Ultra-miniaturized and Surface-mountable Glass-based 3D IPAC Packages for RF Modules

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Abstract

This paper demonstrates ultra-miniaturized RF passive components integrated on thin glass substrate with small Through Package Vias (TPVs) to realize 3D Integrated Passive and Actives Component (IPAC) concept. Miniatuerization is achieved through; a) ultra-thin glass, b) low-loss thin dielectrics and c) small TPVs. Inductors, capacitors and low pass filters functioning in the frequency range of 0.8 GHz to 5.4 GHz were modeled and fabricated between thin dielectric layers on 100μm thin glass, and then assembled on PCB through BGA interconnections. The simulated results corroborated well with measured results, providing guidelines for RF module fabrication.

Keywords: RF passive components, glass interposer

I. Introduction

For wireless systems, planar ceramic and organic substrates have been investigated to integrate basic RF circuit elements such as inductors, capacitors and filters [1]. Ceramic substrates have been well recognized to have the best RF performance, but are limited by high temperature and high processing cost. Low-loss organic substrates have gained in popularity for RF applications; but their poor dimensional stability and warpage, as well as their moisture uptake pose challenges for miniaturizing RF devices. To address these challenges, silicon interposers are being developed, but the high electrical loss of silicon, and high cost associated with materials and processes are two major problems for RF applications. Glass has been proposed as an ideal material for RF applications at the package level by the Georgia Tech Packaging Research Center (GT-PRC), combining the benefits of ceramic, organic and silicon [2][3]. Glass offers high dimensional stability, good CTE match to silicon chip, low electrical loss, and high precision wiring for embedding RF passives. Based on these facts, Integrated Passive Devices (IPDs) on glass, fabricated using standard wafer-based technologies such as thin film, and photolithography processes have been under production for a number of years by ST Microelectronics [4]. However, these glass IPDs, fabricated using wafer processes, require wire bonds to connect to the board level, thus limiting form factor reduction and RF performance at high frequencies.

To address the above challenges, GT-PRC has explored a new concept of ultra-miniaturized and highly-functional sub-systems, called 3D IPAC. The concept involves the use of ultra-thin glass interposers with small TPVs to interconnect either passives or a combination of active and passive components on both sides, as depicted in Figure 1. Such an approach can provide a breakthrough in system miniaturization, performance and cost for complete modules including RF, power and digital functions.

Figure 1: 3D IPAC concept

An RF module applying such a concept enables form factor reduction through double-side integration of various high density RF components on ultra-thin glass substrates as depicted in Figure 2.

Figure 2: 3D IPAC RF module

The first attempt to integrate band-pass filters in low cost, double-sided glass interposers using coarse design rules was presented by GT-PRC [5]. This paper goes beyond prior work to demonstrate ultra-miniaturized RF components such as capacitors, inductors and low pass filters, towards a more complete 3D IPAC RF module using, a) ultra-thin glass, b) novel low-loss and thin dry film polymers, and c) excimer laser process to realize small TPVs. This paper is organized into five sections. Novel materials and processes for miniaturization are discussed in Section 2. In Section 3, design of miniaturized inductor and capacitor library, and low pass filters is explained. The fabrication processes of the miniaturized RF components are elaborated in Section 4, and Section 5 discusses the characterization results.

II. Novel Materials and process for miniaturization

Ultra-thin glass

Asahi Glass Company (AGC) has developed EN-A1, borosilicate glass which has a low CTE (CTE=3.8ppm/°C) and excellent electrical characteristics for RF applications. Table 1 shows the material properties of EN-A1 glass. AGC has also developed manufacturing techniques, to produce ultra-thin sheet glass using the float process. Figure 3 shows 100μm thin glass, rolled into a coil. Such ultra-thin glass enables one to achieve small TPVs at higher through-put, and also minimizes electrical parasitic loss of TPVs.