MOLECULAR BEAM EPITAXIAL GROWTH AND FABRICATION OF MICROWAVE AND PHOTONIC DEVICES FOR HYBRID INTEGRATION ON ALTERNATIVE SUBSTRATES

APPROVED BY
DISSERTATION COMMITTEE:

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This work is dedicated to my father, James Jhy-Yuan Tsao, my mother, Vicki I-shien Wei Tsao, my brother Allen Tsao, my sister, Debbie Tsao and my wife, Jenn Fen Liu Tsao

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by

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DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT AUSTIN

May 1993

ACKNOWLEDGEMENTS

I would like to first thank my advisor, Professor Dean P. Neikirk, whose guidance, support, patience, "gee-whiz" ideas , and friendship have allowed me to finish this work. To Professors Ben G. Streetman and Joe C. Campbell, I owe a great deal of thanks for their interest in this work and use of their facilities. I would also like to thank the other members of my committee, Professors Willis Adcock and Mike Downer, for their time and effort. To Terry Mattord, I would like to express my appreciation for his time and help on equipment related issues. In addition, I would like to thank Professor Alex DeLozanne for use of his scanning electron microscope used to obtain all the SEM micrographs shown in this study.

I have been very fortunate to work with many outstanding graduate students in the Microelectronics Research Center (MRC). I would like to thank Stu Wentworth for his help in the area of fabrication and equipment related issues. To my "ENS 405 brothers", Douglas Miller, Vijay Reddy and Kiran Gullapalli, I would like to extend a heartfelt thanks for their friendship, for the many discussions we've had, and the help they have given to me over the years. I would also like to thank Saiful Islam for many useful discussions related to processing and CPWs. In addition, I would like to thank the members of the MBE group for the pleasure of working with them and learning from them: Ananth Dodabalapur, Tom Block, Tommy Rogers, Kayvan Sadra, Albert Shih, Anand Srinivasan, Alex Anselm, Chad Hansing, and Andy Tang. To Carl "Goobaby" Kyono, Kevin Klein, and Marty Agnostinelli, I thank them for the profit and the fun I had in the high-stakes tennis matches we played. I would also like to thank Ravi "Truck" Kuchibhotla for useful discussions on LEDs, lasers, and his opinions on everything. For the other members of "Team Neikirk", I would like to express my sincere appreciation for their assistance in many lab related issues. In addition, I would like to thank Bernice Wooton for her help in taking care of many administrative tasks.

Finally, I would like to acknowledge the sources of financial support for this research: Texas Advanced Technology Program, Joint Services Electronics Program and the VLSI Fabrication Lab at the University of Texas at Austin.

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Publication No. _____

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The University of Texas at Austin, 1993

Supervisor: Dean P. Neikirk

In recent years, there has been considerable work on improving the high frequency and output power properties of double barrier resonant tunneling diodes (DBRTDs) which exhibit negative differential resistance (NDR) in their DC current-voltage (DC-IV) characteristics. Structural device parameters such as quantum well, barrier, and spacer layer thicknesses significantly impact the peak-to-valley current ratio (PVCR), the peak current density (J_p), the difference between the peak voltage and the valley voltage (ΔV), and the difference between the peak current density and the valley current density (ΔJ). Furthermore, variations in the dopant profiles, thickness of the spacer layers, and the contact resistance can significantly alter device characteristics. Optimization of the ohmic contacts to the DBRTDs was investigated. The impact of barrier asymmetries in AlAs/GaAs and AlAs/AlGaAs/GaAs DBRTD structures were studied. Through the use of an AlGaAs/AlAs "chair" barrier or composite barrier, a PVCR of 6.3 was measured. The impact of intentional small barrier thickness asymmetries on the DC-IV characteristics of AlAs/GaAs high current density DBRTDs was also examined. The thickness of the asymmetric barrier is adjusted nominally in increments of a half-monolayer based on growth rates using Reflection High Energy Electron

Diffraction (RHEED) intensity oscillations. From this study, an AlAs/GaAs DBRTD was produced with a PVCR of 5.6. These PVCRs remain the highest reported to date for their respective material systems.

The typical current densities of AlAs/GaAs DBRTDs are in the range of 20 kA/cm^2 - 100 kA/cm^2. As a result of the significant device heating that can occur, the Epitaxial Lift Off (ELO) technique was used to remove the DBRTDs from their original substrates for subsequent hybrid integration to hybrid substrates of higher thermal conductivity. The ELO technique was used to create optically controlled Schottky contacted coplanar waveguide (CPW) phase shifters which are bonded to transparent substrates. In a similar fashion, ELO light emitting diodes (LED) such as AlGaAs/GaAs double heterostructure and multi-quantum well LEDs have been grown and hybrid bonded to transparent and pre-patterned substrates.

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