Optimizing the sampling parameter in STEM Moiré interferometry for 2D strain field characterization

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Strain characterization at the nanometer scale has been a subject of great interest over the last few decades. A variety of techniques have been developed through diffraction-based methods, electron holography and high-resolution imaging [1]. Recently, due to the development of more stable microscopes, a new approach, based on Moiré interferometry in a scanning transmission electron microscope (STEM) has emerged [2]. A STEM Moiré hologram is recorded on an annular dark-field detector by bringing in interference the scanning grid of the beam raster with the periodic lattice of a crystalline material. Two dimensional strain characterization has been made possible by linking the STEM Moiré hologram to the crystalline structure using principles from sampling theory. The variation of the spatial frequencies in the STEM Moiré hologram are thus related to the variation of the crystalline wave vectors. From those variations, the relative deformation can be quantified locally using, for example, the geometric phase analysis (GPA) algorithm [3]. The spatial evolution of the Moiré features with the sampling parameter is not trivial but can be predicted using sampling principles in Fourier space. The flexibility in choosing the sampling parameter opens the possibility in finding an optimal condition for strain characterization.

In this study, a discussion is proposed to describe a first step in the optimization strategy by either changing the number of pixels used to record the STEM Moiré hologram or by adjusting the field of view. The sample proposed for the study is an epitaxial InP/$InAs_{0.35}P_{0.65}$ grown stack on an InP substrate (Fig. 1 a)). Dark-field electron holography (DFEH) is used as the reference strain characterization method for comparison purposes (Fig. 1 b), d) and e)). Experimental STEM Moiré GPA maps (such as shown in Fig. 1 c)) extracted from STEM Moiré holograms with various sampling conditions (such as shown in in Fig 1 a)) are proposed to be quantitatively compared to each other revealing the parameters to optimize regarding sensitivity and resolution. The reflections used for the GPA processing, their frequencies and their seperation with respect to the other reflections are the key parameters influencing the quality STEM Moiré GPA maps. By adjusting carefully those parameters, the STEM Moiré GPA method appears to be a competitive complement to DFEH technique.

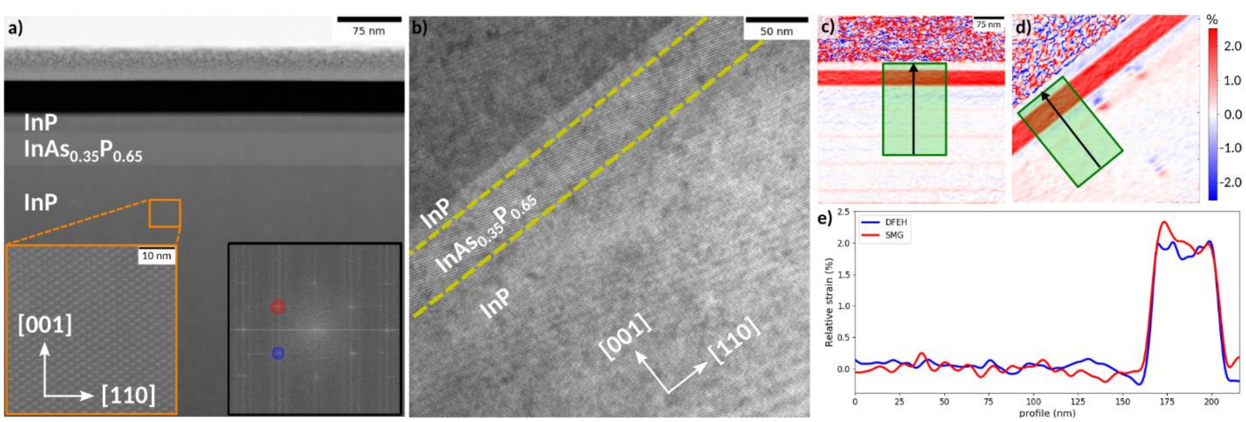

Figure 1: Strain characterization results on a InP/$InAs_{0.35}P_{0.65}$/InP sample. a) STEM Moiré hologram recorded using a pixel size of 0.466 nm. The bottom left inset corresponds to a digital zoom of the

orange rectangle area and the bottom right inset represents the Fourier transform of the STEM Moiré hologram. The reflections used for the STEM Moiré GPA (SMG) processing [4] are highlighted by the circles in the Fourier transform inset. b) Dark-field electron hologram from the [002] diffracted beam. c) SMG uniaxial strain map along the growth direction [001] using the STEM Moiré hologram a). d) DFEH uniaxial strain map along the growth direction [001] (calculated using the hologram b) and a dark-field electron hologram from the [110] diffracted beam not shown in the figure). e) Comparison of DFEH and SMG line profiles extracted from c) and d) maps along the black arrow and averaged over the green rectangle.

References

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[4] STEM Moiré GPA software available at https://github.com/slimpotatoes/STEM_Moire_GPA