Precession Diffraction Based Strain Mapping in STEM and SEM

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Measuring strain on a nanometer scale is relevant for a number of novel material systems: from intentionally strained semiconductor devices to enhance charge carrier mobilities to some topological insulator systems where the strain is needed to open up a bulk gap. Strain mapping using nano-beam precession electron diffraction has proven to be very powerful [1].

Here we show results of the topological insulator system HgTe/CdTe where the achieved high strain sensitivity ($3 \cdot 10^{-4}$) and spatial resolution (1.9 nm) are crucial for the investigation of the system [2]. Sharp strain gradients at the interfaces of the HgTe are vital for the topological properties to arise [3]. In Fig. 1 (a)-(b) HR-HAADF of the sample is depicted with a typical diffraction pattern in (c) and a comparison of a virtual dark-field to HR-HAADF in (d). From the HR-HAADF the real interface width can be determined due to the negligible beam size and thus the comparison can yield the real beam width including broadening of the diffraction mapping (1.9 nm). This information was used in combination with finite element simulations of strain relaxation to compare the experimental profile with the expected one assuming perfect interfaces (e). The difference between those yields the real strain gradient width at the interfaces and is compared to the extension of the surface wave function.

Strain mapping is also performed by transmission diffraction in an SEM as shown in Fig. 2. The thinned sample as depicted in the secondary electron image in (a) is $GaN/AlN/Al_2O_3$. A pattern from the diffraction mapping at 30kV in the SEM is shown in (b) and a virtual dark field image of the mapped region in (c). The maps of the lattice parameters in growth direction and perpendicular are given in (d) and (e) and reveal almost completely relaxed GaN and AlN layers. We will discuss the implementation of precession in the SEM by means of a piezo driven sample stage that is installed in the SEM.

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[2] B. Haas et al., Appl. Phys. Lett. **110**, 263102 (2017).

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Acknowledgements:

Benedikt Haas acknowledges funding from Deutsche Forschungsgemeinschaft (KO 2911/12-1). The authors thank Candice Thomas, Philippe Ballet and Anna Mogilatenko for samples and Nicolas Mollard for sample preparation as well as Nicolas Bernier for help with the finite element simulations.

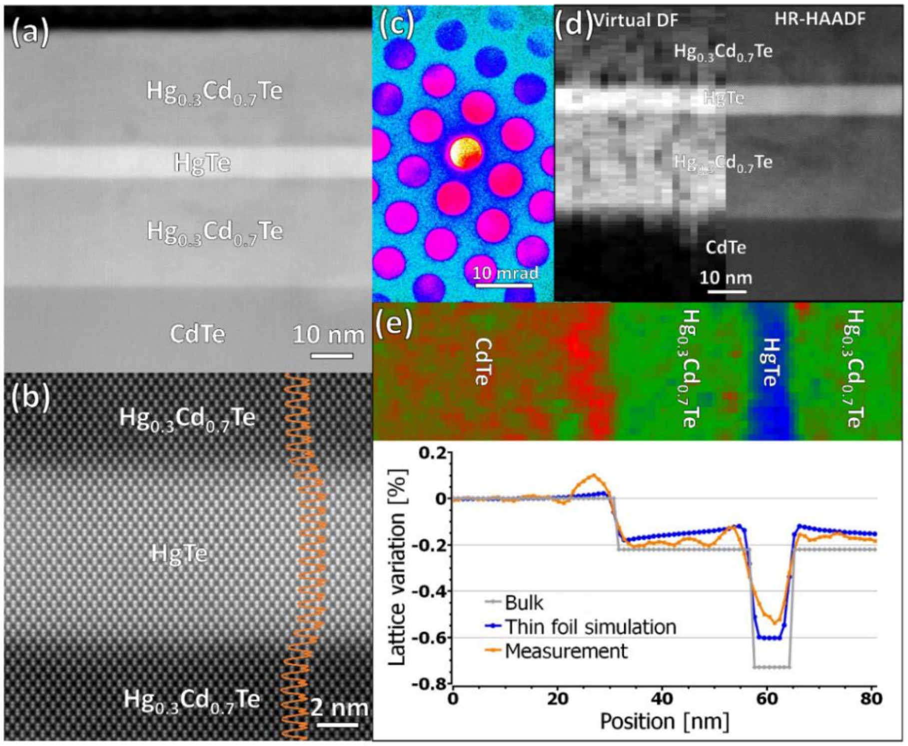

Figure 1: (a) HAADF image of the investigated topological insulator system. (b) HR-HAADF image of the interface regions. (c) Typical nano-beam precession diffraction pattern on logarithmic color scale. (d) Comparison of virtual dark-field and HR-HAADF image of the sample used to calculate the effective beam size of the diffraction mapping. (e) Map of lattice parameter variation along growth direction. Grey is for a perfect bulk sample, orange the experimental data and blue finite element simulation of the sample including the beam size but assuming perfect interfaces.

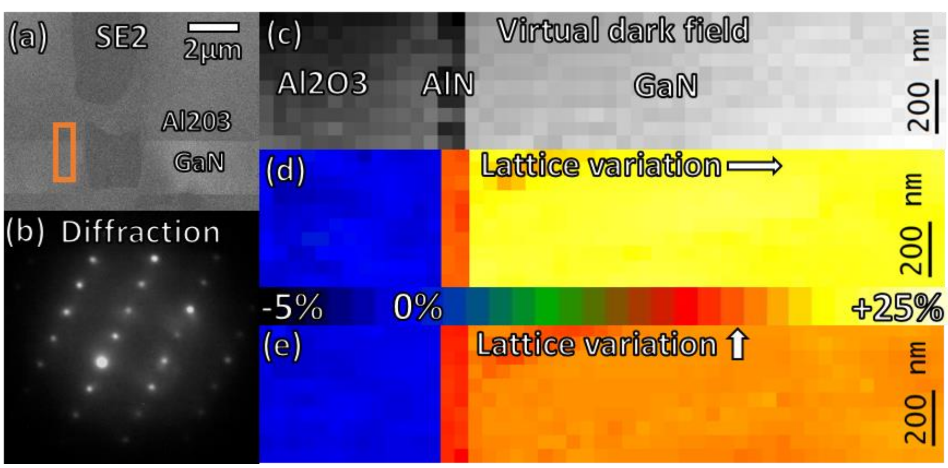

Figure 2: (a) Secondary electron image of a GaN/AlN/Al$_2$O$_3$ sample. (b) diffraction pattern of the sample at 30kV from the SEM. (c) virtual dark field image of a diffraction map from the SEM. (d) lattice variation map in growth direction and (e) perpendicular to it obtained from the SEM data showing almost completely relaxed AlN and GaN.