STRAIN DETERMINATION BY DARK-FIELD ELECTRON HOLOGRAPHY

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Accurate determination of strain in electronic devices has been the subject of intense work during the last decades. Few techniques are able to provide highly localized and accurate information at the nanoscale. Among these, convergent-beam electron diffraction (CBED) combines the advantages of very small probes and remarkable sensitivity to small variations in the lattice parameter [1]. However, elastic relaxation effects make the analysis extremely difficult, necessitating time-consuming dynamical simulations combined with finite element modeling [2]. Rather than collecting data at isolated points, strain distributions can be mapped in a continuous fashion using high-resolution transmission electron microscopy (HRTEM) [3]. Unfortunately, HRTEM suffers from limitations due to specimen preparation, field of view and noise. These problems are minimised using a Cs-corrected microscope [4]. Whilst this technique is highly accurate at the nanometre scale, mapping strain in real devices like multilayers and transistors requires fields of view that are not easily accessible to HRTEM, even with a Cs-corrected microscope. We have therefore thought to develop a new technique for measuring strain at lower magnification, for thicker samples and larger fields of view without sacrificing precision. The new method is a combination of the moiré technique and off-axis electron holography, called dark-field holography [5]. The experiments are carried out on the SACTEM-Toulouse, a spherical aberration corrected microscope fitted with a field emission gun (Schottky FEG) and rotatable biprism. The pseudo-Lorentz mode [6], corresponding to a special setting of the Cs-corrector, is essential to reach the desired field of view. Holograms are analysed using a modified version of GPA Phase 2.0 (HREM Research Inc.) for DigitalMicrograph (Gatan). As an example, the method has been applied to Si/$Si_{0.6}Ge_{0.4}$ multilayers grown on a virtual substrate of $Si_{0.8}Ge_{0.2}$. TEM specimens were prepared by a combination of tripod polishing and PIPS, though FIB preparation is preferable. The results using the (004) dark-field configuration are reported on Figure 1. In this case, the holographic fringes allow a spatial resolution of 2 nm for a precision of 0.07% strain over a half of a micron field of view.

References:

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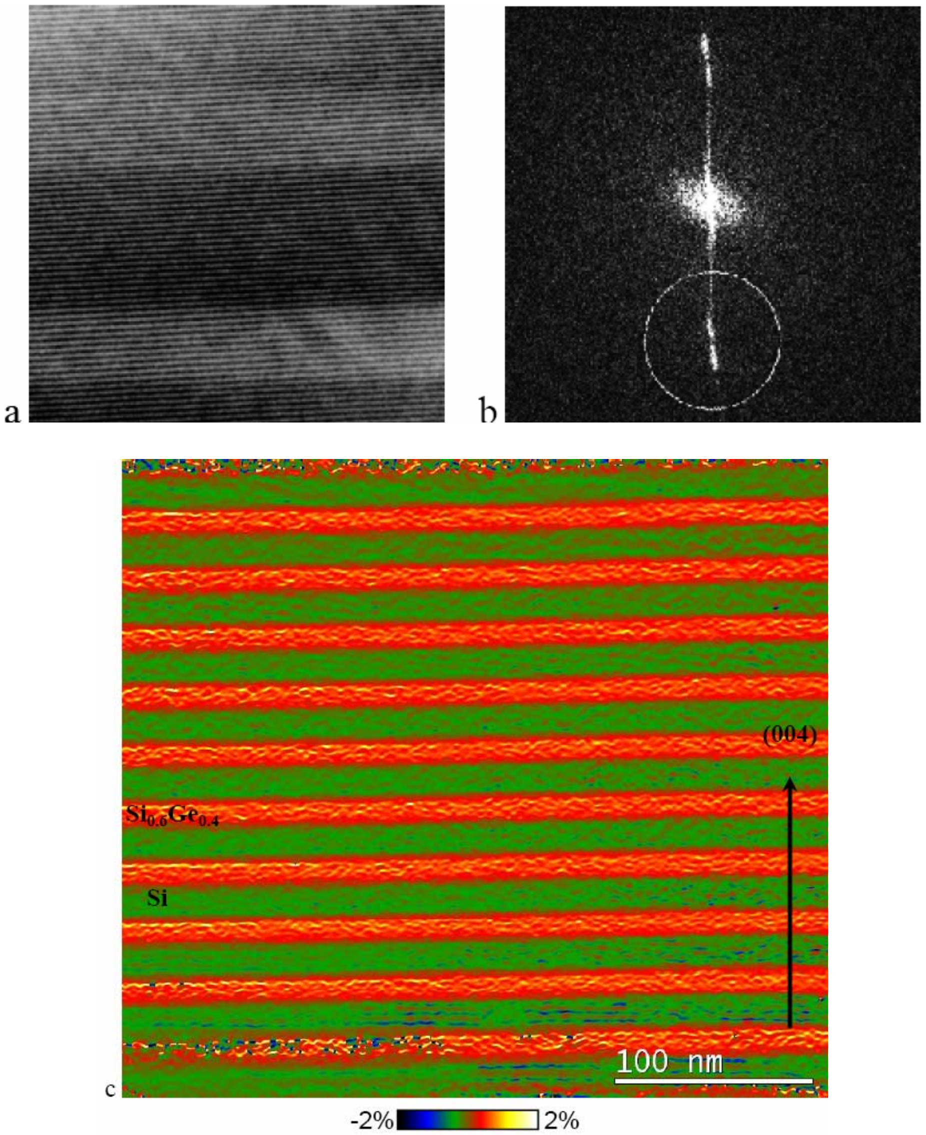

Figure 1. Dark-field holography of a $Si_{0.6}Ge_{0.4}$/Si multilayer using the (004) diffracted beam: (a) holographic detail showing two layers; (b) FFT of hologram; (c) deformation map relative to the substrate of $Si_{0.8}Ge_{0.2}$