Chapter 6

Conclusions and Discussions

Schottky-contacted coplanar waveguide (CPW) on III-V semiconductor (e.g., GaAs) subtrate has been studied and used as a phase shifter at microwave frequencies. In this dissertation, a numerically efficient quasi-static conductor loss model was formulated to calculate the series impedance part of the CPW structure. Also, to calculate the shunt part, a series R_{epi}-C type model was introduced which shows good agreement with the experimental results. Conductor loss model based on conformal mapping can be extended to any transmission line structure [Tuncer et al. 1994]. It allows the evaluation of conductor loss for off-chip interconnects, which are used in multi chip modules (MCM). The ability of this method to accurately extract the circuit parameters of a transmission line from low frequency to very high frequency makes this technique a viable candidate for digital IC interconnect modelling. This new technique is also numerically efficient and leads to new equivalent circuits for the transmission lines that are highly appropriate for time domain simulations [Kim et al. 1993]. Besides its application in interconnect modelling, this model can also be used for microwave CAD simulators. It has a quasi-analytic form and requires less numerically involved calculations. Most of the existing CAD simulators cannot provide a good conductor loss model for CPW at microwave and millimeter wave frequencies, which can be very important for MMIC applications.

In this dissertation, a good deal of work has been presented on a high performance semiconducting phase shifter which can be used up to at least 40 GHz. The best performance has been obtained with optically controlled GaAs-on-Quartz phase shifter [Islam et al. 1991] , where a hybrid integration technique (Epitaxial Lift Off) [Yablanovitch et al. 1987; Tsao et al. 1991] is utilized in addition to simple co-planar waveguide (CPW) fabrication. The Epitaxial Lift Off (ELO) technique makes it possible to transfer the MBE-grown lightly doped thin epitaxial

GaAs layer onto optically transparent quartz from its parent semi-insulating GaAs substrate. This hybrid integration makes back side illumination possible and hence avoids metal shadowing effects. This results in much higher optical power absorbtion in the active GaAs layer causing higher sensitivity, and therefore the phase shifter requires only a very small amount of input power. This allows the use of commercially available LED to control the phase shift, which has been shown to perform well into the millimeterwave regime. The performance obtained upto 40 GHz is the best among all available or reported electronically controlled phase shifters. It also shows the promise to integrate a phase shifter and a semiconductor LED or a Laser on two opposite sides of the same quartz substrate. Preliminary work has been performed on this integrated phase shifter-LED device, but requires further work for its practical implementation. One major drawback observed is the response time of the phase shifter. The response time measured is much lower than any commercially feasible response time. The slow response time, most likely caused by MBE growth related traps residing at the bulk, or at the surface of the GaAs layer. But it is also not impossible to grow trap-free GaAs layers, such as use of some additional interfacial layers to prevent the residing of traps at the interfaces, which might improve the response time largely without affecting other performances.

Other conclusions evolved from this dissertation are different optimization issues deduced from the simple but accurate series and shunt circuit model of a lossy co-planar waveguide structure. The equivalent circuit model gives rise to a number of different optimization variables, such as use of optimum back side sheet resistance, optimum bias voltage required, optimum geometry including the thickness of the lossy layer, etc. The shunt circuit model requires more work in terms of incorporating drift-diffusion model to evaluate the two dimensional effects along the thickness of the GaAs layer. Also more rigorous approach is required to accurately model the interfaces between n- epi GaAs and AlAs or between n- epi GaAs and SI GaAs. These studies when associated with the proposed R_{epi}-C type shunt model would predict both low and very high frequency results more accurately. Use of a series circuit model to calculate the conductor loss also gives rise to different conclusions, such as effect of finite width of ground plane or finite thickness of the lossless subsrtate, besides the effect of conductor geometries on the propagation characteristics of the line. Use of a high T_C superconducting model also suggests that superconducting material can be used with CPW structure, and much lower losses should be expected.