For low cost and high performance applications, InGaP/GaAs heterojunction bipolar transistors (HBTs) are the preferred technology widely used due to their inherently excellent characteristics. With the smaller dimensions for improving speed and functionality of the InGaP/GaAs HBTs, which dissipate large amount of power and result in heat flux accumulated in the junction, device reliability issues are the first concern for the commercialization. As the thermally triggered instabilities often seen in InGaP/GaAs HBTs, a carefully derived technique to define the stress conditions of accelerated life test has been employed in our study to acquire post-stress device characteristics for the projection of long-term device degradation pattern. To identify the possible origins of the post-stress device behaviors observed experimentally, a two dimensional TCAD numerical device simulation has been carried out. Using this approach, it is suggested that the acceptor-type trapping states located in the emitter bulk are responsible for the commonly seen post-stress base current instability over the moderate base-emitter voltage region.

Since MMIC’s performance is very sensitive to the variation of device characteristics and the reliability issues put the limit on its RF behavior. While many researchers have reported the observed stress-induced degradations of GaAs HBT characteristics, there has been little published data on the full understanding of stress impact on the InGaP HBT-based MMICs. If care is not taken to understand this issue, stress-induced degradation paths can lead to built-in circuit failure during regular operations. However, detection of this failure may be difficult due to the circuit complexity and lead to erroneous data or output conditions. Thus, a practical and analytical methodology has been developed to predict the stress effects on the MMICs with the InGaP/GaAs HBT devices. It provides a quick way and guidance for the RF design engineer to evaluate the circuit performance with reliability considerations. Using the present existing EDA tools (Cadance SpectreRF and Agilent ADS) with the pre- and post-stress extracted transistor models, the electrothermal stress effects on InGaP/GaAs HBT-based RF building blocks including power amplifier, low-noise amplifier and oscillator have been systematically evaluated. This provides a potential way for the RF/microwave industry to save tens of millions of dollars annually in testing costs.

The world now stands at the threshold of the age of advanced GaAs device and circuit technology and researchers have been exploring here for years. The device- and circuit-level reliability of GaAs HBT is no longer the post-design evaluation, but the pre-design consideration. The successful and fruitful results of this dissertation provide methods and guidance for the RF designers to achieve more reliable circuits with advanced GaAs HBT technology in the future.
The public is welcome to attend.