MMIC Transmission Lines for Multi-Layered MMICs

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Abstract

Multi-layered MMIC transmission line configurations have been proposed, and their performance experimentally investigated. Four transmission line structures have been fabricated using polyimide films. Four transmission lines discussed in this paper are: (1)Microstrip line with overlay, (2)Inverted microstrip line, (3)Trapezoid microstrip line, and (4)Valley microstrip line.

INTRODUCTION

ATR has been developing very small multi-layered MMICs[1]-[4]. These structures utilize narrow width microstrip lines on thin dielectric materials fabricated on a GaAs substrate. Although multi-layered MMICs can substantially reduce the circuit size, these circuits have larger transmission line losses than conventional MMICs [4]. To decrease the circuit loss, MMIC transmission lines whose losses are smaller than those of narrow width microstrip lines must be introduced using multi-layered structures.

This paper proposes four transmission lines utilizing multi-layered structures. Fig.1 shows the cross section of these transmission lines. Figs.1(a) and (b) are the microstrip line with overlay and the inverted microstrip line. These structures are well known in microwave integrated circuit schemes. However, these transmission lines are first fabricated using very thin dielectric materials on a GaAs substrate. Reducing the transmission line loss is done in basically the same way as reducing MIC transmission line loss.

The trapezoid microstrip line and the valley microstrip line are shown in Figs. 1(c) and (d), respectively. These new structures can eliminate the current concentration at both sides of the microstrip conductor. The effect of the current distribution in the trapezoid microstrip conductor is slightly less pronounced in the valley microstrip conductor. Since the distance between the ground plane and the center of the trapezoid microstrip conductor is smaller than that between the ground plane and the edge of the conductor, the current concentrates at three points, that is, the center and both edge of the microstrip conductor. This effect can reduce the conduction loss of transmission lines.

The coupled trapezoid microstrip lines and the coupled valley microstrip lines are also considered for use as transmission line components of multi-layered MMICs. Fig.2 shows the cross section of each coupled line. The coupled trapezoid microstrip lines can make the phase velocity difference of each orthogonal mode larger than that of conventional coupled microstrip lines[5]. On the other hand, in the coupled valley microstrip lines, the odd-mode phase velocity is close to that of the even-mode, because the field of the odd mode is concentrated between two valley conductors. Fig.3 shows the ratio of the effective dielectric constant of even mode and odd mode. The dotted lines correspond to the conventinal coupled microstrip lines on a 20-μm thick substrate[6] while the solid lines the coupled valley microstrip lines. The reduction effect of the difference of each orthogonal mode is shown in Fig.3.

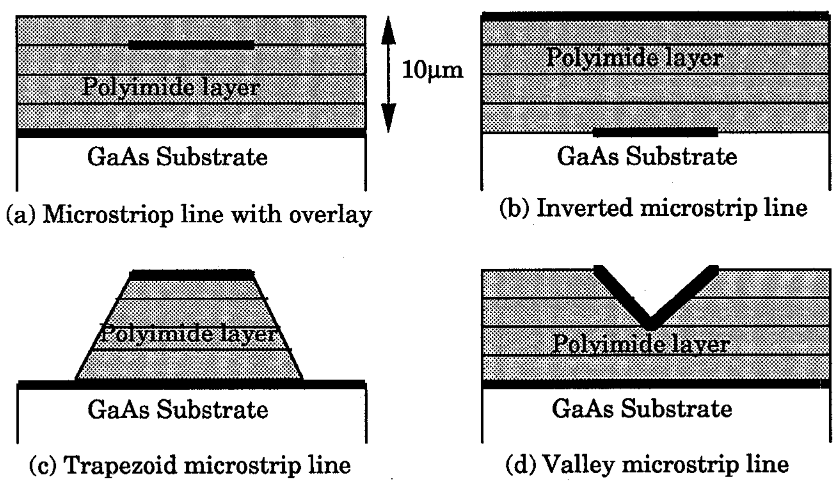

Fig.1. Configuration of Multi-layered MMIC transmission lines.

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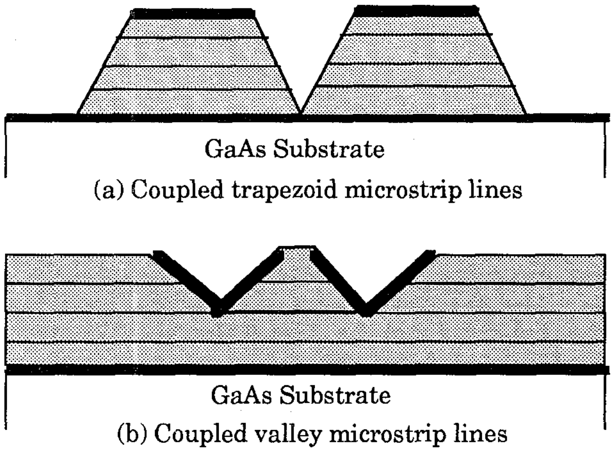

Fig.2. Configurations of Multi-layered MMIC coupled transmission lines.

FABRICATION PROCESS

The fabrication process introduced for multi-layered MMICs utilizes chemically etched polyimide films[4]. This process can generate the cone-shaped through hole[7] which connects the microstrip conductor on the polyimide film with the ground plane conductor on the GaAs substrate. The fundamental structure consists of four 2.5μm polyimide films. Each polyimide film is fabricated by spin-coating and prepared through heat-treatments at 150 degrees and 185 degrees C[7]. The postbaking time of each layer is optimized to avoid over-curing the lower layers and over-etching the upper layers. Fig.4 shows the process sequence for multi-layered MMICs.

Figure 5 shows the photographs of the trapezoid microstrip line and the valley microstrip line. The thickness of the microstrip conductors is 1 μm. The height of the trapezoid structure is 7.5μm. The depth and width the of valley structure is 5 μm and 12μm, respectively. The relative dielectric constant of the polyimide film is 3.3μm.

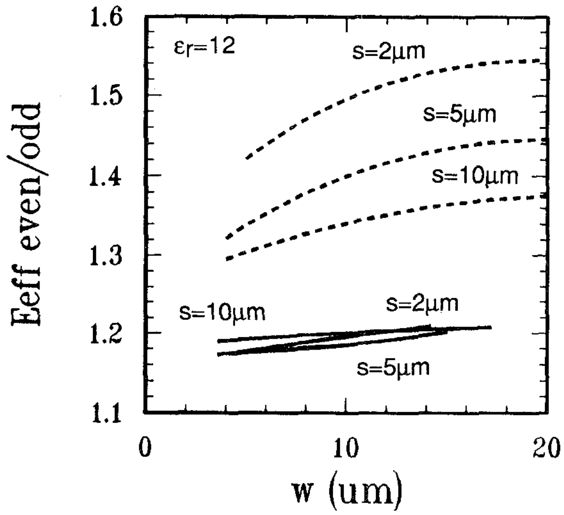

Fig.4. Effective dielectric constant of coupled valley microstrip lines.

EXPERIMENT RESULTS

Each transmission line was tested using on-wafer probers and an HP8510 network analyzer. Four microstrip lines with overlay, whose polyimide layer thickness is 2.5μm, 5μm, 7.5μm and 10μm respectively were fabricated on a GaAs substrate. The width of each transmission line is 5μm, 10μm, 16μm and 22μm, respectively. The characteristic impedance of each line is 50ohm. Fig.6 shows the

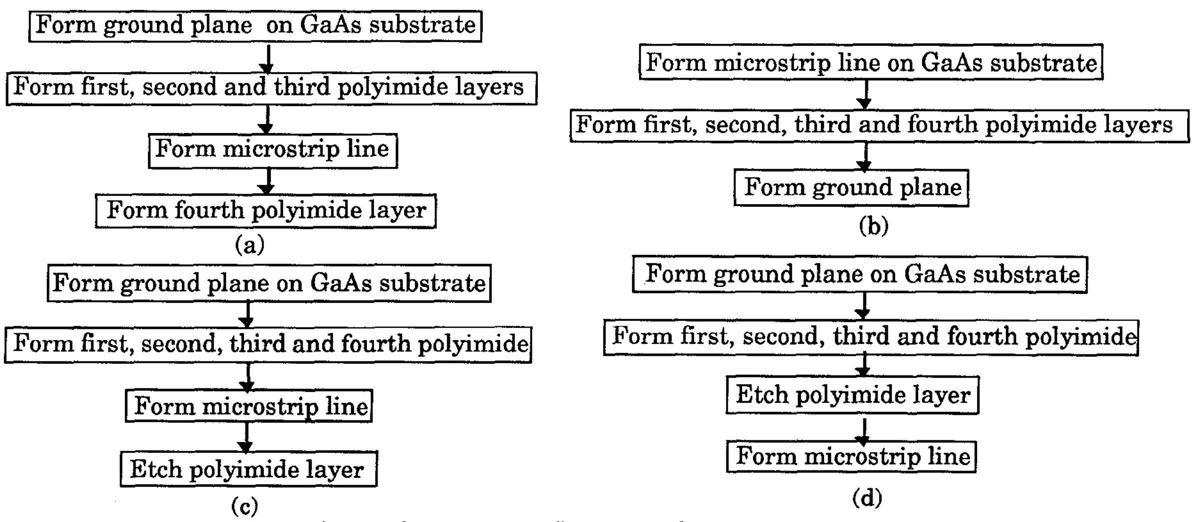

Fig.3. Process sequence of multi-layered MMICs using polyimide layers.(a) Microstrip line with overlay. (b) Inverted microstrip line. (c) Trapezoid microstrip line. (d) Valley microstrip line.

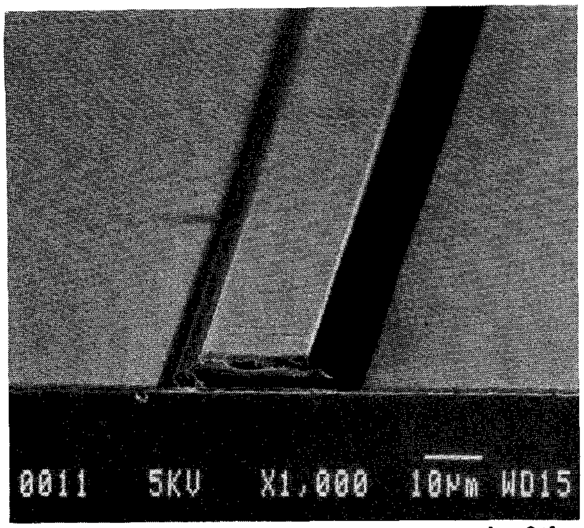

Fig.5(a) Cross sectional SEM micrograph of the trapezoid microstrip line.

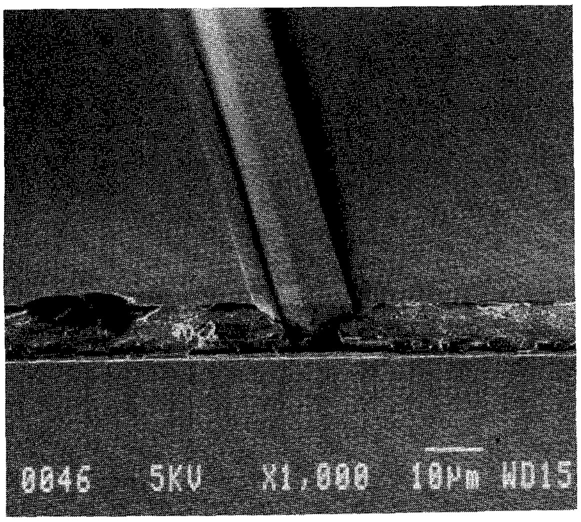

Fig.5(b) Cross sectional SEM micrograph of the valley microstrip line.

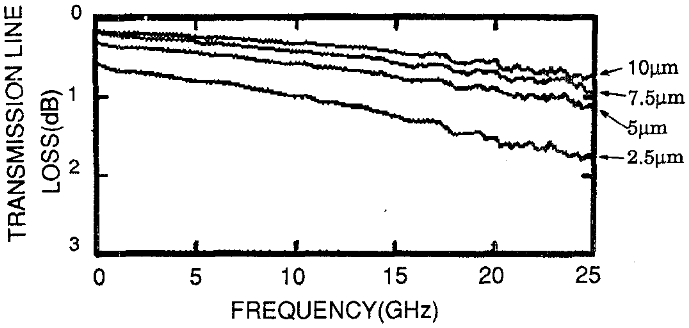

Fig.6. Frequency response of microstrip lines with overlay.

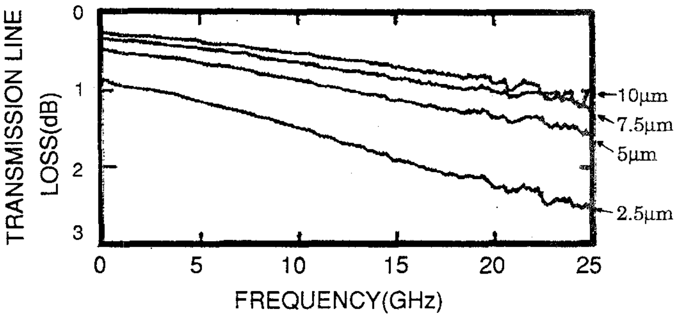

Fig.7. Frequency response of inverted microstrip lines.

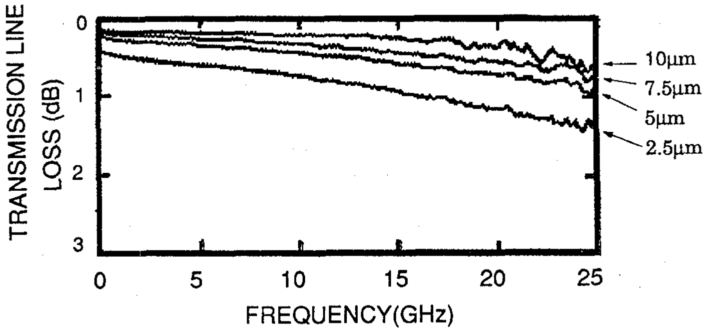

Fig.8. Frequency response of trapezoid microstrip lines.

transmission line loss of the microstrip lines with an overlay. To reduce the transmission line loss, the thickness of the polyimide film must be greater than 5μm.

The transmission line loss of the inverted microstrip line is shown in Fig.7. Four lines whose width is 3μm, 6μm, 9μm and 12μm respectively were fabricated under 2.5-μm, 5-μm, 7.5-μm and 10-μm polyimide films. The width of the inverted microstrip lines is 60% smaller than that of the microstrip lines with an overlay because of the high relative dielectric constant of the GaAs substrate. Because of the narrow microstrip width, the inverted microstrip lines have a larger line loss than conventional microstrip lines.

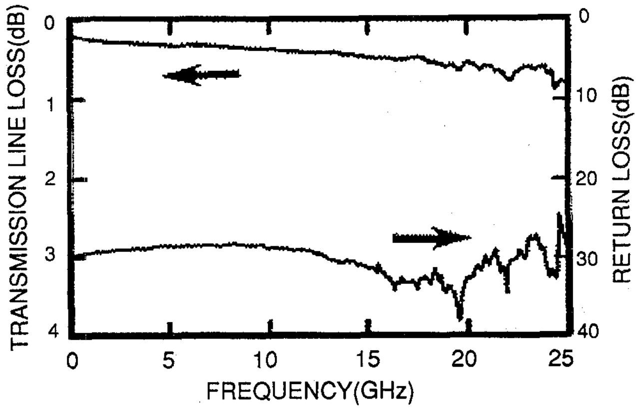

Fig.9. Transmission line loss and return loss of valley microstrip line.

Table 1 Transmission line loss of each transmission line. (Polyimide layer thickness=10μm, Transmission lin length=1.4mm, Characteristic impedance=50ohm, Frequency=20GHz)

Multi-layered MMIC Transmission lines	Line width(μm)	Line loss(dB)
Microstrip line with overlay	22	0.5
Inverted microstrip line	12	0.9
Trapezoid microstrip line	25	0.35
Valley microstrip line	12	0.55

Figure 8 shows the transmission line loss of trapezoid microstrip lines. The height of the trapezoid polyimide layers / the width of the trapezoid microstrip conductors are 2.5μm/7μm, 5μm/13μm, 7.5μm/19μm, and 10μm/25μm, respectively. The line width is determined from the calculation results by Finite Element Method[8]. Although the width of the trapezoid microstrip line is 20% greater than that of the microstrip lines with an overlay, the transmission line loss of the trapezoid lines is 30% less.

The transmission line loss and return loss of the valley microstrip line is shown in Fig.9. The microstrip width is 12μm. Despite the narrow microstrip width, the transmission line loss of valley microstrip lines can be made 20% less than that of conventional microstrip lines. Table 1 summarizes the experiment results of each transmission line. The valley microstrip line has the potential to reduce the size of multi-layered MMICs.

CONCLUSION

Four transmission lines for multi-layered MMICs are experimentally investigated. Two structures, i.e. trapezoid and valley microstrip lines utilizing polyimide characteristics are newly developed. The minimum transmission line loss can be achieved by the trapezoid microstrip line if the characteristic impedance of each line is the same. The valley microstrip line can have the minimum line loss if the line width of each line is the same.

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