0-Level packaging techniques for flip-chip mounted MMICs

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INTRODUCTION

Currently, the thin film microwave multi-chip module (MCM) technology offers many benefits for a compact, lightweight and low cost integration of RF and microwave circuits [see Carchon et al (1)]. This technology allows the realisation of low loss transmission lines with a variety of characteristic impedances (between 10 and 100 Ohm) up to the higher mm-wave frequencies (>50 GHz). The technology also allows mounting active circuits (such as MMICs) by e.g. flip-chip technology. However, when placing different functions closely together, an adequate shielding and also mechanical protection of the active dies may be required. For this purpose, we developed a wafer level (called 0-level) package concept using micromachined cavities to realise versatile, microwave compatible protection and shielding structures on the thin film substrate. 0-level packaging refers to packaging before separation of the dies of the thin film integration substrate. In order to illustrate this concept and the benefits in real microwave functions, the realisation of a Ka-band LNA module, including 0-level package, bias circuits and RF feedthrough structures is discussed in this contribution.

LAYER BUILTUP AND PACKAGING STRATEGY

First, the passives (TaN resistors, Ta_2O_5 capacitors) are realised on a glass substrate. In the next step, a first BCB dielectric layer, an electroplated Cu layer and a 2nd BCB dielectric layer are added. These layers define the microwave transmission lines and the feedthrough structures. Feedthrough structures are needed to carry the RF signal from the outside world inside the cavity and out again. These feedthrough structures are optimised for low insertion loss and low mismatch at the desired frequency and are described in depth elsewhere [Carchon et al. (2)]. Finally the MCM built-up ends with a top metallisation (sputtered Cu, electroless Ni/Au) which is applied as the seed for the solder sealing ring.

Secondly follows the preparation and the mounting of the micromachined cap. The mounting method is called the Indent Reflow Sealing technique (Tilmans et al. [3]) and allows to realise sealed cavities at low temperatures (220-320°C). After deposition of a seed layer on the future cap wafer, a solder layer (SnPb) is electroplated in order to define a solder ring. Subsequently, the cap is patterned, the cavity is wet etched and the backside of the cap wafer is metallised. Finally, the capping wafer is diced, aligned on top of the glass substrate, prebonded using thermocompression and finally reflowed in a furnace around 230 °C, the melting point of the solder. A schematic cross-section of the total built-up is represented in Figure1.

OPTIMISATION OF THE RF SIGNAL PATH

One of the critical parts in this whole assembly are the parasitics introduced in the signal path by the feedthrough structure and the MMIC mounting technology. A careful analysis was carried out (with HFSS) in order to optimise the influence of all the transitions in the signal path. The various contributions from the feedthrough structure (to route the RF signal under the shielding cap), the MCM transmission line and the optimised flip-chip interconnection towards the MMIC itself are shown in Figure 2. As can be seen a total insertion loss of less than 0.2 dB can be achieved at 30 GHz.

MEASUREMENTS OF TRANSMISSION LINES ON CAPPED STRUCTURES

In order to evaluate and quantify the influence of the placed micromachined caps, co-planar transmission lines, realised on the glass substrate were characterised before and after mounting of the micromachined cap. The S-parameter measurements are depicted in Figure 3. In these measurements, simulations are compared with measurements on 2.7 mm long transmission lines before and after mounting a Si micromachined cap (45 µm inner cavity height). The resistivity of the silicon is 1-10 Ωcm. As can be seen in these graphs, the influence of the vicinity of the Si cap can be neglected over the whole measured frequency band (1-50 GHz). The lines remain well matched (> 20 dB) up to 50 GHz and the low losses are not increased by the Silicon cap. Also simulation predictions of this whole structure (input pads, feedthrough, line in the cavity, 2nd feedthrough, output pads) match very close to the measurements.

THE REALISATION OF AN AMPLIFIER MODULE

Using the techniques described above, a Ka-band LNA module was designed. In this module, all the capabilities of the thin film microwave technology are brought together with the 0-level package concept. A top view of a realised module is depicted in Figure 4. The left hand side contains the DC bias circuitry (with embedded resistor networks, capacitors and chip mounted diodes and bipolar transistors). The right hand side contains the microwave circuit part with the flip-chip mounted MMIC, decoupling capacitors, and in- and output transmission lines. The microwave part is surrounded with the sealing ring for the caps. Substrate testing is performed with success and currently, passives mounting and sealing cap fabrication are on-going. Measurement results on the assembly will be presented at the conference.

CONCLUSIONS

A very compact and high performance shielding and protection cap solution for flip-chip mounting MMICs is presented. After detailed modeling and optimisation of the RF signal path, a Ka band LNA module is designed and resulted in a compact, low cost and lightweight solution. The technology presented enables also further integration in the future of additional functions such as bandpass filters, attenuators etc… which can be easily integrated in the glass substrate.

ACKNOWLEDGEMENTS

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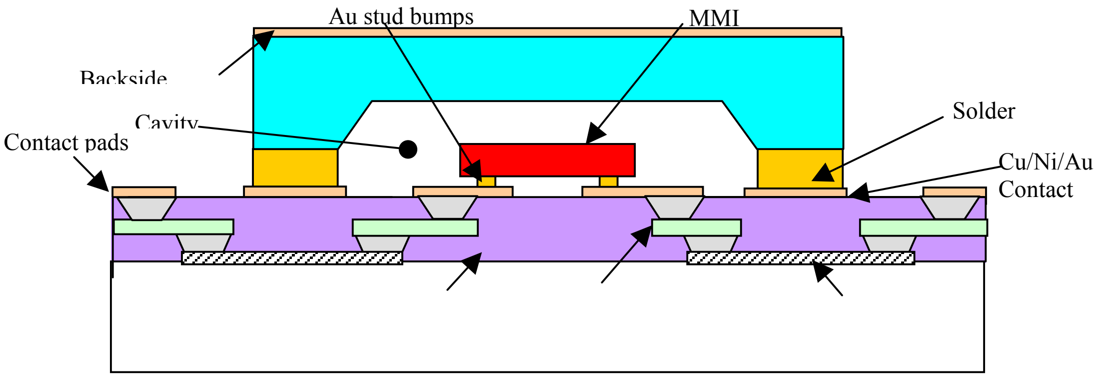

Figure1: Cross-section of the 0-level package on top of the thin film MCM built-up

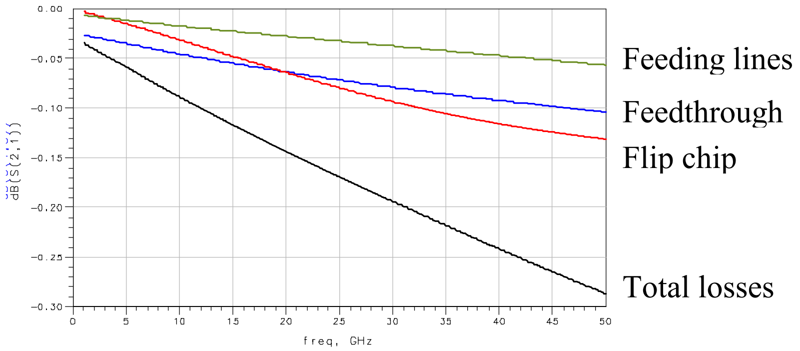

Figure 2: Influence of different contributions in the insertion loss of the total signal path versus frequency

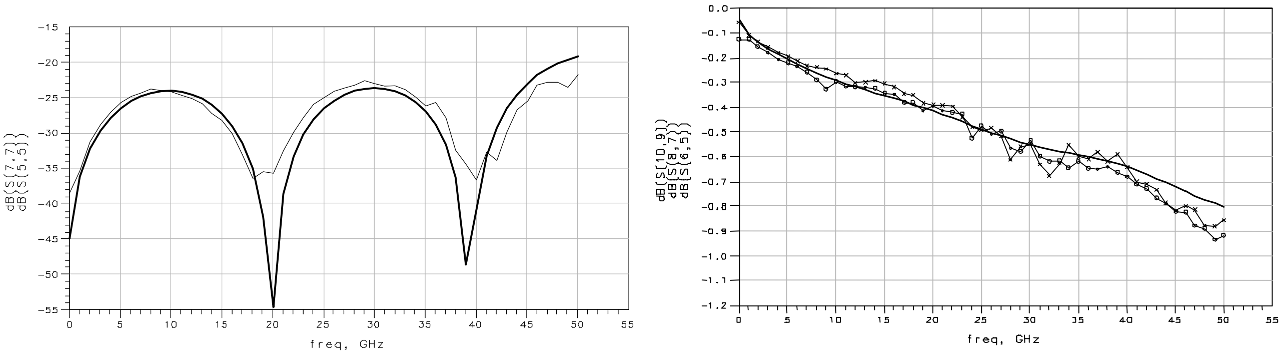

Figure 3: Simulations and measurements (full lines) of both uncapped (x) and capped (□) transmission lines, 2.7 mm long. The height of the cavity is 45 µm. The left graph depicts S_{11}, while the right hand graph represents S_{21}

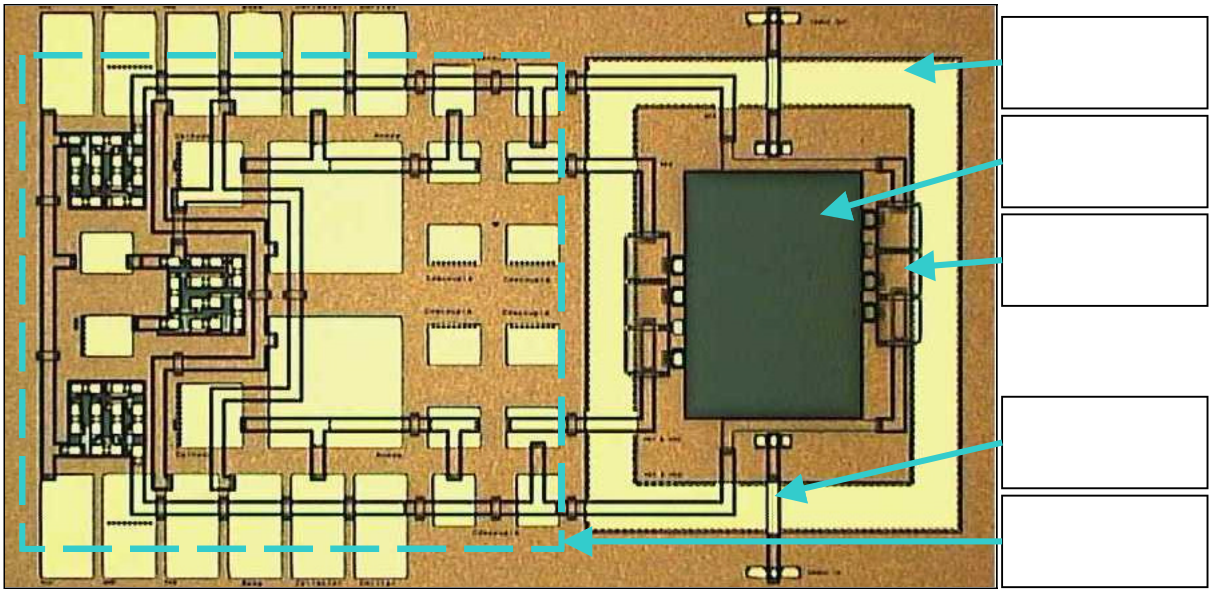

Figure 4: Picture of the realised thin film Ka-band LNA module (9.0 x 6.6 mm^2) before cap mounting

References

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