CHARACTERIZATION OF HIGH FREQUENCY OSCILLATOR AND VARACTOR DIODES GROWN BY MOLECULAR BEAM EPITAXY

by

VIJAY KUMAR REDDY, B.S.E.E., M.S.E.E.

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 1994

CHARACTERIZATION OF HIGH FREQUENCY OSCILLATOR AND VARACTOR DIODES GROWN BY MOLECULAR BEAM EPITAXY

APPROVED BY
DISSERTATION COMMITTEE:

____

____

____

____

____

This work is dedicated to my family for their loving support and encouragement

ACKNOWLEDGEMENTS

I would like to first express my gratitude and appreciation for my advisor, Professor Dean P. Neikirk, for his guidance, inspiration, patience, and support. His incisive comments and suggestions have greatly improved this dissertation. To Professors Ben G. Streetman and Joe. C. Campbell, I thank them for their interest in this work and the use of their experimental facilities. I would also like to thank the other members of my committee: Professors Francis X. Bostick and John G. Ekerdt for their time and interest.

I would like to express my deep gratitude to the "ENS 405" gang: Doug Miller, Alwin Tsao, and Kiran Gullapalli for their friendship and invaluable help over the years. I thank Doug for our numerous discussions (a few technical) and for his thoughtful advice. To Alwin, I would like to express my thanks and appreciation for the experimental help, sharing his processing expertise, the wide ranging discussions, and the late-night rides home. I would like to thank Kiran for the many illuminating discussions that have greatly improved my understanding of DBRTDs and QWITTs, his considerable help in data analysis, and his careful reading of this work. I thank Carl "Yahoo Chuck Yeager" Kyono for his friendship, late nights jaunts, and his considerable help in processing matters. I would like to also express my thanks to Shiva Javalagi for many useful discussions on microwave oscillators and measurements. To the rest of "Team Neikirk": Saiful Islam, Jason Lewis, Vikas Gupta, Youngmin Kim, and Emre Tuncer, I extend my thanks for their friendship and help over the years. Also, I would like to thank the MBE group: Kayvan Sadra, Albert Shih, Anand Srinivasan, Tommy Rogers, Tom Block, Ananth Dodabalapur, Alex Anselm, and Chad Hansing for the many interesting discussions and friendship. I thank Terry Mattord for sharing his knowledge of vacuum systems and for keeping things working. I also would like to thank Bernice Wootton and Terrace Demerjian for their help in dealing with the bureaucracy and keeping things going smoothly.

Finally, I would like to acknowledge the financial assistance of the Texas Advanced Technology Program and the Joint Services Electronics Program without whose support this work could not have been undertaken.

CHARACTERIZATION OF HIGH FREQUENCY OSCILLATOR AND VARACTOR DIODES GROWN BY MOLECULAR BEAM EPITAXY

Publication No._____________

Vijay Kumar Reddy, Ph.D.
The University of Texas at Austin, 1994

Supervisor: Dean P. Neikirk

This work addresses the output power optimization of semiconductor based submillimeter wavelength power sources. This wavelength region, from 1 mm to 100 µm (300 GHz to 3 THz), is of great importance in such applications as space-borne radio astronomy, spectroscopy, plasma diagnostics, and atmospheric remote sensing. Two candidate devices were investigated for their potential as submillimeter wavelength power sources: the double barrier resonant tunneling diode (DBRTD) and the heterojunction barrier varactor (HBV) diode. A reproducible molecular beam epitaxial growth process for AlAs/GaAs and AlAs/$In_{0.53}Ga_{0.47}As$ devices was developed. The effect of a growth interruption at the DBRTD hetero-interface was studied and shown not to have a significant effect on the electrical characteristics. Furthermore, interface roughness at the normal and inverted interfaces was not found to play a significant role in determining high current density DBRTD transport characteristics.

The DBRTD oscillator output power is proportional to the $\Delta V \Delta J$ power density product where ΔV is the difference between the peak and valley voltage and ΔJ is the difference between the peak and valley current density. To increase ΔV, the downstream spacer layer profile is modified to take advantage of space-charge effects arising from carriers traversing a space-charge region at a constant saturation velocity. Such a layer modification results in the Quantum Well Injection Transit (QWITT) diode. To increase ΔJ, devices should be fabricated in the AlAs/$In_{0.53}Ga_{0.47}As$ material system which offers the highest ΔJ possible. Record DC-to-RF continuous wave conversion efficiencies of 52% and output powers of 20 mW, the highest reported for DBRTD oscillators, were achieved with AlAs/$In_{0.53}Ga_{0.47}As$ QWITTs.

HBV diodes intended as submillimeter-wavelength frequency multipliers were also studied. HBV diodes in the AlAs/$In_{0.53}Ga_{0.47}As$ and AlGaAs/GaAs material system were investigated. The current transport in these structures was analyzed and record breakdown voltages as high as 12 volts were achieved. This result represents a significant breakthrough for the application of HBV diodes.

Table of Contents