Influence of doping on “exciton gas – electron-hole liquid” phase transition in SiGe quantum wells

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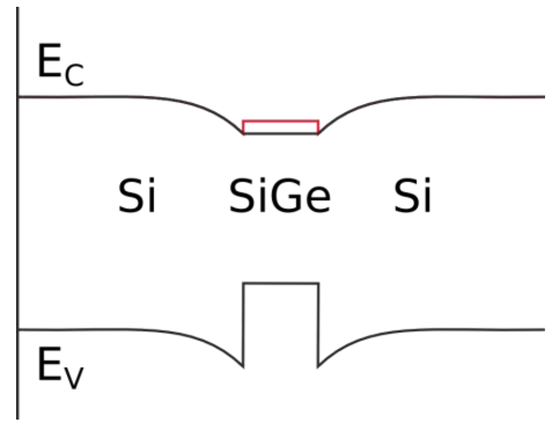
Motivation

- Phase transitions in 2D electron-hole systems with long lifetimes of carriers.
- The possibility of formation and unusual properties of two-component 2D Fermi liquid.
- The influence of doping of SiGe layer on the many-body effects mentioned above

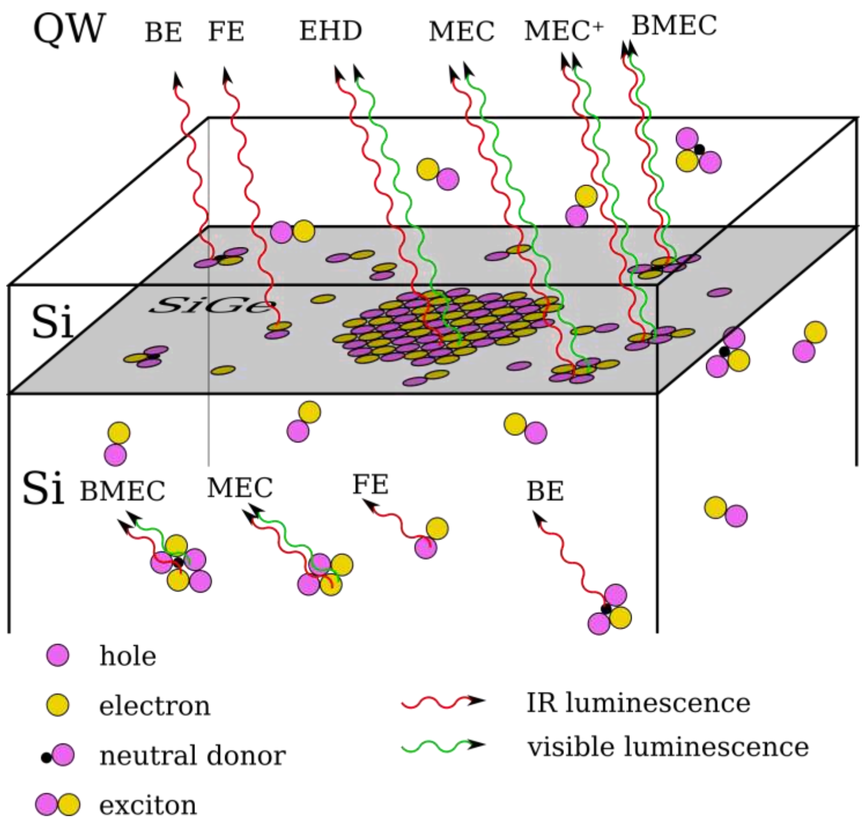
Samples

- Set of quantum wells (QW) $Si/Si_{1-x}Ge_x/Si$ with thickness of 5 nm and germanium content x= 2.9-13.6%.
- MBE grown at 700C, 100 nm buffer and cap layers
- Some samples were δ-doped by boron in the centre of SiGe layer
- The properties were controlled by high-resolution X-ray reflectometry

Band diagram

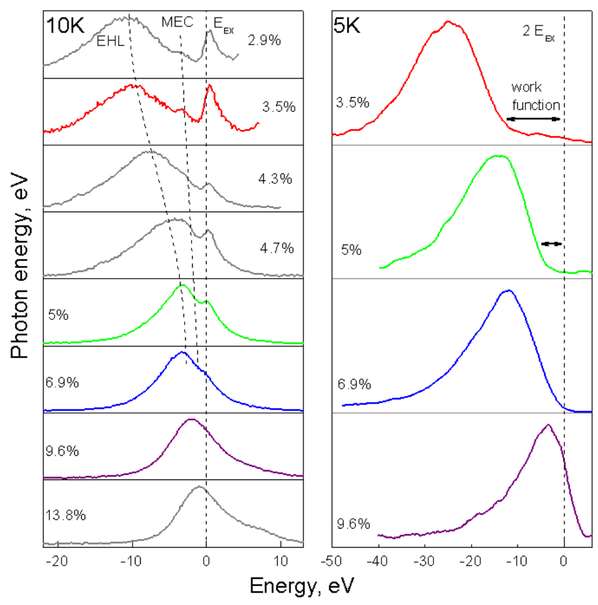


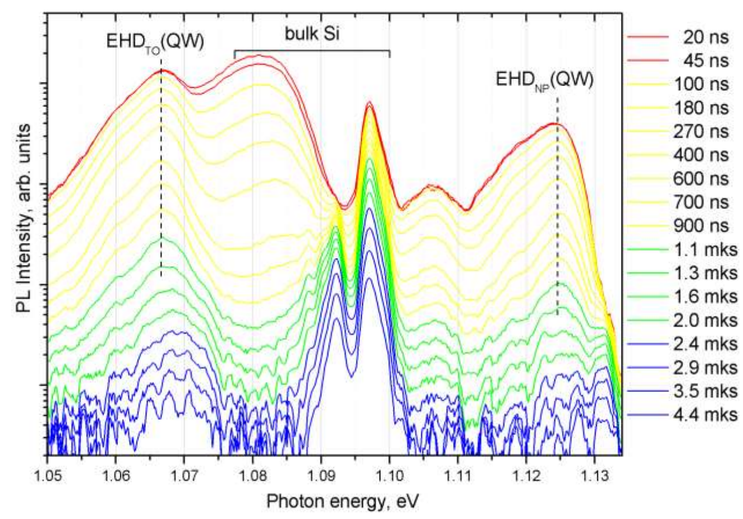
Notations



Evidence of EHD for various Ge content

Typical time-resolved IR photoluminescence (PL) spectra of undoped QW with x=4.5% at 5K. → EHD reveals itself via wide emission bands with fixed shape and position.

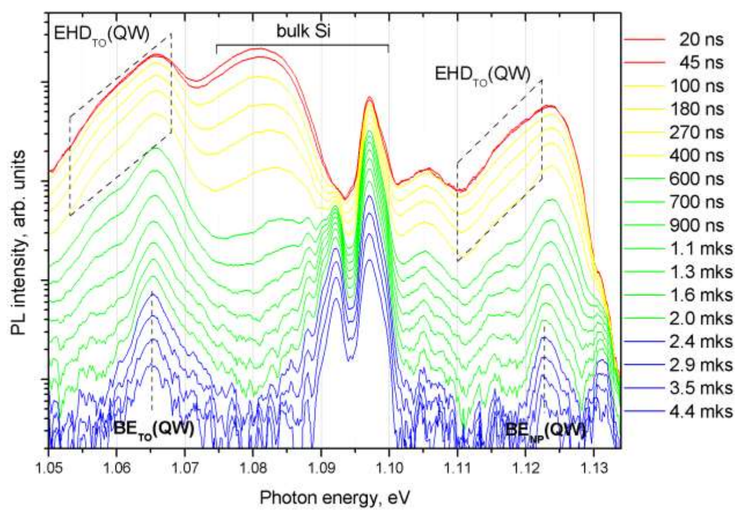


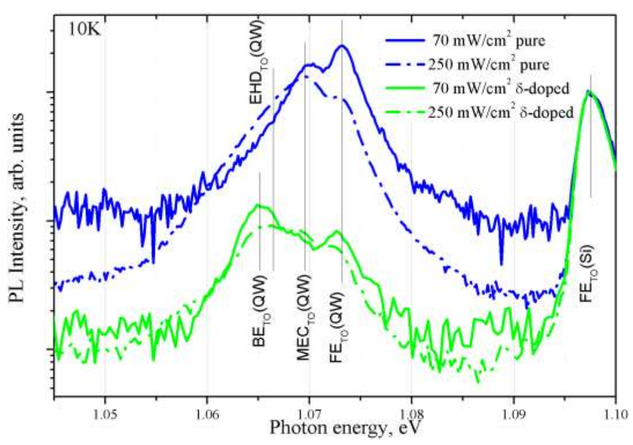


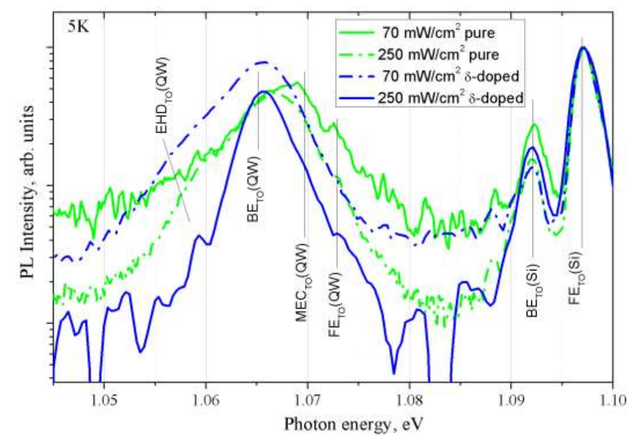
← (Left) Steady state IR PL spectra of QW’s with different Ge content at 10K. One can observe coexistence of EHD, MEC and FE in the QW’s with x<7%. (Right) Visible PL spectra at 2K demonstrating the reduction of EHD work function with icreasing Ge content. E_{EX} – excitonic band bottom.

Influence of δ-doping

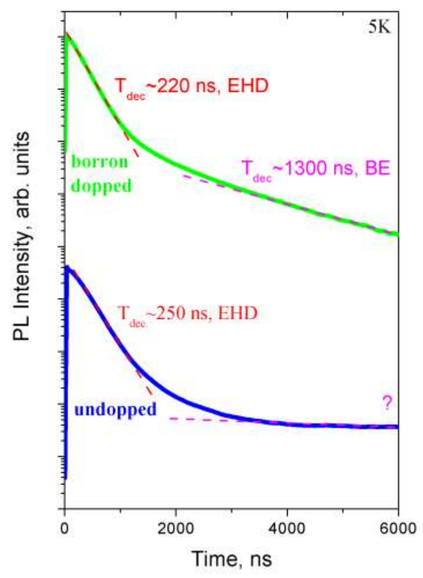
Time-resolved IR PL spectra of δ-doped QW with x=4.5% at 5K. → Boron concentration ~10^{10}cm^{-2}.
Emission of EHD and BE in the QW can be well resolved.







Appearance of BE emission and suppression of EHD emission for the boron doped QW with x=4.5%. Spectra recorded at steady-state excitation (excitation densities shown at the figures) . Temperature is equal to 10K for upper figure and 5K for bottom one.



← PL decays recorded for the doped and undoped QWs with x=4.5% at 5K. Spectral region corresponds to BE_{TO} and EHD_{TO} emission lines. For both samples EHD life-time can be determined. For the doped one BE decay time well resolved as well.

Conclusions

- Phase separation for quasi-2D “Plasma - excitonic gas” transition in SiGe/Si quantum wells with thickness of 5nm has been demonstrated.
- Quasi-2D condensed phase are stable in the quantum wells with germanium content lower than 7%.
- Boron δ- doping suppresses formation of electron hole droplets at low excitation densities and reduces its life time.
- Exciton bound at boron in the centre of SiGe QW has been revealed. For the quantum well with Ge content x=4.5% we found its binding energy of 6 meV and life time of ~1300 ns.