Direct and indirect-gap emission from $Ge_{1-x}Sn_x$ semiconductors

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Mixing germanium (Ge) and tin (Sn), both group-IV materials, is an attractive approach to create direct band-gap semiconductor on silicon platforms. The study of germanium-tin (GeSn) has long been limited but crystal growth challenges [1]. It is relatively recently that it has become possible to efficiently grow GeSn epitaxial layers, thanks to improvements in growth techniques [1, 2]. This enabled the experimental study of the predicted properties of GeSn. Among these, a customisable bandgap suitable for mid-infrared (from 1.8 to 5μm [1, 2, 3]) optoelectronics and quantum applications (LEDs/photodetectors and lasers for telecommunications [1] or transistors [3], quantum dots and wells [3, 4]). Most significantly, GeSn becomes an efficient direct-gap emitter when the Sn concentration exceeds a threshold estimated between 6 and 11% [1] and removes one of the most significant limitations associated to Si and Ge for large-scale optoelectronics integration [2]. The indirect/direct gap crossover concentration sensitively depends on the strain state of the GeSn epilayer and, up to now, most studies on GeSn have focused on samples with tin concentrations away from the crossover concentrations [1, 2, 5].

In this work, we report on the low-temperature spectroscopy of both indirect- and direct-gap GeSn semiconductors very close to the crossover concentration, allowing us to probe the dynamic of charge and spin carriers as function of the nature of the gap. The emission from samples with tin concentrations of 9% (indirect) and 10.5% (direct) was studied as a function of excitation intensity and temperature. In both samples, relatively narrow ($\approx$10 meV) and well-defined excitonic emission is observed. The indirect gap sample shows low recombination efficiency and a weak Moss-Burstein shift at high excitation, indicating the presence of a competing recombination channel. In contrast, the direct gap emission is dominated by excitonic recombination and exhibits a clear band filling effect at high excitations. Luminescence as function of temperature reveals the evolution of the gap and the transition to non-excitonic recombination processes. This comparative study of radiative processes on either side of the crossover concentration deepens our understanding of dynamics of photoexcited charge carriers in GeSn.

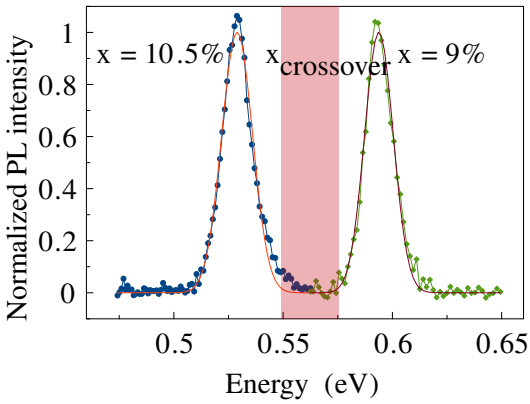

Fig. 1. Photoluminescence spectra of the direct (blue) and indirect (green) band gap samples on either side of the indirect to direct band gap crossover (red area)

References

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