In-situ magnification inferred curvature measurement applied to dilute bismide growth

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ABSTRACT. Probing in real time thin film processes is an efficient way to unravel the impact of key parameters as this approach offers a direct insight on the involved mechanisms. MBE has benefited from a large number of in-situ techniques like RHEED, reflectivity, or optical thermometry. Despite the direct measurement of stress in the growing layers that they allow, curvature measurement tools based on laser deflectometry have not been widely adopted by the MBE community, due to intrinsic technological limitations. We have developed a novel curvature measurement technique, named Magnification Inferred Curvature (MIC), that overcomes these limitations. We will explain the principle of the measurement and illustrate its unique capabilities with a few selected examples, focusing on the $GaAs_{1-x}Bi_x$ alloy.

Keywords: in-situ, curvature, stress, dilute bismide

Curvature measurement tools based on laser deflectometry (kSA MOS, Laytec Epicurve) are mainly confined either to highly strained materials like GaN-based alloys inducing large enough curvatures to be detectable [1], or to dedicated studies where peculiar conditions, like the use of very thin high-quality wafers, are necessary to reach relevant sensitivities [2]. The Magnification Inferred Curvature (MIC) tool [3] we present here overcomes these issues. It is sensitive enough to monitor curvature changes even in quasi-matched systems like GaAs/AlGaAs, whatever the surface quality and reflectivity of the wafer. Thanks to its very high sensitivity and acquisition rate, it allows us to monitor continuously the curvature of rotating 2” and 4” standard wafers with 350 and 650 µm thicknesses respectively in our Riber MBE412 growth chamber.

We will explain the principle of the MIC, show its unique capabilities for low mismatch growth, and discuss how it can be of great help for controlling complex mismatched structures. Finally, we will emphasize on the help it has provided in the case of controlling the growth of $GaAs_{1-x}Bi_x$ dilute bismuth alloys which are promising for optoelectronics, photovoltaics or spintronics. MBE growth of these alloys is tricky, mainly due to the high lattice mismatch of about 12% between its two binary constituents. As a result, the Bi concentration highly depends on growth parameters. Different surface reconstructions have been reported during the growth of GaAsBi layers, but the relationship between the different growth regimes and the measured post-growth Bi content remained unclear [4][5] until the in situ RHEED and MIC characterization techniques were used simultaneously [6].

GaAsBi layers were grown on (001) GaAs wafers. A 12 kV RHEED and a dedicated homemade video acquisition system synchronized with the wafer rotation was used to follow the intensity of different reconstruction streaks and the in-plane lattice parameter of the growing surface in [011] and [0-11] directions, whereas MIC was continuously used to record wafer curvature and thereby strain and Bi-content in the growing structure. We will illustrate the benefit brought by the coupling of real-time techniques, acquired and treated thanks to a common dedicated homemade software**,** to understand the growth mechanisms of these peculiar III-V alloys.

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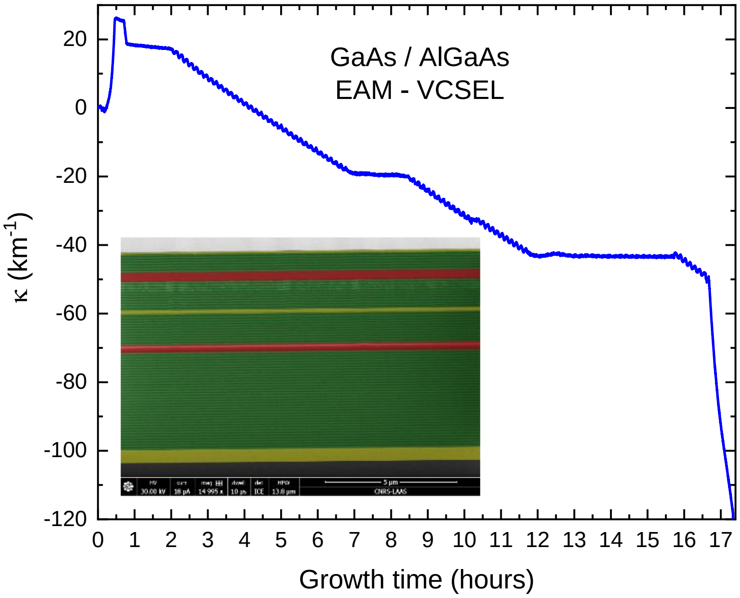

Figure 1: Curvature as a function of growth time, measured continuously during the complete growth of an EAM-VCSEL GaAs/AlGaAs structure on a 100mm, 650 µm thick rotating GaAs (001) wafer with the Magnification Inferred Curvature (MIC) technique. Insert: SEM colored image of a cleaved face of the grown structure.

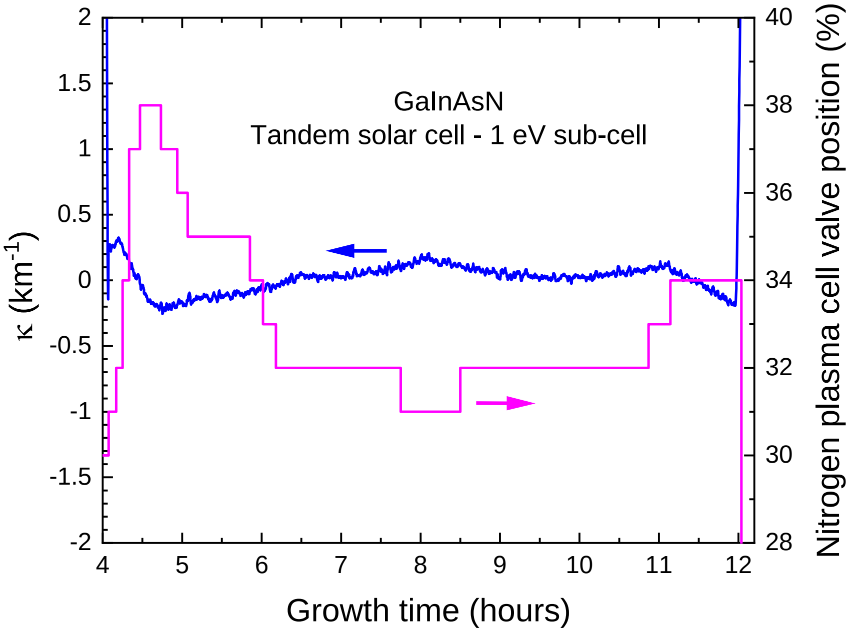

Figure 2: Curvature (blue, left) and nitrogen plasma cell valve position (pink, right) during the growth of a 3 µm thick 1 eV GaInAsN layer. The nitrogen plasma cell valve position was adjusted in live in order to keep a perfect lattice match to the 100 mm, 650 µm thick GaAs (001) wafer, thanks to the continuous curvature monitoring during the growth with MIC