Quantum Cascade Lasers (QCLs) are semiconductor devices that, currently, have been observed to emit radiation from \( \sim 2.6 \text{ um} \) to \( 250 \text{ um} \) (1 to 100 terahertz range of frequencies). They have established themselves as the laser of choice for spectroscopic gas sensing in the mid-wavelength infrared (3-8 um) and long-wavelength infrared (8-15 um) region. In the 4-12 um wavelength region, the highest performing QCL devices, in terms of wall-plug efficiency and continuous wave operation, are indium phosphide (InP) based. The ultimate goal is to incorporate this InP-based QCL technology to silicon (Si) substrate since most opto-electronics are Si-based. The main building blocks required for practical QCL-on-Si integrated platforms were demonstrated and will be covered in this presentation. The experimental results of a 40-stage indium phosphide based quantum cascade laser grown on a lattice-mismatched germanium-coated silicon substrate with metamorphic buffer (M-buffer) will be discussed. The QCL's strain-balanced active region was composed of Al\(_{0.78}\)In\(_{0.22}\)As/In\(_{0.73}\)Ga\(_{0.27}\)As and an 8 um-thick all-InP waveguide. Since the M-buffer was insulating, the wafer was processed into ridge-waveguide chips with lateral current injection scheme. Lasing was observed from 78K up to 170K for QCL-on-Si devices. Also in this presentation is the first room temperature operation of QCL grown on a lattice-mismatched gallium arsenide (GaAs) substrate with metamorphic buffer (M-buffer). Similar to QCL-on-Si, lateral injection scheme was utilized since M-buffer was insulating. Lasing was observed from 78K up to 303 K for QCL-on-GaAs. Material characterization of QCL-on-InP, QCL-on-GaAs, and QCL-on-Si using Transverse Electron Microscopy (TEM) will also be covered in this presentation. A very small section, 10 um x 10 um, of the QCL active region was used to give an estimate of the defect density for each of the QCL configuration. Lastly, characterization of the material quality of the remaining 6-inch wafer of QCL-on-Si using photoluminescence spectroscopy (PL) will be discussed. This method helped determined the best portion of the material for subsequent processing into ridge waveguide devices.

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Approved for distribution by Arkadiy Lyakh, Committee Chair, on June 19, 2020.

The public is welcome to attend.