Mechanical stress investigations in semiconductor micro and nano-structures for photonic applications

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We have investigated different methods to measure, map and quantify crystal deformation occurring in semiconductor devices due to the mechanical stress produced by different processing steps. Mechanical stress/strain can significantly affect devices, either through modification of the electronic and optical properties of the semiconductor materials involved, or through degradation and reliability issues.

In this work, we discuss measurements on some simple test devices made using InP. These test devices consist in thin and narrow dielectric stripes at the surface (using SiNx as the dielectric material) or etched features with various widths and etch depths. In this 2nd case, plasma etching was done in an inductively coupled plasma reactor using chlorine-based chemistries.

In a first part, photo-luminescence (PL) and cathodo-luminescence (CL) were used. The test devices were measured from the top (100) surface and from cleaved (110) cross sections. For the PL part, we used a specific configuration that allows measuring the degree of polarization (DOP) of the spectrally integrated PL signal from bulk InP. It was shown that this DOP is a quantitative measure of the anisotropic part of the crystal deformation in the plane where the measurements are done. For the CL part, we acquired both images from the spectral shift of the InP-related spectrally resolved signal, and images from the DOP of the spectrally integrated signal. The spectral shift gives us information on the hydrostatic contribution to the deformation while the DOP, as in the DOP-PL measurements, yields information on the anisotropic deformation. The main difference with the DOP-PL is of course the spatial resolution. The devices were also analyzed using high resolution scanning transmission electron microscopy. Additionally, we did some simulation of the experimental strain profiles using analytical models for the simple cases where such models exist, or finite elements models.

The figures below illustrate some of our recent results on the test devices.

**Figure 1**
DOP-PL profiles measured from the (100) surface with SiNx narrow stripes deposited on InP: a stripe width 10 µm; b stripe width 20 µm
CL spectral shift profiles on the same surface: c stripe width 10 µm; d stripe width 20 µm
Red: experimental curves / Black: analytical edge force model.

**Figure 2**
DOP-PL experimental map below a 10 µm wide SiNx stripe. The measurement was done on a cleaved (110) cross section in InP.

**Figure 3**
CL spectral shift experimental map below a 6 µm wide SiNx stripe. Measurement on a cleaved (110) cross section in InP.