling, Vacuum control, etc.
- Proven film process technology
  - Dry film PR, Thin-film tech.
Panel Level Package: Application

### Automotive
- Advanced Driver Assistance System
- ADAS Radar Sensor
  - RF Performance (77GHz)
  - Thermal Dissipation
  - High Reliability
- System in Package
  - Multi-Die, Passives, 4 RDL Layers

### Consumer
- Smartphone, IoT, Wearables
- RF, Power, Audio, etc.
  - Performance, Form factor
- Antenna Switch
  - Multi-chip Integration
- Bluetooth Low Energy

### Photonics
- Low cost & Easy Optical Alignment

### FPS, Bio & Medical Sensor
- Face-up, Via-frame, Open Cavity

### SiP Compound
- Multi-chip Integration
IV. Summary
Summary

Market Trend

Smaller & Thinner Form-factor (Based on Wafer-Level Platform)

Highly integrated System in Package

Packaging Technologies

QFP, QFN, FBGA
- QFP
- QFN
- FCBGA

Flip-Chip Bumping
- Gold Bumping
- Solder Bumping
- Cu Pillar Bumping
- Cu/Ni/Au Bumping (Wire bondable)

WLP
- Fan-in WLP
- Fan-out WLP

Fan-out WLP

SiP (Module)
- Multi-Chip Packaging
- System in packaging
- One Package Module
- AP, PMIC
- Flash Memory
- Over 100 Passives

Wafer (Panel) level platform with EDS and Backend
(Micro-bump, WLP, FOWLP, Large panel Module Package)

Position

Conventional wire bonding packaging & Typical WLP technology

Other OSATs
"Co-development for competitive edge of customer"

- Dielectric material co-development

"Co-investment for packaging technology innovation"

- Fingerprint Sensor
- Automotive Radar

"Co-challenge to nurture the packaging industry"

- Stock share, JV
- PLP consortium
Thank you

To Him who alone does great wonders, His love endures forever. Psalm 136:4

* A dandelion means ‘Gratitude’ in the language of flowers.