Title: THz silicon photonics - an intersubband emitter

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Keywords: terahertz, silicon-germanium, quantum cascade emitter, CMOS

250-words technical abstract

An electrically pumped Si-based laser is a long standing wish of microelectronics and photonics technology. The main problem for realizing such a laser is the indirect bandgap of group IV materials. Using unipolar transitions, the quantum cascade laser (QCL), so far only realized in III-V materials, represents an elegant way to circumvent this issue. Terahertz (THz) electroluminescence due to hole-hole transitions has been observed in p-type Si/SiGe quantum cascade devices.

We recently proposed an n-type Ge/SiGe four quantum well design where non-equilibrium Green's functions (NEGF) based calculation predict gain up to room temperature. The proposed system employs L-valley electrons with an effective mass along the growth direction of 0.135. The non-polar material system presents an interesting candidate for realizing an integrated THz QCL, because mainly the thermally activated LO phonon emission hinders room temperature operation.

Along the path of realizing a THz QCL on a Si-based material system, we demonstrate THz electroluminescence. For this purpose we designed a Single Quantum Well (SQW) active region aiming for a low current density, low voltage drop per period and narrow spectral peak. The SQW Ge/SiGe QCL structures are characterized by Fourier transform infrared spectroscopy (FTIR). The active region was grown epitaxially by means of ultra-high vacuum chemical vapor deposition (UHV-CVD). The 4µm thick active region (AR) with 51 periods was fabricated to mesa devices with top diffraction gratings to measure the surface emission. The SiGe emitters were benchmarked against a similar III-V structure with identical device geometry.

100-words summary

A terahertz intersubband emitter based on silicon is presented. The emission originates from n-type Ge/SiGe quantum cascade structures. We designed a strain-compensated single quantum active region based on a vertical optical transition and tensile-strained $Si_{0.15}Ge_{0.85}$ barriers. The 51 quantum cascade periods (corresponding to 4.2 µm) were grown on a $Si_{1-x}Ge_x$ reverse graded virtual substrate on Ge/Si(001) substrates. Deeply etched diffraction gratings were processed and the surface emitting devices were characterized at 5 K with an Fourier transform infrared spectrometer. We observed two distinct peaks at 3.4 and 4.9 THz with a line broadening of 20%. This is an important step towards the realization of an Ge/SiGe THz quantum cascade laser.