"Quantitative High Resolution Electron Microscopy of III-V semiconductor nanostructures "

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The introduction of aberration correctors in Scanning Transmission Electron Microscopy (STEM) has represented a great advance in the field of microscopy and materials science, allowing nanostructures to be analyzed with sub-Angstrom spatial resolution [1]. We present here a methodology developed in our group to extract quantitative compositional information with atomic-column resolution from high resolution High Annular Angular Dark Field (HAADF) images [2]. This analysis contributes to the characterization of the shape, size and composition distribution of nanostructures. This is an important issue because functional properties of nanostructures depend on these characteristics.

The method is based on the local integration of intensities around atomic columns positions of aberration corrected HAADF-STEM images. These intensities are normalized with respect to an area of the sample of known composition; the resultant quotient between the intensity of each atomic column in a selected area, with respect to the intensity in the area of reference is called the normalized intensity ratio, and it is denoted as R. It has been demonstrated that R is almost independent of thickness and has a simple dependence on the material composition. Hence, the determination of the parameter R of each atomic column leads quite straightforwardly to quantify column-by-column the chemical composition. The method was originally developed for $InAs_xP_{1-x}$ alloys, but it has been extended to other ternary semiconductor alloys like $In_xGa_{1-x}As$ and $GaAs_xSb_{1-x}$ [3], and has been applied to a different number of materials and nanostructures [4, 5]. Fig. 1 shows a high-resolution HAADF-STEM image of an InAs/InP nanowire and the corresponding integrated intensity map around each atomic column. For this example, red colour corresponds to InAs-rich zones whereas the blue colour represents pure InP.

We have to notice that the direct application of this method allows quantifying composition in bulk or heteroepitaxial layers; on the other hand, composition of strained nanostructures can be estimated combining this method with image simulations from supercells representing the nanostructures [6]. Results obtained from this and other high resolution techniques, such as strain distribution determined from High Resolution Transmission Electron Microscopy (HRTEM) images in phase contrast mode [7], give valuable information to improve our understanding of nucleation of nanostructures. We review in this communication the application of these methods to a number of semiconductor nanostructures with telecommunication, photonic and photovoltaic applications.

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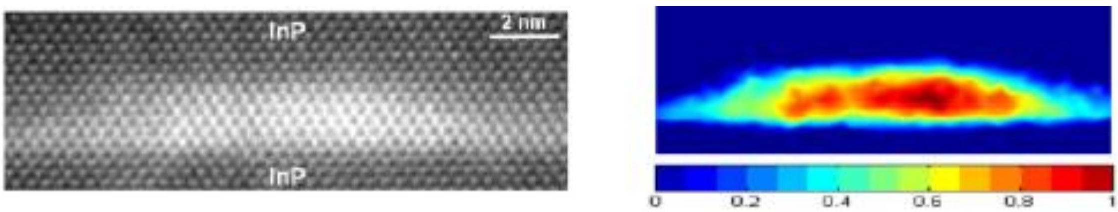

Figure 1. *High resolution HAADF-STEM image of an InAs/InP quantum wire and its corresponding normalized integration intensity maps (reproduced from [4] with the permission of the copyright owner).*

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