The electron coherent transport in nonpolar m-plane ZnO/MgZnO resonant tunneling diodes

X. Wang*, A. Demić, Z. Ikonić, R. W. Kelsall and D. Indjin
School of Electronic & Electrical Engineering, University of Leeds, Leeds, LS2 9JT, U.K.
**e-mail: el17xw@leeds.ac.uk*
UNIVERSITY OF LEEDS

Introduction

GaAs-based THz quantum cascade lasers (QCLs) are fundamentally limited by electron-optical LO-phonon resonance at around 36meV in GaAs, causing parasitic non-radiative depopulation of the upper laser level at room temperature. Promising alternative semiconductors to solve this problem include new material systems like ZnO-based with their larger LO-phonon energy (~72meV) [1]. it was established [2] that the ZnO-based terahertz sources can cover the spectral region of 5–12 THz, which is very important for THz imaging and detection of explosive materials, and which cannot be covered by conventional GaAs-based terahertz devices. Recent progress in growth of non-polar m-plane ZnO-based heterostructures and devices with low density defects [3], opens a wide perspective towards design and fabrication of non-polar m-plane ZnO-based unipolar intersubband structures capable of operation at elevated temperature. A theoretical analysis of ZnO-based resonant tunnelling structures would provide a considerable amount of information about the quantum mechanical aspects of electron transport in these novel heterostructures and would act as an optimisation tool for specific applications and device designs.

Methods

- Transfer-matrix method
- Self-consistent Schrodinger-Poisson solver
- Resonant-tunnelling current calculated following the Tsu-Esaki approach [4]
- Fermi-Dirac statistics in highly doped emitter/collector

Results

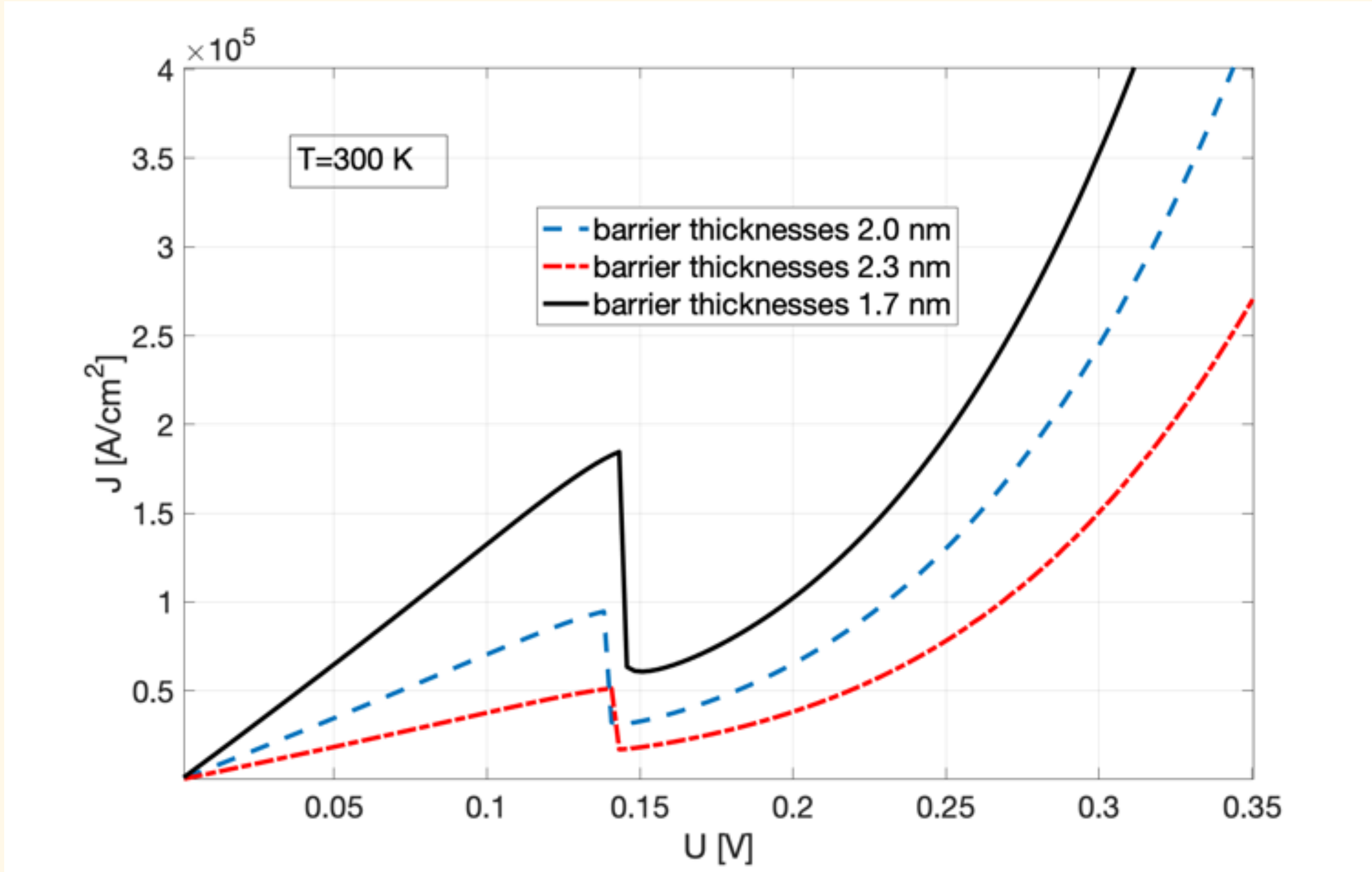

Figure 1. Current density-voltage characteristics of ZnO/$Mg_{0.15}Zn_{0.85}O$ resonant tunneling diodes with monolayer-scale fluctuation of barrier thickness. Nominal layer thickness in nanometres are 5.7/**2.0**/4.0/**2.0**/5.7 – see Figure 2. (bold faces - barriers with fluctuating thicknesses) .

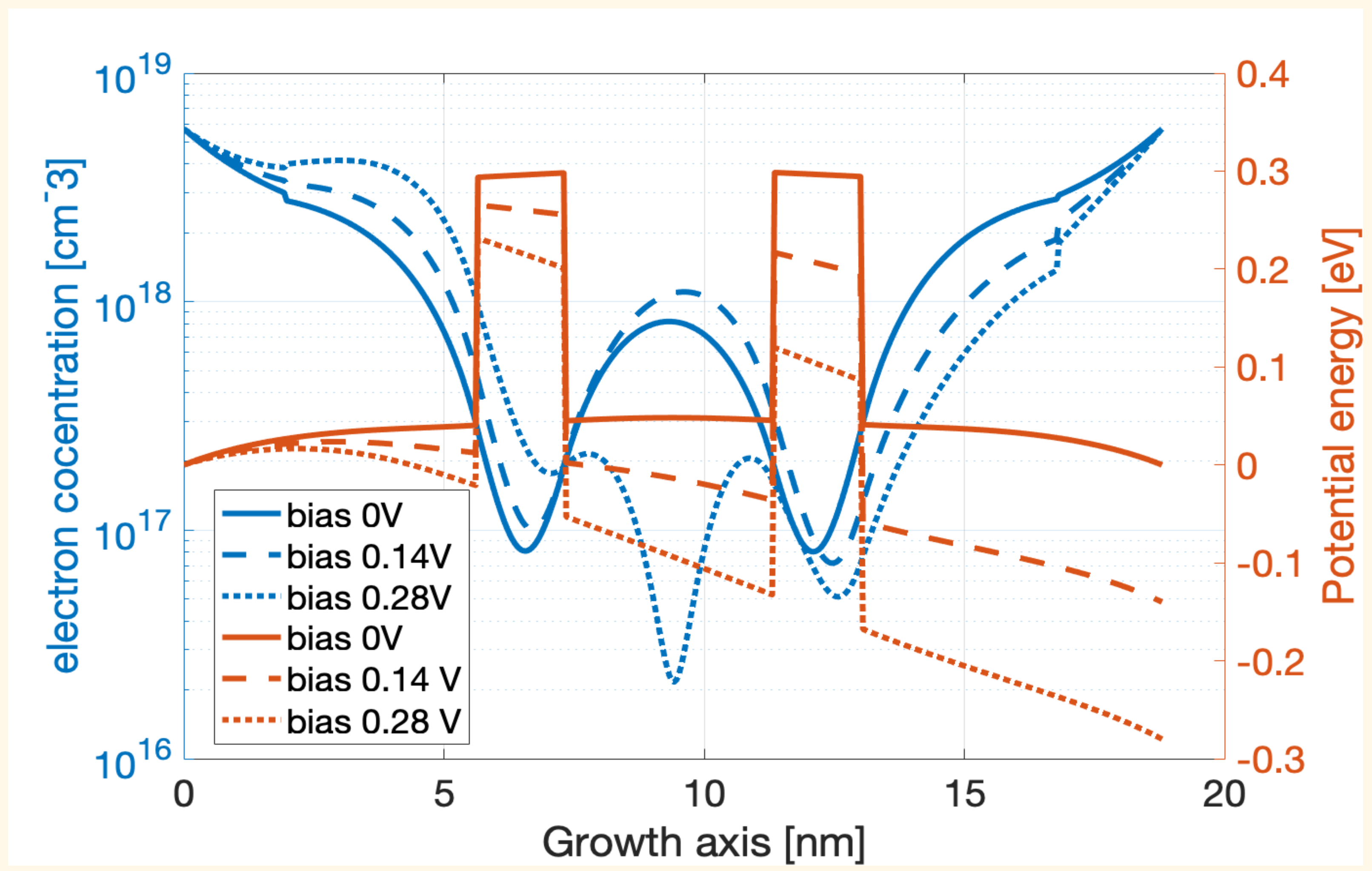

Figure 2. Self-consistent potential and corresponding electron concentration for three different biasing conditions. Emitter and collector layers (underlined) doping is used to be $1\times10^{18}cm^{-3}$

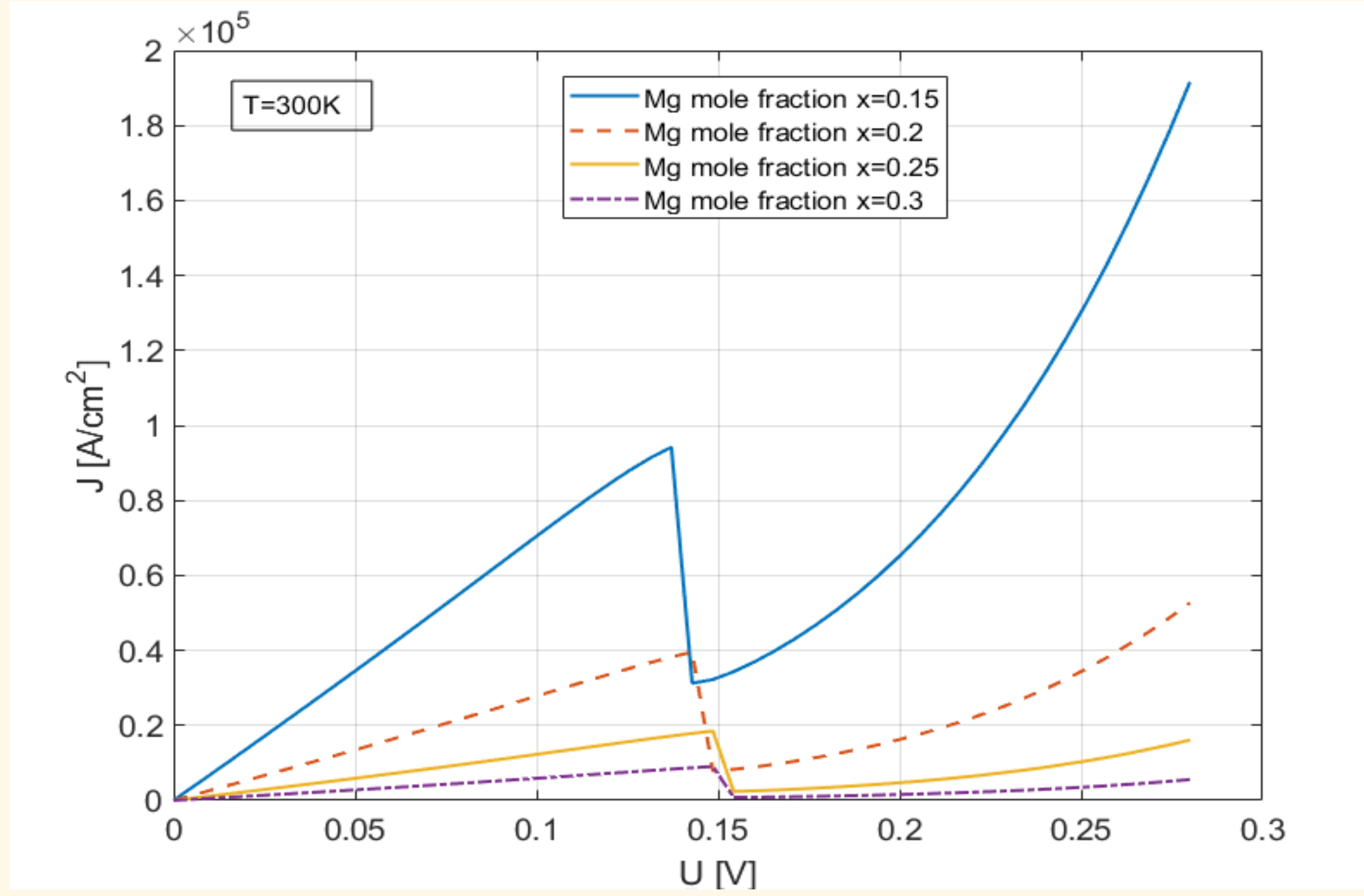

Figure 3. Current density-voltage characteristics of ZnO/MgxZn1-xO resonant tunneling diodes, where x is content of Mg in ZnO/$Mg_xZn_{1-x}O$ Nominal layer thickness in nanometres are 5.7/**2.0**/4.0/**2.0**/5.7 (same as in Figure 2).

Conclusion

- A simulation of coherent electron transport in non-polar m-plane ZnO/MgZnO double-barrier resonant tunneling diode by solving Schrödinger-Poisson equations self-consistently.
- A region with pronounced negative differential resistance in current density-voltage characteristics of such devices,
- peak-to-value ratio is highly sensitive on barrier thickness and Mg composition fluctuation.

References

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