Semiconductor Nanowires (NWs) are known to exhibit crystal structures that can differ from the stable bulk crystal structure. In GaAs, which has Zinc-Blende (ZB) structure in the bulk, NWs can also crystallize in Wurtzite (WZ) crystal structure which – in contrast to ZB – can show spontaneous polarization (SP) due to the lower symmetry of the WZ crystal lattice. The SP occurs along the crystallographic (0001) axis which corresponds to one of the cubic {111} axes and arises as virtual “sheets” of alternatingly charged planes perpendicular to the (0001) axis. We will show a first direct evidence of the SP in WZ-GaAs together with a quantified measurement of its strength.

We use Differential Phase Contrast (DPC) microscopy in a FEI Tecnai F30 scanning TEM to detect the SP. As electrons pass the sample perpendicular to the (0001) axis they get deflected by the electric field generated by the charged planes which act like a series of capacitor plates. By using a position sensitive four quadrant detector we can measure this deflection and thus visualize the effect of the SP [1]. The system was calibrated to allow quantification of the electric fields that deflect the electron beam.

In fig. 1 we show measurements from the tip of a GaAs NW where the crystal structure changes from WZ to ZB. As expected the charge distribution (fig. 1(C)) differs significantly between ZB and WZ crystal structure where the latter reveals an oscillating behavior while the former is zero despite some noise. In addition it can be seen that also twin defects in the ZB where the stacking order reverses from ABC to CBA show significant charging (fig. 2).

As quantitative measurement of SP are not possible directly on the WZ structure we use an arrangement of two closely related twin defects which can be treated like a plate capacitor filled with a dielectric. By measuring the electric field difference between inside and outside this structure we can calculate SP to be 0.0027(6) C/m² which is in very good agreement with theoretical estimations [2].

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Fig. 1: Overview (A) and HRTEM (B) of the NW tip region. (C) Charge distribution map with superimposed line scan profile showing the difference in charge density between WZ (oscillating behavior) and ZB (only noise) structure.

Fig. 2: (A) Overview over two twin defects in the ZB region of a NW. (B) HRTEM of one twin boundary showing the stacking reversal. (C) Charge distribution map revealing one positive and one negative charged layer at the twin boundaries.