Multilayer (3D) Wireless, RF and Millimeter-Wave Passives and Modules Using SOP Technology

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Emerging wireless communication and sensor applications in the RF/microwave/millimeter (mm) wave regimes require miniaturization, portability, cost, and performance as key driving forces in the electronics packaging evolution. The system-on-package (SOP) approach [versus the system-on-chip (SOC)] for module development [1] has become a primary focus of research due to the real estate efficiency, cost-saving, size reduction, and performance improvement contributed by its inherent capability for the easy integration of embedded functions, thus, simultaneously satisfying the specifications of the next generation wireless communication systems. Also, the three-dimensional (3-D) integration approach is an emerging and very attractive option for these systems. However, current 3-D RF module integration is still based on low-density hybrid assembly technologies [2], [3]. In this paper, we present novel liquid crystal polymer (LCP) multilayer technologies, and stacking board technique using uBGA as the candidates of choice for the 3-D integration of RF front-end modules up to 35 GHz.

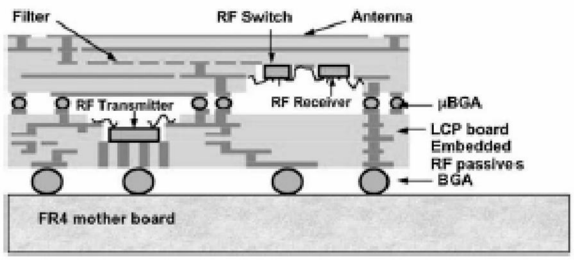

Fig.1. 3D integrated module concept view.

Fig. 1 illustrates the proposed multilayer module concept. Two stacked SOP multilayer substrates are used and board-to-board vertical transition is ensured by BGA balls. Standard alignment equipment is used to stack the board and, thus, provide a compact, high-performance, and low-cost assembly process. Multistepped cavities into the SOP boards provide spacing for embedded RF active devices (RF switch, RF receiver, and RF transmitter) chipset and, thus, lead to significant volume reduction by minimizing the gap between the boards. Active devices can be flip-chiped, as well as wire-bonded. Cavities also provide an excellent opportunity for the easy integration of RF MEMS devices, such as MEMS switches or tuners. Passive components, off-chip matching networks, embedded filter, and antennas are implemented directly into the SOP boards by using multilayer technologies [4]–[6]. Standard BGA balls ensure the effective broadband interconnection of this high density module with motherboards such as the FR4 board. The top and the bottom substrates are dedicated respectively to the receiver and transmitter building blocks of the RF front-end module. The receiver board includes antenna, bandpass filter, active switch, and RF receiver chipset (LNA, VCO, and downconversion mixer). The transmitter board includes RF transmitter chipset (upconverter mixer and power amplifier) and off-chip matching networks. Ground planes and vertical via walls are used to address isolation issues between the transmitter and the receiver functional blocks. Arrays of vertical vias are added into the transmitter board to achieve better thermal management.

Characterization and modeling of high-Q RF inductors using LCP is described in this paper. The key to optimize the performance of RF inductors is to identify the relevant parasitic and their effects. The fabricated inductor exhibits inductance values ranging from 1.1 up to 4 nH and self-resonance frequency from 8 to 16 GHz. In Table I [7], we have reported typical measured performances of RF inductors fabricated on LCP multilayer substrate. A single-input-single-output (SISO) dual-band filter (Fig.2)

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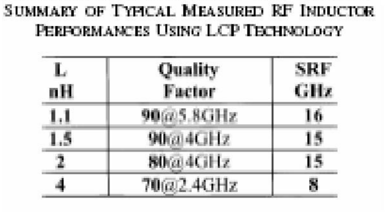
operating at ISM 2.4–2.5 GHz and UNII 5.15–5.85 GHz frequency bands, two dual-polarization 2x1 antenna arrays operating at 14 and 35 GHz, and a WLAN IEEE 802.11a-compliant compact module (volume of 75x35x0.2 mm^3) have been fabricated on LCP substrate, showing the great potential of the SOP approach for 3-D-integrated RF and mm wave functions and modules. A standard non-metallized liquid crystal polymer (LCP) 4 mil thick microwave substrate with depth controlled laser-micromachined cavities is investigated as a system-level packaging layer for integrated packaging of monolithic microwave integrated circuits (MMICs) and radio frequency microelectromechanical systems (RF MEMS) switches. The concept of a system-level package on a flexible, low-cost, organic substrate has been demonstrated for the first time. The same technique could be used for integrating MMICs all in a near-hermetic low-cost LCP module. The prototypes, shown in Fig. 2, has been fabricated in LCP substrate, characterized by ε_r=2.9, tanδ=0.002, substrate thickness 275 um, conductor thickness 9 um. Fig. 2 shows the good agreement between simulation and measurement.

TABLE I
SUMMARY OF TYPICAL MEASURED RF INDUCTOR PERFORMANCES USING LCP TECHNOLOGY


SUMMARY OF TYPICAL MEASURED RF INDUCTOR PERFORMANCES USING LCP TECHNOLOGY

L nH	Quality Factor	SRF GHz
1.1	90@5.8GHz	16
1.5	90@4GHz	15
2	80@4GHz	15
4	70@2.4GHz	8

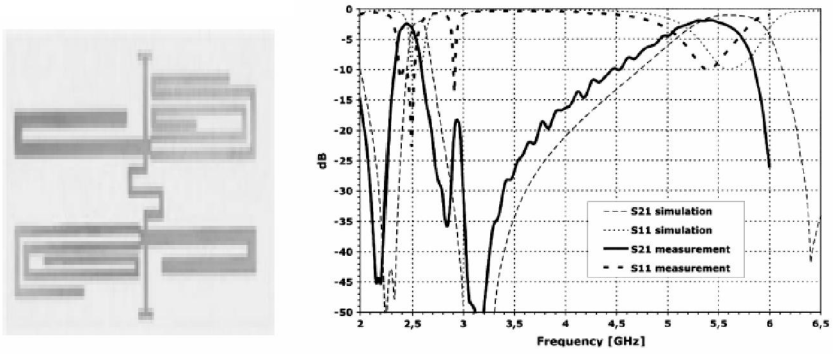


Fig. 2. SISO LCP dual-band filter: (i) left: photograph, (ii) right:performance.

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