APEX® Glass RF IPDs

For Applications up to 40 GHz
About 3D Glass Solutions

- 3DGS is an OEM provider of glass-based devices and systems

- Markets include RF, telecommunications, internet infrastructure, millimeter wave, & satellite communications

- APEX® Glass is a patented, scalable, advanced engineered glass-ceramic material with existing customers within the electronics packaging industry

- APEX® Glass enables the largest systems-level integration of passive and active devices into electronic packages
  - Enabling significant product differentiation and creating new product definitions in electronic packages for our customers
  - up to a 70% reduction of device size leading to a ~20% reduction in production costs
  - up to 50% reduction in power consumption
  - up to 50% more data transfer rates
The **Material** Challenge Today

- Advanced RF communications protocols require more functionality and performance in a smaller space at greater and greater frequencies

  5G ➔ 28GHz ➔ Wideband DC – 40GHz ➔ 802.11ad (60GHz)

- Current filter materials/manufacturing face the follow challenges
  - Low insertion losses
  - Line widths and spacing are too large
  - Surface roughness is too high
  - Layer to layer alignment is too variable
  - System Qs are too low

- APEX® Glass is an advanced glassy material that overcomes these hurdles, providing next-generation material and design solutions for Integrated Passive Device (IPD) filters
Why APEX® Glass Filters?

- Precision manufacturing & ideal material properties create compact device foot prints
  - Ideal for mobile, base station, sat-com
  - DC – 40+ GHz, ensures common platform for multiple product generations
- Advanced manufacturing and design enables market-leading High-Q products by significantly reducing unwanted parasitic effects
- Proven low-cost wafer-level manufacturing
- Scalable manufacturing to meet any HVM needs
- Quick-turn prototypes speeds time to market
- Eliminate wire bonds and unwanted inductances
3DGS Building Blocks for RF SiP Devices

**Conductor Undercuts**
- CD > 20μm
- Configurable Effective $\varepsilon_r = 1.5 - 6.5$

**Magnetic Core Devices**
- 0.2 – 60GHz
- Critical for Wide Band Devices

**Capacitors**
- High SRF
- Breakdown V = 1,000
- 0.5 – 10pF

**Inductors**
- Q = 85 - 110
- 0.5 – 30nH
- On Glass / In Glass

**Grounding**
- EMI Protection
- Any Shape

**Coaxial Waveguides**
- 0.5dB/cm Loss at 60GHz
- DC – 120GHz

**Through Glass Vias (TGVs)**
- >30μm Diameter
- 10:1 Aspect Ratio
- 89° Sidewall Angle

**Thick Film RDLs**
- Up to 20μm
- CD: 20μm
- >0.5A Current Handling

**Thermal Vias**
- >100W/m K Effective Thermal Transfer

**Cavities**
- 25-800μm Deep
- 89° Sidewall Angle
- Any Shape

**In-Glass Power Inductors**
- 0.5 – 15nH
- Q = 50
- 3A Continuous Handling @ 65C

**Phased Array Antenna**
- On Chip
- Configurable Effective $\varepsilon_r = 1.5 - 6.5$

Covered under non-disclosure agreement
APEX® Glass LC Devices

High-Q Inductors
- Quality Factor: 85
- Thickness: 300μm
- Inductance: 0.5-30nH

Parallel Plate Capacitors
- Breakdown V: 1,000V
- Thickness: 300μm
- Capacitance: 0.5-10pF

Differentiated Filter Product
- 1-40 GHz
- 50Ω Terminations
- SMT Compatible
- RoHS Compliant
- Miniature size: 3mm x 4mm
- Super thin: 0.3mm
IPD Filter Integration

Surface Mount Filters

Integrate Filters into larger Glass Interposer Package
RF IPD Design Features

- Parallel Plate In-Glass Capacitor enables smaller package size
- High-Q Inductor
- Perimeter TGVs for Grounding & Shielding Minimizes EMI
- GSG Terminal Layout for Ease of Testing
- Low Pass
- High Pass
- Capacitor Breakdown V: 1,000V
- Current handling: 400-750mA
- Footprint: 5.8mm x 3.8mm x 0.3mm
- Terminal type: 250um GSG Probe
- Packaging: Final Product could be SMT

Covered under non-disclosure agreement
1GHz Diplexer – Modeling vs. Measurement

Current test vehicles are intended to demonstrate capability and not perfect performance.

<table>
<thead>
<tr>
<th>Part Code</th>
<th>E-06-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat File</td>
<td>E-06-F.sat</td>
</tr>
<tr>
<td>Footprint</td>
<td>E (3.8mm x 5.8mm)</td>
</tr>
<tr>
<td>Terminal type</td>
<td>250um GSG</td>
</tr>
<tr>
<td>Design Blocks</td>
<td>1 &amp; 2</td>
</tr>
</tbody>
</table>

S Parameters

Port 2 Low Pass

Port 3 High Pass
Current test vehicles are intended to demonstrate capability and not perfect performance.
Current test vehicles are intended to demonstrate capability and not perfect performance.
Bias Networks: 2-40 GHz Bias T

- Parallel Plate In-Glass Capacitor enables smaller package size
- Parameter TGVs for Grounding & Shielding Minimizes EMI
- GSG Terminal Layout for Ease of Testing
- 300μm Thick
- Ultra Wide Band Inductor

**Capacitor Breakdown V**
- 500V

**Current handling**
- 400-750mA

**Footprint**
- 5.8mm x 3.8mm x 0.3mm

**Terminal type**
- 250um GSG Probe

**Packaging**
- Final Product could be SMT

**Graphs**
- S parameter vs. Frequency (GHz)
- VSWR vs. Frequency (GHz)
Ultra Wideband SMT Inductor Measurements

Case #4: After test fixture removal using shunt mount 3D Glass 0603 Inductor, 2.7nH

![Graph showing S(1,1), dB and S(1,2), dB](image1)

![Graph showing S(2,1), dB and S(2,2), dB](image2)
DC Resistance, 400 Thermocycles

- The parts were tested under the JEDEC JESD22-A104D (Test Condition G)
- Temperature range: -40°C to +125°C
- Evaluation of TGVs, parallel plates, and redistribution metal
- No glass cracking
- No copper delamination
- Stable resistance

Before 400 Cycles

Capacitors

Inductors

Variance: <3%

Covered under non-disclosure agreement
RF Performance Post 100 Thermocycles

- RF performance after 100 TCs (-40°C → +125°C)
Thermal Shock Test

- Test Approach: 1 minute on a hotplate at 120 °C and 1 minute on a heat sink at room temperature (~24 °C).
- Observations: No cracks, no metal delamination, no through glass via pistoning out of glass holes.

Notes:
The scratches were caused by tweezers during part handling.
Thank You!

Contact Information:
Jeb H. Flemming
5201 Venice Ave NE, Bldg. D
Albuquerque, NM 87113
Cell: (505) 349-0303
Jeb.Flemming@3DGlassSolutions.com  |  www.3DGlassSolutions.com