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# Advances in Low-Cost Manufacturing - Quasi Thin Film Technology Produces Low-Loss MIC-Components

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## ABSTRACT

A unique method of quasi thin film (QTF) MIC fabrication on soft substrate has been developed. The new technology provides finer lines and interspaces narrower than 1.mil with tolerances of typically + 2.microns. The manufacturing process is especially promising for millimeter-wave circuits since transmission line losses and manufacturing tolerances can be reduced significantly.

## INTRODUCTION

There has been developed an enormous need for millimeter wave fabrication technology due to the rapid increase of satellite communications and defence requirements worldwide.The method of manufacturing has not kept pace with design capabilities. Demands for extremly fine lines and interspaces, virtually shrinkage free circuits, low-cost fabrication in conjunction with low tolerances etc., can not be satisfied with standard technologies.

Conventional fabrication methods are not capable to produce lines and interspaces narrower than 5.mil. The accuracy and repeatability of a circuit pattern is limited to typically +/- 12.microns which is not satisfactory for MIC-components in the millimeter-wave range.Furthermore, line edges are jagged and due to underetching or overetching errors the conductors feature a concave, convex or rounded shape. Especially jagged edges can cause higher losses on transmission lines where a narrow line width is required. In addition, very narrow gaps in finline structures, for example, are not only difficult to realize but show also increasing losses when the metallization in the slot section is jagged. In summary this results in "trial" and "error" fabrication loops when fine line and space definitions are required to meet a specified circuit performance.
The conventional photoetching technique is therefore no longer a low-cost manufacturing process. Moreover, in some applications (especially in the millimeter-wave range) the requirements for extremly fine line and space resolution is far beyond the capability of this process and the designer must chose an alternative circuit solution which is appropriate to the manufacturing capabilities available but might be much more expensive.

The present contribution, therefore, introduces a new manufacturing method which can be described as quasi thin film (QTF) technology. In contrast to conventional photoetching methods the new technology provides finer lines and spaces narrower than 1.mil with tolerances of + 2.microns. Though, circuit repeatability is guaranteed and "trial" and "error" fabrication loops are avoided. Therefore, although the individual circuit manufacturing is more expensive compared with conventional photoetching, the new technology remains still a relatively low-cost manufacturing process. In addition, thanks to the high line resolution, the QTF method offers the realization of planar and quasi-planar circuits with extremely small dimensions which could not be realized before.

## MANUFACTURING PROCESS

In the new manufacturing method microwave and millimeter wave circuits are realized on PTFE soft substrates with smooth surface and dielectric constants ranging from 2.17 to 10.5. The method provides metallization thicknesses ranging from 3.µm to 50.µm and more with straight line edges (no jagging, no underetching or overetching errors). This aspect together with a smooth substrate surface finish leads to lower circuit losses. In addition, plated through-holes down to 0.005" in diameter can be realized and -important when a good temperatur stability is required- a circuit shrinkage limitation to less than 0.0002"/inch.

The basic steps of the process are as follows: First of all the copper is stripped off from the laminated boards. The substrate material is then subjected to stress removal and stabilization techniques whereby most of the causes of dimensional instability are eliminated. This procedure is basically a thermal cycling process. At the end of the processing, the material is virtually "shrink free", and thus allows the accurate deposition of fine lines and spaces.
In a second step the substrate material is then remetallized with oxygen-free copper utilizing a high vacuum sputtering technique especially developed for soft substrate (additive method).
In an intermediate step the circuit pattern is realized on the thin metallized surface by using conventional photolithographic techniques. Finally, the copper is build up to its required thickness and is thenelectroplated gold flashed finished.
For a copper thickness of up to 1/2 oz the line definition is within 0 to 2.µm tolerances, whereas up to 1.oz copper thickness the tolerances can range between 0 to 4.µm. It should be pointed out that these tolerances are always positive what means a correction factor can be used to improve the tolerance range.

## RESULTS

The advantage of the new manufacturing method in terms of improved electrical circuit characteristics is obvious and shown in Fig.1. Compared with a conventional photoetched 5inch long microstrip line (50 Ohm) on a 177µm thick substrate ( RT/Duroid 5880, $\varepsilon r$=2.22), the transmission losses on an identical line, fabricated with the QTF method, is clearly reduced (0.5 dB at 26.5 GHz).
Fig. 2 shows the performance of a parallel coupled microstrip bandpass filter with 5.4 GHz bandwidth at a midband frequency of 12.4 GHz. Due to the large bandwidth the gaps between the strips became relatively narrow. The performance of several samples realized with the QTf method were repeatable within less than 0.1 percent, whereas the photoetched samples deviate significantly in midband frequency and insertion loss. The best photoetched sample was compared with an average sample realized with the new method. The results are also given in Fig.2.

Following the tendency of the measurements, it is believed that the new manufacturing method provides even better results for component design in the millimeter-wave range. Thus, supporting the application of microstrip structures at very high frequencies.
Fig. 3 shows the photograph of a Lange coupler designed for 12.GHz. Note the excellent line resolution and straightness of the edges. It should be noted that the component could not be realized with photoetching techniques.
Finally, Fig.4 shows the roughness of the conductor surface realized with the QTF method. Note the rectangular shape of the 10.µm thick metallization.

## CONCLUSION

A unique method of quasi thin film circuit fabrication has been introduced. The new method provides finer lines and interspaces with tolerances of typically + 2.microns. Circuit shrinkage due to temperature cycling is virtually eliminated, and transmission lines fabricated with the new technology show reduced losses towards higher frequencies. Thus, high accuracy and moderate fabrication costs combined with improved circuit performance makes the new technology very promising for applications up to very high frequencies.

## Acknowledgement

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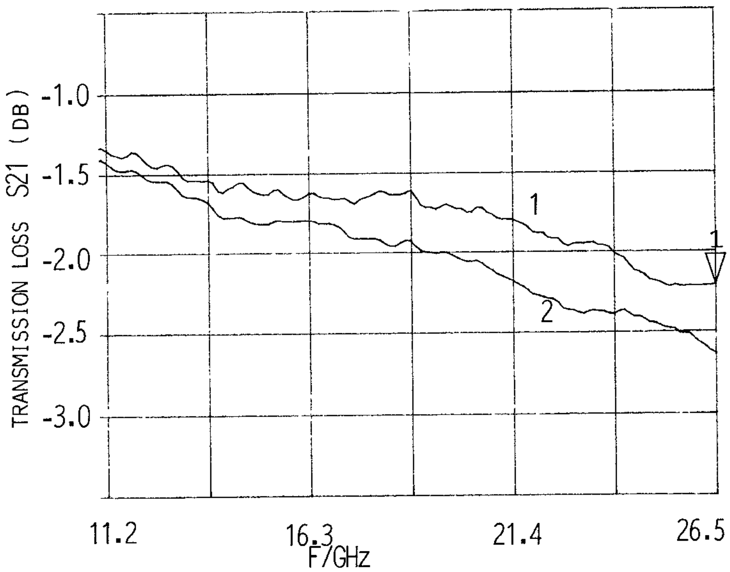



Fig.1

Transmission loss measurements on a 5 inch long, 50.Ohm microstrip line. Substrate material RT/Duroid 5880, $\varepsilon r$=2.22, substrate thickness 177.$\mu$m.
Curve 1 manufactured with the QTF method.
Curve 2 manufactured with conventional photoetching process.

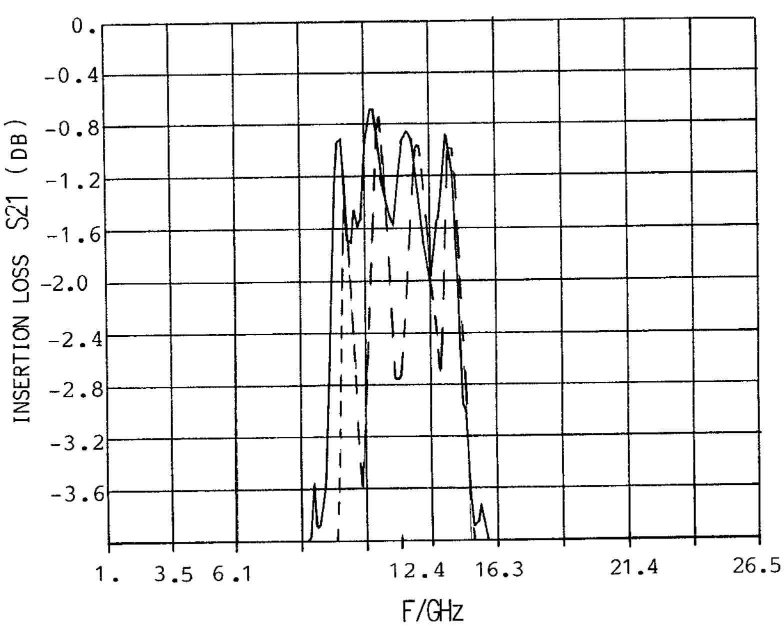



Fig.2

Parallel coupled microstrip bandpass filter. Average gap width beteen the strips 75.$\mu$m.
Solid line:manufactured with the QTF method
Dotted line: conventional photoetching method.

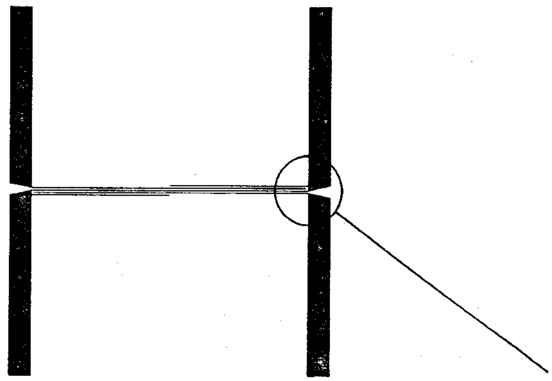
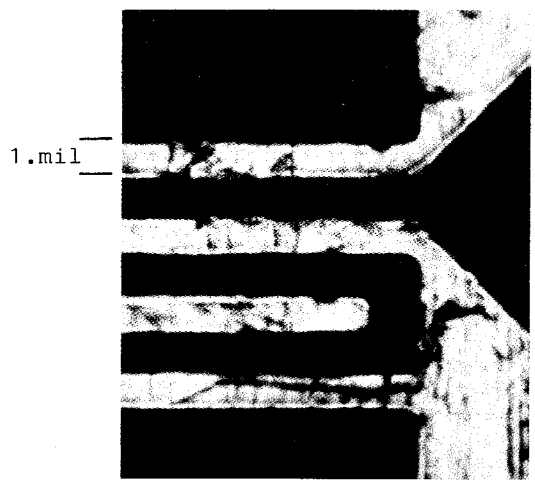


Fig.3

Photograph of a Lange coupler designed for 12.GHz with lines and spaces of 1.mil.

a) Enlargement

a)



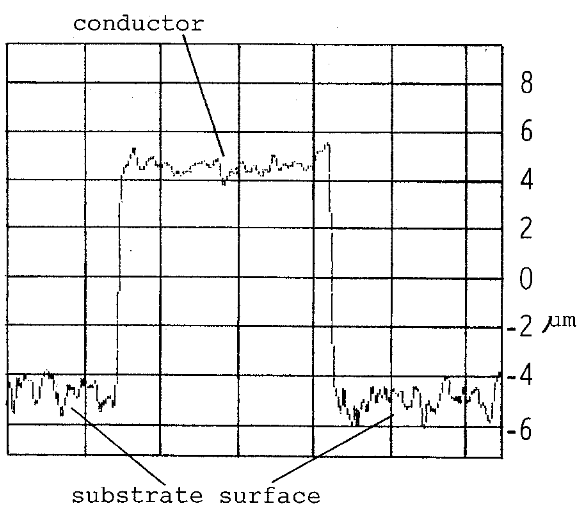




Fig. 4

Measurement of the surface roughness of the conductor and substrate.