Group-IV double hetero structure diodes for efficient telecom LEDs up to room temperature

Andreas Salomon, Johannes Aberl, Diego Haya-Enriquez, Enrique Prado-Navarrete, Moritz Brehm, Thomas Fromherz

Institute for Semiconductor and Solid State Physics, Johannes Kepler University (4040 Linz, Austria)

Corresponding author email: thomas.fromherz@jku.at

Up to now, the Si and Ge lattice mismatch limited the thickness of highly-crystalline SiGe layers of > 40% Ge content grown epitaxially on Si substrates to about 2 nm. At larger thickness, the SiGe layers release strain through plastic (dislocation formation) or elastic [quantum dot (QD) formation] relaxation processes. While such epitaxial Ge-rich QDs enhance light emission [1], Ge-rich two-dimensional layers would be preferred for scalable integration of the nanostructures.

Recently we have demonstrated that within an ultra-low temperature (ULT) window (100°C - 300°C), unrelaxed, two-dimensional SiGe layers with low point defect densities, approximately one order of magnitude thicker than possible up to now, can be grown in an MBE reactor [2]. Based on such a 16 nm thick $Si_{0.6}Ge_{0.4}$ layer sandwiched between Si bottom and top layers, we demonstrate the first pn double–heterostructure (DHS) light emitting diode realized in the group-IV material system. Intense electroluminescence emission is observed even for temperatures above room temperature. In the GaAlAs material system (exhibiting type-I band alignment), DHSs are routinely used for implementing high efficient LEDs. However, to the best of our knowledge, for optoelectronic applications the DHS concept was not yet applied to type-II band alignment DHSs, typically for the Si/SiGe/Si system. Based on Poisson-current simulations, we argue that despite the electron-repelling conduction band profile in the SiGe layer of our DHS, similar efficiency enhancing effects as in type-I DHSs are responsible for the enhanced electroluminescence efficiency observed for the Si/SiGe/Si DHS diodes of this work.

[1] P. Rauter, L. Spindlberger, F. Schäffler, T. Fromherz, J. Freund, M. Brehm, *ACS Photonics* 2018, 5, 431-438.

[2] A. Salomon, J. Aberl, L. Vukušić, M. Hauser, T. Fromherz, M. Brehm, *Phys. Status Solidi A* 2022, 219, 2200154.