Increasing the bit density from quantum-confinement physically unclonable functions

H. Shokeir[a], R. Bernardo-Gavito[a], M. R. Osorio[b], D. Granados[b] and R. J. Young[a]
[a]Physics Department, Lancaster University, Lancaster, LA1 4YB, UK. Tel: 01524 65201
[b]IMDEA Nanociencia. Faraday, 9, 28049, Madrid, Spain. Tel: 9129987 00
E-mail: h.shokeir@lancaster.ac.uk

Lancaster University

early stage researchers workshop in nanoscience

INTRODUCTION

Resonant tunneling diodes (RTD) are heterostructures that visualize quantum tunneling. Such devices exhibit a characteristic negative differential resistance (NDR) as the structure allows electrons to tunnel through some resonant states at certain energy levels Fig 1.

They are comprised of a AlAs/InGaAs/AlAs quantum well structure. RTDs have had a wide variety of applications such as THz oscillators and photodetectors.

Recently it has been shown that RTDs can be used in unique identification as a physically unclonable function [1] and in random number generation. We utilize the unique resonant peak position of the IV characteristic and implement such as a quantum-confinement physically unclonable function (QCPUF).

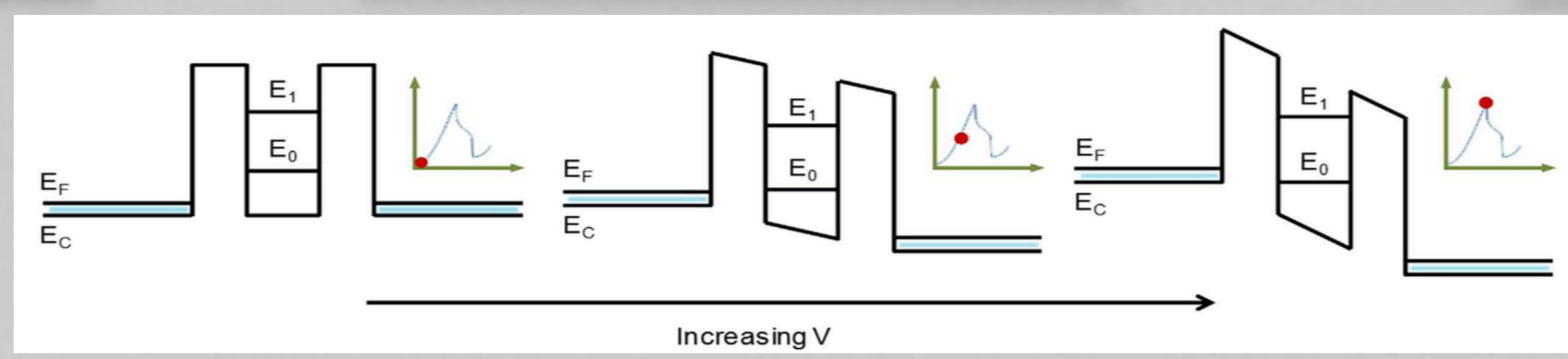

Fig 1. Quantum well structure of RTD under a positive bias showing the resonance mechanism, E_f –Fermi energy, E_c –Conduction band, E_0, E_1 –Confined states within well. Inset shows IV characteristic. [1]

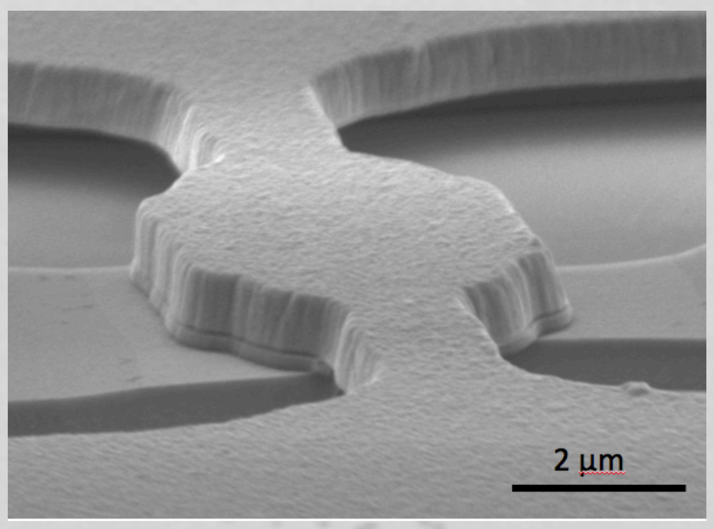

Fig 2. SEM image of 3x3 µm RTD, two port device.

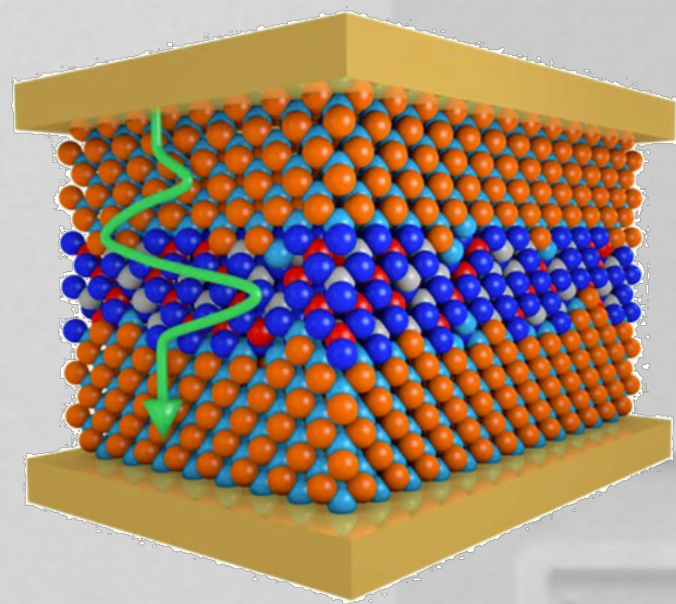

Fig 3. Schematic highlighting the tunneling mechanism between different layers of materials.

METHODS

In this work we aim to increase the complexity of the QCPUF by introducing further minutia. This will increase the bit density per unit volume of the QCPUF which would be seen as multiple resonance peaks.

A focused ion beam (FIB) which uses a gallium ion source can be used effectively to etch semiconductor nanostructures due to their relatively high resolution (~ 5nm). We aimed at increasing the areas of confinement within the heterostructure by etching large areas of the device.

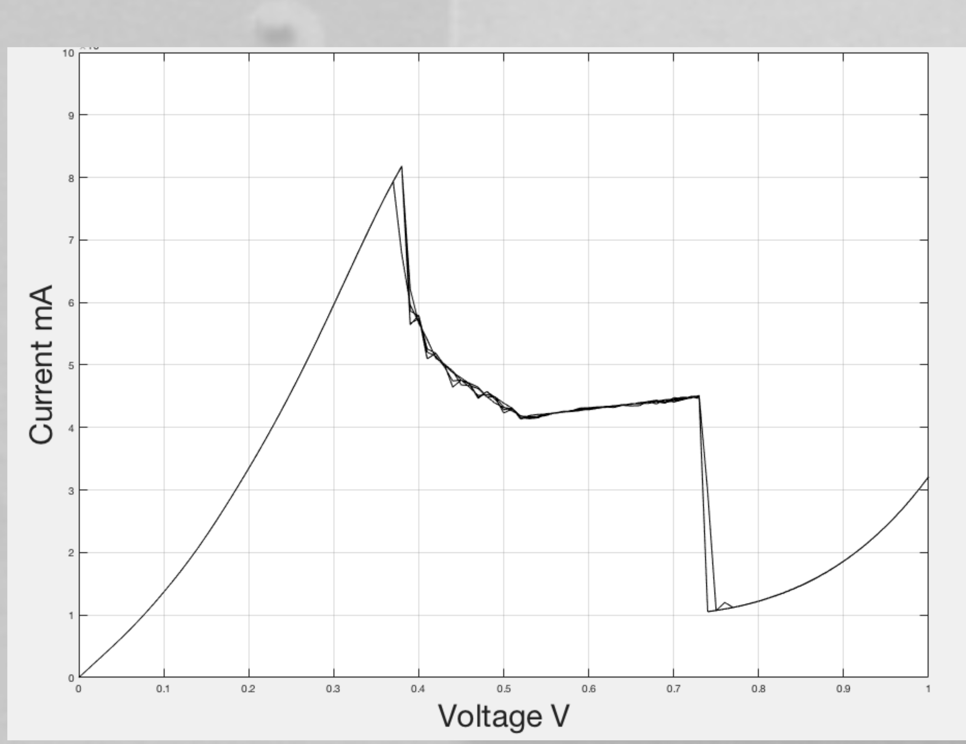

Fig 4 IV characteristic of a RTD, showing its resonance peak,

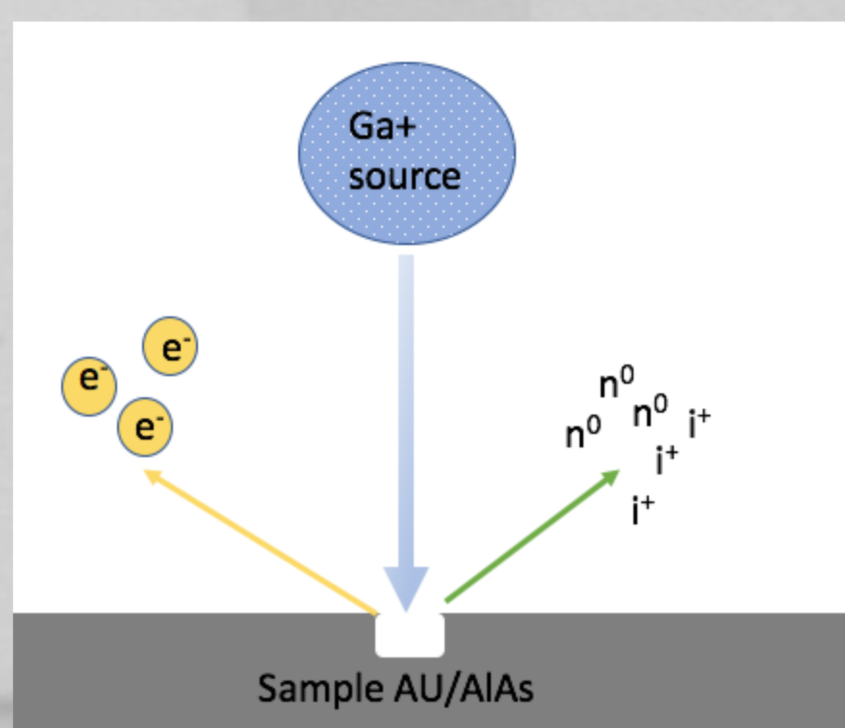

Fig 5. Schematic of FIB etching process, a Ga^+ source targeted at a Au/AlAs substrate.

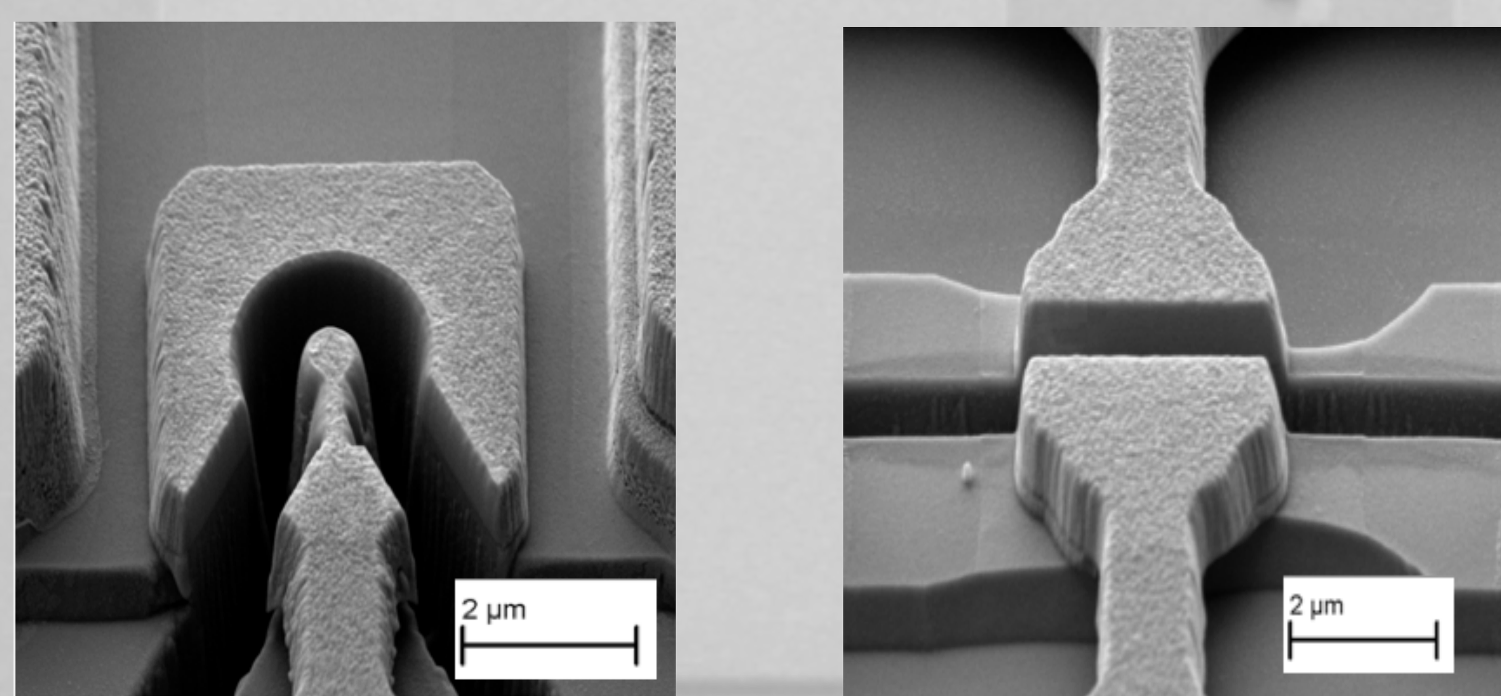

Fig 6. SEM images of RTD that have been etched with a FIB to introduce more quantum condiment dot-left, lateral-right.

RESULTS & CONCLUSION

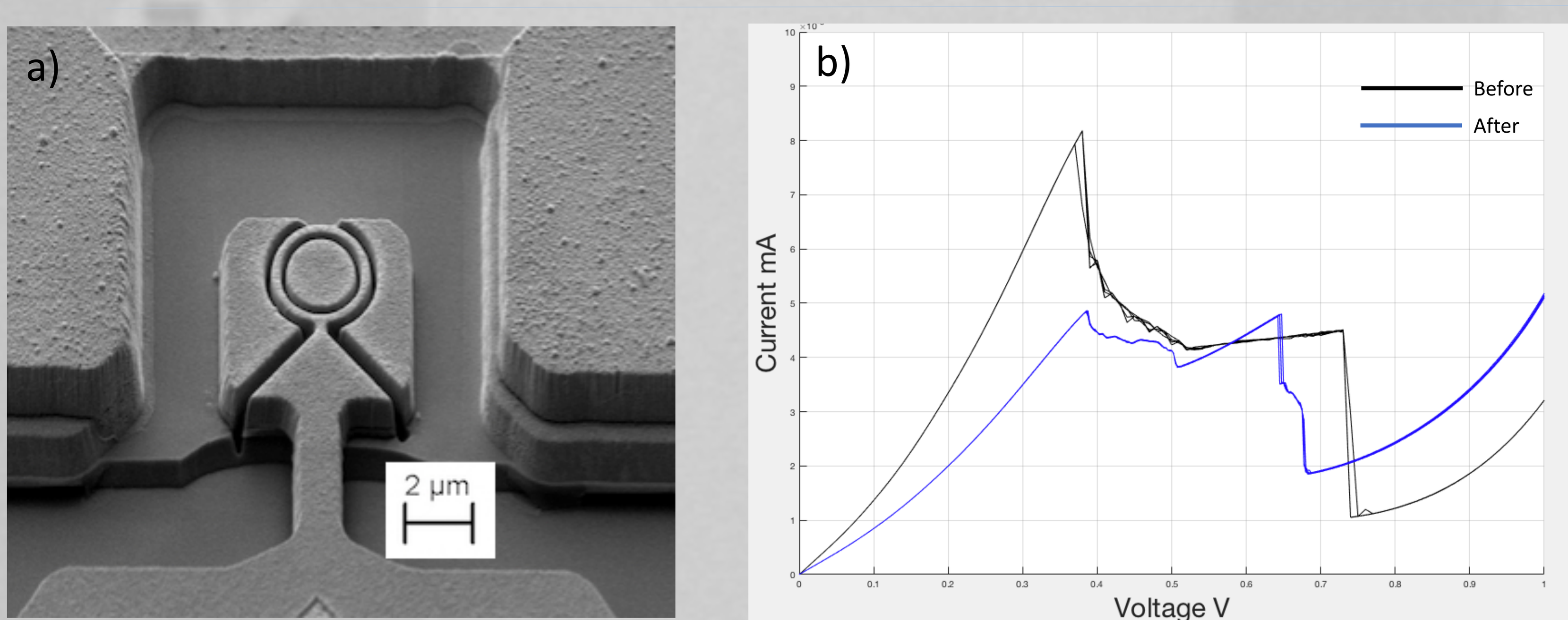

Fig 7 (a). SEM of etched device (b) IV characteristic of RTD prior to FIB (black) and after FIB showing multiple resonance peaks.

We successfully managed to obtain a more complex IV characteristic from a single device. This took the form of a double peak on the IV spectrum of the device and hence increasing its overall bit density per unit volume.

Further tests to study the nature of the double resonance peak is required. We wish to explore other etch designs and parameters to replicate the double peak. Furthermore the variation of the FIB parameters and studying their implications on the RTD is required.

References [1] Roberts et al. Sci. Rep. (2015)