Influence of substrate orientation on AlAs/GaAs Distributed Bragg Reflectors

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Data transmission through optical fibres demands a rapidly increasing transmission rate for the next years. One possible solution are the surface emitting devices, such as VCSEL (Vertical Cavity Surface Emitting Laser) or MCLED (Microcavity Light Emitting Diode), working at the wavelength of 1.3µm. These devices lead to many advantages as single mode beam profile and low divergence output, desirable for optical fibres coupling. Moreover the short cavity length provides low threshold current density. Further improvement of their performance is expected by using InGaAs quantum dots (QDs) as active medium. In this case, due to the low active material density, very high reflectivity facets are required , in order to lower vertical cavity losses. Such a purpose can be obtained by using the Distributed Bragg Reflectors (DBR), i.e. periodic multi−layers containing alternatively high and low refractive index quarter−wavelength layers. However, very high control of the technological process is required to fully benefit of the described advantages.
In this work, we compare the surface morphology and reflective behaviour of AlAs/GaAs DBRs grown by low pressure metal−organic−chemical−vapour−deposition (MOCVD) on exact and misoriented GaAs substrates. The mirrors are optimised in both reflectance stop band centred at 1.3 µm and surface morphology, suitable for the growth of InGaAs QDs, emitting at 1.3 µm.
The choice of our DBR sample thickness and periodicity result from a previous analysis through a software simulation (TFCalc3.5).The surface morphology has been studied by Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) has been used in order to evaluate the multilayer thickness and uniformity. Finally, the reflectance spectra have been detected by spectrophotometer measurements.
The mirrors consist of 10 period AlAs/GaAs DBR, for a design reflectivity of 94,7% centred at the wavelength of 1.3 µm, which corresponds to the optical emission of our QDs. The mirrors were grown in an AIXTRON 200 low pressure (20mbar) metal−organic vapour phase epitaxy (MOVPE) horizontal reactor, equipped with a rotating substrate holder. The employed precursors were Trimetilindium (TMIn), Trimetilgallium (TMGa) and Arsine (AsH3). Pd purified Hydrogen has been used as the carrier gas. The studied DBRs were grown on undoped exact (100) and 2°Off(100) GaAs substrates, at the growth temperature of 750°C.
The reflectivity spectra of the samples are shown in Fig.1. Both samples exhibit the expected stop band centred at around 1.3 µm, and the same line−shape and reflectance efficiency. The reflectivity of the sample grown on the exactly oriented substrate is centred at 1327 nm, in perfect agreement with the designed wavelength of 1320 nm. A slight red−shift of 50 nm occurs in the mis−oriented substrate.

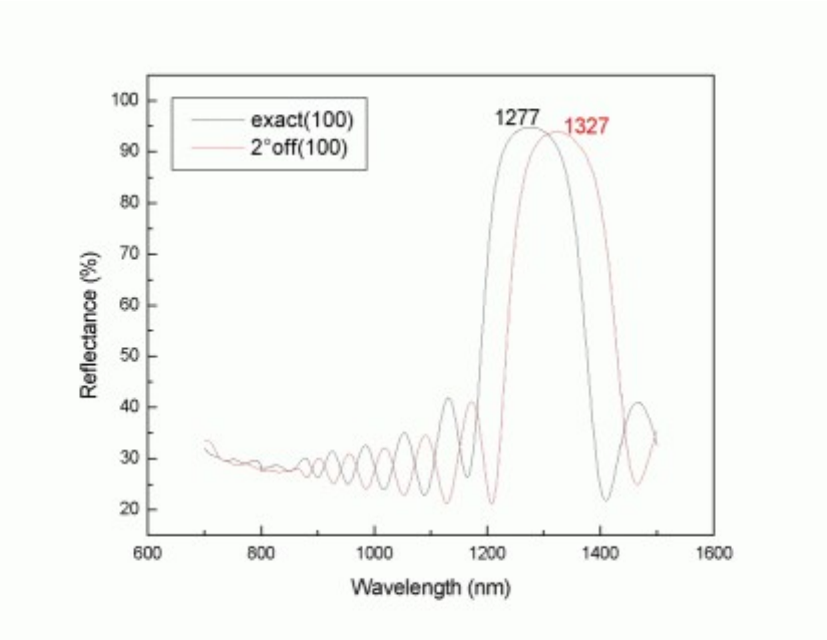

Fig.1

As shown by SEM images (Fig.2−3), the wavelength shift is due to a greater thickness of 11% for the layers grown on the exact substrate (Fig.2) with respect to those grown on the misoriented one (Fig.3). It means that a slightly lower growth rate has occurred on the mis−oriented substrate.Moreover high uniformity and sharp interfaces are shown on both the samples.

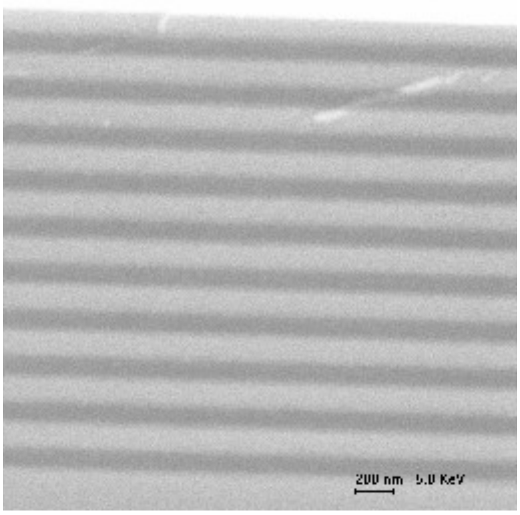

Fig.2

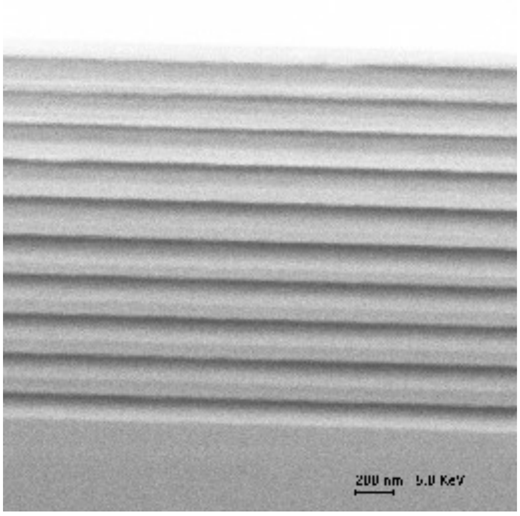

Fig.3

The knowledge of different surface morphologies as effect of the substrate orientation can be used to control the surface quality of our samples, especially concerning InGaAs QD growth. Controlling the terrace width and, consequently, the number of preferential nucleation sites, allows to regulate QD density and, thus, device performance. As shown in fig.4, we have been able to obtain InGaAs QDs on the DBR structure, with density (3×10^{10} dot/cm^2) and sizes (average height of 3nm and average radius of 10nm), suitable for vertical emitting devices operating at 1.3 µm.

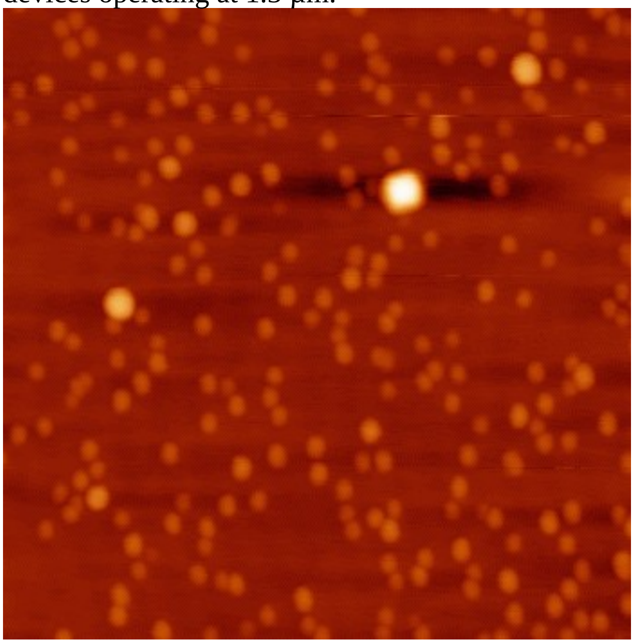

Fig.4