III-8. MICROSTRIP TRANSMISSION ON SEMICONDUCTOR DIELECTRICS

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As a result of both a larger number of microwave functions performed by semiconductor devices and a larger number of functions required in modern systems, it has become highly desirable from both the system and the device standpoint, to fabricate multiple microwave semiconductor devices on a common substrate. The use of multiple devices in a single package has system and reliability advantages, but there is also offered the possibility of improved performance of the microwave components. This results from the elimination of packaging of each individual element and the ability to place the package interface in a more advantageous position in the circuit.

To effect such an improvement an efficient means of microwave interconnection must be available. The interconnections must have not only low dissipative losses through the microwave region, but be capable of providing the impedances necessary for transformations by the various microwave functions and for circuit resonating elements. The range of impedance commonly required is of the order of 20 to 80 ohms.

To be compatible with semiconductor materials and processing the choice of dielectric material was limited to film dielectrics, possibly SiO_2, or the use of the semiconductor material itself as a dielectric. For the range of impedances required, the thicker dielectric, available through the use of the semiconductor material, offered a more practical approach for microwave interconnection in monolithic systems. The suitability of semiconductor materials as the dielectric of microstrip transmission line was the subject of this investigation.

As silicon is the material most widely used in microwave devices, the primary investigations were based upon this material. Slices of p-type silicon of various resistivities were polished to 0.010 ± 0.0005 inch thickness, leaving an optical quality surface suitable for evaporation and processing. One side of each slice was completely metallized to serve as a ground plane and on the opposite side, the lines of various widths from 1 mil to 12 mils were produced. Both aluminum and silver were used as the conductors. The length of line used for insertion loss and characteristic impedance determination was 0.625 inch. The measured insertion loss of the 50 ohm transmission line as a function of silicon resistivity is shown in Figure 1. Resistivities used were in the order of 100 Ω-cm, 300 Ω-cm and 1300 Ω-cm. The range and accuracy of resistivity measurements is reflected by the length of the rectangle representing the measured points, and the range and accuracy of the insertion loss measurements are represented by the height of the rectangles. The resistivity and dielectric constant of silicon has recently been shown to be practically unchanged at microwave frequencies from DC measurements (References 1 and 2). Based upon this assumption and approximations for the insertion loss of microstrip line presented by Assadourian and Rimai (Reference 3), the line loss as a function of resistivity was calculated. This is presented as the solid curve also shown in Figure 1. The fact that the experimentally determined points have less insertion loss than was predicted may be attributed to the approximate character of the formulae relating to microstrip transmission.

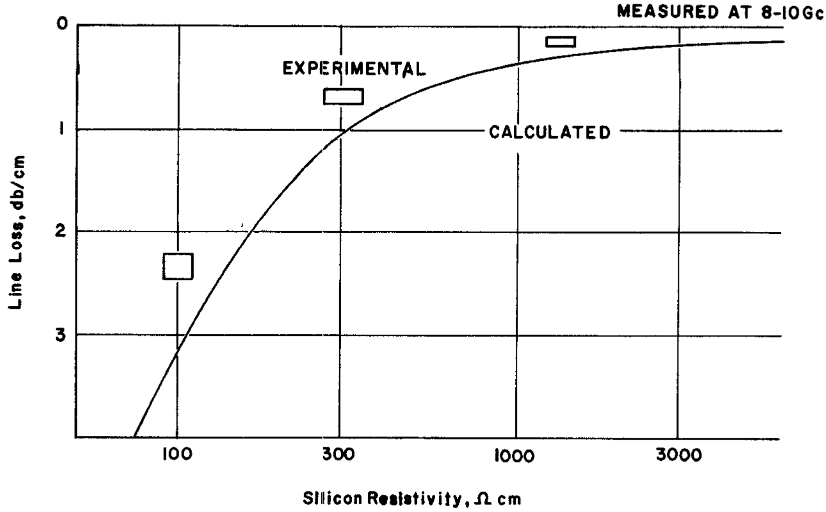

Figure 1. Line Loss versus Dielectric Resistivity

The insertion loss as a function of line thickness was also determined. Silicon slices of resistivity in the 1400 to 1600 Ω-cm range were prepared with aluminum conductors as previously described. Conductor thicknesses from 25 to 400 microinches were tested, and the insertion loss as a function of line thickness is presented in Figure 2.

The characteristic impedance as a function of line width was determined on lines having low loss. The range of impedance obtainable with reasonable line width is from approximately 30 to 80 ohms corresponding to line widths from 1 to 15 mils as shown in Figure 3. Fifty ohm impedance occurs at a convenient 6.5 mil line width. The characteristic impedance from Assadourian and Rimai is shown as the dash line. Again this is an approximate solution and is valid only in the region of line width much greater than dielectric thickness.

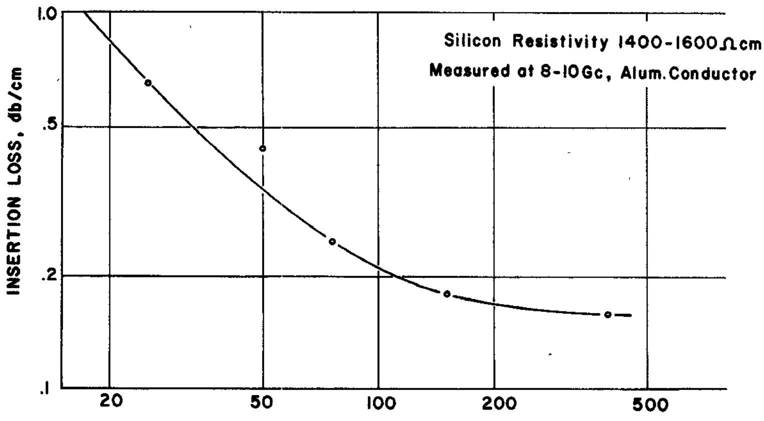

Figure 2. Line Loss versus Conductor Thickness

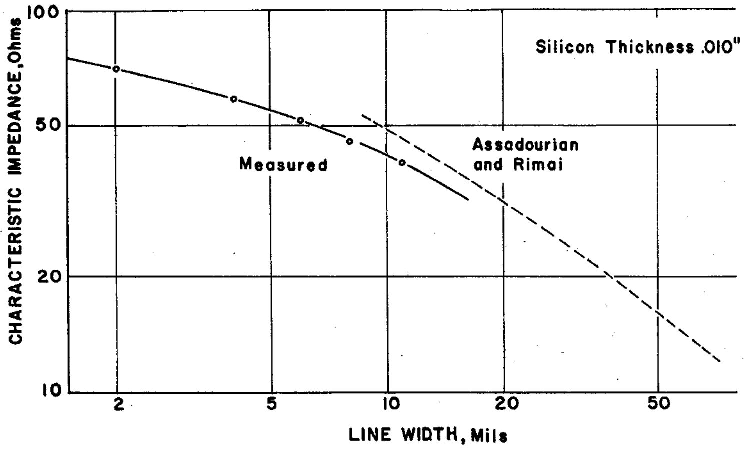

Figure 3. Impedance of Microstrip Lines on Silicon Dielectric

Semi-insulating gallium arsenide (resistivity greater than 10^8 Ω-cm) was evaluated as a microstrip dielectric material in a manner similar to that described for silicon. Measured losses were slightly lower than that observed for silicon and, in fact, approached very closely the losses inherent in the conductor. For both the semi-insulating gallium arsenide and silicon of resistivity greater than 1000 Ω-cm, the loss is sufficiently low to perform efficient interconnection of devices on a common substrate. Under many circumstances it should even be possible to fabricate devices such as couplers and hybrids where extremely high "Q" is not required.

REFERENCES

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