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Si-based n-type THz Quantum Cascade Emitter

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***Abstract*—Employing electronic transitions in the conduction band of semiconductor heterostructures paves a way to integrate a light source into silicon-based technology. To date all electroluminescence demonstrations of Si-based heterostructures have been p-type using hole-hole transitions. In the pathway of realizing an n-type Ge/SiGe terahertz quantum cascade laser, we present electroluminescence measurements of quantum cascade structures with top diffraction gratings. The devices for surface emission have been fabricated out of a 4-well quantum cascade laser design with 30 periods. An optical signal was observed with a maximum between 8-9 meV and full width at half maximum of roughly 4 meV.**

I. INTRODUCTION

THE indirect bandgap of group IV materials hinders the realization of Si-based semiconductor lasers relying on electron-hole transitions. Using unipolar transitions, the quantum cascade laser (QCL), so far only realized in III-V materials, represents a promising candidate to build integrated Si-based lasers. Terahertz (THz) electroluminescence due to hole-hole transitions has been observed in p-type Si-based quantum cascade devices [1]. Valavanis et al. predict that n-type SiGe-based heterostructures exploiting L-valley transitions is the best material configuration for achieving a THz laser [2]. Experimentally, narrow intersubband transitions and electron tunneling have been observed in n-type strain compensated Ge/SiGe multi-quantum well structures [3,4].

The operation temperature of current III-V THz QCLs is limited due to very efficient electron-phonon interaction. Recently, non-equilibriums Green's function (NEGF) calculations proved to be efficient in optimizing high temperature performance of GaAs/AlGaAs THz QCLs [5]. Exploiting different materials is an alternative strategy to overcome the temperature limitation of THz QCLs. The non-polar Ge/SiGe platform is attractive due to their weak electron-phonon interaction and NEGF calculations predict room-temperature [6].

II. RESULTS

We report the characterization of a Ge/SiGe QCL structure by Fourier transform infrared spectroscopy (FTIR). The QCL structure was designed with NEGF (see Fig1(a)) [6] and grown epitaxially by means of UHV-CVD. The 1.6 µm thick active region (AR) with 30 periods was fabricated to mesa devices with top diffraction gratings to measure the surface emission (see inset of Fig. 1(c)). The observed spectra at

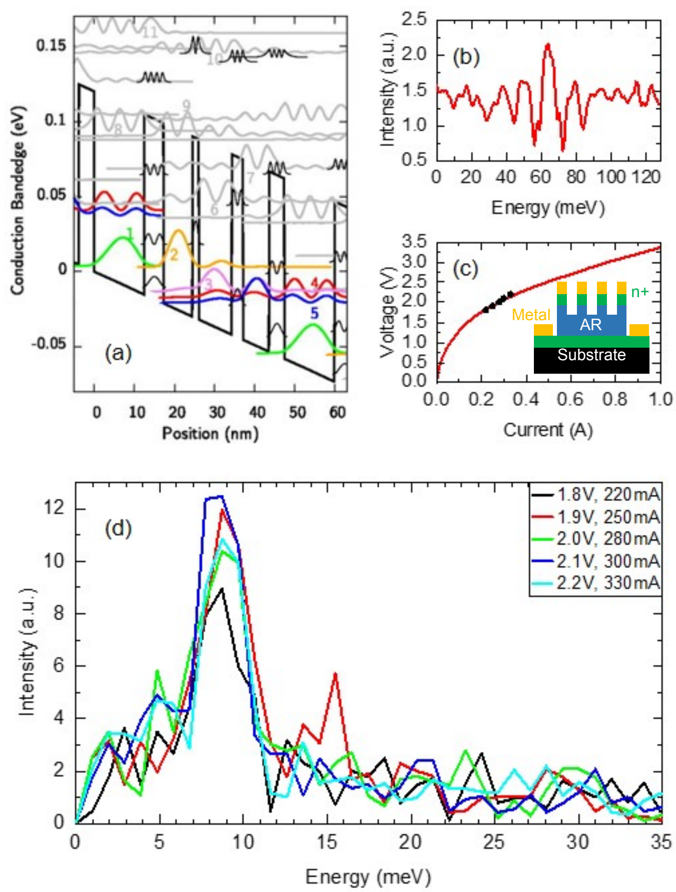

Fig. 1. (a) Simulated bandstructure of the 4-quantum well Ge/SiGe QCL design [6]. (b) Interferogram corresponding to 330 mA. (c) Pulsed V-I curve and the measured bias points (indicated with black dots). Inset: Cross section of the mesa device with top diffraction grating. To enhance the extraction efficiency the grating gaps have been dry-etched 300nm into the active region. (d) FTIR spectra measured at 9 K. To avoid heating effects a micro-macro voltage pulse scheme with 415 Hz repetition frequency, 1.92 µs period and 90% duty-cycle is applied. Each spectrum is the average of one hour acquisition.

different bias points are shown in Fig. 1(d). The spectra show well-defined peaks with FWHM of roughly 4 meV and maxima between 8-9 meV. The measured interferograms are similar to the one in Fig. 1(b). The V-I characteristics and the measured bias points are shown in Fig. 1 (c). In another measurement shown in Fig. 2 the spectra around 300mA could be reproduced. For the negative bias point with the same electrical input power we observe a shifted peak. The relatively narrow spectral peaks could indicate electroluminescence and that the optical signal is originating from intersubband transitions.

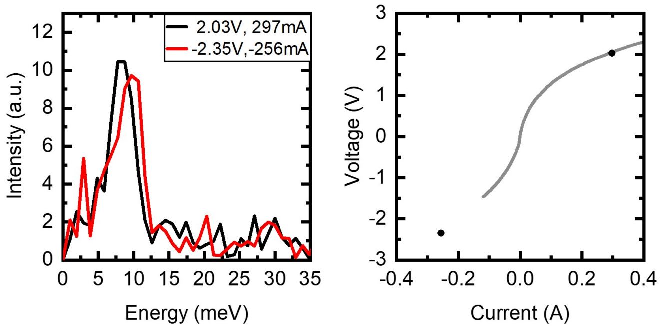

Fig. 2. (a) Inteferogram for negative and positive points with the same electrical input power of 0.6W. (b) Pulsed V-I curve with negative branch and the measured bias points (indicated with black dots).

These results are promising for future experimental work with the proposed QCL structure and a step towards Si-based lasers.

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