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PCTF® Approach Saves MW/RF Component/Module Costs

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This advanced ceramic SMT packaging approach offers high performance and reliability, but with impressive cost benefits in small to medium volume production.

Norwood, MA USA: Packaging is a critical part of RF/microwave component and module design. The package provides protection but, at higher frequencies, is also part of the circuitry. For that reason, the package must provide excellent electrical performance, environmental protection, shielding, and a host of other characteristics in support of a module or component. Ceramic materials are often the primary choice for these critical packaging applications. Ceramics feature stable dielectric properties over wide frequency and temperature ranges, the capability of handling high processing and operating temperatures without degradation of performance, good mechanical strength and integrity, and good moisture resistance and hermeticity. Critical to their use with high-frequency circuits, ceramic materials also have a coefficient of thermal expansion (CTE) that is closely matched to the semiconductor die that will be mounted in the package, and ceramics support a high degree of circuit integration to achieve small housings with complex input/output (I/O) pin or lead arrays.

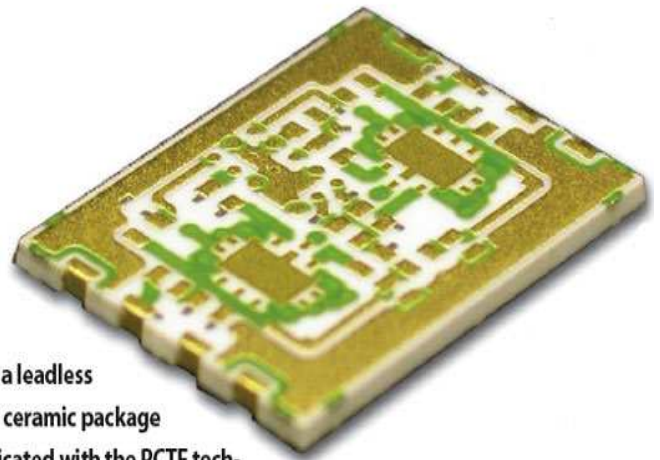
Common fabrication techniques for ceramic packaging include cofired ceramic processes as well as thick-film and thin-film processing. Cofired ceramic approaches are well suited for high-volume production. For low or medium volumes, or when greater design flexibility in terms of custom packaging is required, thick-film or thin-film approaches are typically used. While all these fabrication technologies are mature and reliable, each has varying cost, process, and material limitations for surface-mount-technology (SMT) packaging. One approach that offers an optimal combination of economy, performance, and reliability for SMT packaging is the Plated Copper on Thick Film (PCTF®) process developed by Remtec, Inc. (www.remtec.com) for production volumes ranging from a few thousands parts per year to 100,000 parts per month.

PCTF technology offers RF component and module designers a viable, cost-effective packaging option with low up-front costs and fast market entrance. The technology features consistent dielectric properties, enhanced thermal management, and improved reliability. PCTF technology also supports direct attachment of large ceramic packages and substrates to microwave printed-circuit boards (PCBs), robust RoHS-compliant soldering, and large-panel multiple-array formats. Substrates and packages based on PCTF technology have been used at frequencies from 100 MHz to 24 GHz, especially where thermally demanding applications require low thermal resistance of 1 to 2°C/W or lower.

The benefits of developing and using leadless ceramic SMT packages for direct PCB mounting are numerous. By applying the PCTF technology to fabricate the ceramic SMT package, the ceramic substrate is always the base of the leadless SMT package ([Fig. 1](#)), with either a b-stage epoxy-attached lid or a metal ring-frame/cover soldered to a substrate for a fully hermetic housing. The substrate metallization is plated copper over a seed layer and Ni-Au finish. It is capable of withstanding multiple solder and brazing operations up to +400°C. It also accepts all standard assembly techniques such as die attach with high temperature alloys and epoxy as well as ball-grid-array (BGA), flip-chip attachment, and ribbon-bonding approaches. PCTF SMT packages can be also fabricated using non-magnetic materials for applications, such as magnetic-resonance-imaging (MRI) systems, in which magnetic materials are not permitted.

A PCTF SMT package includes three noteworthy features: copper metallization, copper-plated solid plugged via holes, and PCTF wraparounds (castellations). Copper metallization is quite suitable for RF signal transmission and also creates an excellent heat spreading effect beneath a semiconductor die. Solid via holes and castellations serve multiple functions. They reduce the thermal resistance of ceramic substrates and serve as signal and ground connections for the package. They also provide low-inductance interconnects, which are essential for good high-frequency performance. Plugged via holes with DC resistance below 1 mW exhibit RF losses below 0.1 dB at 4 GHz. Solid viaholes with thermal conductivity greater than 200 W/m-°C result in thermal resistance below 1°C/W and provide excellent power management. Via holes hermeticity ($1 \times 10^{-8} \text{ cm}^2/\text{s}$) enable fabrication of fully hermetic leadless SMT packages.

Figure 1



1. In a leadless SMT ceramic package fabricated with the PCTF technology, substrate metallization is plated copper over a seed layer.

The PCFT process provides an important benefit of enhanced package reliability. Because the process results in castellations with copper deposits, larger leadless ceramic SMT packages produced with the PCFT approach can be mounted directly onto PCBs with reliable solder joint connections. Typical packages sizes range from 0.160 in. square to 1.00 in. square. Packages are typically shipped to a customer in a multiple array pack, often a 4.5 X 4.5-in. panel size. This permits fully automated component assembly, die attach and wire bond as well as the final assembly and testing, all in a multiple web format.

These ceramic arrays have a perforation (laser scoring), which simplifies the singulation process step. If and when required, dicing can be substituted for laser scoring. The capability to process and supply packages in large panels is a major reason for the cost-effectiveness of PCTF substrates and packaging. The time-proven capability of directly soldering large (greater than 0.5 in. on a side) leadless ceramic packages onto PCBs is another important and unique benefit. It allows fabricating relatively large surface-mountable RF modules, even hermetic versions (as an option) onto PCBs. Another benefit is excellent solderability and the capability of withstanding multiple and prolonged soldering operations compliant with RoHS requirements without any degradation in package integrity and reliability.

Fully hermetic and non-hermetic SMT packages have demonstrated reliable operation by passing all the qualification testing of customer product qualification test plans. The SMT packages have been subjected to stresses such as mechanical shock, extreme hot and cold environments (temperature cycling), and several stresses as part of the qualification process. This testing was performed to ensure that customer products housed within the packages are robust against potential failure modes of various die and package failure mechanisms under thermomechanical stresses. All testing was performed while packages were mounted directly on high-frequency PCBs. The reliability data are shown in the table.

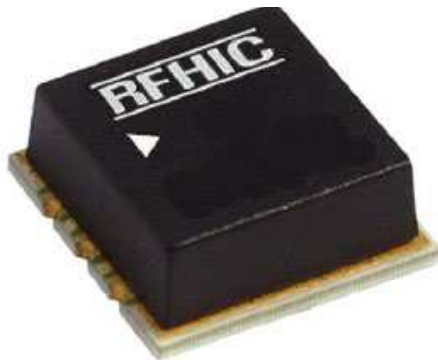
<i>PCFT packaging reliability data at a glance</i>		
TEST	TEST DESCRIPTION	TEST RESULTS
IR reflow simulation	$T_{\text{peak}} = +250^{\circ}\text{C}$, 5 cycles	Pass
Temperature cycling	-65 to $+150^{\circ}\text{C}$, 1000 cycles	Pass
High-temperature operating lifetime	1000 hours at $T_j = +150^{\circ}\text{C}$	Pass
HAST	$T_{\text{amb}} = +100^{\circ}\text{C}$, 85% RH, 264 rs	Pass
High-temperature storage	1000 h, $T = +150^{\circ}\text{C}$	Pass
Mechanical shock	1500 G's	Pass

Table 1

Because of the effective thermal design of these ceramic packages, they can support a wide range of both passive and active components and modules. For example, a single-die option is popular for power applications and QFN-compatible packages. In addition, PCTF packages either serve as magnetic SMT headers or integrate embedded passive components such as attenuators and filters. Larger leadless SMT packages can accommodate multichip modules (MCMs) with two or more ICs, resistors, capacitors and microstrip lines for developing RF power amplifiers, LNAs, transmitters, and other multifunction modules.

RFHIC, the leading Korean manufacturer of RF and microwave components and modules, uses Remtec's PCTF technology for packaging its families of low-noise amplifiers (LNAs), gain-block amplifiers, and wideband LNAs, including the CL, GB, WL, and LCL Series amplifiers (Fig. 2). These low-cost products are manufactured in high volume in a compact footprint of 10.16 X 10.16 X 4 mm. The company's wideband LNAs provide high gain and low noise figures by relying on thermally efficient and robust ceramic packages. Small size, high operation temperature, low thermal resistance, ease of manufacturing and reliability are the major benefits for this application.

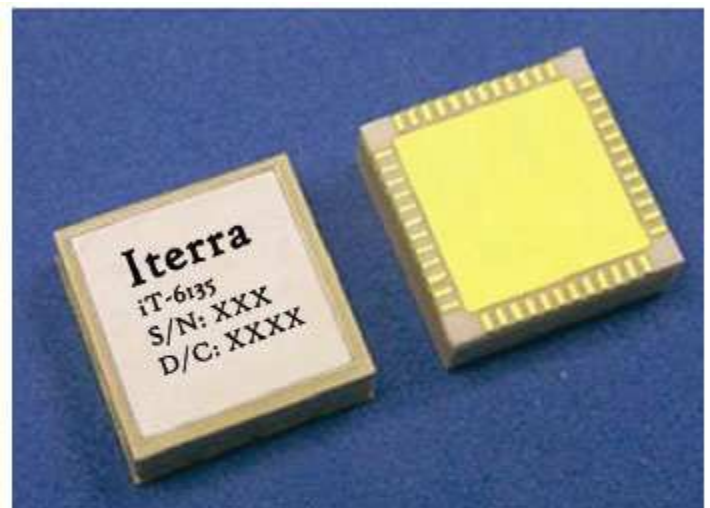
Figure 2



2. The CL, GB, WL, and LCL Series of broadband LNAs from RFHIC are supplied in compact PCTF SMT housings. (Photo courtesy of RFHIC, Suwon, Korea.)

Another high-frequency company relying on Remtec's ceramic packaging process is iTerra Communications, which supplies advanced microwave and digital solutions for high-speed optical and digital communications networks. iTerra sought the hermeticity (to $1 \times 10^{-8} \text{ cm}^2/\text{s}$) provided by Remtec's high-reliability, leadless ceramic SMT packaging, in the form of a 16 X 16-mm power package capable of dissipating 5 W total power. The package features impedance-matched transitions with very low thermal resistance (under $1 \text{ W}/^\circ\text{C}$). It houses complete non-return-to-zero (NRZ) to return-to-zero (RZ) encoder circuitry at 10.709 Gb/s with high integration level and circuit density (Fig. 3). This high-performance packaging solution with impedance-matched transitions ensured the signal-integrity performance needed to achieve less than 8 ps jitter over a broad operating temperature range.

Figure 3



3. This miniature PCFT housing holds complete NRZ-to-RF encoder circuitry with less than 8 ps jitter at 10.709 Gb/s. (Photo courtesy of iTerra Communications, Palo Alto, CA.)

Figure 4



4. This bandpass filter requires low insertion loss across its 400-MHz passband. The 6-GHz filter was fabricated with PCTF technology to reduce size while meeting electrical performance goals. (Photo courtesy of Multispectral Solutions, Inc., Germantown, MD.)

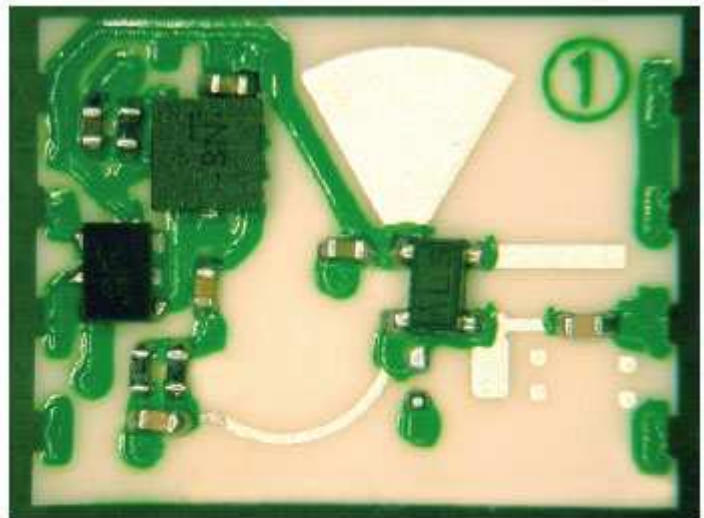
The company also designed a wideband 6-GHz transmit module (Fig. 5) using Remtec packaging technology, with cost equivalent to a standard PCB approach. The size of the transmitter, which was developed for RFID/RTLCS systems, was significantly reduced compared to conventional PCB techniques with dramatic improvement in electrical performance and reliability.

The packages described above are custom or semi-standard products designed and built per customer specifications and requirements. However, PCTF technology is capable of offering cost effective, quick-turn alternatives for standard industry footprints and customized versions, including air cavity configurations.

Because of contractual restrictions, many of the military and space applications for the Remtec packaging approach cannot be disclosed here. However, it is worth mentioning that high power (10 W) hermetic leadless SMT packages with low inductance connections were fabricated on alumina and beryllium ceramics. They passed stress and functional testing and were qualified to a 14-GHz range.

In the commercial world, however, RF identification (RFID) technology is growing rapidly as retail and industrial users find uses for this reliable, short-range wireless technology. One of the innovators in combining ultra wideband (UWB) technology with RFID solution is Multispectral Solutions based in Germantown, MD. The firm designed a wideband 6GHz filter for one of its RFID reader systems using Remtec's packaging technology to hit goals that combined performance with small size and low cost (Fig. 4). The filter was required to exhibit extremely low insertion loss over its 400MHz passband. By using thick-film-based PCTF technology for this application, the company was able to achieve significantly lower loss and much more repeatable performance than with a traditional microwave PCB approach. The size of the filter was also dramatically reduced compared to conventional design techniques, and the reliability increased. In addition, the PCTF implementation significantly reduced cross coupling to other circuitry.

Figure 5



5. This 6-GHz transmitter module was developed for RFID/RTLCS applications. (Photo courtesy of Multispectral Solutions, Inc., Germantown, MD.)

Both hermetic and non-hermetic leadless SMT ceramic packages and substrates described above are widely used in standard commercial, high-end commercial, and military applications, including avionics and space systems as well as telecommunications, wireless-communications, and satellite-communications systems. Typical applications for these SMT-packaged components and modules include base-station infrastructure and cable-television (CATV) equipment, radar antenna arrays and phased arrays, RFID tags and readers, and optical networks. The packages and the PCTF technology provide the benefits of small size, low thermal resistance, high circuit density, hermetic viaholes, design flexibility, fast turnaround times, and low up-front tooling costs.

In short, PCTF technology offers a cost-effective solution for component and module designers considering custom leadless SMT packages and substrates, especially for low-to-medium-volume production runs. The technology features consistent dielectric properties, effective thermal management, high temperature operation and enhanced reliability. For more information on the PCTF technology, visit the Remtec website at www.remtec.com

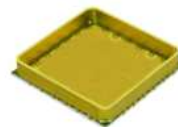
Products of Remtec's PCTF[®] Technology



ISO 9001 Registered and RoHS Compliant

Major Product Lines

- Metallized Ceramic Substrates
- Power Resistors & Terminations
- Leadless SMT Ceramic Packages
- Laser and Photo Diode Submounts
- Multilayer Thick Films



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