ULTRA LOW-COST MEMBRANE TECHNOLOGY FOR MILLIMETERWAVE APPLICATIONS

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ABSTRACT

This paper presents an original technique for implementing membrane structures for millimeterwave applications. The process is described and results on transmission lines and filters are given, with simultaneous comparisons between measurements and simulations. According to the performance which are presented, the proposed process appears as an interesting possible alternative for membrane technology.

INTRODUCTION

Much effort has been made in the last few years to develop technologies compatible with millimeterwave requirements. In this perspective, an original membrane solution was proposed by Rebeiz et al [1] in 1990. It consists in depositing a thin dielectric film (1 to 3µm) on Si or GaAs substrate. Then, a microshielded cavity is developed by photolithographically removing back-side defined regions, while the circuit pattern is etched on the top layer ; in this case, the technology leads to a suspended thin film membrane on Si or GaAs substrate.

On the one hand, this technology is attractive in terms of accuracy, resolution,... but it has quite a few disadvantages concerning costs, membrane access and technological compatibility.

In this paper, we propose an original alternative process for developing membrane supports, taking into account such limitations.

TECHNOLOGICAL PROCESS

Figure 1 describes the basic generic topology based on the proposed technological process.

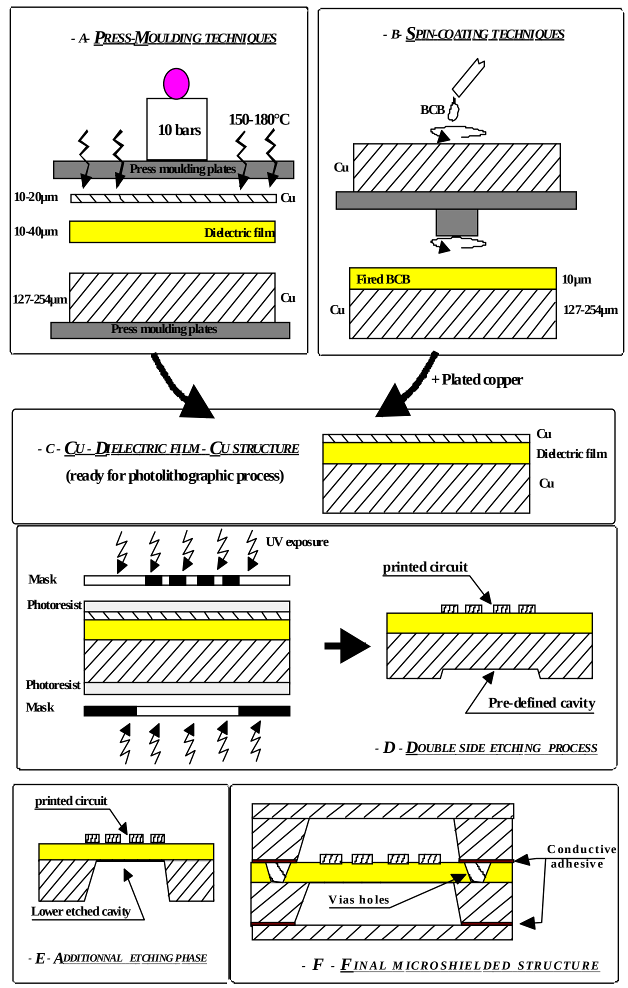


Figure 1 : New membrane process - Technological steps

- At the first step (fig.1a), a perfectly thickness-controled thin dielectric sheet is laid down on a copper base support. Two procedures were used

✐ The first one uses press-moulding technology, thus involving polymer dielectric materials, leading to a bout 10 to 40 µm dielectric layer thickness, with an upper 9 to 20µm Cu metallization.

✐ The second procedure (fig.1-b), which is more suitable for millimeterwave applications, is based upon BCB dielectric, from ***Dow Chemical***, thus obtaining a spin-coated dielectric film on a copper base. An upper 5 to 20µm Cu metallization procedure follows (thin film techniques).

- After a photoresist deposition process on the overall structure, a double side etching-mask procedure is applied, which then reveals the circuit pattern on the top side, while a predefined cavity region is formed on the back-side mass-copper support (fig.1-d).

- An additional etching operation is involved in order to fully describe the lower cavity shape, the membrane dielectric film behaving as an etching- stop layer (fig. 1-e).

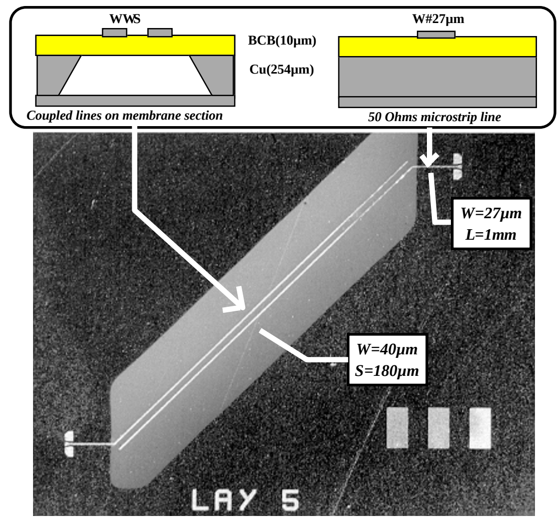
With respect to conventional membrane technology on Si or GaAs, no additional shielding operation is needed because of the intrinsic nature of the membrane suppport. The same procedure can be used to fully enclose the upper level, with an inverted copper etched cavity mounted by means of conductive glue (fig.1-f).

THEORICAL AND EXPERIMENTAL RESULTS

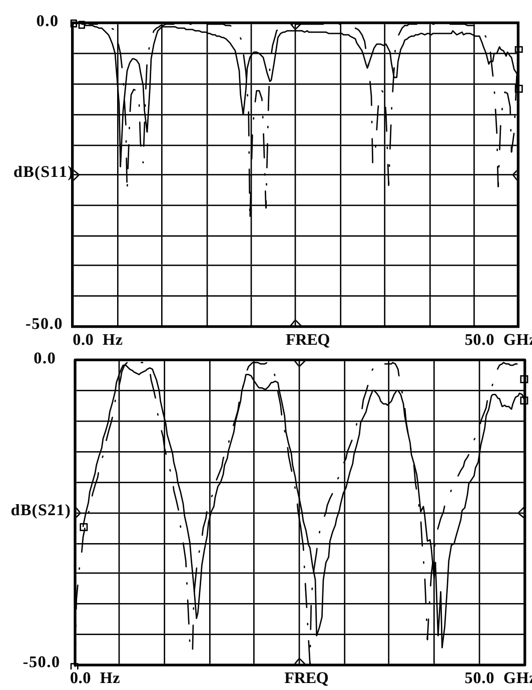
Different investigations have been carried out in order to check the validity of this technology in the microwave domain.

a) <u>Transmission lines :</u>

Figure 2 shows a structure composed of two coupled transmission lines on a membrane section, with input and output microstrip line sections for convenient excitation and measurement facilities. Ideal transmission line theory is used to model the structure, and simplifications are made concerning 3D discontinuities between microstrip and membrane sections (no influence of the ground plane modification). Under such approximation, standard CAD tools like HP-MDS, can be used, by means of multileveled multiconductor quasi-TEM models.



<u>Figure 2</u> : Coupled lines on a BCB-membrane section



<u>Figure 3</u> : Coupled transmission lines : experimental (—) & simulated (- - -) [S] parameters

The good agreement between simulation and measurement (fig.3) clearly emphasizes the validity of the procedure in both the technical and electromagnetic domains.

In addition, the periodicity of the responses up to 50GHz denotes the relative low dispersion of such a shielded structure; the dielectric membrane film has a fairly weak effect on propagated signals, thus explaining the low effective permittivity of such a structure (less than 1.1), justifying TEM approximations.

b) Low pass filter design under TEM approximation :

Under quasi-TEM assumptions, low pass filter synthesis was investigated, considering stepped impedance configurations, with various transmission line technologies.

As an example, the filter depicted in figure 4 is completely integrated on the BCB-membrane section, with cascaded inductive and capacitive coplanar transmission lines.

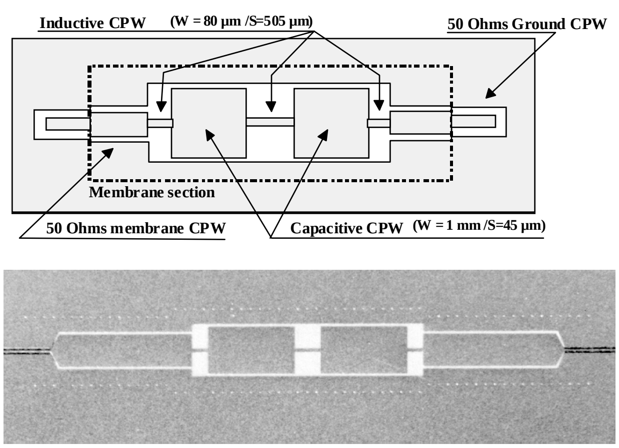


Figure 4 : Low-pass filter design on BCB-membrane

Experimental results are shown in fig. 5, in comparison with simulated ones. Note that the grounded coplanar waveguide feeding structures are not taken into account in the calibration procedure, therefore increasing conductive and dielectric losses. In addition, the discontinuities between each section of the previous filter (cascade of wide and narrow CPW lines) involve significant electrical perturbations, so degrading the filter response.

Great problems were encountered at once, in relation to the input-output port excitations, where parallel plate modes can be excited (grounded CPW region). This can be solved by forcing the continuity of the ground plane between upper and lower conductive layers by means of via hole interconnections

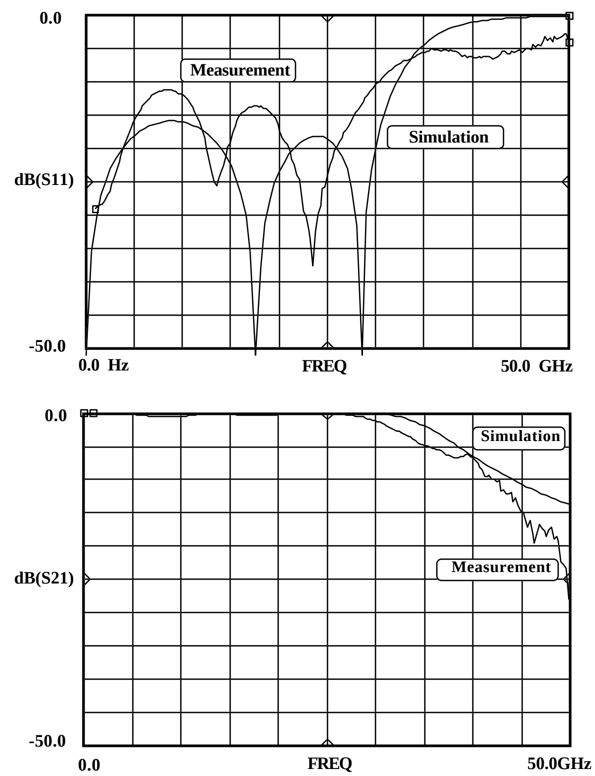


Figure 5 : Simulated and experimental [S] parameters

Nevertheless, microstrip line excitation would be more appropriate, because of a better correspondance between electromagnetic fields in the different sections.

c) Design improvements by combining various topologies :

In this second example, only stripline configurations are now considered in the membrane region, so as to remain compatible with microstrip feeding ports (minimization of ground plane 3D discontinuities).

Measurements are performed by means of a probe station, requiring CPW to microstrip transitions at input ports.

In order to reduce discontinuity effects for the filter, an original and alternative solution consists in combining various transmission line technologies. As illustrated in fig. 6, we have developed a new low-pass filter where the inductive elements are synthetized through a microshielded line on BCB-membrane sections, while capacitive effects are obtained by means of microstrip lines on thin BCB-substrate sections. The filter is then composed of cascaded microshielded and microstrip transmission lines on BCB dielectric.

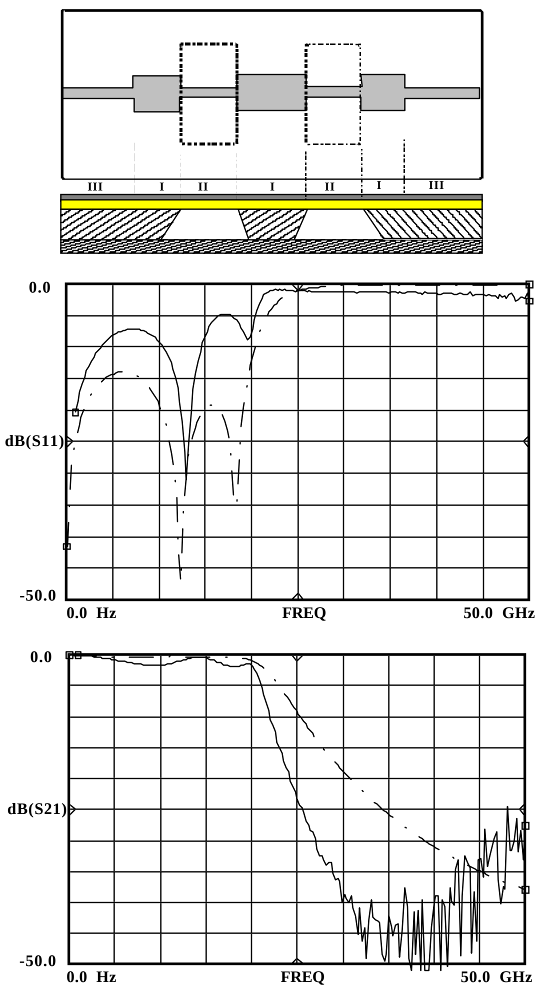


Figure 6 : Low pass filter with alternative membrane and thin-film microstrip sections

Fairly good agreement was obtained between experimental and theoretical results in this case also, even if quasi-TEM modeling is still used in spite of the 3D-nature of the structure.

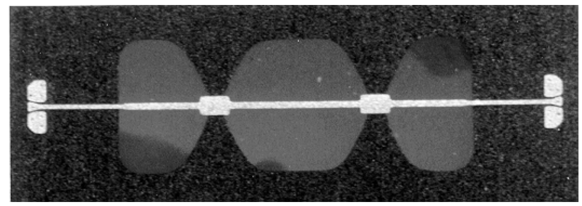


Figure 7: Photography of the membrane low pass filter

Investigations were also done concerning a dual version, by replacing capacitive microstrip sections by capacitive CPW membrane.

CONCLUSION

This paper proposes an original technological procedure in order to develop very low-cost membrane structures for millimeterwave applications. Very common materials and processes are used, in contrast with the different technologies developed recently. In addition, the proposed membrane configuration is quite attractive in relation to the interconnection possibilities offered, and design flexibility.

Different representative examples have been implemented, and original design solutions have been specifically proposed by combining various transmission line topologies, so as to minimize electrical discontinuities and physical limitations.

This new membrane technology appears as a very convenient way to design functions and sub-systems, mainly in the millimeterwave frequency range, and we intend to use it extensively in different domains, in combination with other complementary technologies.

REFERENCES

[1] : Rebeiz et al.,"Monolithic millimeter wave two dimensional horn imaging arrays", IEEE trans. on Antennas and Propagation, Vol.38, pp1473-1482, Sept 1990