Compact Multilayer Filter Structures for Coplanar MMIC's

Wolfgang Menzel, *Senior Member, IEEE*, Hermann Schumacher,
Wolfgang Schwab, *Member, IEEE*, and Xiangkun Zhang

Abstract— **Coplanar filter structures using two metallization layers separated by a polyimide film on GaAs were investigated. This arrangement provides additional degrees of freedom compared to standard coplanar line resulting in extremely compact filters suitable for monolithic integration.**

I. Introduction

COPLANAR line and related transmission line types are gaining increased interest, especially for MMIC's [1], [2]. These transmission lines allow the realization of series as well as shunt connections on one side of the planar substrate avoiding substrate thinning and via hole connections. Equally important to improve yield is a small chip size. This is especially critical for passive components. One way to cope with this problem is the implementation of multilayer structures on the substrate surface [3]–[5].

Among the wide range of components, filters are of great importance in microwave systems; their implementation in MMIC's, however, was mostly limited by size considerations; only a few examples of passive or active filters have been reported, e.g., [6], [7].

This letter describes first results of very compact passive filter structures for coplanar MMIC's using two metallization layers separated by a thin dielectric film.

II. Technology

The two-layer PCM (portable conformable mask) resist technology used here allows the lift-off realization of thick metal layers, essential for low losses.

The metallization image is first defined in the top resist (KTI809) and transferred into the bottom PMGI (polydimethyl glutarimide) layer by a deep-UV flood exposure. The two resists have virtually exclusive developers, hence the pattern width in both layers can be controlled independently. With a suitable prebake temperature, an undercut resist profile as required by the lift-off processing, can be obtained. This resist technology is compatible with optically defined sub-μm HEMT structures.

Here, PMGI (Shipley SAL110) was spun on a cleaned semi-insulating GaAs substrate and baked at 190° C for 30 s on a hot plate, for a film thickness of 2.5 μm. Then the imaging KTI809 layer was spun directly on top of the PMGI and baked at 90° C for 60 s. The mask pattern was transferred into the KTI809 by contact printing at a wavelength of 405 nm, where the PMGI is not sensitive.

Manuscript received September 2, 1992.

W. Menzel and W. Schwab are with Microwave Techniques, University of Ulm, P.O. Box 4066, D-7900 Ulm, Germany.

H. Schumacher and X. Zhang are with Electronic Devices and Components, University of Ulm, P.O. Box 4066, D-7900 Ulm, Germany.

IEEE Log Number 9205150.

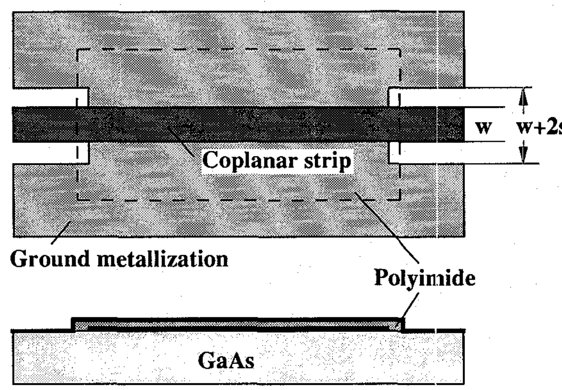

Fig. 1. Set-up of coplanar-fed microstrip resonator. (w = 0.2 mm, $w + 2s$ = 0.456 mm).

A subsequent flood exposure at 250 nm for 12 min at 4 mW/cm transfered the KTI pattern into the PMGI bottom layer. After baking the KTI resist in a convection oven (180°C for 30 minutes), the PMGI was developed in an aqueous base developer (Shipley SAL 101) at 20°C for 2 min. 50-nm Ti and 1-μm Au were e-beam evaporated and lifted off by dissolving the PMGI.

Pyralin polyimide PI-2570 was used as the interlayer dielectric for the filters, a self-priming coating with a high volume resistance 10^{17} Ω cm and a low dielectric constant $\epsilon_r = 3.4$. It was spun on at 7000 rpm for 30 s and soft baked for 90° C for 4 min followed by 150° C for 13 min. KTI809 resist was used for the pattern transfer, KTI809 developer was also used to etch the polyimide film. Finally, the dielectric film was cured at 300° C for 30 min.

III. Results

For a first test, the structure given in Fig. 1 was investigated. For the given dimensions, the microstrip line section has a characteristic impedance of 2 Ω only. From the transmission performance, an attenuation constant of 0.09/mm of the microstrip line could be calculated. These losses are almost completely due to conductor losses which are, in a first approach, inversely proportional to the dielectric thickness [4]. A reduction of these losses mainly is possible by increasing the thickness of the dielectric film.

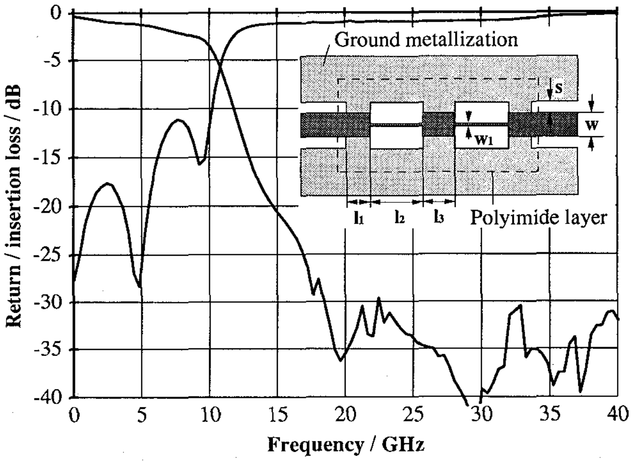

Fig. 2. Set-up and results of low-pass filter ($w = 0.2$ mm, $w + 2s = 0.456$ mm, $w_1 = 0.02$ mm, $l_1 = 0.118$ mm, $l_2 = 1.246$ mm, $l_3 = 0.174$ mm).

As a first filter structure, a low-pass filter as shown in Fig. 2 was tested. It consists of three low-impedance (2 Ω) microstrip and two high-impedance (100 Ω) coplanar sections similar to the low-pass filter described in [8]. For a corner frequency of 10 GHz, the overall dimensions of the filter amount to 0.45 * 3 mm only; increasing the value of the high-impedance further, this can be reduced once more. Due to the small dimensions, a simple design based on transmission line theory was used.

The results of this filter are plotted in Fig. 2, also. The insertion loss increases with frequency up to 2.5 dB close to the passband edge; this is due to the microstrip losses as previously discussed. The stopband extends to more than 40 GHz.

As a second filter structure, a broadside coupled transmission line section was employed as highpass filter or dc stop (Fig. 3, see [8]). The design can be made either by a full-wave procedure [9], or, as in this case of an extremely thin dielectric layer, by an approximate coupled line analysis. Due to the extreme low odd-mode impedance (about 1 Ω only), a very low cut-off frequency as well as an extreme bandwidth was achieved, while, up to 30 GHz, losses were kept around 0.4 dB only (Fig. 3). Return loss, too, was rather low.

IV. Conclusion

Using a second metallization layer separated from the basic conductor plane by a thin dielectric sheet, very compact filters can be realized on coplanar MMIC's. For some structures, losses have to be taken into account; however, increasing the dielectric layer thickness, this problem will be reduced in a next development step.

On the other hand, as this are conductor losses, the proposed structures could be equally useful in high-T_c superconductor microwave circuits once such multilayer structures become available in this technology.

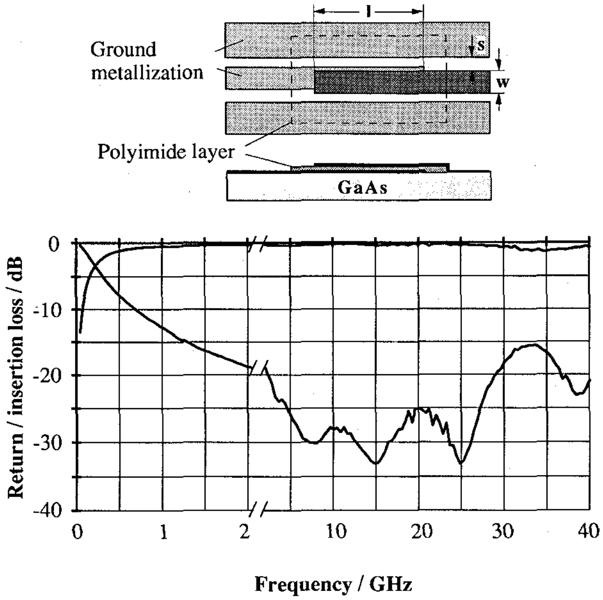

Fig. 3. Set-up and results of high-pass filter. ($w = 0.2$ mm, $w+2s = 0.456$ mm, $l = 2$ mm. In the investigated structure, both strips are centered along the symmetry plane; their displacement in this figure was introduced for clarity only.)

Acknowledgment

Thanks are due to U. Erben performing the coplanar probe measurements on the GaAs substrates.

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