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Electroluminescence of excitons in an InGaAs quantum well

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Abstract

We report on electrical injection of excitons in a quantum well placed in the intrinsic region of a p–i–n photodiode. Both the narrow linewidth of the electroluminescence at 70 K and the evolution of the emission spectra with increasing current are signatures of the excitonic character of the emission. This structure is ready to be integrated in semiconductor microcavities in order to evidence the strong coupling regime under electrical injection.

Keywords: Excitons; Electrical injection

Microcavity polaritons have attracted considerable interest in recent years because of their strong optical non-linearities [1] and because they represent a good solid-state system in which to achieve Bose–Einstein condensation [2]. Electrical injection of polariton is a desirable step toward the exploitation of polaritons in realistic devices. Very recently, a work by Tischler and co-workers [3] reported on strong coupling under electrical injection using organic semiconductors: the active material was a J aggregated dye and the optical cavity was defined by two silver mirrors.

No evidence of electrical injection of polaritons in an inorganic microcavity has been reported so far. The first step to achieving this result consists in electrically injecting excitons in an

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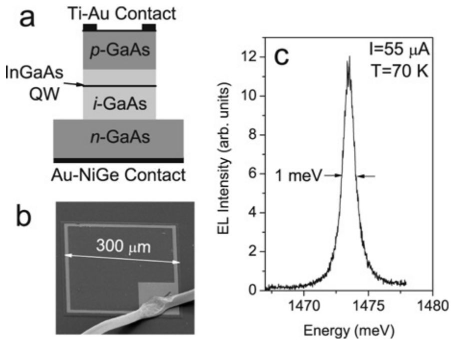

Fig. 1. (a) Schematic view of our sample structure. (b) Scanning electron microscope image of a mesa. (c) EL spectrum measured at $T = 70$ K for a current $I = 55$ μA.

inorganic based quantum well (QW). In this work, we are interested in a GaAs based device, since the growth of high quality microcavities is now well controlled.

Resonant tunneling diodes have been used in several works [4,5] to study electroluminescence from excitons. In these structures electrons and holes are resonantly injected in QW levels by selecting the applied bias. The band gap in the emitter and collector regions of a resonant tunneling diode is however necessarily at lower energy than the exciton. The absorption introduced by these regions therefore makes these samples unsuitable for integration in an optical cavity.

Non-resonant injection of excitons seems to be observed in spin polarized light emitting diodes [6–8]. In these samples the polarization of the exciton line is used to study the efficiency of the spin current injection. The linewidth of the exciton resonance varies in these works from ∼3 meV [7] to ∼10 meV [8]. The typical vacuum Rabi splitting in GaAs based microcavities is of ∼4–5 meV, and an exciton linewidth of less than 1 meV would be desirable in order to clearly evidence the strong coupling regime. Electroluminescence from non-resonantly injected excitons can also be seen in a figure of [9], a work on tunable lasers based on the quantum confined Stark effect.

In this paper, we perform electroluminescence in a single quantum well placed in the intrinsic region of a p–i–n photodiode. Considering both the linewidth of the spectra and their behavior when increasing current, we evidence signatures of the excitonic character of the emission.

A schematic view of our sample grown by molecular beam epitaxy is shown in Fig. 1(a). A 300 nm 2×10^{18} cm^{-3} Si-doped n-GaAs layer is covered by 117.5 nm of unintentionally doped GaAs. Then a 8 nm $In_{0.05}Ga_{0.95}As$ QW is grown, followed by 50 nm of unintentionally doped GaAs. The structure is then covered with 300 nm of 2×10^{18} cm^{-3} Be-doped p-GaAs and finally with 100 nm of 2×10^{19} cm^{-3} Be-doped p-GaAs. A Au–NiGe contact was deposited on the substrate. The sample was processed in square mesas with 300 μm side by optical lithography followed by chemical etching. Annular Ti–Au contacts, completed in the inside with 3 nm thick semitransparent gold layers, were defined on top of the mesas. A scanning electron microscope image of the sample is shown in Fig. 1(b).

The sample is operated in forward bias: as the flat band condition is approached, electrons (resp. holes) flow from the n-side (resp. p-side) into the QW and recombine. The applied bias is varied between 1.32 and 1.63 V: the electric field at the QW position always remains below 1 kV/cm, and the Stark effect can be neglected. Fig. 1(c) shows a typical EL spectrum taken under an injected current $I = 55$ μA, at a temperature $T = 70$ K. The spectrum is