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ZnO-based Resonant Tunneling Diodes for Quantum Cascade Structures

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1. Introduction

The terahertz (THz) spectral region lying in the wavelength range between 30µm – 300µm covers various relevant and interesting real-world applications like spectral imaging [1], medical diagnostics [2], trace gas spectroscopy, security screening or optical free-space communications. Unfortunately, due to the lack of high-performance solid state laser sources, it is also often referred to as the "THz-gap" in the electromagnetic spectrum. Therefore, a crucial step to close this gap is the realization of THz-emitting lasers at room temperature. Currently GaAs-based quantum cascade lasers (QCLs) [3] are the most promising devices but they lack significant improvements within recent years concerning their maximum operating temperature (~200K). They are basically limited by the parasitic, non-optical LO-phonon transitions (36meV in GaAs), being on the same order as the thermal energy at room temperature (kT = 26meV). Promising candidates to solve this problem include new material systems like e.g. ZnO with its larger LO-phonon energy (E_{LO} = 72meV).
To master the fabrication of ZnO-based QC structures, a high quality epitaxial growth is crucial combined with a well-controlled fabrication process including (selective) Zn(Mg)O etching, and the deposition of low resistance ohmic contacts.

2. Results

Our devices are grown on m-plane [10-10] ZnO-substrate by molecular beam epitaxy (MBE) and patterned by dry etching in a CH_4-based chemistry into square MESAs (see Fig. 1). The CH_4-process protects the mask by an amorphous carbon-layer increasing the selectivity of the etching [3].
Resonant tunneling diode structures are investigated in this geometry and are presented including different barrier- and well-configurations. We extract contact resistances of ~4-7e-6 Ω cm² and ~1-3e-6 Ω cm² for the top and bottom contact, respectively, for un-annealed Ti/Au contacts and an electron mobility of above 130cm²/Vs, all in good agreement with the highest published literature values.
Demonstrating resonant electron tunneling in Zn(Mg)O structures is one of the crucial building blocks for a future QCL (see Fig. 2).

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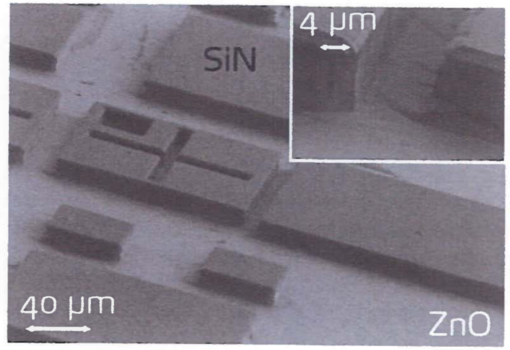

Fig. 1: Typical ZnO-based MESA RTD structures after ICP-RIE dry and additional H_3PO_4 wet etching. The inset shows the vertical and smooth sidewalls.

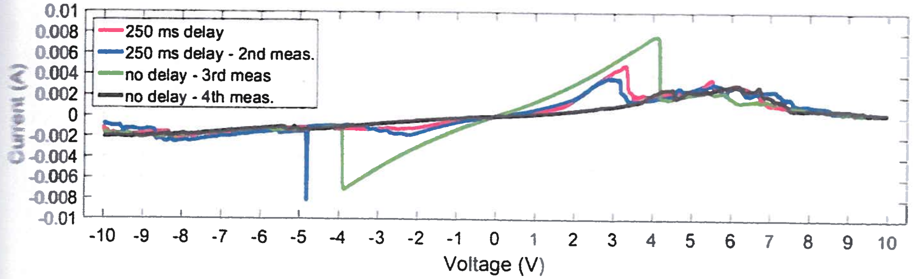

Fig. 2: Comparison of exemplary IV-curves of a 75 µm MESA RTD structure at room temperature with (250 ms) and without additional delay for each measurement point (resolution: 0.01 V).